

The expert high-speed and multi-axis solution

Training Course





PowerMill 2017 Five Axis Contents

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1. 3+2 Axis Machining

Introduction

3+2 Axis Machining involves indexing the head and\or bed to re-align the tool at a fixed angular, orientation, to perform machining strategies. The **3+2** alignment is actioned either by manual adjustment or as part of the CNC control.

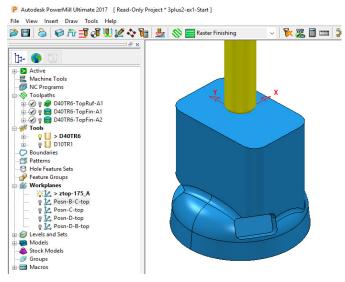
The most common method of creating a **3+2 Axis** is by using a **Workplane** with the **Z-Axis** arranged at an appropriate **Tool Axis** alignment. Standard **3 Axis** strategies and their **plunge** and **retract** moves will occur relative to the **Workplane**.

3+2 Axis machining enables:-

- a All faces of a component (except the base) can be machined in one set-up, relative to a common tool setting datum.
- **b** Access to deep sidewalls with standard length tooling.
- c Access to undercut features.

3+2 Axis - Machining Example

- 1 **Open** the following **Project**:
 - ...\PowerMill_Data\five_axis\3plus2_as_5axis\3Plus2-ex1-Start



- 2 Save the Project as:
 - ...\COURSEWORK\PowerMill-Projects\3Plus2-ex1

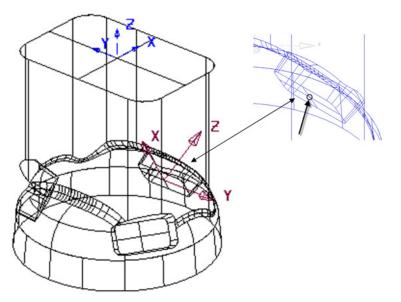


A **3-Axis Roughing** strategy and two **3-Axis Finishing** strategies already exist in the imported **Project**.

Also, a series of **workplanes** are already included in the **Project**, with one just above the top of the model at **Ztop-175_A** at 750mm above the **Transform**. This **workplane** will be used as the main machining datum.

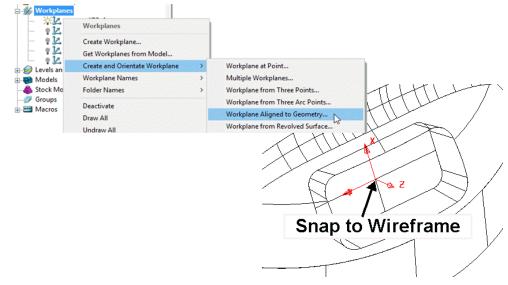


Note the relatively high sides of the component and the orientation of the three recesses making it impossible to machine them as **3** Axis with the tooling aligned to the vertical axis.



The pocket located along the **X direction** will be the first to be assigned with a new **workplane** to control one of the **3+2** - **Tool Axis** alignments.

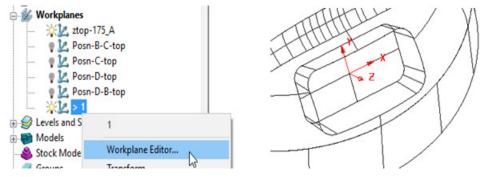
- **3** From the **PowerMill** *explorer* select **Workplane** > **Create and Orientate Workplane** > **Workplane Aligned to Geometry**.
- 4 Using the left mouse button, snap or box the wireframe crossover at the base of the first pocket (located along X from workplane *ztop-175_A*).



5 Activate the new Workplane 1.

The **workplane** is automatically aligned to the wireframe with the **Z** Axis normal to the **surface**. It still requires further editing as it is advisable for the **X**-Axis to align anticlockwise as viewed from the top of the component

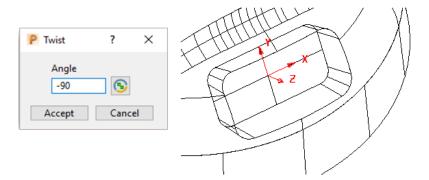
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6 From the **PowerMill** *explorer*, right-click on **Workplane 1** and from the local menu, select the **Workplane Editor** toolbar to open the following toolbar.

🕒 Name 1 📓 🕉 💥 🥰 🖾 🖾 🎽 🕸 🧚 🗰 2	<u>講</u> らく	💤 🕅	12 🔤 🤘	1 <u>x</u> 1 <u>x</u> 1	¥	🕉		1	Name
--------------------------------	-------------	-----	--------	-------------------------	---	---	--	---	------

7 Select **Twist about Z** such as and in the dialog, input an **Angle** of **-90** (normal to the base of the recess).



The **X-Axis** of the **workplane** should be pointing anticlockwise relative to the **Transform** (Global Datum) as viewed from the top of the component (If not already the case).

- 8 Select **V** to save the changes and exit the **Workplane Editor** toolbar.
- 9 Rename Workplane 1 as Align_B.
- 10 Activate the Workplane ztop-175_A.
- 11 Right-click on the **Workplane**, **Align_B**, and from the local menu select Transform.



12 Select the Rotate workplanes option (shown arrowed below).

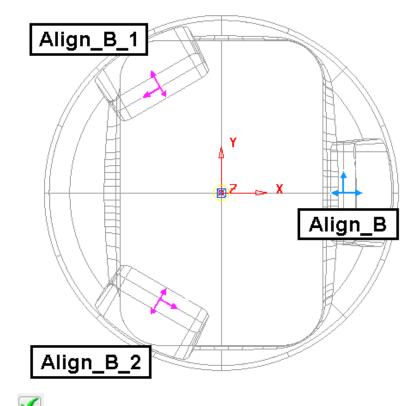


13 In the Rotate dialog, select Keep original.

14 Input **No. of Copies 2**, **Angle 120**, to create two new **workplanes** (Positioned normal to the base of the next pocket in an anticlockwise direction as viewed from the top).

Rotate								
No. of Copies	2	An	gle	120	\sim	昬	1 🕄	×

15 Select the *small cross* on the right of the toolbar to exit the dialog.

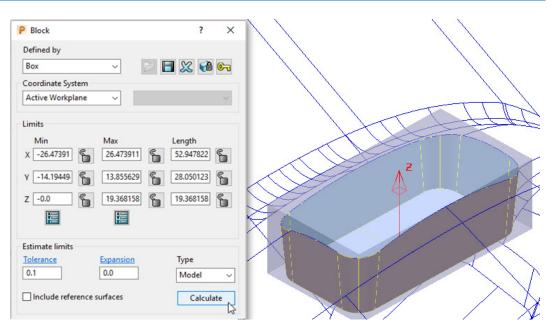


- 16 Select **V** at the end of the **Workplane Editor** toolbar to accept the new **Workplanes** (Align_B_1 & Align_B_2).
- 17 Rename the 2 new **Workplanes** (in anticlockwise order) as **Align_C** and **Align_D** respectively.

The component is now ready to have the **3 Plus 2** machining strategies created, relative to the three new workplane alignments. (*Align_B*, *Align_C*, and *Align_D*).

For each of the 3 Pockets a rectangular material **Block** will be created locally, relative to the aligned **3+2 workplane**. A **Model** *Boundary* will also be created around each pocket to provide even more control of the machining strategy limits.

- **18** Activate the **Workplane** *Align_B*.
- 19 Select the 2 surfaces that define the pocket around **Workplane** *Align_B*.
- 20 Calculate a Block using *Defined by*, Box and *Type*, Model.



- 21 Ensure that the pocket surfaces are still selected so that the **Rapid move heights** calculation ignores the de-selected surfaces.
- 22 In **Rapid move heights** input the operational **Workplane** as **Align_B** and select **Calculate** to create values for **Safe Z** and **Start Z** aligned to the appropriate coordinate system.

P Toolpa	th connections								?	×
Safe area	Moves and clea	rances	Start and end point	Lead ins	Lead outs	Links	Point distribution			
Safe are					Calcula	te dimer				
	Туре	Plane		\sim			Measured from Block and Mo	del	~	
	Workplane	Align_l	3	~			Rapid cleara	ince 10.0		
							Plunge cleara	ance 5.0		
Norm	0.0	0.0	1.0					Calcul	ate	
			Rapid height	29.368158						
			Plunge height	24.368158						
			Use pol	ar links 🗌						

Input the **Workplane** (**Align_B**) for a **Rapid move height** plane that is parallel to the pocket base.

Rapid move heights are calculated from the maximum Z value of the **Block** and **Model** (or selected **Model** entities), whichever has the **maximum Z height**.

- 23 Create a User Defined Model Boundary named Pkt-B1 around the top edge of the pocket (surfaces still selected!) that surrounds the Workplane (Align_B).
- 24 Activate the existing Tiprad tool D10TR1.

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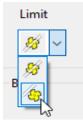
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- 25 Set the 1st Choice, Lead In to Ramp with Ramp Options as Zig Angle 4, Follow Circle, and Diameter (TDU) 0.6.
- 26 In the **Strategy Selector** dialog in **3D Area Clearance** select **Model Area Clearance** and fill in the options in the pages, exactly as shown below:

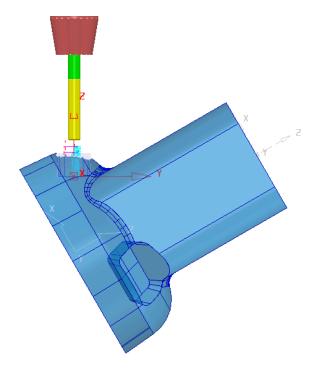
P Model Area Clearance	? >
Toolpath nar	me D10TR1-Rgh-B1
Workplane /	Model area clearance
	Style
Model area clearance	
General Street	Offset model
Step cutting	
	Cut direction Profile Area
Flat machining 	Climb ~ Climb ~
······································	Tolerance
	0.1
Cutter compensation	Thickness
 Point distribution Cool axis 	
Machine axis control	Stepover
	2.0
	✓ Stepdown
- A End point	Automatic V V 5.0
Alto	
	Constant stepdown
	Rest machining
	Calculate Queue OK Cancel

- Toolpath name: D10TR1-Rgh-B1
- Style: Offset model
- 27 In the Limit page input the Boundary Pkt-B1 and set Limit tool periphery to boundary.



28 Select **Calculate** to create the toolpath and then **Cancel** the dialog.

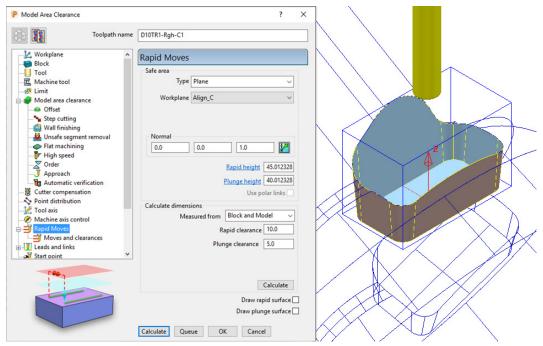




The toolpath plunge moves are aligned to the **Active workplane's**, Z Axis.

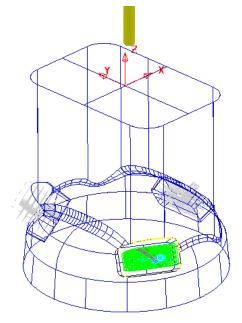
29 Use **Copy** to create cloned strategies for the other two recesses, adjusting the values and settings as required to create toolpaths, **D10t1-Rgh-C1** and **D10t1-Rgh-D1**.

a Rapid Move Heights must be defined separately for each toolpath with an appropriate **Workplane** selected in the dialog (Remember to check for the correct **Workplane** in the dialog).





30 Don't forget to create and activate the correct User defined - Model -Boundaries named Pkt-C1 and Pkt-D1.



After the creation of **toolpaths** for **3 + 2 Axis** valid ncdata can only be output using a compatible, post-processor. For programs containing multi-alignment toolpaths the **NC Programs** output options create the ncdata from one datum (In this case the **Workplane - ztop175_A**). This option is selected in the **NC Preferences** or **NC Program Settings** dialog.

- **31** In the **PowerMill** *explorer*, right-click on **NC Programs** and select **Preferences**.
- 32 From the Machine Option File select Mazak_Variaxis_5axis_ref.pmoptz as the controller.
- 33 For the **Output Workplane** select **ztop-175_A**.

P NC P	references						?	\times
Output	Toolpath	Fixture offset	Verification					
Chan	ges made h	ere will not cha	nge existing N	C Programs				
	Use Pro	ject Off 🗸	Output	Folder C:\Ten	np\NCPro	grams		2
		Outpu	t File {ncprog	gram}				
	Ma	chine Option Fi	le C:\dcam\	config\ductpo	st\Mazak_	Variaxis_5axis	n	2
	Machine	e Tool	~	Model L	ocation			\sim
0	utput Work	plane ztop-175	_A ~	S F	Part Name			
				-	Tool Value	Тір		\sim
	Automat	tic Tool Alignm	ent On 🗸	Connecti	on Moves	Move,Rotat	te	~
			С	lose				

34 Close the dialog.

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1 1	5,		•								
🛓 🚫 Toolpaths											
🎚 🕜 🥊 🥩 D40TR6-Top	Ruf-A1										
🔠 🧭 🥊 😂 D40TR6-Top	🖩 🧭 🖉 🛢 D40TR6-TopFin-A1										
🛓 🔗 🥊 😂 D40TR6-Top	Fin-A2										
🏨 🕜 🥊 🕩 D10TR1-Rgh	-B1										
🚊 🧭 🗣 🥩 D10TR1-Rgh	-C1										
🗄 🔗 💡 🥩 > D10TR1-	Toolpaths	(3)									
🖃 🛷 👬 Tools	Draw Selected										
🛓 👘 🔮 📙 D40TR6											
🗄 – 💡 📙 > D10TR1	Undraw Selected										
Boundaries	Add to	>	Stock Model								
🕀 🧛 💭 Pkt-B1	Create Individual NC Program	ns	NC Program	N							
I Pkt-C1	Load Tool Cutting Data		Group	13							

			NC F	rogra	m : 1			?	×
é	N	lame 1							88
	Outpu	t File C:	Temp\N	CProgra	ims\{ncpro	gram}			0
Mac	hine Option	File C:	dcam\co	onfig\xt	a-posts\M	S-GV503-1.opt		¥	ø
	Mac	nine Tool			~ M	lodel Location			*
	Output W	orkplane	ztop-17	5_A	~	Part Name	1		
		Program	n Numbe	r 1		Tool Value	Tip		۷
	Automa	tic Tool A	lignmen	t On	Y Conr	nection Moves	Move, R	otate	۷
Toolpath	Num	Diame	Tip	Gauge	Overha	Toleran	Thickn	Tool ID	
D10TR1-Ruf-B1	1	10	1	130	70	0.1	0.5	DIOTRI	
D10TR1-Ruf-C1	(1)	10	1	130	70	0.1	0.5	D10TR1	
D10TR1-Ruf-D1	(1)	10	1	130	70	0.1	0.5	DIOTRI	
<									>
T	fool Chang	e On Ne	w Tool	۷	Too	ol Numbering	As Speci	fied	¥
M 🕅 💷	Reset				Tool Ch	ange Position	After Co	nnection	*

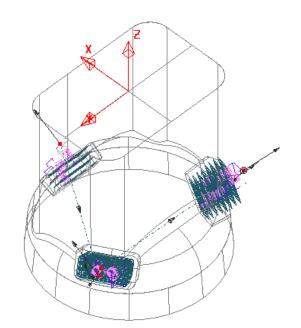
36 In the **NCProgram:1** dialog select **Write** to successfully create the **Output File** but note the red warning messages in the displayed **Information** dialog.

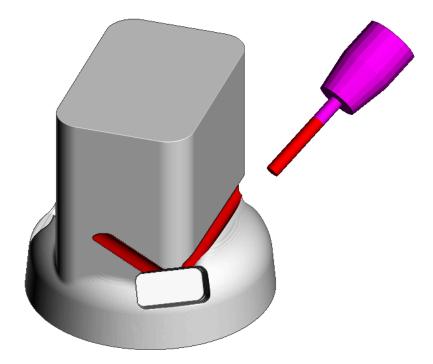
P Information ?	×
Complete	^
Write NC Program	
NC program : C:/Temp/NCPrograms/1.tap	
NC program potentially has safety problems, inspect the NC program	n
verification form for more information	
Toolpath D10TR1-Rgh-B1	
Toolpath D10TR1-Rgh-C1	
The toolpath Z axis has changed.	
Toolpath D10TR1-Rgh-D1	
The toolpath Z axis has changed.	
Postprocessed.	
r osiprocesseu.	



37 In the **PowerMill** explorer switch on the lightbulb adjacent to **NCProgram 1** to display it in the graphics area.

The **link** moves between the three individual **3+2 toolpaths** are displayed in the **NC Program** and in this case are shown to be passing straight through the component!



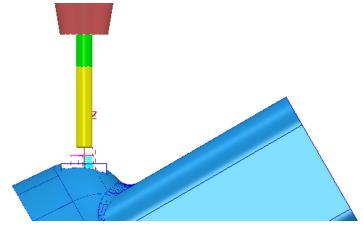


Automatic gouge protection only exists within a toolpath (Between the **Start and End Point**). After inserting the toolpaths into an **NC Program**, it is essential for the user to independently control the **Positional Moves** outside the toolpaths to eliminate any collisions with the component and fixtures.

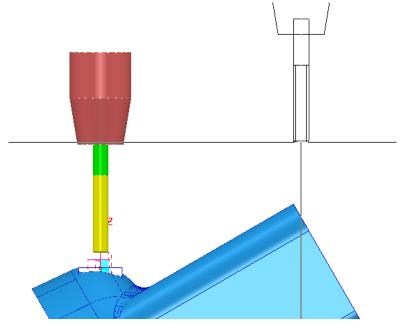
Link moves controlled by Absolute Start and End points

This method of creating safe link moves between separate **3+2** toolpaths is the most universal and reliable method for all types of application and post-processor. The start and end point for each toolpath is defined with **absolute** coordinates positioned above the maximum Z height of the component.

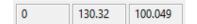
- 38 Activate the toolpath **D10TR1-Rgh-B1**.
- **39** Select a **View from right (X)**.



- 40 Switch on both Draw Cursor Crosshair (Ctrl H) and Tool (Ctrl T).
- 41 Move the cursor to a suitable *Start/End* point above the top of the model.



The **X**, **Y**, and **Z** coordinate values are displayed in the *information* toolbar located below the graphics area.



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42 Make a note of the individual Y and Z values as integers eg. 130 and 100.

The **Rapid Move** - **Safe Z** value must now be matched to the **Z** value in **Start and End Point** dialog.

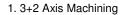
43 Open the **Rapid Move Heights** dialog, edit the **Safe Z** value to **100** before selecting **Apply** at the bottom of the dialog (to update the toolpath).

P Toolpat	h connections								?	×
Safe area	Moves and clea	arances	Start and end point	Lead ins	Lead outs	Links	Point distribut	ion		
- Safe are	a				Calcula	te dimer	nsions			
	Туре	Plane		~			Measured from	Block and Model	~	
	Workplane	Align_B		~				Rapid clearance 10	.0	
								Plunge clearance 5.0)	
Norm		0.0	1.0	1						
	0.0	0.0						Cal	culate	
				100.0						
			Plunge height	4.368158						
			Use pol	ar links						

44 Open the Start and end Point dialog

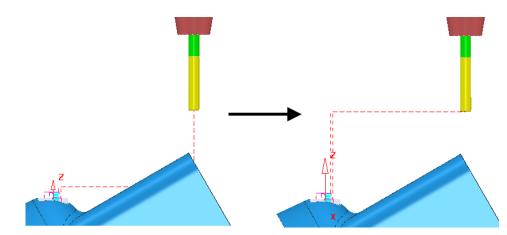
P Toolpath connections	? ×
Safe area Moves and clearances Start and end point Lead ins Lead outs Links Point distribution	
Start point Use Absolute Incremental plunge Direct move Override tool axis Override tool axis	
✓ Separate approach Approach along Tool axis Approach distance Incremental plunge distance Distance 5.0 Measured from Stock	
Coordinates Coordinates 0.0 130.0 100.0 Tool axis 0.0 0.0 1.0 0.0 0.0 1.0 Image: Coordinates 0.0 0.0 1.0 Image: Coordinates 0.0 0.0 1.0 Image: Coordinates 0.0 0.0 1.0 Image: Coordinates	
Apply start Apply end Apply b	poth
Apply Accept Cancel	

- 45 For both the Start point and End point select Use Absolute and input the new Y value (130).
- **46** Select **Apply** both(to update the toolpath).



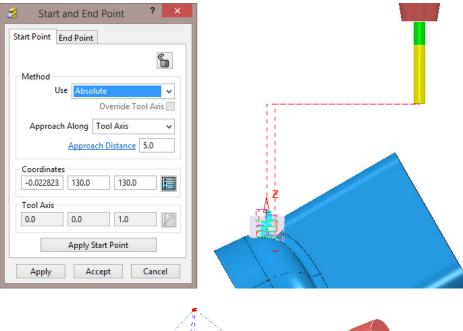
1

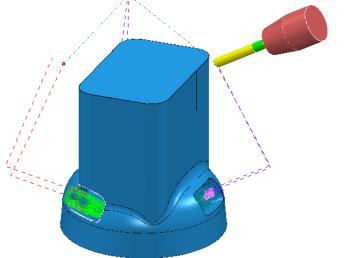




47 Repeat the above editing process on the other two **3+2** toolpaths **D10TR1-Rgh-C1** and **D10TR1-Rgh-D1** but this time use the values **130** and **120**.

Note the new values (eg 130 120) due to these pockets being in the corners of the main section with more of the main body to clear.









48 Select File > Save to update the contents of the previously stored **Project**.



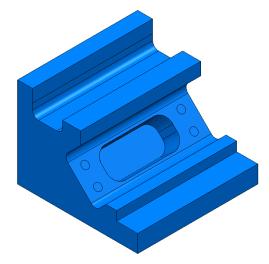
3+2 Axis – Stock Model Application

The **Stock Model** represents the un-machined material at any point in the machining process. An empty **Stock Model** is created, followed by applying the material **Block** and\or any number toolpaths to be considered in the process. The **Stock Model** is then updated by selecting **Calculate**, to display the current `un-machined' material remaining.

- 1 Select File Delete All and Tools Reset forms.
- 2 Import the Model:

...\PowerMill_Data\five_axis\AnglePad\StockModelRest.dgk

- 3 Save Project As:
 - ...\COURSEWORK\PowerMill_Projects\StockModel-3Plus2



The **model** includes undercut features which for a normal **3-Axis** application, would require the component to be machined in two separate set ups. However, by applying **3+2** with separate **workplanes** controlling the **tool alignments**, the whole project can be completed in one setup. During an initial **3-Axis** operation, the undercut pockets will be partially machined which provides an application for using **Stock Model** to enable the user to optimise the **3+2** machining.

4 Calculate a Block using Defined by – Box, Type - Model, and the Coordinate System set to Global Transform.

P Block	
Defined by	
Box	\sim
Coordinate System	
Active Workplane	\sim
Active Workplane	_
🗕 Global Transform 📐	
Named Workplane 场	
IVIIN	IVIAX

5 Accept the dialog.

By creating and locking the material Block to the Global Transform (world co-ordinate system), the orientation and position will remain unchanged if a Workplane is made Active.



- 6 Create a Dia 16 tip radius 3 tool named **D16TR3**.
- 7 Create a Dia 12 tip radius 1 tool named **D12TR1**.
- 8 Activate the tool **D16TR3**.
- 9 Activate Workplane 1.
- 10 In the **Rapid Move Heights** dialog select **Calculate**.
- 11 Use the default settings for both the **Start point** and **End point**
- 12 Select the **Strategy Selector** and from **3D Area Clearance** select **Model Area Clearance** filling in the options in the pages, exactly as shown below:

P Model Area Clearance	?	×
Toolpath name	D16TR3-TopRgh	
Workplane Block Tool Machine tool Step cutting Unsafe segment removal Flat machining Flat machining Moves Machine axis control Rapid Moves Leads and links Start point Cutter compensation Machine axis control Machine axis control	Model area clearance Style Offset model Cut direction Profile Climb Climb Tolerance 0.1 Thickness Image: Stepover Image: Stepover </td <td></td>	

🗄 Leads and links	Lead in	
Lead in	1st choice	
	Ramp	~
i i mart		$\langle \rangle$

13 In the strategy *explorer*, select the **Lead in** option and in the new page select

1st choice Ramp followed by Ramp options



14 In the **Ramp Options** dialog, Input **Max zig angle 4** using a **Circle** with a diameter of **0.65** (**TDU**).

P Lead In Ramp Options		?	×
1st Choice 2nd Choice			
Follow Circle ~	<u>Max zig angle</u> 4.0		
Circle diameter (TDU) 0.65			
Closed segments only			
Ramp height Type	<u>Height</u>		
Incremental v	5.0		

- 15 Accept both the Ramp Options and Leads and Links dialogs.
- **16** Back in the **main** strategy dialog, select **Calculate** to create the toolpath and then **Close**.
- 17 Select an **ISO 1** view.
- 18 Activate **Workplane 2** (The **Block** remains in situ!).
- 19 In the **PowerMill** *explorer*, right-click on **Stock Models** and from the local menu, select **Create Stock Model** to open the following dialog.

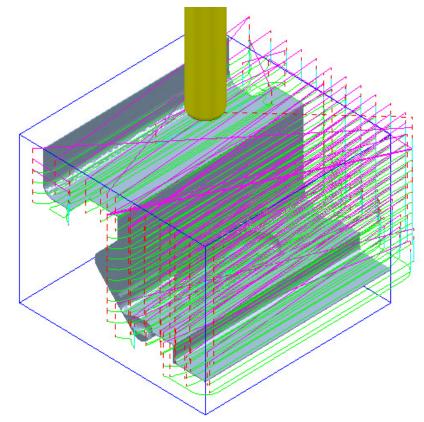
P Stock Model	? ×
Name	
1	9
Tolerance	Stepover
0.05	1.0
Rest thickness	Workplane
0.1	2 ~
Accept	Cancel

- 20 Input the above values and **Accept** the dialog.
- 21 In the **PowerMill** *explorer*, right-click over the **toolpath** *D16TR3-TopRgh* and from the local menu select, **Add to Stock Model**.

E S Toolpaths E S ? S > D16TR3-T	opRgh			
⊡ <mark>#</mark> Tools 		D16TR3-TopRgh		
🖽 👰 📙 D12TR1		Simulate from Start		
Boundaries 🕅 Patterns	~	Activate		
🕀 🖯 Hole Feature Sets		Activate Workplane	_	
	¥	Ļ	Ļ	
	Add to		>	Stock Model
	Grapta	IndividuaLNC Brogram.		NG Program



- 22 In the **PowerMill** *explorer*, right-click over the new **Stock Model 1** and from the local menu, select **Calculate**.
- 23 With the local Stock Model menu still open, select, Drawing Options > Shaded and Show Rest Material.



The **3-Axis Roughing** operation has removed all accessible material leaving a **0.5 thickness** on the component form. This is clearly visible on the displayed **Stock Model**.

- 24 Activate the tool **D12TR1**.
- 25 From the **main** toolbar select **Rapid Move Heights** and input the correct **Workplane** definition **2** or **Toolpath Workplane** into the dialog before selecting **Calculate**, followed by **Accept**.

roolpa	th connections								?	>
afe area	Moves and clea	arances	Start and end point	Lead ins	Lead outs	Links	Point distributi	on		
Safe are	a				Calcula	te dimer	nsions			
	Туре	Plane		~			Measured from	Block and Model	\sim	
	Workplane	Toolpa	ath workplane	\sim				Rapid clearance 10	.0	
								Plunge clearance 5.0	0	
Norm	nal									
	0.0	0.0	1.0	1				Cal	culate	
			Rapid height	78.461941				Cal	culate	
			Plunge height	73.461941		2				
			Use pol			15				



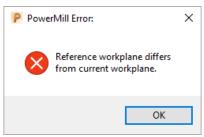
26 Select the **Strategy Selector** and from **3D Area Clearance** select **Model Rest Area Clearance** and input settings exactly as shown in the following illustration:

P Model Rest Area Clearance			?	>
Toolpath	name	D12TR1-AngleRgh		
 Workplane Block Tool Machine tool Limit Model rest area clearance Rest Offset Step cutting Wall finishing Unsafe segment removal Flat machining Flat machining Order Approach Automatic verification Point distribution Tool axis 	^	Model rest area clearance Style Offset model Cut direction Profile Area Climb Climb Tolerance 0.1 Thickness 0.5	~	
Machine axis control Rapid Moves Leads and links Start point End point	~	Stepover Stepdown Automatic Stop Stepdown Constant stepdown Rest machining Calculate Queue OK Cancel		

- 27 In the local explorer select the **Rest** page and input **Rest Machining** Toolpath D16t3-TopRgh.
- 28 Select **Calculate** to create the toolpath.

Workplane Block Tool Machine tool Model rest area clearance A come	Rest Rest machining Toolpath D16TR3-TopRgh
 Brest Offset Step cutting Wall finishing 	Detect material thicker than 0.2 Expand area by 0.4

a The strategy fails to calculate and the following **PowerMill Error** message box appears!





b

- It is not possible to apply **Area Clearance Rest machining** using a reference toolpath that has been generated relative to a different **Workplane** alignment.
- c It is however possible to use a **Stock Model** as the reference item for **rest machining**.
- 29 Select OK to close the **PowerMill Error** message and return to the strategy (that is still in Recycle mode).
- 30 Set the option Rest machining as **Stock model** using **1**, and input **Detect material thicker than 0.6** as shown in the following illustration.

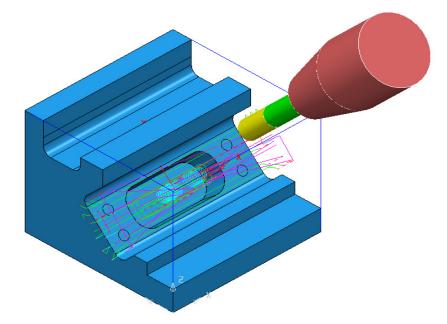
Workplane	^	Rest
		Rest machining Stock model V 1 V
☐		Stock Model state D16TR3-TopRgh ~ <u>Detect material thicker than</u> 0.6
Step cutting Usaff finishing Unsafe segment removal Flat machining		Expand area by 1.2 Minimum gap length 18.849556

31 In the local strategy *explorer*, open the Limit page and select Limit tool

centre to block edge

Limit 🧕 🗸

32 Select **Calculate** to create the toolpath and then **Close** the dialog.



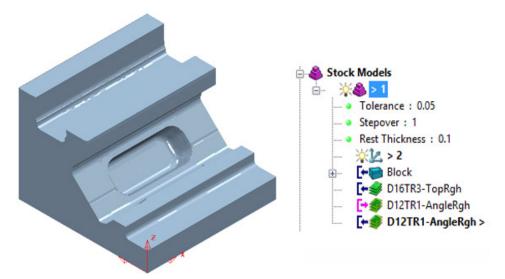
The modified **Rest Roughing** toolpath now successfully operates within the defined **Stock Model** volume (as shown above left).

The material removed by the toolpath, although referenced, is not physically included as part of the **Stock Model** at this stage.

33 In the **PowerMill explorer**, right-click on the **Toolpath** *D12TR1-AngleRgh* and from the local menu select, **Add to** - **Stock Model**.



34 In the **PowerMill explorer**, right-click over the new **Stock Model 1** and from the local menu, select **Calculate**.

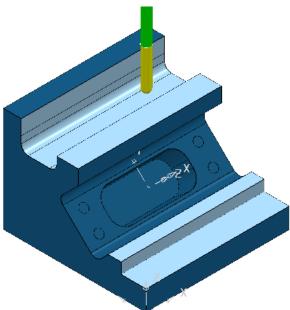


The **Stock Model** now displays the remaining material after both the **3-Axis Roughing** and **3+2 Roughing** operations.



Unlike **Area Clearance**, **Finishing** strategies cannot be directly **rest** machined to a **Stock Model**. However it is possible to create and apply **Stock Model Rest Boundaries** where required, providing suitable **rest** limits for subsequent finishing operations.

- 35 Activate the toolpath **D16TR3-TopRgh** to reinstate the settings used.
- 36 Create a Dia 6 Ball Nosed Tool named BN6.
- 37 Un-draw the Stock Model (click the light bulb off).
- **38** Select the Surfaces (shown shaded below) required for initial finish machining relative to **Workplane 1**.





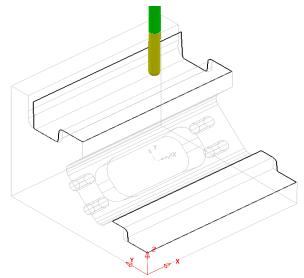
39 In the **PowerMill** *explorer*, right-click over **Boundaries** and select **Create Boundary** followed by **Selected Surface** to open the following dialog.

1		Name 1
Tolerances	Top Roll Over Tolerance 0.01 Thickness 0.0 xial Thickness 0.0	Limit Boundary Inside Limiting Boundary Outside
<u></u>	Use Axial Thickness	Automatic Collision Checking
Tool		Holder Clearance 0.0
街 🗸 🛛 BN6	~	Shank Clearance 0.0
		Block Limit 💇

40 Input data in the **Selected Surface Boundary** dialog exactly (as shown above) with the box named **Top** ticked and the **Limit** option set to **Limit tool centre to block edge**.



41 Select **Apply** and when processed, **Cancel** the dialog.



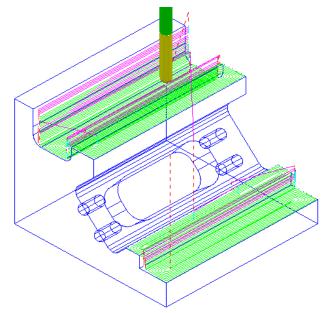
When created, the new **Boundary** will be **Active** and by default included as the **limits** (keep inside) in the following finishing strategy.

- 42 Select the **Strategy Selector** and from the **Finishing** dialog select the **Steep and Shallow** finishing option.
- **43** Enter the name **BN6-TopFin** along with the remaining values and settings exactly as shown below before selecting **Apply**.



Steep and Shallow Finishing		?
🚯 🋐 Toolpath na	ame BN6-TopFin	
Workplane Block Tool Machine tool Steep and shallow finishing Automatic verification Automatic verification Automatic verification Automatic verification Automatic verification Machine axis control Rapid Moves Leads and links Leads and links Leads and speeds History Notes and Description User defined settings	Steep and shallow fini Order Top first v Threshold angle 30.0 Steep Spiral Cut direction Climb v Stepdown $\underbrace{\begin{subarred} \limits $	ishing Additional_stock 0.3 Steep shallow overlap 0.0 Shallow Spiral Cut direction Climb ∨ Stepover Ø 0.3 0.007509 Type 3D offset ∨ Smoothing
	Tolerance 0.01 Thickness 	٣

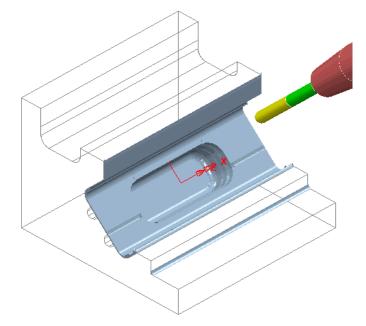
- 44 Set both Lead In and Lead Out to Surface normal arc (Angle 90, Radius 3).
- **45** Select **Calculate** to create the toolpath and then **Close** the dialog.



All of the features accessible from the top have now been finish machined. This finishing strategy will be added to the **Stock Model** ready for a **Stock Model Rest Boundary** to be created and applied to a **3+2** finishing strategy along **Workplane 2**.

\Lambda AUTODESK.

- **46** In the **PowerMill** *explorer*, right-click on the **Toolpath BN6-TopFin** and from the local menu select, **Add to Stock Model**.
- 47 In the **PowerMill** *explorer*, right-click over the new **Stock Model 1** and from the local menu, select **Calculate**.
- **48** With the local **Stock Model** menu still open, select **Show Rest Material**, followed by **Drawing Options Shaded**, and finally **Calculate**.
- 49 Select an **ISO 1**.
- **50** Activate Workplane 2.
- 51 From the main toolbar select Rapid Move Heights and input the correct workplane definition 2 or Toolpath Workplane into the dialog before selecting Calculate.

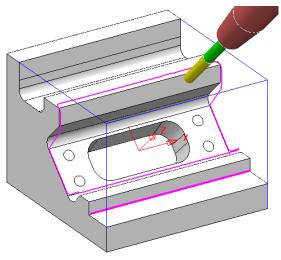


52 In the **PowerMill** *explorer*, right-click **Boundaries** and select **Create Boundary** followed by **Stock Model Rest** to open the following dialog.

Stock Model Rest Boundary	? ×
11 😜 🗳	Name 2
Stock Model 1 ~ Stock Model State BN6-TopFin ~	Limit Boundary Inside Limiting Boundary Outside
Detect Material Thicker Than 0.2 Expand Area By 0.0	
Tolerance 0.01	Automatic Collision Checking
Thickness 0.0	Holder Clearance 0.0 Shank Clearance 0.0
Use Axial Thickness	Block Limit 😏 🗸
Private Allow boundary to be private	()



53 Input data in the **Stock Model Rest Boundary** dialog exactly as shown above.

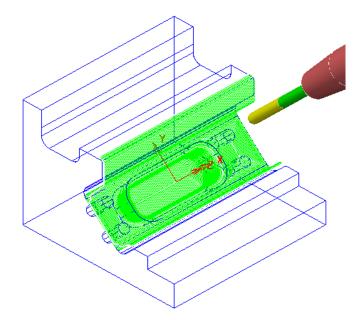


- 54 Apply and when processed, Cancel.
- 55 Select and delete the narrow segment at the base of the lower vertical wall.
- 56 Ensure that new **Boundary 2** is **Active**.
- 57 Select the **Strategy Selector Steep and Shallow** finishing option.
- 58 Enter the name **BN6-AngFin** along with the remaining values and settings exactly as shown below.

Steep and Shallow Fini	shing		? ×
te 👔	Toolpath name	BN6-AngleFin	
 Workplane Block Tool Machine tool Limit Stock engagemer Automatic vel Point distribution Tool axis Machine axis con Rapid Moves Leads and links Start point Feeds and speeds History Notes and Descrip Viser defined setti 	v finishing rification trol	Steep and shallow fit Order Top first Threshold angle 30.0 Steep Spiral Cut direction Climb Stepdown Climb Cl	Additional stock 0.3 Steep shallow overlap 0.0 Shallow Shallow Spiral Cut direction Climb ~ Stepover , 0.3 , 0.007509 Type 3D offset ~ Smoothing
		Tolerance 0.01 Thickness	٢
		Calculate Queue	OK Cancel

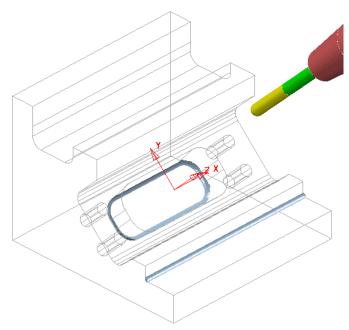


59 Select **Calculate** to create the toolpath and then **Close** the dialog.



The resultant **toolpath** will be added to the **Stock Model** mainly to confirm whether machining is now complete.

- 60 In the **PowerMill** *explorer*, right-click on the **Toolpath** *BN6-AngleFin* and from the local menu select, **Add to Stock Model**.
- 61 In the **PowerMill** *explorer*, right-click over the new **Stock Model 1** and from the local menu, select **Calculate**.



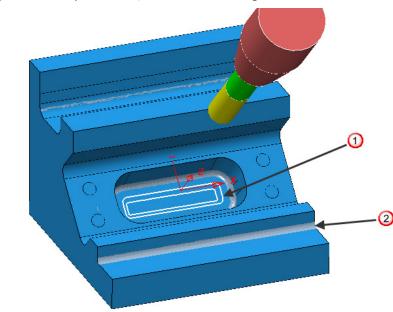
There are now 2 areas remaining as part of the **Stock Model**. As both include sharp internal corners they will need to be finished off using an End Mill.

- 62 Create a Dia 12 End Mill named EM12.
- 63 In the **PowerMill** *explorer*, right-click over **Boundaries** and select **Create Boundary** followed by **Stock Model Rest** to open the following dialog.



P Stock Model Rest Bounda	ary	? >
11 🖇		Name 3
Stock Model Stock Model State <u>Detect Material Thic</u>	1 ~ BN6-AngleFin ~ ker Than 0.2	Limit Boundary Inside Limiting Boundary Outside
Tolerances <u>Tole</u> <u>Thic</u>	Area By 0.0 rance 0.01 kness 0.0 kness 0.0	Automatic Collision Checking Holder Clearance 0.0 Shank Clearance 0.0
Use A	xial Thickness 🗌	Block Limit 🧕 🗸
Private	private	()
Edit History Apply edit history on t	calculation	9

- 64 Input data in the **Stock Model Rest Boundary** dialog exactly as shown above.
- 65 Apply and when processed, **Cancel** the dialog.



① A new **Stock Model Rest** *Boundary* has appeared where the remaining material is accessible to the **EM12** tool.

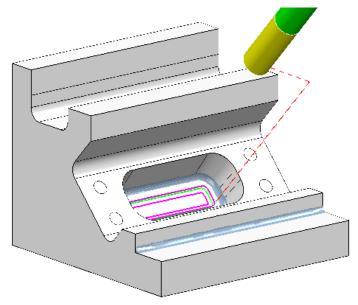
② This area is not accessible to the **EM12** tool, and as a result **Boundary** segments will not be created.

- 66 Ensure that the new **Boundary** (**3**) is Active.
- 67 Select **Toolpath Strategies** and from the **Finishing** dialog, select the **Constant Z** option.
- 68 Enter the name **EM12-AngleFin** along with the remaining values and settings exactly as shown on the following page.



P Constant Z Finishing			?	×
Toolpath name	EM12-AngleFin			
 Workplane Block Tool Machine tool Limit Stock engagement Constant Z finishing Constant Z finishing Mutomatic verification Point distribution Tool axis Machine axis control Rapid Moves Kapid Moves Leads and links Start point Start point Feeds and speeds History Notes and Description User defined settings 	Constant Z finishing Order by Region ~ Spiral Machine down to flats	Additional stock 0.6 Undercut Flat tolerance 0.		
	Tolerance 0.01 Thickness 0.0 Stepdown Minimum s	Cut direction Climb	1	

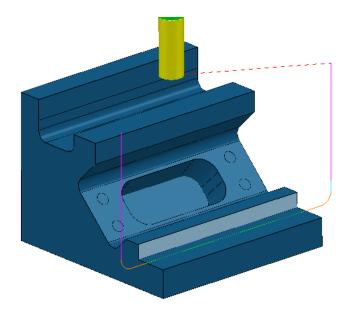
69 Select **Calculate** and then **Close** the dialog.



The angled pocket is now fully machined and the latest toolpath will now be added to the **Stock Model**.

- 70 In the **PowerMill** *explorer*, right-click on the toolpath **EM12-AngleFin** and from the local menu select, **Add to Stock Model**.
- 71 In the **PowerMill** *explorer*, right-click over the new **Stock Model 1** and from the local menu, select **Calculate**.
- 72 Activate the toolpath **D16TR3-TopRgh** to reinstate the settings used.
- 73 De-activate the toolpath **D16TR3-TopRgh** and activate the **EM12** tool.



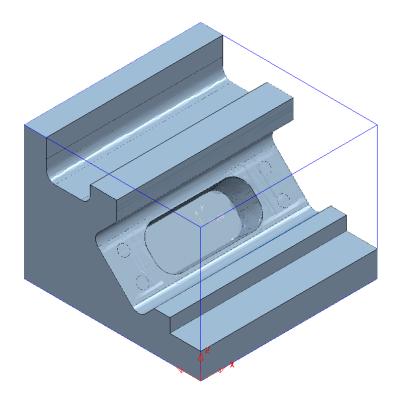


74 Create a **Swarf Finishing** strategy named **EM12-TopFin** on the selected, vertical surface (shown shaded above).

EM12-TopFin
Swarf finishing Drive curve Surface side Qutside Radial offset 0.0 Minimum fanning distance 0.0 Fan at end on planes Reverse axis Follow surface laterals Surface joining tolerance 0.3 Gouge avoidance Gouge check Degouge tolerance
ToleranceCut direction0.01Climb
Thickness O.0 Preview Draw Calculate Queue OK Cancel

- 75 Set both Lead In and Lead Out to Vertical arc with Distance 6, Angle 90, and Radius 4.
- **76 Add** the new toolpath **EM12-TopFin** to the **Stock Model** and **Calculate** to visually confirm that all excess material has now been removed.







The **Stock Model** is only visible when the **Show Rest Material** option is unticked.

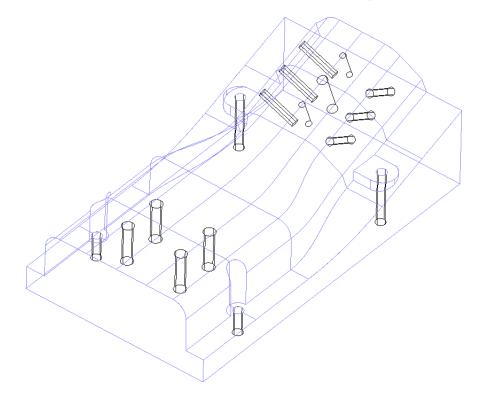
77 Select **File** > **Save** to update the contents of the previously stored **Project**.

3+2 Axis - Drilling Example

The **PowerMill** - **Drilling** options operate on **Hole Features** and not directly on the **Model**. This enables drilling to take place without the need to modify or trim back the existing surface data. When the **Multi-Axis** option is ticked the **Hole Features** at different alignments will be created to a common workplane.

- 1 Select File Delete All and Tools Reset Forms.
- 2 **Import** the **Model**:

...\PowerMill_Data\five_axis\drill_5axis\drill5ax_ex1.dgk



3 Select File - Save Project As:

...\COURSEWORK\PowerMill-Projects\MultiAxisDrill-ex1

The first stage is to create a **Hole Feature Set** into which all cylindrical surfaces in the selected model are inserted as **Hole** features.

Any cylindrical surfaces within the selection will automatically be recognised as a **Hole Feature**. It is important that no **Block** exists to ensure that the **Hole Features** are arranged with the top at the **maximum Z height**.



The existence of a Block will affect the orientation of individual Hole Features in that they are more likely to be created to an unsuitable alignment.

- 4 Use the left mouse to select all of the **surfaces**.
- 5 In the **PowerMill** *explorer*, right mouse click on **Hole Feature Sets**, and from the local menu select **Create Holes**.



6 Enter data into the **Create Holes** form exactly as shown.

P Create Holes	?	\times		
Name root				
Н				
Create from Tolerance				
Model ~ 0.1		$\overline{0}$		
Create compound holes				
Use active workplane only				
○ Find holes in both directions				
Find holes going down				
○ Find holes going up				
Group holes by axis				
Create holes from partial cylinders				
Minimum span angle				
300.0				
Ignore capped cylinders				
Edit after creation				
Apply Close				

The **Group holes by axis** option must be un-ticked for a **Multi Axis Hole** > **Feature Set** to be created (All of the *Hole Features* including those at different orientations will be input into a single **Feature Set**).

7 Apply and Close the dialog.



All cylindrical surfaces within the selection will automatically be recognised as **Multiaxis Hole Features**.

8 Undraw the model to view the newly created Features.

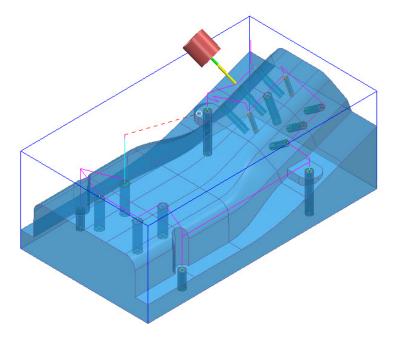
All 17 **Holes** in the **Feature Set** are correctly aligned, with the cross at the base representing the bottom of the hole.

- 9 Create a material Block using Defined by Box and Type Model.
- 10 In the **Rapid Move Heights** idalog, select **Calculate**.
- 11 Create a Dia 3 Drill named **Drill3** of Length 40.
- 12 Add a **Shank** component Upper\Lower Dia 3 Length 40.
- **13** Add a **Holder** component Upper Dia 30 Lower Dia 30 Length 30 Overhang 60.
- 14 Select Toolpath Strategies Sand in the Strategy Selector dialog, select **Drilling**.
- **15** In the Drilling dialog, select the option **Drilling**.
- 16 Rename the toolpath **CentreDrill-Dia3**.



P Drilling		?	×
Toolpath n	ame CentreDrill-Dia3		
	Drilling		
	Cycle type		
	Break chip ~		
	Define top by		
	Hole top V		
¹ I _I Pecking 	Operation Centre drill		
automatic verification			
— 12 Tool axis — 10 Machine axis control	Clearance Start 5.0 0.0	1	
Rapid Moves	Peck Depth	1	
Start point]	
	. Dwell tim	ie	
	0.0		
Notes and Description User defined settings	Tolerance		
	0.1		
	Thickness		
	Drilling cycle output		
	Select		
	Calculate Queue OK Cancel		

- 17 Back in the main **Drilling** page select **Calculate** to create the **Centre Drilling** toolpath, and then **Cancel** the dialog.
- **18 Simulate** the toolpath.



The **Multiaxis** option has created all of the **Hole Features** aligned at different elevations in a single **Feature Set**.



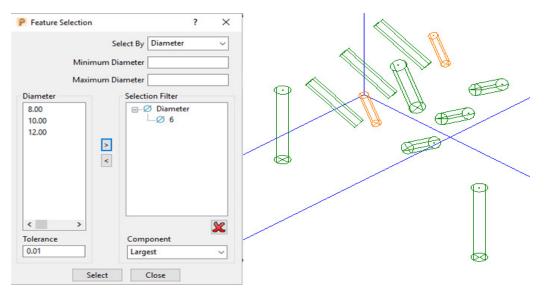
The two **Dia 6 Hole Features** are to be drilled to depth with a **Dia 5 Drill** and then **Tapped**. To allow for the inevitable point angle at the bottom of the blind holes the **Tapping** operation needs to stop short of the full depth by applying a suitable **Axial Thickness** value.

- 19 Create a Dia 5 Drill named DRILL5 of Length 60
- 20 Add a **Shank**, Upper Dia 5, Lower Dia 5, Length 30.
- 21 Add a Holder, Upper Dia 30, Lower Dia 30, Length 30, Overhang 50.
- 22 Select **Toolpath Strategies** and in the **Strategy Selector** dialog select **Drilling**.
- 23 In the **Drilling** dialog select the option **Break Chip**.
- 24 Rename the toolpath as **Drill5**.

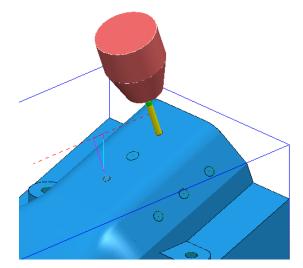
P Drilling		?	×
Toolpath name	Drill5		
🖯 Holes 	Drilling		
	Cycle type Break chip ~		
	Define top by		
	Hole top Operation Drill to hole depth		
 Automatic verification Tool axis Machine axis control 	<u>Clearance</u> <u>Start</u> 5.0 ↑ 0.0		
a → → Rapid Moves ↓ ↓ Leads and links ↓ ↓ Leads and links ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	Peck Depth Depth		
 Feeds and speeds History Notes and Description 	Dwell time		
Ser defined settings	Tolerance 0.1		
	Thickness		
8	Drilling cycle output		
	Select		
	Calculate Queue OK Cancel		

25 Select the two Dia 6 Hole Features (shown coloured orange below).





- **26 Close** the **Feature** Selection dialog.
- 27 Select Calculate to create the Drilling toolpath, then Cancel the dialog.
- 28 Simulate the toolpath.



The two Dia 6 Holes have now been drilled to full depth using a Dia 5 Drill.

They will now be **Tapped** to a depth of **5** (*Axial thickness*) from the base of each *Dia 6 Hole* using a *Dia 6 Tap* with a **1mm** *Pitch*.

- 29 Create a Dia 6 Tap (Named M6Coarse-TAP) with Pitch 1 and Length 25.
- 30 Add a **Shank**, Upper Dia 4, Lower Dia 4, Length 30.
- 31 Add a Holder, Upper Dia 30, Lower Dia 30, Length 30, Overhang 50
- 32 Select Toolpath Strategies and in the Strategy Selector dialog select Drilling.
- **33** In the **Drilling** dialog select the option **Tap**.
- 34 Rename the toolpath as M6-Tap.

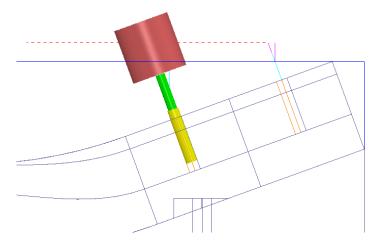


P Drilling			?	×
Toolpath name	Мб-Тар			
Holes Workplane Block Machine tool Machine tool Machine tool Mathine tool Mathine at source of the second Machine axis control Rapid Moves Leads and links Machine axis control End point History History Notes and Description User defined settings	Drilling Cycle type Tapping V Define top by Hole top V Operation Drill to hole depth V Clearance 5.0 Pitch 1.0 Tolerance 0.1	Start 0.0 Depth 24.99999 Dwell time 0.0		
C C C C C C C C C C C C C C C C C C C	Thickness 	5.0		

35 Select the two Dia 6 Hole Features.

36 In the **Drilling** dialog select the option **Tapping**.

- 37 Rename the toolpath as **M6-Tap**.
- 38 Set Cycle Type Tapping, Operation Drill to hole Depth, and Pitch 1.
- **39** Input an **Axial Thickness** value of **5**.
- 40 Select the two Dia 6 Hole Features.
- 41 Select **Calculate** to create the toolpath and then **Close** the dialog.
- 42 Select a View from front (-Y).



The *selected holes* have been **Tapped** to a distance of 5mm short of the full depth.

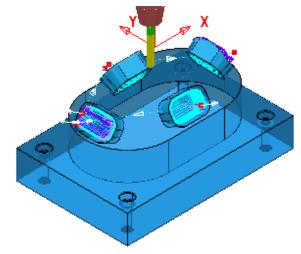
43 From the main pulldown menus, select File > Save to update the contents of the stored Project.

2. Positional Tool Moves

Positional Tool Moves – Essential Information

When performing multi-axis, **Positional Tool Moves**, it is the user's responsibility to pay careful attention and take appropriate action to prevent collisions.

- All individual toolpaths should be created such that the Start and End Points are clear of any <u>undercut</u> features in the CAD model.
- PowerMill <u>does not</u> gouge check positional moves before and after an individual toolpath. These Pale Blue dashed connection moves are only visible if the NCProgram is drawn (as shown below).



- Neither, **PowerMill**, or a **Postprocessor** will be aware of any obstructions within the confines of a machine tool.
- The **Positional** moves displayed in a **PowerMill** toolpath **simulation** will not necessarily match all moves performed by the actual machine tool.
- For a more accurate simulation a Machine Tool Model along with an associated mtd file can be created. It must be stressed that a machine tool simulation is essentially a visual animation and <u>not</u> an ncprogram, verification.

Three suggested methods in **PowerMill** to create **Positional Tool Moves** include:

- a Use of **Absolute** coordinates in the toolpath **Start** and **End Point** dialog.
- **b** The insertion of a *Drive Curve* **Pattern Finishing** strategy suitably positioned in 3D space.
- c The insertion of strategically placed **Workplanes** into an **NC Program**.

Postprocessor option file – Safe Z Positional Moves

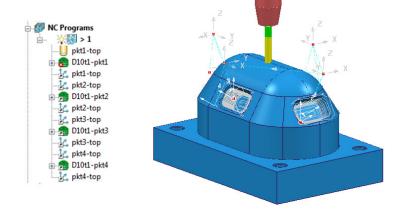
There are two different ways that a specific **Postprocessor Option file** can be created to deal with positional moves (Method 1 is the default).

Method 1 – The Postprocessor Option file automatically outputs moves from/to the Machine Tool, maximum Z height (Home) at the start and end of each Toolpath. Note! In this case any Workplanes inserted into the NC Program (Item c on the previous page) are completely ignored.

The name for a typical **Postprocessor Option file** using Method 1 includes **ZMAX** at the end of the name:- **DMG_DMU10p_H530_ZMAX.pmopt**

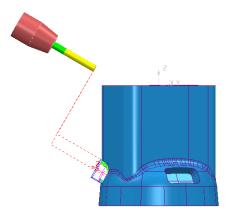
b Method 2 – The **Postprocessor Option file** does not automatically output Machine Tool **Safe Z** moves. All additional, safe positional, moves must be added by the user in **PowerMill** (In this case a network of **workplanes** can be used as shown in the illustration below).

The name for a typical **Postprocessor Option file** using Method 2 will <u>not</u> include **ZMAX** at the end of the name:- **DMG_DMU10p_H530.pmopt**



Tool Move with Start and End Point

Positional Tool Moves can be controlled in the **Start and End Point** dialog by use of **Absolute** (along with specific XYZ coordinates).



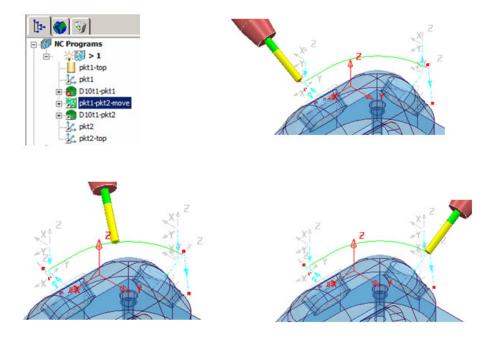
Start and End Points input as **Absolute** coordinates, above the component where it is safe to re-align the tool and/or perform rapid XY moves.



Tool Moves using a Pattern Finishing in 3D Space

Positional Tool Moves can be controlled by running the tool along a **Pattern Finishing** strategy used as a *Drive Curve* in 3D space.

A *lean* angle can be applied to maintain an angular **tool alignment** during transit.

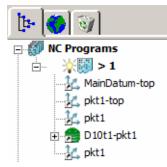


Tool Move via Workplanes in an NC Program

Positional Tool Moves can be controlled by strategically placed **Workplanes** inserted between the **Toolpaths** in the **NC Program** list. A **Workplane** in the **ncprogram** list can also be registered as a **Toolchange Point** if required.



This method is only applicable to non-**ZMAX post-processor** applications.

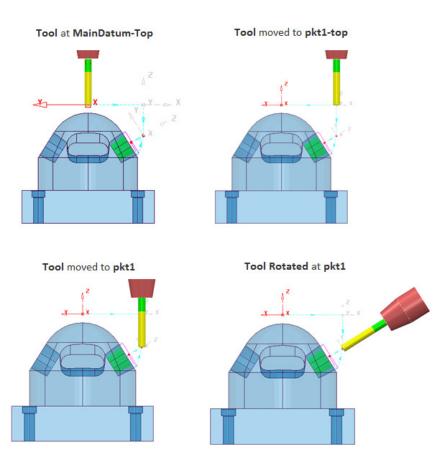


While a **tool** moves to a **Workplane**, it will simultaneously re-align to align to the **Workplane - Z Axis (Simultaneous** is the **NC Preferences** - *default* setting).

The following 4 illustrations show the tool movements to 3 workplanes including a rotational move prior to performing the machining strategy.

L)





Example

An existing **Project** will be opened that contains 4 separate **3 Plus 2**, finishing toolpaths ready to be added to an **NC Program**. Once included in the **NC Program**, appropriate positional moves must be added to prevent the tool from passing through the component form while moving between toolpaths.

1 Select File - Open Project:-

....\PowerMill_Data\FiveAxis\PositionalMoves\AngledPockets-Start

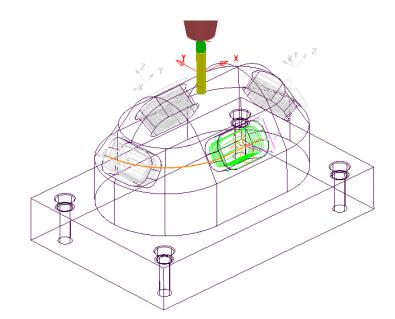


2 Select File - Save Project As:-

....\COURSEWORK\PowerMill_Projects\AngledPockets



Connection moves using a Safe Z calculated to a 3-Axis Workplane



3 In the **PowerMill** *explorer*, right-click on **NC Programs** and from the local menu, select **Preferences**.

Use Project Off V Output Folder C:\	Temp\NCPrograms
Output File {ncprogram}	
Machine Option File :onfig\ductpost\Maz	ak_Variaxis_5axis_ref.pmoptz
Machine Tool V Mod	el Location 🗸 🗸
Output Workplane MainDatum-top 🗸 🔓	Part Name
	Tool Value Tip ~
Automatic Tool Alignment On 🗸 Conne	ection Moves Simultaneous 🗸

- Select a suitable *Five Axis*, Post-Processor *Option File*:
 C:\dcam\config\xtra-posts\ Mazak_Variaxis_5axis_ref.pmoptz
- 5 Select **Close** (The **NC Preferences** settings will be updated).
- 6 Create a new **NC Program** (It will be **Active** on creation).
- 7 Select the four *3plus2* Toolpaths (*D10t1-pkt....*) then right-click over them and in the local menu select Add to > NC Progam.

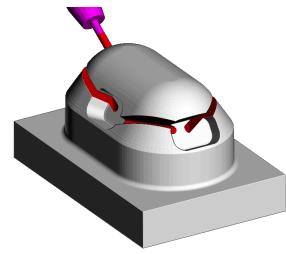


🛓 👘 NC Programs			-	
Toolpaths				🖃 👩 NC Programs
🛓 🔗 🥊 🕩 d40t6-rgh1				📄 – 💡 🔣 > 1
🚛 🕢 🥊 😂 BN16-sem1				🕞 奯 D10t1-pkt1
庄 - 🔗 🥊 😂 D10t1-pkt1				🔒 🔧 D10t1-pkt2
🚊 - 🔗 🥊 🍔 D10t1-pkt2	Toolpaths	(4)		🚽 🕢 🔧 D10t1-pkt3
🚊 - 🔗 🥊 🍔 D10t1-pkt3	······			n 🔁 🚰 D10t1-pkt4
🗄 🔗 🥊 😂 D10t1-pkt4	Draw Selected		/	
🖃 👘 Tools	Undraw Selected			
🖽 🖷 🔮 🚺 D40T6	Add to	•	Stock Model	
	Create Individual NC Programs		NC Program	
in the second s	Load Tool Cutting Data		Group	
🕀 📆 Patterns	Edit		Folder	
Workplanes	Delete Toolpaths			
Market Briter			-	

- 8 Select an **ISO 4** view.
- 9 Run a ViewMILL simulation on the first two, 3 Axis toolpaths; d40t6-rgh1, BN16-sem1, followed by the NC Program containing the four 3plus2 toolpaths.

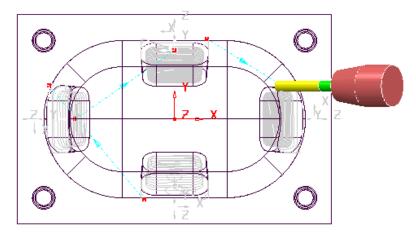


On closer inspection it will be observed that the **3plus2** - **Positional Tool Moves** have ploughed through the component between the individual machining strategies.





If the **Model** is displayed as **wireframe** then the displayed **NC Program** will also include the **link** moves (Pale Blue dashed lines) between the 4 stored **Toolpaths**.

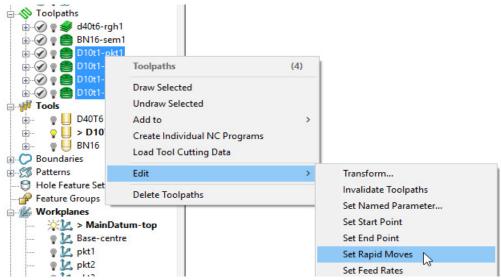




- 10 Activate the workplane MainDatum-top.
- 11 Calculate a Block using *Defined by* Box to the Model dimensions.
- **12** Open the **Rapid Move Heights** dialog.

P Toolpa	th connections								?	×
Safe area	Moves and clea	irances	Start and end point	Lead ins	Lead outs	Links	Point distribut	ion		
Safe are	a				Calcula	te dimer	nsions			
	Туре	Plane		\sim			Measured from	Block and Model	~	
	Workplane	MainD	atum-top	~				Rapid clearance	10.0	
								Plunge clearance	5.0	
Norm	nal <u>]</u> 0.0	0.0	1.0							
	0.0	0.0	1.0					(Calculate	
			Rapid height	2.287618						
			Plunge height	7.287618						
			Use pola	ar links 🗌						

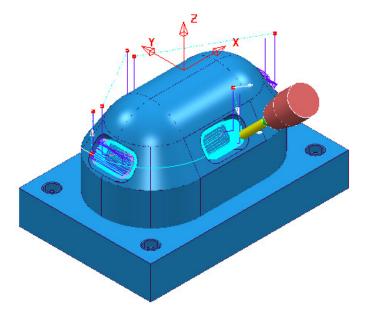
- 13 Input *Workplane* MainDatum-top and Calculate before selecting Accept.
- 14 In the **PowerMill explorer** use the **Shift** key to multi-select the four, 3+2 **toolpaths**.



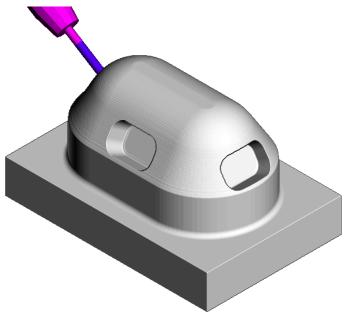
15 Right mouse click anywhere on the four selected **toolpaths**, and from the local menu select **Edit** – **Set Rapid Moves**.



The **Tool** will now perform rapid moves above the top of the **model**, relative to **workplane MainDatum-top**.



16 Run a ViewMILL simulation on the first two, 3 Axis toolpaths; D40t6-rgh1, Bn16-sem1, followed by the NC Program containing the four 3plus2 toolpaths.



The toolpath connection moves no longer collide with the model.

Connection moves using (Drive Curve) Pattern toolpaths

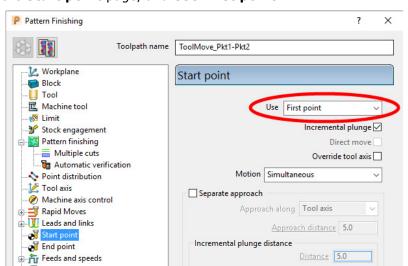
17 From the **Strategy Selector** Select **Finishing** select the **Pattern** finishing strategy and enter data exactly as shown below.

P Pattern Finishing				?	×
	Toolpath name	ToolMove_Pkt1-Pkt2			
Workplane Block Tool Tool Machine tool Mither tool Machine axis control Machin	n	Pattern finishing Drive curve Use toolpath Image: Second stress Drive curve Use toolpath Image: Pkt1-Pkt2 Lower limit Base position Gouge avoidance Tolerance 0.1 Thickness Image: 0.5	Axial offset 0.	0 check	

18 Select the Tool Axis page, and input a *Tool axis* Lead/Lean with *Mode* Vertical selected and a <u>Lean</u> value of 60.

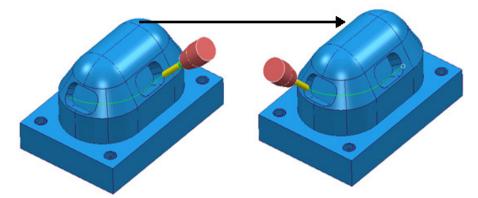
P Pattern Finishing		? ×
Toolpath name	ToolMove_Pkt1-Pkt2	
Workplane	Tool axis	
Tool	Tool axis	
🖳 Machine tool 🕺 Limit 🌮 Stock engagement 🌠 Pattern finishing	Lead/Lean V Lead/Lean angles Lead 0.0	Lean 60.0
Multiple cuts		
Point distribution	Mode Vo	ertical 🗸
···· 🧭 Machine axis control ⊕ - 🛒 Rapid Moves	Fixed angle Ta	angent normal
E-UL Leads and links	None v Po	owerMill 2012 R2





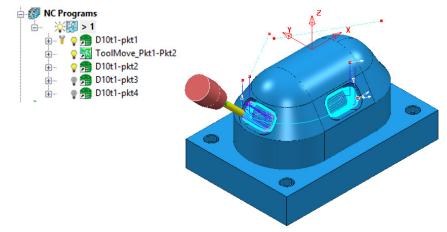
19 Select the **Start point** page, and **Use First point**.

- 20 Select the End point page and Use Last Point.
- 21 In Leads and links set both Lead in and Lead out to None.
- 22 **Calculate** the **Pattern** finishing toolpath.



The **Tool** 'winds' along the **Pattern Finishing** strategy creating a collision safe, transition around the component.

23 Insert the Pattern Finishing strategy (ToolMove-Pkt1-Pkt2) between the toolpaths, D10t1-pkt1 and D10t1-pkt2.



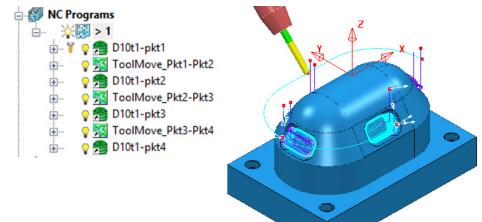


Exercise

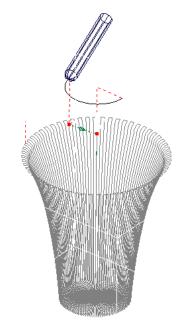
1 Create 2 more suitably positioned, tool move **Pattern Finishing** toolpaths named **ToolMove_Pkt2-Pkt3** and **ToolMove_Pkt3-Pkt4**.

Check the direction of each new Pattern Strategy and if necessary, reverse.

2 Insert the new Pattern Finishing toolpaths into the NC Program.



Tool Axis 'Rewind' Move





A useful application for using a **Pattern** as a **Positional Tool Move** is in cases where a **rotary axis limit** has been reached. A circular, **Pattern Finishing** strategy can be used to '**Rewind**' the **tool** in 3D space, back to the start of its rotary travel limits.





3. Five Axis Tool Alignment

Introduction

For **5-Axis** applications where the machine tool head and\or table, are required to perform both *linear* and *rotational* axis moves simultaneously, **PowerMill** provides a range of appropriate **Tool Axis Alignments** and **Machining Strategies**.

Five Axis Tool Alignment and Machining Options

By default the **Tool Axis** alignment in **PowerMill** is set to **Vertical** for **3-Axis** applications and other options will only be available to users with a multiaxis licence.



Some strategies only support multiaxis Tool Axis alignments if used with Ballnose or Spherical tools.

The **Tool Axis Direction** dialog is accessed via the **Tool Axis** icon kiele located in the **Main** toolbar or directly from supported **Machining Strategy** forms.

The dialog provides a list of basic **Tool Axis** alignment options which are further controlled by a *Strategy* dependent selection of **Mode** options.

P Tool Axis		7	?	×
Smoothing	M	lachine axis cont	trol	
Definition	Limits	Collision avoi	idance	
Tool axis Lead/Lean Lead/Lean angles Lead 0.0	~	Lean 0.0		
Fixed Angle None	Cor	ntact normal ntact normal tical verMill 2012 R2 90.0	\$	

Tool Axis alignment - Mode options

- a **Contact Normal** This measures a **Lead** angle relative to the toolpath contact normal.
- **b** Vertical This measures a Lead angle relative to the Z Axis.
- c **PowerMill 2012 R2** Reverts back to this version that did not offer a choice of **Mode** options (The actual **Mode** options used is strategy specific).
- d Preview frame normal This measures a Lead angle relative to the projection direction to or from the *normal* to the *Projection Strategy*, Preview pattern.
- e **Toolpath** For a basic **Tool Axis** of **From** or **Towards** the actual alignment is relative to the *model surface* instead of the **Preview** pattern.
- f **Preview frame** For a basic **Tool Axis** of **From** or **Towards** the actual alignment is relative to the **Projection Strategy**, **Preview** pattern.
- g Reference tool axis This measures the Lead angle form the tool axis used in a reference toolpath used as the Drive curve in a Pattern Finishing strategy.
- h Tangent Normal This measures the Lead angle relative to the perpendicular to the tangent direction of a Pattern used as the Drive curve in a Pattern Finishing strategy.
- Undercut angle This measures the Lead angle from the projection direction corresponding to the specified undercut angle in a Parametric Spiral strategy.

Lead/Lean - Example1

Lead allows the tool to be aligned to a specified angle <u>along</u> the **toolpath direction** and **Lean** a specified angle <u>across</u> the **toolpath direction**. If both angles are zero the **tool** will be aligned along the direction that a **toolpath** is projected onto the model during creation. For **Pattern** finishing this will always be vertical and for **Projection Finishing** it will vary depending on the defined strategy projection options.

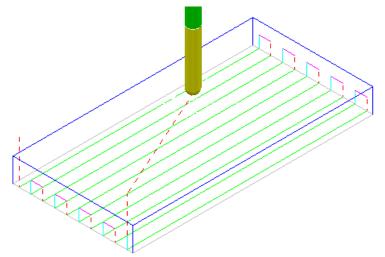
> ► I	
E A	
Z	
1 .	
ŏΖ	
ել ը	
at F	
GLE lpath	

LEAD ANGLE Along Toolpath

1 From the **main** pull down menus select **File** - **Delete All** and **Tools** - **Reset Forms**.



- 2 Open the (Read Only) Project:-
 -\Five_Axis\ToolAlignments\PlaneAlignments_Start



3 Save Project As:-

....\COURSEWORK\PowerMill_Projects\PlaneAlignments_Demo

4 Activate and then Simulate the toolpath BN5-Vertical.

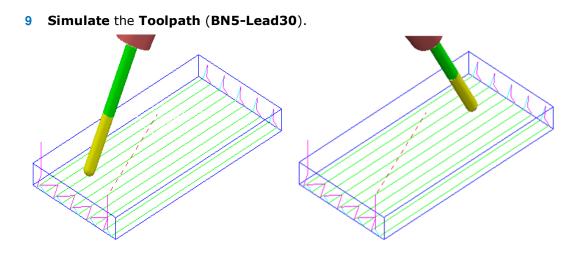
The above **Raster** toolpath is machined with the tool aligned to the **vertical** axis.

- 5 Right-click the **Toolpath Raster Vertical** in the **PowerMill** explorer and select **Settings** to open the original **Raster Finishing** dialog.
- 6 Make a Copy ^[1] of the Toolpath and rename it as BN5-Lead30.
- 7 Select the **Tool axis** page, with the **Tool axis** as **Lead\Lean**, with **Lead -30**, and use **Mode Vertical**.

P Raster Finishing		?	×
Toolpath na	me BN5-Lead30		
- 22 Workplane 	Tool axis		
Тоо	Tool axis		
	Lead/Lean ~		
Stock engagement	Lead/Lean angles Lead Lean		
Raster finishing	-30.0 0.0		
High speed			
Beint distribution	Mode Contact nor	mal 🗸	
Tool axis	Contact norr		-
wiacrime axis control	Vertical		
Rapid Moves	Fixed angle PowerMIN 20	12 R2	
Eads and links	None ~ 90.0		

8 **Calculate** the **Toolpath** and then **Close** the dialog.

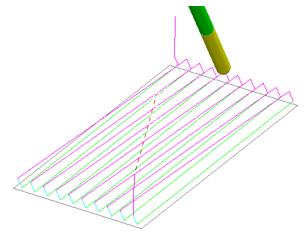




A Raster toolpath has been created with the Tool axis direction set to Lead at -30 degrees relative to the *vertical axis* (Z).

With the Two Way option, the Tool Axis direction will switch on opposing passes. This is due to the **Lead** angle being dependant on the tool track direction.

- 10 In the PowerMill explorer, right-click on the toolpath BN5-Lead30 and select Settings to open the Raster Finishing dialog.
- 11 Select *Re-cycle* May and change *Style* to **One Way**.
- 12 Calculate the Toolpath and then Close the dialog.





With the Style set to One Way the Tool Axis direction remains fixed.

13 Right-click the toolpath BN5-Lead30 in the PowerMill explorer and then select **Settings** to open the toolpath dialog.

14 Select Make a Copy of the Toolpath and rename it as BN5-Lean45.

15 Select the **Tool Axis** icon **I** to open the **Tool Axis Direction** dialog.

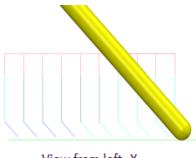
⁵



16 In the **Tool Axis** page, change the **Lead angle** to **0**, and input **Lean 45**.

Workplane	Tool axis
Tool	Tool axis
	Lead/Lean V
	Lead/Lean angles
	Lead Lean
🚊 🚍 Raster finishing	0.0 45.0
<mark>]</mark> ≓ High speed	
🔚 Automatic verification	
	Mode Vertical 🗸
	Contact normal
wiachine axis control	Vertical N
🛓 🚽 Rapid Moves	Fixed angle PowerMit 2012 R2
🛓 🔰 Leads and links	None ~ 90.0
L E . Winstein State	

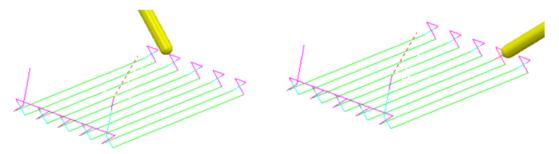
- 17 Calculate the Toolpath and then select Cancel to close the dialog.
- **18 Simulate the Toolpath**.



View from left -X

A **Raster** toolpath has been created with the **Tool Axis Direction** set to **Lean 45** degrees across the **toolpath**.

If a **Two Way** had been directly applied in the strategy dialog, the tool axis would lean in the opposite direction across alternate tool tracks.



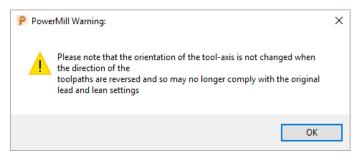
It is possible to create a **Two Way** strategy with a constant **Lean** direction by retrospectively editing a *one way* - **Toolpath**.

19 Right-click on the (One Way) toolpath BN5-Lean45 and from the local menu, select Edit > Reorder to open the Reorder Toolpath Segments dialog.

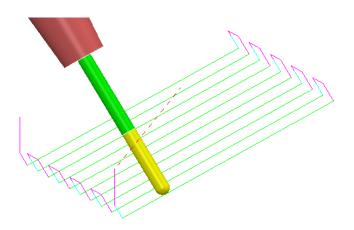
20 Select the **Alternate directions** option (All tool tracks will be edited).



P Reorder Toolpath Segments			?	×	
\sim	#	Start point	End point	Length	Poi
	0	-50.00, -22.50, -9.27	50.00, -22.50, -9.27	100.00	2
	1	50.00, -17.50, -9.27	-50.00, -17.50, -9.27	100.00	2
_	2	-50.00, -12.50, -9.27	50.00, -12.50, -9.27	100.00	2
$\overline{}$	3	50.00, -7.50, -9.27	-50.00, -7.50, -9.27	100.00	2
$\mathbf{\Sigma}$	4	-50.00, -2.50, -9.27	50.00, -2.50, -9.27	100.00	2
$\mathbf{\nabla}$	5	50.00, 2.50, -9.27	-50.00, 2.50, -9.27	100.00	2
	6	-50.00, 7.50, -9.27	50.00, 7.50, -9.27	100.00	2
\approx	7	50.00, 12.50, -9.27	-50.00, 12.50, -9.27	100.00	2
	8	-50.00, 17.50, -9.27	50.00, 17.50, -9.27	100.00	2
T	9	50.00, 22.50, -9.27	-50.00, 22.50, -9.27	100.00	2



21 Select **OK** to close the above **PowerMill Warning** dialog.



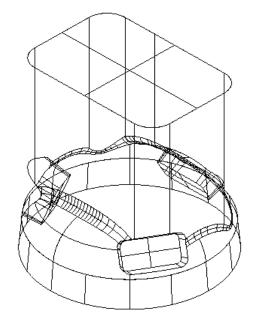
22 Save Project to update:-

....\COURSEWORK\PowerMill_Projects\PlaneAlignments_Demo



Lead/Lean - Example2

- 23 Select File Delete all and Tools Reset Forms.
- 24 **Open** the **Project** (saved earlier during Chapter 1) from:
 -\COURSEWORK\PowerMill-Projects\3Plus2-EX1



- 25 Define a Dia 15mm Ball Nose cutter named BN15.
- 26 Activate the Workplane ztop175_A.
- 27 Create a material Block defined by Box to the Max\Min Limits of the Model and then edit the following values as shown below:

Xmin -95 Xmax -52.5 Ymin -50 Ymax 50

- 28 Open the Rapid Move Heights dialog and select Calculate, then Accept.
- 29 In the Start and End Point dialog in Start Point set First Point Safe and in End Point set Last Point Safe.
- 30 Select Leads\Links 🛄 and in the Toolpath connections dialog set:-

Moves and Clearances:

Axial clearance 15, Incremental plunge distance 5

Lead In\Out: Vertical Arc: *Angle* 90, *Radius* 6 Links: 1st choice\2nd choice: *Skim* and *Default:* Incremental

31 Ensure that no **Boundary** is **Active**.

An area of the component will be machined using **Raster Finishing**. The **Tool Axis** will be aligned to a fixed *Lean angle* of **40** degrees relative to the **Vertical** axis.



- 32 Select the **Toolpath Strategies** icon and in the **Strategy Selector** dialog, select the **Finishing** tab.
- **33** Select the **Raster Finishing** dialog and enter data exactly as shown below:

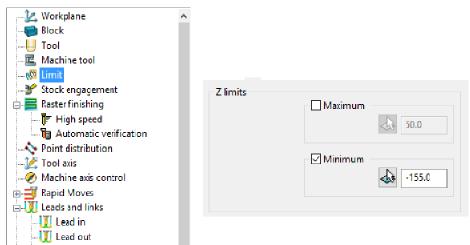
P Raster Finishing	? ×
Toolpath name	BN15-Raster-Lean40
Workplane	Raster finishing
Block	
	Fixed direction
	Angle 90.0
Raster finishing	Start corner Upper left 🗸 🗸
🕞 High speed	Perpendicular pass
Automatic venication	Perpendicular pass
	Shallow angle 30.0
Machine axis control	Optimise parallel pass
Start point	Ordering Style One way ~
Feeds and speeds	Arc radius 0.0
	Tolerance
& User defined settings	0.03
	Thickness
(CTREES	Stepover
	Preview Draw
	Calculate Queue OK Cancel

34 Select the **Tool axis** page and enter data into the dialog exactly as shown in the following illustration.

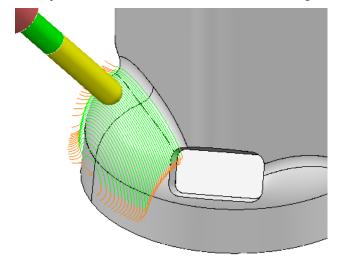
P Raster Finishing	? ×	
Toolpath name	BN15-Raster-Lean40	
Workplane	Tool axis	
	Tool axis	
	Lead Lean	
Raster finishing ☐F High speed	0.0 40.0	
Point distribution	Mode Vertical 🗸	



35 In the Limit page, Z limits, tick Minimum and input the value -155.



36 Calculate the **Toolpath** and then **Cancel** to close the dialog.



The resultant toolpath starts at the lower corner and progresses towards the centre using a climb milling action (**One Way**). If it is required for the strategy to be **Two Way** then it can only be retrospectively changed using **Edit** > **Reorder** > **Alternate Direction**.

To compare the effect of applying a different machining strategy, the same area of the component will be machined using **Projection Plane Finishing**. This time the **Tool Axis** will be aligned using a **Lean** of **0** degrees relative to the *projection direction* of the strategy.

- 37 Calculate a Block, Defined by Box using Type Model.
- 38 Select the **Toolpath Strategies** icon and in the **Strategy Selector** dialog select the **Finishing** tab.
- **39** In the **Finishing** options select **Projection Plane Finishing**.
- **40** Enter data into the following 3 pages of the Plane Projection Finishing dialog, exactly as shown below:



P Plane Projection Finishing	? ×
Toolpath name	BN15-ProjPlane-Lean0
Workplane Block Tool Cool Cool Cool Cool Cool Cool Cool	Plane projection Location -110.0 0.0 -75.0 Image: Comparison of the second se
Feeds and speeds History Notes and Description User defined settings	0.03 Thickness
	Calculate Queue OK Cancel

• Set **Azimuth** to **270**.

🙏 AUTODESK.

• Set **Elevation** to **50**.

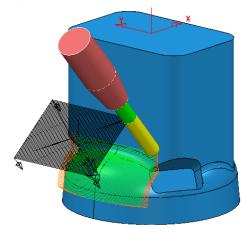
Plane Projection Finishing		?	×
Toolpath name	BN15-ProjPlane-Lean0		
Workplane Block J Tool Kachine tool Stock engagement Stock engagement Stock engagement Automatic verification Comparison Automatic verification Comparison Machine axis control Automatic stribution Comparison Machine axis control Automatic stribution Comparison Machine axis control Comparison Machine axis control Comparison Comparis	Pattern Pattern direction U Ordering One way One way Sequence None Image: Sequence Image: Sequence Limits Height Start -50.0 End 25.0 Width Start 50.0 End -50.0	``	

41 Set **Pattern** direction to **U**.



Workplane	Tool axis
Tool	Tool axis
	Lead/Lean V
🔞 Limit	Lead/Lean angles
	Lead Lean
🚊 🤣 Plane projection	0.0
🔚 Automatic verification	
	Mode Preview frame normal 🗸
🛃 Tool axis	Contact normal
Machine axis control	Vertical
🖶 🚽 Rapid Moves	Fixed angle Preview frame normal
🗉 👿 Leads and links	None V PowerMill 2012 R2
Start point	

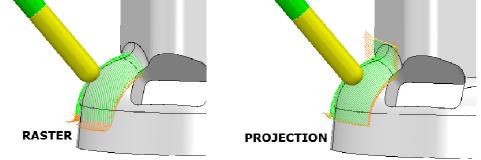
- 42 Calculate the toolpath and then Close the dialog.
- **43 Simulate** the **toolpath** and observe the associated tool alignment.



The resultant toolpath starts at the lower corner and progresses towards the centre with a **Lead in** and **Lean out** both set to **0** creating tool alignment relative to the projection direction. Due to **Lead** and **Lean** being **0** a directly calculated **Two way** strategy is a feasible option.

44 Select a view along the **Y** Axis and then **Simulate** both toolpaths in turn to visually, compare both strategies.

The tool alignment is the same for both toolpaths due to a **Lean** value of **40** being applied to the **Raster** strategy.

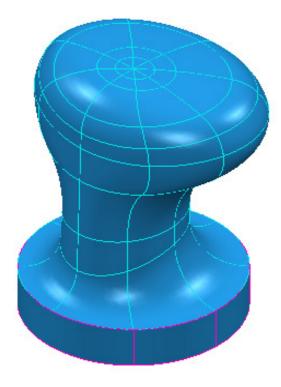


45 Select File - Save Project.



Lead/Lean - Example 3

- 1 Select File Delete all and Tools Reset forms.
- 2 **Import** the **model**:
 - ...\PowerMill_Data\five_axis\joint_5axismc\joint5axis.dgk



3 Save Project As:-

...\COURSEWORK\PowerMill_Projects\Joint-EX1

- 4 Create the material **Block** using **Defined by Box** to the **Model** dimensions and then **expand** it by **15** in **X** and **Y** only.
- 5 Create a Dia 25 Ball Nosed cutter (BN25).
- 6 Select Calculate in the Rapid Move Heights dialog.
- 7 Use the **Start and End Point** default settings.

8 Select Leads and Links 🔛 and input the following settings:

- In Moves and clearances: Tick the box Automatically extend with Maximum length 50, input Incremental plunge distance 10, and Axial clearance 45.
- In Start and end point: *Tick* the box Incremental plunge.
- For *Links* set both **1**st choice and **2**nd choice to Skim.



- 9 Select the Toolpath Strategies icon and in the New Strategies dialog, select the Finishing tab.
- **10** Select **Projection Line Finishing** and enter data exactly as shown in the following 3 pages of the dialog.

Line Projection Finishing	? ×
Toolpath name	BN25-LineProj-1
Workplane	Line projection
Tool 	Pattern Style Spiral ~
	Location 0.0 0.0 22.0
Pattern Automatic verification Point distribution Tool axis	Azimuth 0.0
Machine axis control Hapid Moves Leads and links	Elevation 0.0
	Projection Direction Inwards
Notes and Description	Tolerance 0.02
	Thickness 0.0
The second second	Stepover 2.0 0.080258
1 star	Preview Draw
	Calculate Queue OK Cancel

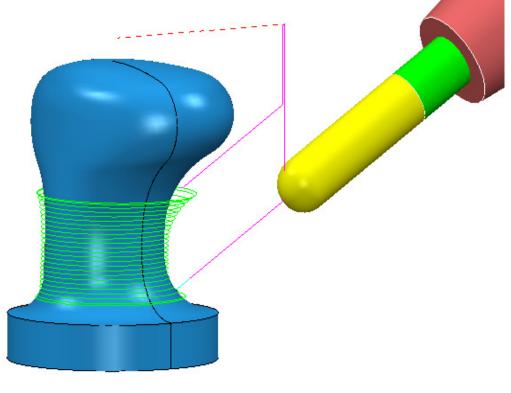
- Set Azimuth to 0
- Set Elevation to 0

Workplane	Pattern
Block	
Tool	
Machine tool	Pattern
🕅 Limit	Style Spiral 🗸
🚊 🛷 Line projection	Direction Clockwise V
🔚 Automatic verification	Limits
	Limits
	Height
Machine axis control	Start 5.0 End 50.0
🗄 🚽 Rapid Moves	
🗄 👿 Leads and links	
	Preview 🗹 Draw



Workplane	Tool axis
Tool	Tool axis
	Lead/Lean V
🕅 Limit	Lead/Lean angles
	Lead Lean
🖕 🍫 Line projection	0.0 -30.0
🔚 Automatic verification	
Point distribution	Mode Preview frame normal 🗸
🔀 Tool axis	

11 Calculate the **Toolpath** and then **Cancel** to close the dialog.





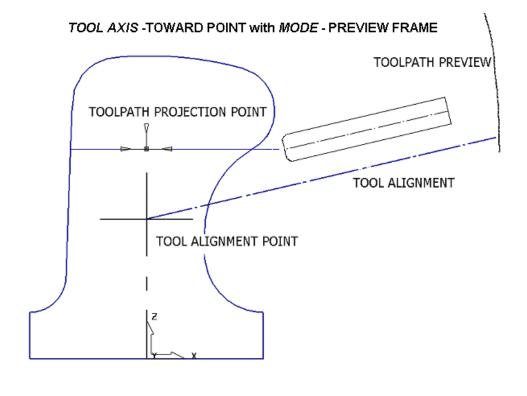
The next section continues with the machining of the upper part of this component.

12 Save the Project (but do not close it down).



Toward \ From Point

These options allow the **Tool Axis** alignment to be based on a user-defined point during the generation of toolpaths (In this case **Towards Point**). If **Mode** - **Preview frame normal** is used then the actual alignment is taken relative to the **Preview** pattern for the strategy and not the final toolpath.



13 Set Leads/Links 💹 as follows:

- In *Moves and clearances*: *Tick* the box Automatically extend with Maximum length 50, input *Incremental plunge distance* 10, and Axial clearance 45.
- Lead In/Out: Surface normal arc, Angle 90 Radius 6
- Lead In/Out Extensions: Extended Move, Distance 30
- Links: Skim
- 14 Select the **Toolpath Strategies** icon and select the **Finishing** tab located in the new **Strategy Selector** dialog.
- **15** Select the **Projection Point Finishing** option.
- **16** In the **Point Projection Finishing** dialog main page, enter data exactly as shown in the following illustration.



P Point Projection Finishing		?	×
Toolpath name	BN25-PointProj-2		
Workplane Block Machine tool Machine tool Machine tool Machine tool Machine pojection Point projection Point projection Point distribution Point distribution Machine axis control Automatic verification Machine axis control Automatic verification Machine axis control Automatic verification Machine axis control Automatic verification Machine axis control History History Notes and Description Viser defined settings	Point projection Pattern Style Spiral Location 0.0 0.0 Projection Projection Direction Inwards Tolerance 0.02 Thickness 0.0 Angular stepover 1.5 Preview Draw		
	Calculate Queue OK Cancel		

17 Select the **Pattern** page and enter data into the dialog exactly as shown in the following illustration.

Workplane	Pattern
Ū Tool ಔ Machine tool 	Pattern Style Spiral ~ Direction Clockwise ~
Pattern Automatic verification Point distribution Yool axis Machine axis control Rapid Moves Leads and links	Limits Elevation angle <u>Start</u> 90.0 <u>End</u> 0.0
Start point End point	Preview 🗹 Draw

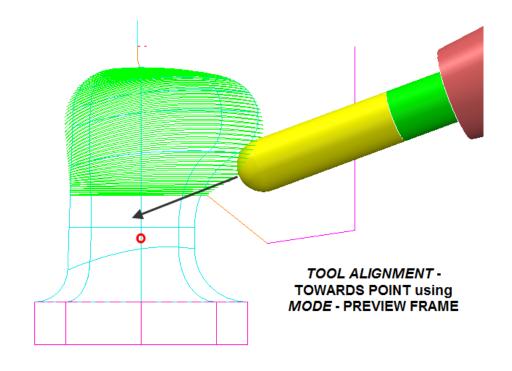
18 Input Elevation Angle data as:- Start 90 and End 0.



19 Select the **Tool Axis** page and enter data into the dialog exactly as shown in the following illustration.

Workplane	Tool axis
	Tool axis
🖳 🔟 Machine tool	Towards point 🗸
	Point
	0.0 0.0 50.0
🖕 👆 Point projection	
🔓 Automatic verification	
🛃 Tool axis	Mode Preview frame V
🔗 Machine axis control	
🗄 🚽 Rapid Moves	Fixed angle
🗄 🖳 🚺 Leads and links	None ~ 90.0
Start point	

20 Calculate the Toolpath but <u>do not</u> close the dialog.





The **Tool Alignment** point is approximately **20mm** below the **Projection Finishing** focal point to ensure that the spindle axis remains at an elevation angle to the machine tool table during machining hence avoiding collision.

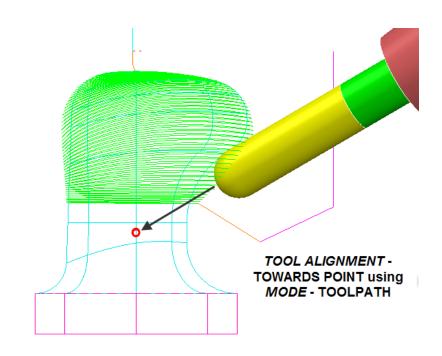
Mode – Preview Plane:- The actual **Tool** alignment occurs on the **Projection Point Finishing - Preview** pattern, after which the tool is then projected on to the model (towards the **strategy - focal point**).



- 21 In the **Point Projection** dialog select *Re-cycle* and then open the **Tool Axis** page.
- 22 Change the *Tool axis* Mode to Toolpath.

	Workplane	Tool axis
		Tool axis
		Towards point ~
	🔞 Limit	Point
		0.0 0.0 50.0
	🚊 🗄 boint projection	
I		
I	🔚 Automatic verification	
I		
I		Mode Toolpath V
	Machine axis control	
	🗄 🚽 Rapid Moves	Fixed angle
	🗄 🖳 🚺 Leads and links	None ~ 90.0
L	Start point	

23 Calculate the Toolpath and then Cancel to close the dialog.



Mode – Toolpath:- The **Tool** alignment is applied directly on to the finished toolpath (towards the **strategy focal point**).

24 Select File - Save Project.

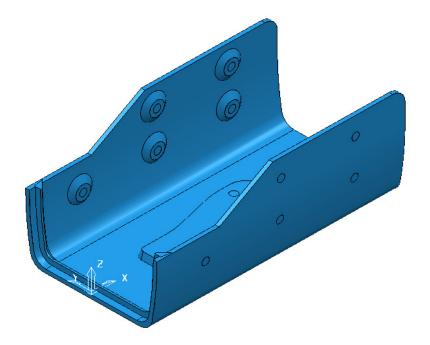


Toward\From Line

These options allow **tool axis alignment** to be **towards** or **from** a user-defined line, specified by a **Vector** direction through a suitably positioned **XYZ** coordinate.

- 1 Select File Delete all and Tools Reset forms.
- 2 Import the Model:-

...\PowerMill_Data\five_axis\Casing\from-line-model.dgk



3 Save Project As:

...\COURSEWORK\PowerMill_Projects\CameraCasing

- 4 Create a Dia 12 Ball Nose cutter named BN12 of Length 55 with:-
 - Shank of Dia 12 Length 40.
 - 1st Holder Lower Dia 25 Upper Dia 40 Length 40.
 - 2nd Holder Upper/Lower Dia 40 Length 60 Overhang 90.
- 5 Define the **Block** (use **Box**) to the **Model** limits.
- 6 Select Calculate in the Rapid Move Heights dialog.
- 7 Set Leads\Links 🛄 as follows:
 - Z heights: Skim 5, Plunge 5
 - Lead In/Out: 1st Choice Surface normal arc, Angle 45, Radius 5.0
 - Links: 1st choice Circular Arc, Tick Apply constraints

with **Distance < 3**, and **2nd choice** – **Skim**.

- 8 Select the **Toolpath Strategies** icon and in the new **Strategy Selector** dialog, select the **Finishing** tab.
- 9 Select the **Projection Line Finishing** option.

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10 In the **Line Projection Finishing, Pattern**, and **Tool Axis** pages enter data exactly as shown in the following illustrations.

P Line Projection Finishing	? ×
Toolpath name	e BN12-LineProj-FIN1
Workplane	Line projection
	Pattern Style Circular ~
	Location 0.0 75.0
Pattern Automatic verification Point distribution Tool axis	Azimuth
Machine axis control	Elevation 90.0
Start point End point ⊕ Freeds and speeds History	Projection Direction Outwards ~
	Tolerance 0.1
~	Thickness
The second second	Stepover
A PRIM	Preview Draw
	Calculate Queue OK Cancel

- Set Style to Circular
- Input *Location* as 0 0 75
- Set Azimuth to 0
- Set Elevation to 90
- Set Direction Outwards
- Use Tolerance 0.01
- Use Stepover 1



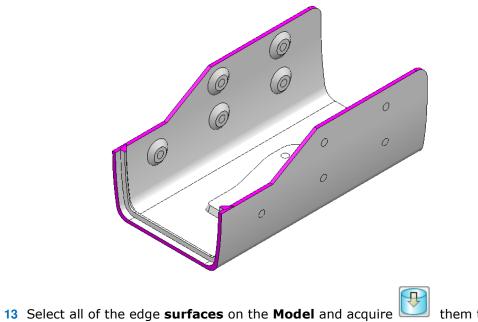
Ø

k	Workplane	Pattern			
	Block				
E	Tool Machine tool	Pattern			
629	Limit		Style	Circular	~
	Stock engagement		_		
	Line projection		Ordering	Two way	~
	Pattern Automatic verification		Sequence	None	~
	Point distribution				
12	Tool axis	Limits			
	Machine axis control	Azimuth angle			
÷-=	Rapid Moves	Start 90.0		End -90.0	
÷ Ū	Leads and links				
	Start point				
	End point	Height			
ur 🗉	Feeds and speeds	Start 0.0		End 200.0	
	History				
	Notes and Description				
-	User defined settings	Prev	riew 🔽 🖸)raw	

- 11 Back in the main Line projection page, select Component Thickness
- **12** Select any one of the 8 rows in the **Component Thickness** dialog.

	ponent Thickn	ess					?	×
urfaces	Verification	Surface De	faults					
Entity Clone								
12.		ing nin	-		~ ~		【	8
Image: Second secon								
Machi	ning Mode			Thickness			_	-
Collisi	on v			0.0			¥	1
Set	Mode	Thickness	Axial	Total Thicknes	ss Total Axial	#		
∞0	Machine	0	-	0	-	0		
1	Machine	0	-	0	-	0		
∞ 2	Machine	0	-	0	-	0		
≪3	Machine	0	-	0	-	0		
∕⊗4	Collision	0	-	0	-	12		
∕⊗5	Machine	0	-	0	-	0		
∞6	Machine	0	-	0	-	0		
-∞7	Machine	0	-	0	-	0		
×	Machine	-	-	0	-	87		
			Apply	Accept	Cancel			





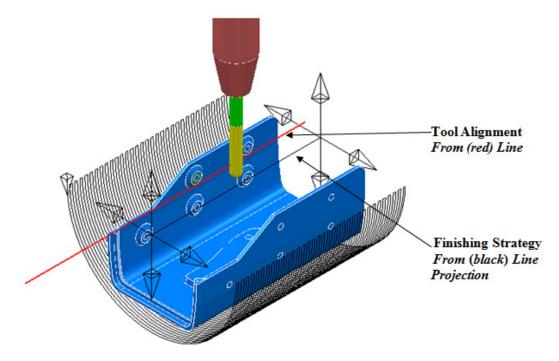
- 13 Select all of the edge surfaces on the Model and acquire between the selected row in the Component Thickness dialog.
- 14 Set the Machining Mode to Collision.
- **15** Apply and Accept the Component Thickness dialog.
- **16** Back in the **Line Projection** dialog select the **Tool Axis** page and enter data exactly as shown below.

Line Projection Finishing	?	×
Toolpath name	BN12-LineProj-FIN1	
Workplane Block Tool Machine tool Machine tool Machine tool Machine action Pattern Automatic verification Point distribution Machine axis control Machine axis control Heads and links Machine axis control Heads and links Machine axis control Machine axis control Heads and links Machine axis control Machine axis	Tool axis Tool axis From line Point 0.0 0.0 Direction 1.0 0.0 Direction 1.0 0.0 Mode Preview frame Fixed angle 90.0 Rotary axis configuration 90.0 Tool axis limits Automatic collision avoidance Tool axis smoothing Draw tool axis	

🗹 Draw tool axis

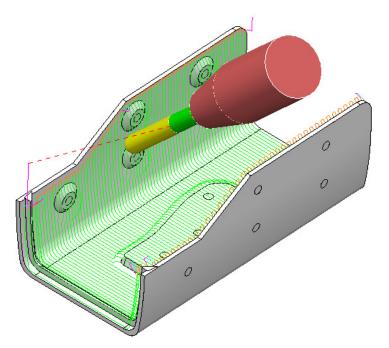
17 Tick the **Draw Tool Axis** box to display the red, **Tool Alignment** line relative to the **Model** (as shown in the following image).





- **18** Click the **Preview** tab to view the strategy before selecting **Calculate** to create the **Toolpath**.
- **19** Close the **Line Projection Finishing** dialog.

The end result (with a larger stepover) is as shown in the following illustration:



The use of **Tool Axis – From line** with **Mode – Preview frame** has ensured that the whole of the internal form, including the undercut areas, is fully accessible. Note that in this case it gives a better result than if **Mode – Toolpath** had been used.

20 Save the Project.



Toward\From Curve

These options allow the **tool axis alignment** to be through a user-defined curve (**Pattern**).

The following example will use the **Surface Finishing** strategy. This is possible due to each of the two different blade areas to be machined being **smooth**, **single surfaces** with the edges aligned to the **surface curves** (The resultant tool tracks will be aligned to these curves).

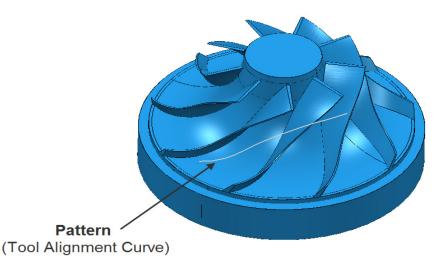
- 1 Select File Delete all and Tools Reset forms.
- 2 Import the Model:

....\PowerMill_Data\five_axis\Impeller\ impeller+Curve.dgk

3 Save Project as:

....\COURSEWORK\PowerMill_Projects\ Impeller+Curve-EX1

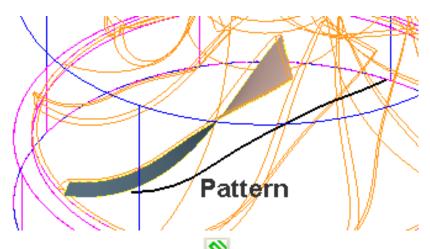
- 4 Create an empty **Pattern** and rename it as **Align2Curve**.
- 5 In the graphics area, select the **wireframe**, *alignment curve* that has been imported with the **Model** (Ensure that both the **Plain Shade** and **Wireframe** views are switched on!).
- 6 Right mouse click on the Pattern (*Align2Curve*) and from the local menu, select Insert > Model to copy the selected *alignment curve* as a Pattern segment.



- 7 Create a **Dia 3 Ball Nosed** cutter (named **BN3-LR**) of **Length 35** with the following **Shank** and **Holder** dimensions:
 - Shank Upper\Lower Dia 3 Length 25
 - Holder 1 Upper Dia 15 Lower Dia 10 Length 50
 - Holder 2 *Upper\Lower* Dia 15 *Length* 35
 - Overhang 50
- 8 Create a **Block** defined by **Cylinder** to the **Model** dimensions.
- 9 Set Links as 1st choice/2nd choice to Skim and Default to Incremental.
- 10 In the Rapid Move Heights dialog select Calculate.



11 Select the underside face of the blade (nearest to the **Pattern**) to be used in the first **Surface Finishing** strategy.



- 12 Select the **Toolpath Strategies** icon and in the **Strategy Selector** dialog select the **Finishing** tab.
- **13** Select **Surface Finishing** and fill in the pages of the dialog exactly as shown in the following illustration.

P Surface Finishing		?	×
Toolpath name	BN3-LwrBlade-FIN		
 Workplane Block Tool Machine tool Limit Stock engagement Pattern Pattern Automatic verification Point distribution Tool axis Machine axis control Tool axis Machine axis control Engli Moves Leads and links Start point Freeds and speeds History Notes and Description User defined settings 	Surface finishing Surface Surface side Outside Surface units Degouge tolerance 0.3 Tolerance 0.02 Thickness 0.0 Stepover (Distance) 0.3 Output Draw Draw	~	
	Calculate Queue OK Cancel		

• Surface side - Outside



Workplane	Pattern
Tool	
🚾 Machine tool	Pattern
🔞 Limit	Pattern direction
🗄 🖖 Surface finishing	Spiral 🗌
Pattern Automatic verification	Ordering One way 🗸 🗸
	Start corner Max U min V 🗸
🖉 Tool axis	
🧹 🖉 Machine axis control	Sequence None ~
Rapid Moves	

- Pattern direction V
- Ordering One way
- Start corner Max U min V

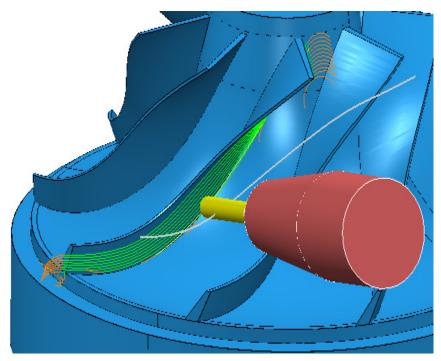
Workplane	Tool axis
	Tool axis From curve Pattern Mign2Curve V 🕅 🕅 🛠
Automatic verification Opint distribution Col axis Machine axis control	Mode Toolpath ~

14 For both Lead in and Lead out use the following for 1st and 2nd choice.

Workplane	Lead in	
Tool	1st choice	
Machine tool	Surface normal arc	~
🔞 Limit		
	Linear move 0.	0
🖕 🖖 Surface finishing	Angle 90	0.0
Pattern		
Automatic verification	Radius 3.	0
Point distribution	Apply constraints	
	Distance V > V 10.	.0
Rapid Moves		
E Leads and links	2nd choice	
	Vertical arc	
	Vertical arc	~
Lead extensions	Linear move 0.	0
Links		
Point distribution	Angle 90	0.0
Start point	Radius 3.	0
- J End point	Apply constraints	
Feeds and speeds	Distance V V 10.	0
\sim		
	× > ×	

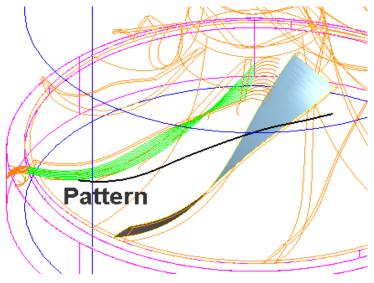
- **15** Click the **Preview** tab and view the strategy before selecting **Calculate** to create the **Toolpath**.
- **16** Close the **Surface Finishing** dialog.





The **Tool Axis** is always aligned through the specified **Pattern** (Curve) while performing the **Surface Finishing** strategy.

- 17 Right-click on the existing **Surface Finishing** strategy and from the local menu, select **Settings** to re-open the dialog.
- 18 In the dialog, select Make a copy of the Toolpath
- Select the upper side, blade surface (nearest to the Pattern) to be used as the Reference Surface in the 2nd Surface Finishing strategy.



20 Open the **Surface Finishing** and **Tool Axis** dialogs, entering the data exactly as shown on the next page and select **Calculate**.

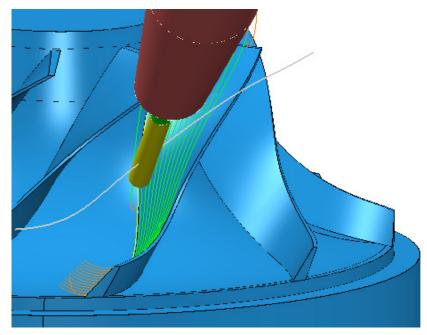


P Surface Finishing		?	×
Toolpath name	BN3-UpprBlade-FIN		
 Workplane Block Tool Machine tool Limit Stock engagement Stock engagement Y Pattern Point distribution Tool axis Machine axis control Rapid Moves Leads and links Start point End point Feeds and speeds History Notes and Description User defined settings 	Surface finishing Surface Surface side Outside Surface units Distance 0.3 Tolerance 0.02 Thickness		

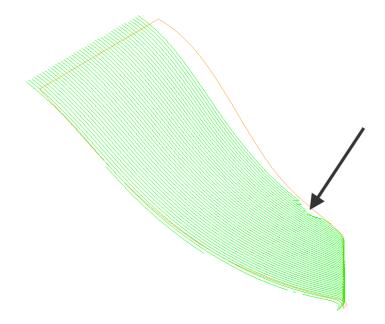
Workplane	Pattern
	Pattern Pattern direction
Surface finishing Pattern	Spiral 📃
Automatic verification	Ordering One way 👻
Tool axis	Start corner Min U max V 👻
Machine axis control	Sequence None -

- Pattern direction V
- Start corner Min U max V
- 21 Click the **Preview** tab to view the strategy before selecting **Calculate** to create the **Toolpath**.
- 22 Close the Surface Finishing dialog.





The **Tool Axis** is always aligned through the specified **Pattern** (Tool Alignment Curve) while performing the chosen machining strategy (**Surface Finishing**).



A small area on the latest toolpath is fragmenting along the top edge as arrowed above. This is caused by one of the other blades getting in the way of the projection process at this point. In this instance an easy fix can be applied by using a copy of the existing **Pattern** and moving it upwards by **1.5**.

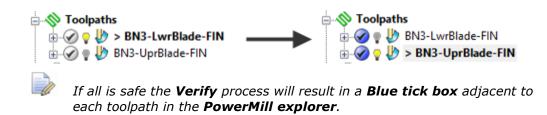
- 23 Create a copy of **Pattern Align2Curve** which will automatically be named as **Align2Curve-1**.
- 24 Move the new **Pattern** upwards by **1.5mm**.
- 25 Recycle the toolpath BN3-UprBlade-FIN with the Tool axis from curve options using Pattern Align2Curve-1.





The toolpath fragmentation on the upper edge has now been fixed.

26 Activate and Verify each toolpath in turn, checking both the Gouge and Collision status (Use a Shank Clearance of 1 and a Holder Clearance of 2).



27 Save the Project.



Fixed Direction

.....

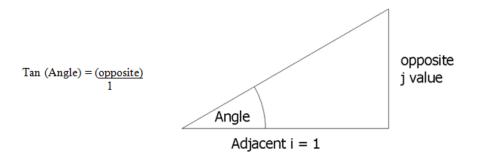
This allows the **Tool Axis** to be set to a fixed angle, specified as a user defined, **Vector**. In this case it is applied to the finishing of an angled recess on the supplied **Model**.

Angle to Vector conversion table

Fixed Direction Tool Alignment - Vectors\Angular equivalents

The table represents angular directions and vectors on the XY plane (Z=0).

	VECTORS	
(I	J	K)
1	0.0000	0
1	0.0875	0
1	0.1760	0
1	0.2680	0
1	0.3640	0
1	0.4660	0
1	0.5770	0
1	0.7000	0
1	0.8390	0
1	1.0000	0
1	1.1920	0
1	1.4280	0
1	1.7320	0
1	2.1450	0
1	2.7470	0
1	3.7320	0
1	5.6710	0
1	11.4300	0
0	1.0000	0
	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	(IJ10.000010.087510.176010.268010.364010.466010.700010.700011.000011.192011.428012.145012.747013.732015.6710111.4300

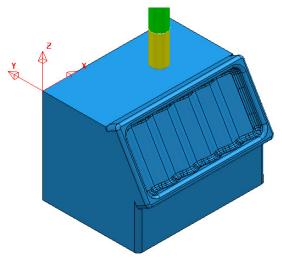


The **Tool Alignment** is set to a **Fixed Direction** relative to the currently active **Workplane** by inputting suitable values as an **I J K vector** along the **Tool Axis** (towards the spindle). Although the correct values for a **vector** may require the user to exercise their trigonometry skills, this method does provide full flexibility for defining compound angles.

- 1 From the **main** pull down menus, select **File Delete All** and **Tools Reset Forms**.
- 2 **Open the (read only) Project:**

📐 AUTODESK.

...\PowerMill_Data\five_axis\AngledFrame\ToolAxisFixed1-Start



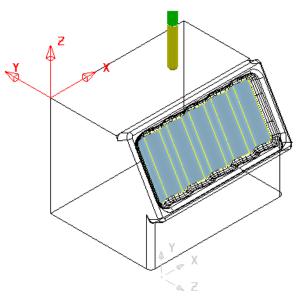
3 Save Project As:

...\COURSEWORK\PowerMill_Projects\ToolAxisFixed-EX1

4 Activate and then *de-activate* the Toolpath **D12t1-ruf-TOP**.

This will restore the settings (**Workplane**, **Rapid Move Heights**, etc) ready to apply a finishing strategy on the corrugated angled form.

- 5 Activate the **BN6** tool.
- 6 Select the undulating **Surface** on the base of the angled recess.

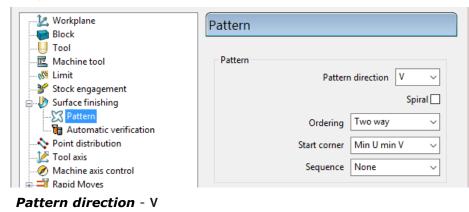




- 7 Select the **Toolpath Strategies** icon and in the **Strategy Selector** dialog select the **Finishing** tab.
- 8 Select the **Surface Finishing** option and fill in the pages of the dialog exactly as shown in the following illustrations.

P Surface Finishing	?	>
Toolpath name	BN6-fin-ANGLE	
	Surface finishing	
	Surface	
	Surface side Outside	
🔞 Limit		
Stock engagement	Surface units Distance	~
 Surface finishing Pattern Point distribution Tool axis Machine axis control Rapid Moves Leads and links Start point Feeds and speeds History Notes and Description User defined settings 	Degouge tolerance 0.3 Tolerance 0.02 Thickness 0.0 Stepover (Distance) 0.5 0.020906 Preview Draw	<u>U</u> ,
	Calculate Queue OK Cancel	

- Surface Side Outside
- Stepover 0.5



• Ordering - Two way

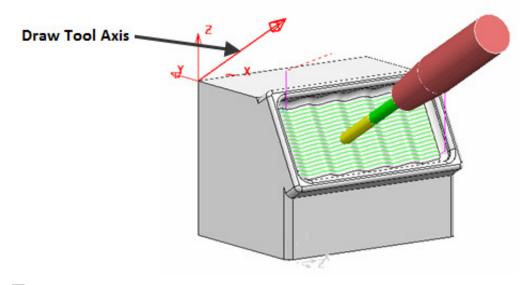


Workplane	Tool axis
U Tool 	Tool axis Fixed direction ~
Surface finishing Pattern Automatic verification Point distribution Cool axis Machine axis control Rapid Moves Casa and links Start point Cool axis Cool ax	Direction 0.0 -1.0 0.577
History Notes and Description User defined settings	 Tool axis limits Automatic collision avoidance Tool axis smoothing ✓ Draw tool axis
9 Set the Tool Axis to Fixed dire10 Input the vector <i>Direction</i> valu	
11 Tick the Draw tool axis box.	

12 From **Leads and links** select the **Links** dialog and enter data exactly as shown in the following illustration.

Workplane /	Links
Block	Ist choice Motion Simultaneous Distance Calculation Simultaneous Distance Calculation Simultaneous Calculation Simulta
Machine axis control Rapid Moves Leads and links Lead in Lead out First and last leads Lead extensions Links Point distribution Start point End point	2nd choice Skim ~ Motion Simultaneous ~
Erects and sneeds	Default Incremental ~ Motion Simultaneous ~

- **13** Click the **Preview** tab to view the strategy before selecting **Calculate** to create the **Toolpath**.
- **14 Close** the **Surface Finishing** dialog.





For viewing purposes, the toolpath shown in the illustration has been created using a 2mm Stepover.

15 From the **main** pulldown menu, select **File - Save** to update the stored **Project**:

...\COURSEWORK\PowerMill_Projects\ToolAxisFixed-EX1

人 AUTODESK.



4. Projection Surface Finishing

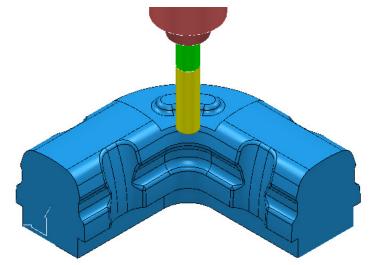
Introduction

In a **Projection Surface Finishing** the strategy is projected **Inwards** or **Outwards** along the normals of a single **Reference Surface**. For five axis applications an appropriate **tool alignmen**t is used. The toolpath runs either across or along the natural **Reference Surface** directions (U or V) with the **Stepover** being defined by unit **Distance** or **Parametric** division between **Surface Curves**. In some cases the **Reference Surface** may form part or all, of the component to be machined.

To create a **Reference Surface** the user will require the services of a suitable **Surface Modeller**, ideally **PowerSHAPE**. For the following example the **Reference Surface** has already been created and stored as a separate *dgk* file to be imported as required. A **reference surface** should be as smooth and simple as possible. It should also be as close as possible to the actual *surfaces* that are to be machined.

1 Open the (Read Only) Project:-

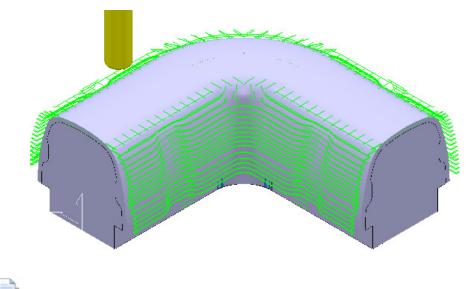
...\PowerMill_Data\five_axis\CornerFixing\ProjectionSurfaceEX1-Start



2 Save Project As:

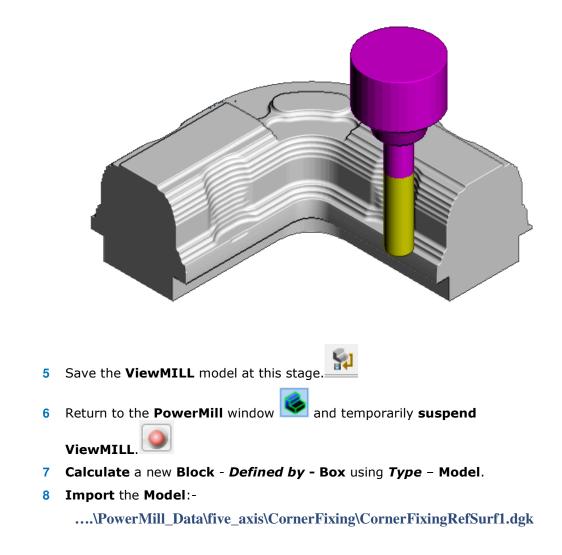
-\COURSEWORK\PowerMill_Projects\ProjectionSurface-Example1
- 3 Activate the toolpath D25TR3-RGH1 to reinstate the settings.





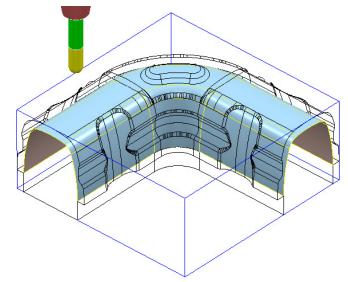
The **Block** used in the toolpath **D25TR3-RGH1** is defined from an imported **Triangle** model (**dmt** file) of a Casting.

4 Run a **ViewMILL** simulation on the toolpath **D25TR3-RGH1**.





- 9 In the **PowerMill** explorer, activate the **BN16** tool.
- 10 In the **PowerMill** *explorer* right mouse click on the **model** named **CornerFixingRefSurf1** and from the local menu select **Select All**.



The newly *imported* (reference) **surface** (shown shaded above) is fully located inside the original component **model**.

- 11 From the main toolbar select the Toolpath Strategies
- 12 From the dialog select the **Finishing** tab followed by the **Projection Surface Finishing** option.
- **13** Enter the values into the *main* page of the **Surface Projection Finishing** exactly as shown below.

P Surface Projection Finish	ing		?	×
وي ال	Toolpath name	BN16-FIN1		
Workplane Block Gottine tool Machine tool Workplane Machine tool Weaking tool Stock engagement Sto	on	Surface projection Surface Surface units Surface Surface units Distance 0.1 Angular smoothing tolerance 0.01 Projection Direction Tolerance 0.1 Thickness 0.0 Stepover (Distance) 2.0	✓ 5535 ✓	
		Preview Draw		



14 Enter the values into the **Pattern** page of the **Surface Projection Finishing** exactly as shown below.

P Surface Projection Finishing			?	×
🔅 🛐 Ta	oolpath name	BN16-FIN1		
Workplane Block Machine tool Stock engagement Stock engagement Stock engagement Stock engagement Automatic verification Pattern Automatic verification Point distribution Point distribution Machine axis control And And And Start point End point Start point Feeds and speeds History Store and Description Vser defined settings	on	Pattern Pattern direction U Pattern direction U Ordering One way Start corner Min U max V Sequence None Limits (Distance) U V Start 0.0 End End 1.0 95.0 Preview Draw	Spiral	

- Pattern direction U
- Start corner Min U max V
- Limits (Distance) V (ticked):- Start 0 End 95
- **15** Enter the values into the **Tool axis** page of the **Surface Projection Finishing** exactly as shown below.

Surface Projection Finishing		?	\times
Toolpath name	BN16-FIN1		
Workplane	Tool axis		
Tool	Tool axis		
	Lead/Lean 🗸		
	Lead/Lean angles		
	Lead Lean		
🚊 🍫 Surface projection	0.0 0.0		
Automatic verification			
	Mode Preview frame	normal 🗸	
🛃 Tool axis	Contact norma	ıl 🗌	1
🖉 Machine axis control	Vertical		
🗄 🚽 Rapid Moves	Fixed angle Preview frame	normal 📐	
	None V PowerMill 2012	2	1
Start point			

16 In the **Tool Axis** page select **Lead/Lean** with both values set to **0**.

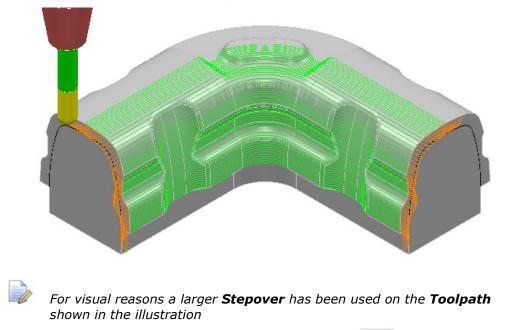


17 Enter the values into the **Tool axis** page of the **Surface Projection Finishing** exactly as shown below.

P Surface Projection Finishing	0	? ×
Toolpath name	BN16-FIN1	
Workplane	Lead in	
U Tool ☑ Machine tool ∞ Limit	Vertical arc	~
Stock engagement	Linear move 3.0 Angle 90.0	_
	Radius 8.0	
> Point distribution > Tool axis > Machine axis control	Distance V V 10.0	
Rapid Moves	× > ×	
	2nd choice None	~
First and last leads		

18 In the Leads and Links pages set:-

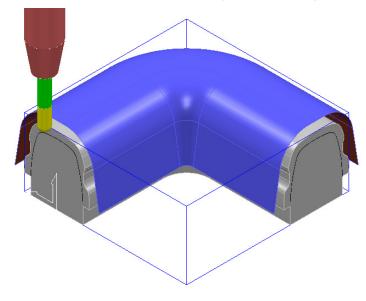
- Set both *Lead in* and *Lead out* Vertical Arc *Distance* 3, Angle 90, Radius 8.
- **19** Select **Calculate** to create the **toolpath**, but do not close the dialog.



20 In the **Surface Projection** dialog select **Make a Copy** to re-activate the **Settings**.

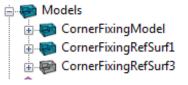
It is possible for all or part, of the **Reference Surface** to exist outside of the component to be machined. In this case the option, **Import Reference Surface** will be used as it is not a part of the component model to be machined.

- 21 Right-click on Models in the PowerMill *explorer* and select Import Reference Surfaces.
- 22 In the Reference Surface dialog, select the Model:
 -\PowerMill_Data\five_axis\ CornerFixing\CornerFixingRefSurf3.dgk





The new **Reference Surface** exists outside the component to be machined. As a result of using the command **Import Reference Surfaces**, the **Machining Mode** is permanently set to **Ignore** for the **Reference Surface**.





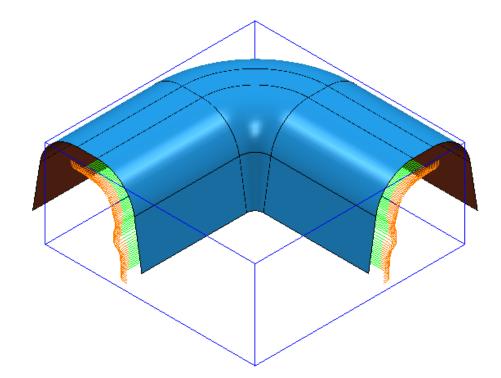
The imported **Reference Surface** is displayed in the **PowerMill explorer** with a different colour (grey).

- 23 Select the *Reference Surface* CornerFixingRefSurf3.
- 24 Rename the **Toolpath** as **BN16-FIN2**.
- 25 In the Pattern page change the Limits (Distance) V as shown in the image below.

Limits (Distan	ce)	
	🔲 U	V
Start	0.0	0.0
End	1.0	130.0
	Preview	Draw

26 Calculate the copied, Projection Surface Strategy.

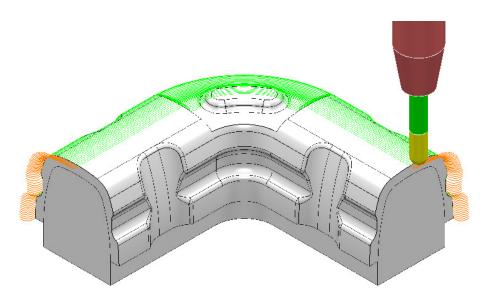




- 27 To update the stored **Project**, select **File > Save Project**:
 -\COURSEWORK\PowerMill_Projects\ProjectionSurface-Example1

Exercise

28 Create a new **Projection Surface Finishing** (named **BN16-FIN3**) starting at the centre of the top face to complete the other side of the component model (as shown below).



29 To update the stored **Project**, select **File > Save Project**:

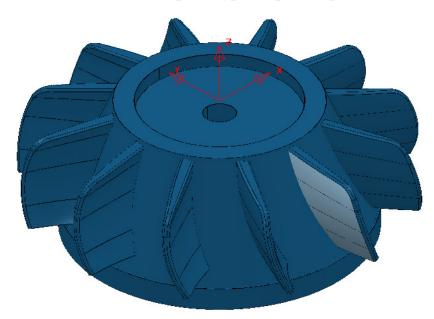


Surface Projection Range.

Depending on the application, it may be necessary to limit the infinite **projection range** while applying the **Surface Projection** strategy. This situation occurs where the part of the model to be machined is shielded by other surfaces that are in the projection path. This command is, at present, only available via typed input into the **PowerMill Command Window**. A more efficient way would be to store the command lines for a range of different distances in a series of **macros**, which in turn could be accessed via a **user defined menu**.

- 1 Select File Delete all and Tools Reset forms.
- 2 **Open** the (Read Only) **Project**:

....\PowerMill_Data\five_axis\ImpellerType2\ImpellerType2-Start



3 Save Project As:-

....\COURSEWORK\PowerMill_Projects\ImpellerType2-EX1

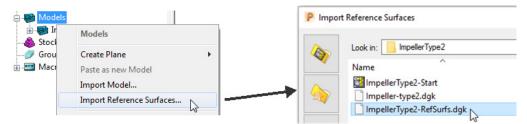
The imported **Project** already contains 3 Roughing **Toolpaths**, and a **Stock Model**.

4 Select an **ISO 1** view.

The next stage is to finish machine the 2 main faces of the blade positioned along the **-Y** direction (Shown shaded light blue in the above image). If the 2 main faces were single surfaces then it would be possible to directly apply the **Surface Machining** strategy (which is not affected by **Projection Range**). This option is not practical in this case as the main faces of the blade consist of several surfaces. As a result it is necessary to obtain 2 suitable single, reference surfaces created using CAD (ideally PowerSHAPE). These will purely be used as **reference surfaces** in the **Projection Surface Finishing** strategy and will not be physically machined.



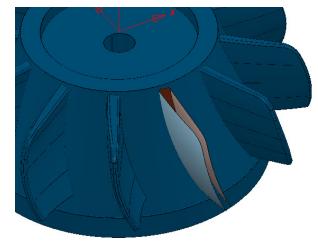
5 In the **PowerMill** *explorer* right mouse click on **Models** and from the local menu select **Import Reference Surfaces**.



6 In the dialog browse to:-

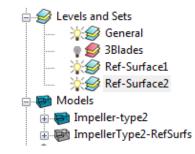
...\PowerMill_Data\five_axis\ImpellerType2\ImpellerType2-RefSurfs.dgk

7 In the dialog select **Open** to import 2 *reference surfaces* (shown below).





By using this import method the 2 **reference surfaces** will always be ignored by a machining strategy during the calculation of a toolpath.





The **reference surfaces** are already acquired to appropriate **levels** (**Ref-Surface1** and **Ref-Surface2**) this being inherited from the CAD process.

- 8 **Calculate** a **Block** using a **Cylinder** to the full **Model** dimensions.
- 9 Calculate the Rapid Move Heights using the default settings.
- 10 Switch off the Level, Ref-Surface2.
- 11 Select the reference **Surface** stored on the **level**, **Ref-Surface1**.
- 12 Activate the Workplane TopFace.
- 13 From the PowerMill explorer, Activate the BN16 tool.



polpath connections						?
area Moves and clearances	Start and end point	Lead ins	Lead outs	Links	Point distribut	tion
ad ins 1st choice Surface normal arc Linear move 0.0 Angle 90 Radius 8.0	Distance	constraints	× > × × > ×	10.0		Separate first lead in
2nd choice Vertical arc Linear move 0.0 Angle 90) Distance	constraints	× > ~	10.0	Le	ad in extension
<u>Radius</u> 5.0			~ > ~			م ج م

14 Set Lead In and Out, 1st choice to use Surface normal arc.

- **15** From the **main** toolbar select the **Toolpath Strategies**
- **16** From the dialog select the **Finishing** tab followed by the **Projection Surface Finishing** option.
- **17** Enter data into the following 3 pages of the **Surface Projection** dialog exactly as shown below.

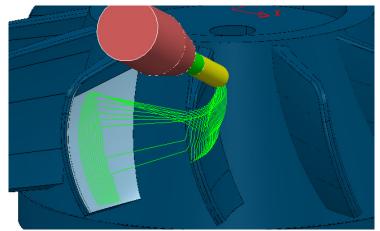
P Surface Projection Finis	shing	? >
	Toolpath name	BN16-Blade1A-FIN
Workplane Block Block Glock G	ification rol	Surface projection Surface Surface units Distance Smoothing tolerance 0.02 Angular smoothing tolerance 0.02 Projection Direction Inwards Tolerance 0.02 Thickness Image: Distance Image: Dist



P Surface Projection Finishing		?	×
Toolpath name	BN16-Blade1A-FIN		
Workplane	Pattern		
Machine tool Machine Limit Stock engagement	Pattern Pattern direction U	~]
Surface projection Pattern Automatic verification	Ordering One way	Spiral]
	Start corner Min U min V Sequence None	~]

Surface Projection Finishing		?	\times
Toolpath name	BN16-Blade1A-FIN		
Workplane Block Glock Gl	Tool axis Tool axis Lead/Lean Lead/Lean angles Lead 0.0 Mode Preview frame n] ormal \	

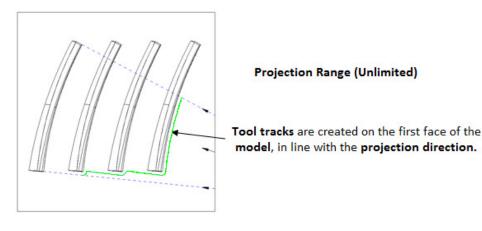
18 Select **Calculate** in the **Surface Projection Finishing** dialog to produce the following toolpath, and then **Close** the dialog.





With the **Projection Range** set to **OFF** (default), ie. No limit, the toolpath is projected inwards towards the surface to be machined from outside the model limits. As the strategy is projected some of it will appear on neighbouring surfaces instead of those intended to be machined and create the toolpath as shown.





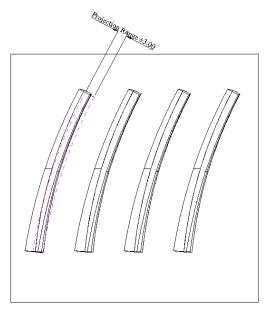
This problem can be resolved by switching to the **Projection Range ON** option and assigning suitable + and - distance values.

19 Right mouse click on the toolpath BN16-Blade1A-FIN and from the local menu select **Settings** to re-open the strategy dialog.



- 20 Select **Recycle**
- 21 From the main pull down menus select: View > Toolbar > Command.
- 22 Enter the following commands into the **Command Window** that has appeared at the below of the graphics area:

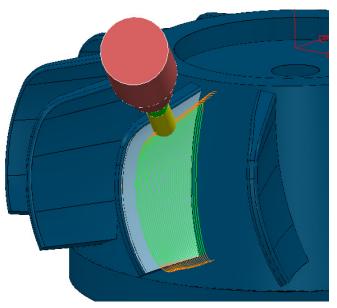
EDIT SURFPROJ AUTORANGE OFF **EDIT SURFPROJ RANGEMIN -3 EDIT SURFPROJ RANGEMAX 3**



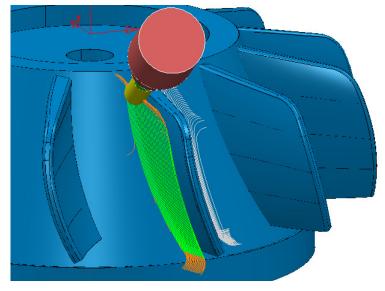
The above command input limits the **Surface Projection** Range to + and - **3mm**.

23 Select **Calculate** to create the new toolpath.





- **24 Simulate** the toolpath to observe the effect of the *limited Projection* Range.
- 25 Create a **Copy** of this **Surface Projection** strategy on the other side of the blade (Use the reference **Surface** stored on **Level**, **Ref-Surface2**).



26 In the **Command Window** type the following to restore the default, *infinite* **Projection Range**:

EDIT SURFPROJ AUTORANGE ON



This command returns to the default **infinite limit** for the **Surface Projection** distance range.

27 select File > Save Project to update the stored Project:

...\COURSEWORK\PowerMill_Projects\Ref-Surfs-Blades

Surface Finishing and Surface Projection - Spiral

Both the **Surface Finishing** and **Surface Projection Finishing** strategies include the option to create a spiral toolpath:



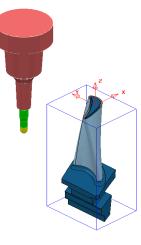
The **stepover** is automatically adjusted so that the final cut finishes exactly on the surface edge at the end of the toolpath.

If you select a **Surface Units** of **Distance**, then the first and last passes will match the edges of the surface. To achieve this, the intermediate passes will adjust to less than or equal to the specified **stepover**.

Projection Surface - Spiral Example

- 1 Select File Delete All and Tools Reset Forms.
- 2 Open the (read-only) Project:

....\PowerMill_Data\five_axis\ProjSurf-Blade\SurfProjSpiral-Start



3 Save Project As:

....\COURSEWORK\PowerMill_Projects\SurfMachine-Spiral

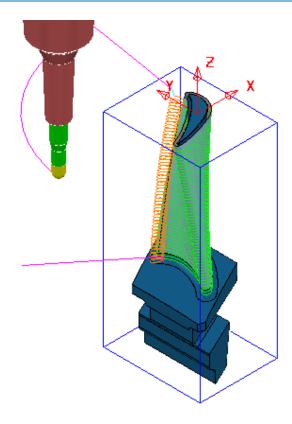


The Strategy in the above **Project** is unprocessed (As indicated by the Calculator icon).

4 In the **PowerMill** *explorer*, right-click on **Toolpaths** to open the local menu and select **Batch Process** to create the toolpath.

Toolpaths		
± 054	Toolpaths	
i ⊡ in tools	Toolbar	
- 💭 Bounda	Create Toolpath	
	Toolpath Names >	
Peature	Folder Names >	
⊡ 🖉 Workp	Batch Process	
🕀 🥩 Levels i	Invalidate All	





The strategy automatically reinstates the original selected **surface** used on a previous occasion. The resultant Toolpath contains independent, stacked tool tracks and Surface Normal Arcs for Lead In/Out. For this strategy it, would be both possible and more appropriate to use the **Spiral** option.

- 5 Right-click on the Active toolpath to open the local menu and select Settings to open the original Surface Projection Finishing dialog.
- 6

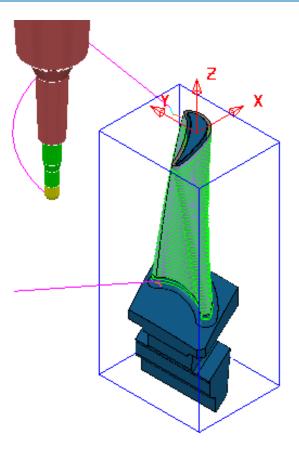
Select *Make a Copy* to re-activate the **Settings**.

Select the **Pattern** page in the **Surface Projection Finishing** dialog. 7

P Surface Projection Finishing		?	×
Toolpath name	SurfaceProjectionSPIRAL		
Workplane Block Jool Machine tool Kimit	Pattern	rection V	
Surface projection	Pattern di	Spir	
Automatic verification	Ordering	ne way	~
Point distribution	Start corner M	lin U min V	~
	Sequence N	one	~

Rename the strategy as **SurfaceProjectionSPIRAL**, tick the **Spiral** box, and 8 check that the *reference surface* is selected, before selecting **Calculate**.





This time the **Projection Surface** strategy consists of a single **Spiral** tool track, providing optimum efficiency and a smooth, consistent material removal.

- 9 Close the dialog.
- 10 Select File Save Project to update:-

....\COURSEWORK\PowerMill_Projects\SurfMachine-Spiral

5. Embedded Pattern Finishing

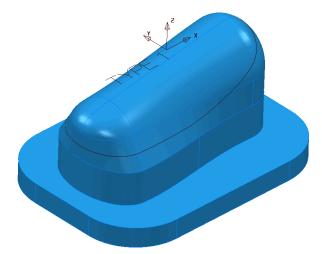
Introduction

This **Five Axis** strategy not only tracks along the **Embedded Pattern** but automatically applies a **Tool Axis** alignment relative to the **Surface Normals**.

An **Embedded Pattern** is created as a projection of an ordinary **Pattern** using the **Edit** - **Embed** option. The **Pattern** projection can be performed down the active **Z Axis** or towards the **closest point** on the **model**.

Embedded Pattern Finishing - Engraving

- 1 Open the (Read only) Project:
 - ...\PowerMill_Data\five_axis\ 5axis_Embedded_Pattern\TrimPart-Start



The **model** includes some wireframe *Text* and a 'scribe line' **curve** running around the form.

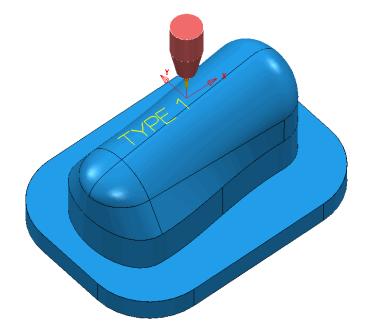
These will each be used create separate **Patterns**. The corresponding **Embedded Patterns** can then created from the 2 new **Patterns**.

2 Select File > Save Project As:

....\COURSEWORK\PowerMill-Projects\Trim-Part

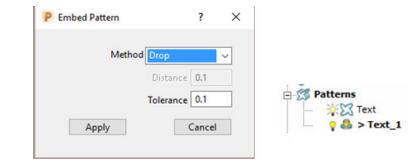


- 3 Activate the toolpath, **BN16-Form-FIN** to reinstate suitable settings for the **Embedded Pattern**.
- 4 Activate the tool **BN2**.
- 5 Ensure that none of the stored **Boundaries** are *active*.
- 6 In the graphics area, select the wireframe part of the model named `**TYPE 1**'.
- 7 In the **PowerMill** *explorer*, right-click on **Patterns** and from the local menu, select **Create Pattern**.
- 8 Right-click on the new (empty) **Pattern** and from the local menu, select **Insert Model** to inherit the selected wireframe text, **`TYPE 1**'.



The first **Pattern** contains the text **`TYPE 1**' and is positioned above the **Model**. This **Pattern** is then used to create an **Embedded Pattern** which projects down **Z** onto the **model**. The **Embedded Pattern** will also pick up and store the **Surface Normals**.

- 9 Rename the **Pattern** as '**Text**'.
- 10 In the **PowerMill** *explorer*, right-click on the **Pattern** and from the local menu select **Edit** > **Embed**.
- 11 From the local menu, select **Method Drop** and **Apply** the dialog.





An **Embedded Pattern** called **Text_1** is created as projected down Z and is identified by the icon ⁴ in the explorer. The original Pattern is retained.



- 12 Select **Toolpath Strategies** and from the **Strategy Selector** dialog sect the **Finishing** tab.
- 13 From the Finishing options, select the Embedded Pattern Finishing.
- 14 Enter the values into the following pages of the **Embedded Pattern Finishing** dialog exactly as shown.

P Embedded Pattern Finishing	? ×
Toolpath name	BN2-Text-FIN
 Workplane Block Tool Machine tool Limit Stock engagement Multiple cuts Automatic verification Point distribution Tool axis Machine axis control Rapid Moves Leads and links Start point Start point Feeds and speeds History Notes and Description User defined settings 	Embedded pattern finishing Drive curve Image: Text_1 Image: Text_1
	Calculate Queue OK Cancel

- Drive curve Text_1
- Axial offset -3
- Untick Gouge Check



PE	mbedded Pattern Finish	ing		?	×
R		Toolpath name	BN2-Text-FIN		
		cation	Multiple cuts Mode Offset down Order by Region Maximum number of cuts 10 Upper limit -1.0 Maximum stepdown 1.0 1.0		~
÷	Teeds and speeds				

15 Tick **Upper limit** with a value of **-1**.

P Embedded Pattern Finishing	?	×
Toolpath name	BN2-Text-FIN	
Workplane Block Tool Kachine tool Kachine tool Kachin	Tool axis Tool axis Lead/Lean Lead/Lean angles Lead Lead 0.0 0.0 Mode Contact normal	

16 Set the **Tool Axis** to **Lead/Lean** both with **0** angles.

It is necessary to ensure that the tool plunges and retracts along the **Tool axis** during **Embedded Pattern** finishing (**Retract distance 5** and **Approach distance 5**).

17 From the main toolbar select Leads and Links, select the Moves and clearances page.

P Toolpath connections							?	×
Safe area Moves and clearances	Start and end point	Lead ins	Lead outs	Links	Point distribution			
Retract and approach moves Along Tool axis Clearances Minimum retract distance 5.0 Minimum approach distance 5.0						<u>Axial clearance</u> Radial clearance	5.0 0.0	
	Maximum length 2	50.0						
□ Incremental plunge distance	Distance 5	.0						

- 18 In both Minimum retract/approach distance, enter 5 (as shown above).
- **19 Accept** the **Leads and Links** dialog.



20 Back in the main strategy dialog select **Calculate** to create the **Toolpath**.



The text **`TYPE 1**' is machined to a total depth of **-3** with the tool aligned to the *Surface Normals*.

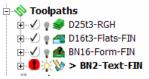
21 Perform a ViewMILL Simulation on all of the Toolpaths.

The **Embedded Pattern** toolpath has been produced with the **tool aligned normal** to the **surface model**.



If the toolpath is **verified** for **gouges** it will take on a **Red** 'gouge' warning. It is not possible to create a toolpath using a -ve thickness value that is higher than the tool tip radius while **Gouge check** is switched on.

This is in technical terms a 'deliberate gouge' and will be ignored.

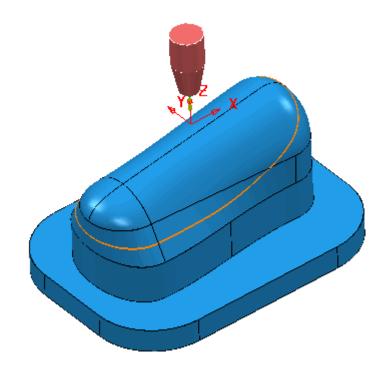


- 22 Create a new **Pattern** named **ScribeLine** and **Insert** the wireframe *Curve*, running around the upper wall of the **model**.
- 23 Create an **Embedded Pattern** from the **Pattern** (**ScribeLine**) but this time select *Closest Point* in the dialog.

P Embed Pattern	?	×
Method Clos	est Point	~
	ance 0.01	
Apply	Cancel	

This time the **Embedded Pattern** results from a projection towards the nearest point on the **Model** (Normals) from the original **Pattern**.





24 Open a new Embedded Pattern strategy named BN2-ScribeLine-FIN using Drive curve - ScribeLine_1.

Embedded Pattern Finishi	ng	? ×
	Toolpath name	N2-ScribeLine-FIN
Workplane Block Block Urool Kachine tool Ka	ation	Embedded pattern finishing Drive curve ScribeLine_1 Image: ScribeLine_1 Ima

- Axial offset: 0
- Gouge check: Ticked
- Thickness: -0.75

This time the required **Depth Of Cut** is less than the **Tool Tip Radius** allowing the **Thickness** option to be used instead of **Axial offset**.



P Embedded Pattern Finishing		?	×
Toolpath name	N2-ScribeLine-FIN		
Workplane	Multiple cuts		
U Tool Machine tool Limit	Mode Off		~
¥ Stock engagement ⊡} Embedded pattern finishing	Order by Region	n	~
Gouge avoidance Multiple cuts Automatic verification	10		
	Upper limit		
Machine axis control Appid Moves Leads and links	Maximum stepdown		
Start point	1.0		

Set Mode: Off

• Upper Limit: Un-ticked

- 25 Select **Calculate** to create the **Embedded Pattern** toolpath.
- 26 Continue the **ViewMILL** Simulation on the new toolpath.



27 Select File > Save Project.





6. Five Axis Swarf Machining

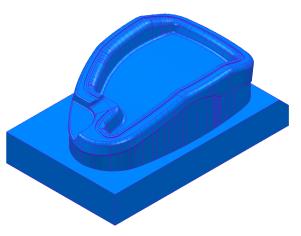
Introduction

Five Axis - Swarf Finishing is designed to create a toolpath where the selected **surfaces** are machined with the side of the tool (the default **Tool Alignment** option is **Automatic**). A **Swarf Finishing** toolpath will only exist where the tool is able to remain in full contact with the selected **surfaces** along the whole cutting depth. In other words, the tool must always be able to find a *Linear* path across the **surfaces**. It is possible for the user to apply a different tool alignment (For example, **Vertical** or **Lead\Lean**) but the selected **surfaces** must still be *Swarfable* for machining to occur.

In cases where imported **surfaces** are supposed to be **Swarfable** but are not of a suitable quality, the upper and lower edges can be created as separate (wireframe) **Patterns** to be used with **Wireframe Swarf Finishing**.

Swarf Finishing - example 1

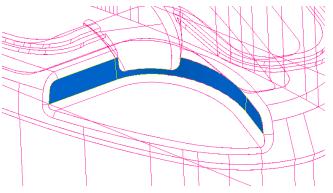
- 1 Select File > Delete All followed by Tools > Reset Forms.
- 2 Import the model:
 -\PowerMill_Data\five_axis\swarf_mc\swarf_model.dgk



- 3 Create a **Block** using **Type Box** and **Defined by Model**.
- 4 Create a Dia 12, tiprad 1, tool named **D12TR1**.
- 5 Calculate the Rapid move heights.



6 Change the view to **ISO 4** and select the local surfaces to be **Swarf** machined (as shown below shaded).

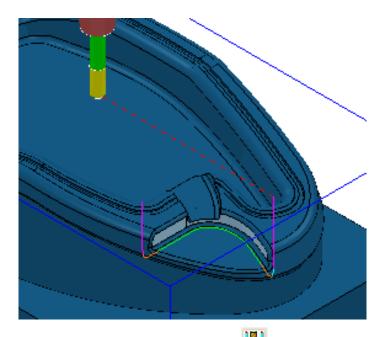


- 7 Select **Toolpath strategies** and from the **Finishing** dialog select the **Swarf Finishing** option.
- 8 Enter the values into the main page of the dialog exactly as shown below and **Calculate**.

The default Tool Alignment is Automatic for this strategy.

P Swarf Finishing	? ×
Toolpath name	e D12TR1-Swarf1
Workplane	Swarf finishing
	Drive curve
Tool	
Machine tool	Surface side Outside 🗸
	Radial offset 0.0
Stock engagement	Minimum fanning distance 0.0
	Fan at end on planes 🗹
Multiple cuts	Reverse axis
High speed	Follow surface laterals
Noint distribution	
- 📝 Tool axis	Surface joining tolerance
Machine axis control	0.3
🖶 📑 Rapid Moves	Gouge avoidance
	Gouge check
	Degouge tolerance 0.3
History	Tolerance Cut direction
Notes and Description	
🕺 User defined settings 🗸 🗸	0.02 Climb ~
	Thickness
THAT	
THE P	
In the	Preview Draw
	Calculate Queue OK Cancel

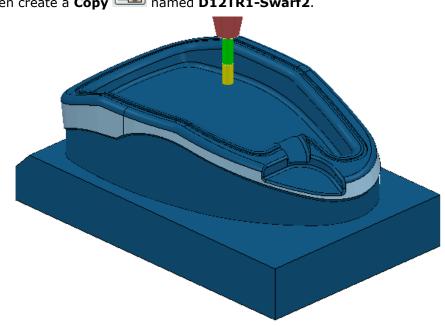




Open the **Leads and links** dialog via the icon **I** and **Apply** the following 9 settings:

Lead in/out:	<i>Vertical Arc</i> - Distance 1	0 - Angle 90 - Radius 5.0
Links:	<i>1st/2nd choice</i> – Skim	<i>Default</i> – Incremental

- 10 Deselect the local surfaces, Simulate the resultant toolpath, and observe the constantly changing tool alignment as it Swarf machines the selected surfaces.
- 11 Select Settings to reopen the existing (active) Swarf Finishing strategy and



then create a **Copy** named **D12TR1-Swarf2**.

12 Select the, upper sidewall, surface (as shown above).



13 Select the **Position** page and set **Base position** - **Bottom** with **Offset** -2.



14 Select the **Multiple cuts** page, with the **Mode** set to **Merge** with **Maximum stepdown 1**.

P Swarf Finishing				?	×	
	Toolpath name	D12TR1-Swarf2				
Workplane Block	^	Multiple cuts				
Tool		Mode	Merge		~	
·····₩ Limit ·····¥ Stock engagement	t l	Order by	Region	`	~	
Swarf finishing		Upper limit	Тор	`	~	
	ice	Workplane			~	
····· <mark> </mark> ■ Multiple cuts ····· ■ High speed			Offset	0.0		
🔚 🖓 Automatic veri	fication	Maximum number of cuts				
Point distribution				10		
Machine axis contr	rol	Maximum stepdown				
E Leads and links		1.0				
Start point						

15 Select the **Tool Axis** page and use the default, **Tool axis** - **Automatic**.

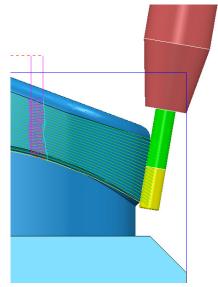
P Swarf Finishing		?	×
Toolpath name	D12TR1-Swarf2		
Workplane Block B	Tool axis Tool axis Automatic		

16 Select **Calculate** at the bottom of the dialog to create the toolpath.



17 Open the **Leads and links** dialog via the icon and **Apply** the following settings:

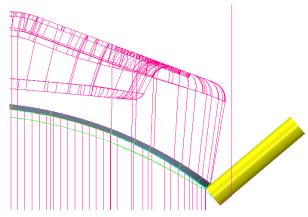
Lead in/out:	Surface normal arc – Dis	stance 0 - Angle 90 - Radius 5.0
Links:	1st/2nd choice - Skim	Default – Incremental



The new **Swarf Finishing** strategy steps down the selected **surfaces** while merging the **stepover** between the **Upper** and **Lower contours**.

Exercise

- 1 Create a Dia 10 End Mill (EM10).
- 2 Create a Copy of the original, single pass, Swarf Finishing strategy to create a new toolpath aligned to the underside of the undercut recess on the outer sidewall.



- 3 Deselect the local surfaces, **Simulate** the resultant toolpath and observe the changing angle of the tool as it **Swarf** machines the selected surface.
- 4 Select File > Save Project As:
 -\COURSEWORK\PowerMill-Projects\Swarf-Example
- 5 Select File > Delete All and Tools > Reset Forms.



Swarf Finishing - Example 2

1 Open the **Project** (created earlier):

```
....\COURSEWORK\PowerMill-Projects\3Plus2-EX1
```

- 2 Activate the Dia 10 tiprad 1 tool (**D10T1**).
- 3 Activate the workplane ztop175_A.
- 4 Make sure that no **Boundary** is **Active**.
- 5 Open the **Block** dialog and select the option **Defined by Cylinder** before selecting **Calculate** (A cylindrical **Block** to the **Model** dimensions will be created).

P Block	? ×	
Defined by		
Cylinder ~	🗁 🖪 🗶 📢 😋	
Coordinate System		
Active Workplane ~	~	
Limits Centre Y 0.000529 -0.000147 Diameter Inner Diameter 174.60261 0.0 Min Max -175.0 -0.251263	Eter Length 174.74873	
Estimate limits		
ToleranceExpansion0.10.0	Type Model v	
Include reference surfaces	Calculate	NET
🗹 Draw	Opacity	
Accept	Cancel	

6 Open the **Rapid Move Heights** dialog and set **Safe area Cylinder** and enter data into the dialog exactly as shown below, before selecting **Calculate**.

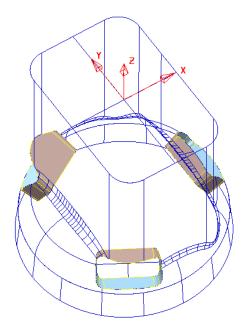
🥐 Toolpat	th connections				3				?	\times
Safe area	Moves and clea	arances	Start and end point	Lead ins	Lead outs	Links	Point distribut	ion		
Safe are					Calcula	ate dimer	nsions			
	Туре	Cylind	er	~			Measured from	Block and Model	~	
	Workplane	Toolpa	ath workplane	~				Rapid clearance 10.0		
Positi	-0.000046	-0.000	-185.0	X Y z				Plunge clearance 5.0		
Direct										
	0.0	0.0	1.0	2				Calcu	ılate	
			Rapid radius	97.301948						
			Plunge radius 9	92.301948						
		Polyg	onisation tolerance).2						

Input the Workplane ztop-175_A and set a Direction (vector) 0 0 1

The use of **Safe area - Cylinder** will produce smoother **link** moves around the cylindrical form instead of point to point, linear moves.



- 7 Set both Lead in/out to Surface normal arc with Angle 90 and Radius 4.
- 8 Select all three *sidewall surfaces* for the three pockets.



- 9 Select Toolpath Strategies and select the Finishing option located in the Strategy Selector dialog.
- **10** Enter the values into the pages of the **Swarf Finishing** dialog exactly as shown.

Swarf Finishing		?
(2)	Toolpath name	D10TR1-FinPkts
- 12 Workplane Block	^	Swarf finishing
Tool		Drive curve
		Surface side Outside
- Millerinie cool		
Stock engagement		Radial offset 0.0
Swarf finishing		
Position		Minimum fanning distance 0.0
Gouge avoidance		Fan at end on planes 🗸
Multiple cuts		Reverse axis
- High speed		
Automatic verifica	tion	Follow surface laterals
Point distribution		
Tool axis		Surface joining tolerance
Machine axis control		0.3
Rapid Moves		
Leads and links		Gouge avoidance
Start point		Gouge check 🗹
		Degouge tolerance 0.3
Feeds and speeds		
		Tolerance Cut direction
Notes and Description	1	0.03 Climb
🤱 User defined settings	¥	Cimb
		Thickness
The	-	
HTY E		

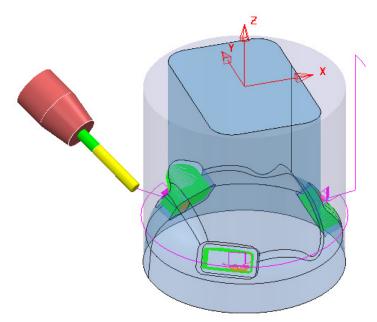


P Swarf Finishing				?	×
	Toolpath name	D10TR1-FinPkts			
Workplane Block	^	Multiple cuts			
····· <mark>U</mark> Tool ····· Ⅲ Machine tool ····· № Limit		Mode	Merge	~	
Stock engagement		Order by	Region	~	
Swarf finishing		Upper limit	Тор	~	
Gouge avoidanc	e	Workplane		\sim	
			Offset 0.	0	
Automatic verifi	cation	Maximum number of cuts			
Tool axis			10)	
Machine axis contro	bl	Maximum stepdown			
Leads and links		1.0			

- Mode Merge provides continuous tool tracks as variable offsets between the upper and lower edges of the swarfable, surfaces.
- Use: Maximum stepdown 1.0

The default **Tool Axis** setting for **Swarf Finishing** is **Automatic**.

11 Select **Calculate** to process the **Toolpath**.



Note the **link** moves follow a *cylindrical path* as defined in the **Rapid Move Heights** dialog. This will provide both smoother tool *link* and **re-orientation** moves between separate machining areas.

- 12 **Simulate** the toolpath (**D10TR1-FinPkts**) and observe the changing angle of the tool as it **Swarf** machines the selected surfaces.
- 13 Select File > Save Project to update:
 -\COURSEWORK\PowerMill-Projects\3+2example

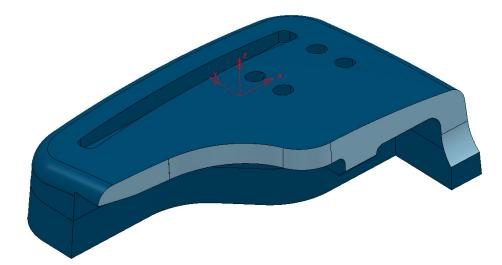
Swarf Finishing - Example 3

There are situations where **swarfable surfaces** do not provide an acceptable **tool alignment** around the component form. In these cases the only obvious solution is to use a separate CAD package (eg **PowerSHAPE**) to re-model the affected **surfaces**.

In the following example a **Swarf Finishing** strategy will be applied on 5 selected **surfaces** (As shown, shaded **pale blue** in the following illustration). Due to the way the **Surfaces** have been designed the resultant toolpath will not produce an acceptable tool track along the existing form. To fix this a new 'fit for purpose' **surface model** of the swarfable face will be **imported** and used to produce a much improved **Swarf Finishing** toolpath.

- 1 Select File > Delete All and Tools > Reset forms.
- 2 Select File > Import Model:

...\PowerMill_Data\five_axis\swarf_mc\SwarfSurfModel-A.dgk



3 Select File > Save Project As:

....\COURSEWORK\PowerMill-Projects\SwarfSurf-EX3

- 4 Activate the *Workplane* TopCentre.
- 5 Calculate a Block, Defined by Box and using Type Model.
- 6 Still in the **Block** dialog, **Lock** the **Z** values, input an **expansion 10**, and **Calculate** again,
- 7 Create a Dia 12 End Mill (named EM12).
- 8 Calculate the Rapid Move Heights.
- 9 Set the Start Point to First Point Safe and End Point to Last Point Safe.
- 10 Set both the Lead in and Lead out to Surface normal arc with Angle 90 and radius 6.
- 11 **Select** the 5 **Surfaces** required to be **Swarf** machined as shown **pale blue** in the above illustration.



12 Select Toolpath Strategies the Strategy Selector dialog.

- and select the **Finishing** option located in
- **13** Enter the values into the main page of the **Swarf Finishing** dialog exactly as shown.

Swarf Finishing		?
💱 🌆 т	oolpath name	EM12-Swarf-1
Workplane	^	Swarf finishing
Block	ion	Drive curve Surface side Outside Radial offset 0.0 Minimum fanning distance 0.0 Fan at end on planes Reverse axis Follow surface laterals Surface joining tolerance 0.3
a		Gouge avoidance Gouge check Degouge tolerance 0.3 Tolerance Cut direction
Notes and Description	~	0.02 Climb ~
		Thickness
-		Calculate Queue OK Cancel

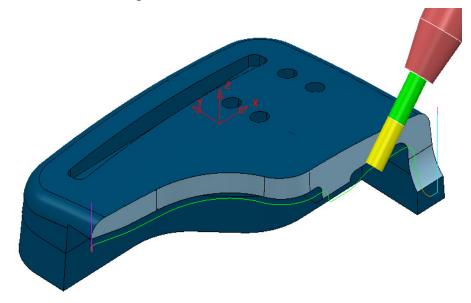
14 Select the Position page and input Offset -1.0

Ρ	Swarf Finishing					?	\times
00		Toolpath name	EM12-Swarf-1				
	🖳 🖳 Workplane	^	Position				
			1 Obition				
	Tool						
			Lower limit				
	🕅 Limit			Base position	Bottom	~	1
							1
	🖳 📶 Swarf finishing			Workplane			
	Position				011-1	0	1
	Gouge avoidance	e			Offset -1	.0	1
	- K.A (42) - 1 4 -						

15 Select **Calculate** to process the toolpath.

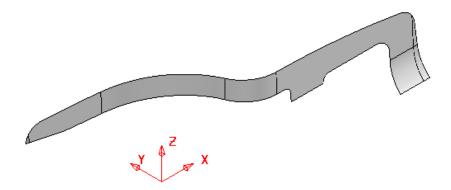


16 Run a slow **Simulation** and observe the changes in tool alignment as it runs along the tool track.



The **Swarf Finishing** toolpath visually looks okay at first until it is run through a **simulation**. This reveals that the **Tool** (**EM12**) is running at an acute angle relative to the **swarfable surfaces** in some areas (as shown in the above illustration). Also, the cutter closely follows the lower edge, causing it to suddenly drop and lift while running around the step.

This strategy can be improved by using different **Surfaces** that are specifically designed to provide a better tool alignment during **Swarf Finishing**.

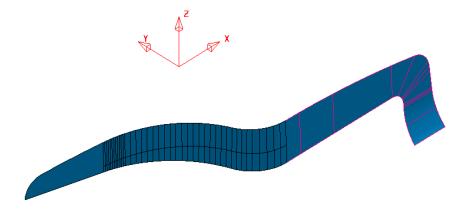


The original 5 **reference Surfaces** used in the **toolpath EM12-Swarf-1** are as shown above. These will be replaced by new **Surfaces** of exactly the same shape within the original model area, but designed specifically to work more effectively with the **Swarf Finishing** strategy.

17 Select File > Import Model:

....\PowerMill_Data\five_axis\Swarf_mc\NewSwarfSurf-B.dgk



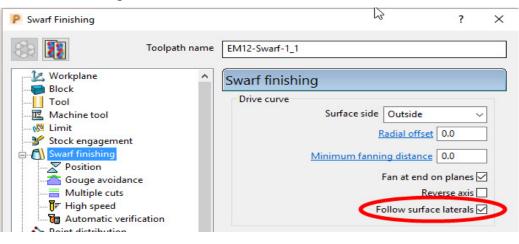


The new **Surfaces** are designed with *surface curves* aligned to match the required **tool alignment**. It is also exactly the same shape as the **5** *surfaces* used in the original **Swarf Finishing** toolpath. Compared with the original 5 surfaces, the lower edge has been extended with a smooth transition constructed along the lower edge of the form.



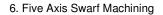
<u>Do Not</u> delete the 5 surfaces used in the original **Swarf Finishing** strategy. They are still required for accurate **gouge** checking.

- **18** Right mouse click on the toolpath **EM12-Swarf-1** and from the local menu select **Settings** to open the strategy dialog.
- 19 In the Swarf Finishing dialog select the option, make a Copy
- 20 Select the new, imported reference surfaces.
- 21 In the main *Swarf finishing* page, tick the box Follow surface laterals to force the tool align to the actual surface curves.

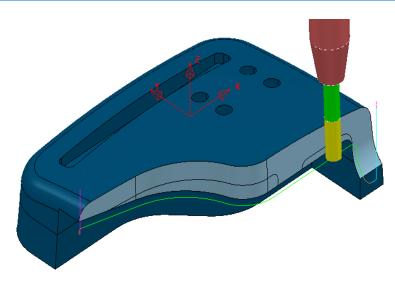


22 Select Calculate to process the new toolpath (EM12-Swarf-1_1).

23 Run a slow **Simulation** and observe the changes in tool alignment as it runs along the tool track.







This time the **Tool** is more suitably aligned to the **swarfable surface** as it runs along the **Toolpath** (**EM12-Swarf-1_1**).

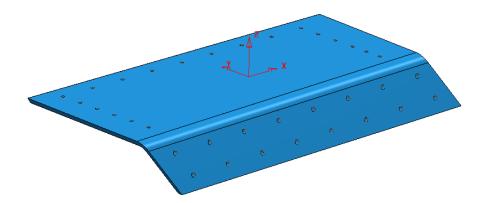
- 24 Select File > Save Project to update:
 -\COURSEWORK\PowerMill-Projects\SwarfSurf-EX3



Swarf Finishing - Example 4

In the following example a **Swarf Finishing** strategy will be applied to trim the edges of an angled plate. Due to the way the original edge **Surfaces** have been designed the tool is unable to maintain a suitable alignment to the model form. To fix this a different set of swarfable edges will be used instead to produce a much improved **Swarf Finishing** toolpath. These surfaces have been created using **PowerSHAPE**.

- 1 Select File > Delete All and Tools > Reset forms.
- 2 Select File > Open Project:-
 -\PowerMill_Data\five_axis\swarf_mc\AnglePlate4-Swarf-Start



3 Select File > Save Project As:

....\COURSEWORK\PowerMill-Projects\ AnglePlate4-Swarf-EX1

- 4 Activate the existing drilling Toolpath **Drill20-Thro**.
- 5 From the **Main** toolbar select **Block**.
- 6 In the **Block** dialog select **Defined by Triangles** with the **Coordinate System** set to **Global Transform**.

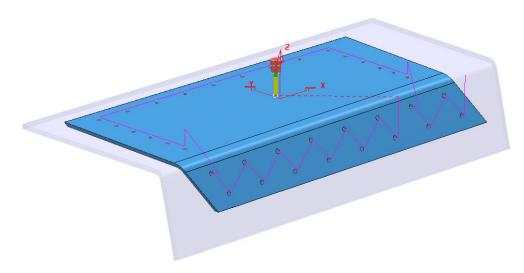
P Block		? ×
Defined by		\sim
Triangles	~	🌔 🛐 🔛 🗶 📢 🕞
Coordinate System		
Global Transform	~	

- 7 Select the Load block from file option.
- 8 In the **Open Block from Triangles** dialog and select the file:-

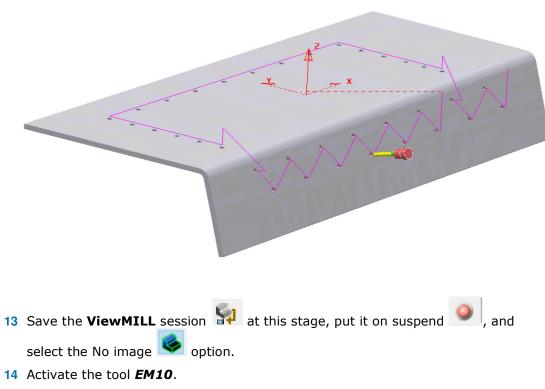
 $....\PowerMill_Data\five_axis\swarf_mc\AnglePlate4-Material.dmt$



9 Select **Accept** to close the dialog.



- 10 Right mouse click on the toolpath **Drill20** and from the local menu select **Simulate from Start**.
- 11 Ensure that the **ViewMILL** toolbar is displayed and click the **Red** button (will change to **Green**) to connect it to the simulation.
- 12 Run a **ViewMILL** simulation on the 2 existing drilling toolpaths **Drill20-Thro** and **EM16-Dia24_Helical**.



15 In the Leads and Links dialog set both Lead in and Lead out to Vertical arc with Angle 90 and Radius 5.

- 16 In the PowerMill explorer, Levels and Sets folder, right mouse click on the Set OriginalEdges and from the local menu click on Select Surfaces.
- 17 From Toolpath Strategies Strategy Selector dialog.

Select the **Finishing** option located in the

18 Select **Swarf fininshing** and enter the values into the pages of the dialog exactly as shown below.

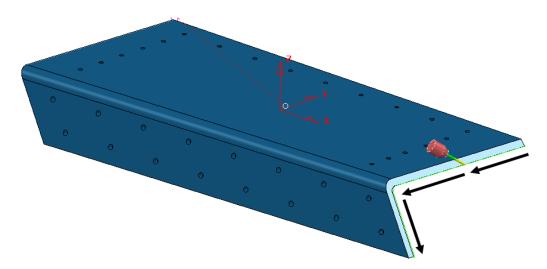
P Swarf Finishing	? ×
Toolpath name	EM10-TrimEdges-FIN1
Workplane Block Tool Machine tool Workplane Yes Machine tool Yes Swarf finishing Yes Position Yes Multiple cuts Yes High speed Yes Yes You distribution Yes You daxis Yes Machine axis control	Swarf finishing Drive curve Surface side Radial offset 0.0 Minimum fanning distance 0.0 Fan at end on planes Reverse axis Follow surface laterals Surface joining tolerance 0.3
Rapid Moves Rapid Moves Leads and links Start point Feeds and speeds History Notes and Description User defined settings	Gouge avoidance Gouge check ✓ Degouge tolerance 0.3 Tolerance Cut direction 0.02 Climb Thickness

Swarf Finishing			?	×
	Toolpath name	EM10-TrimEdges-FIN1		
Workplane Block Dol Machine tool Stock engagement Stock engagement Swarf finishing <u>Position</u> Gouge avoidance	•	Position Lower limit Base positio Workplan		

19 Select **Calculate** to process the toolpath and then **Close** the dialog.

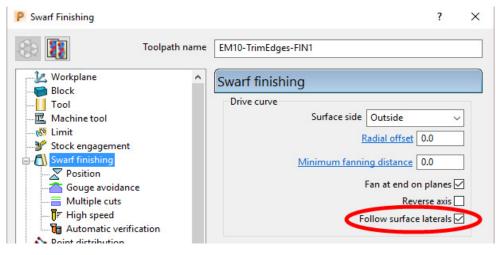


20 Run a toolpath **simulation** and observe the alignment of the tool as it tracks along the selected surfaces.



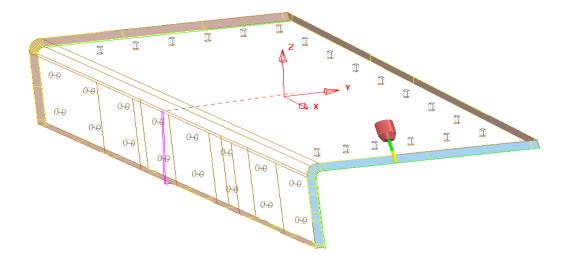
Due to the component edges being planer the alignment of the **EM12** tool is not compelled to remain *Normal* to the main *Angle Plate* surfaces. In the above image the tool has remained cranked over after tracking around a curve in the edge form. There are too many choices for the cutter to use a linear alignment across the swarfable surfaces.

- **21** Right mouse click on the toolpath and from the local menu select **Settings**.
- 22 Select the option to **Recycle** the toolpath.
- 23 In the **Swarf finishing** page tick the box Follow surface laterals.



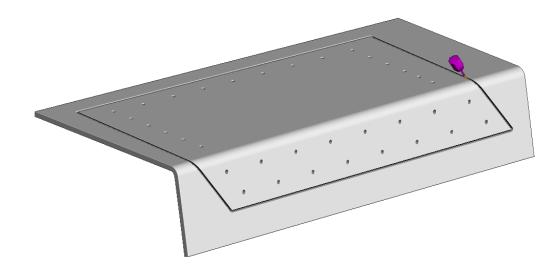
- 24 In the **PowerMill** *explorer*, **Levels and Sets** folder, right mouse click on the **Level NewEdges** and from the local menu click on **Select Surfaces**.
- 25 Calculate the updated Swarf finishing strategy.





This time the tool is aligned to the *laterals* of the replacement swarfable surfaces. These have been re-designed using **PowerSHAPE** surface modelling to produce the above tool alignment.

26 Reconnect the existing **ViewMILL** session and simulate the latest **Swarf finishing** strategy.



27 Select File - Save Project.



Wireframe Swarf Finishing

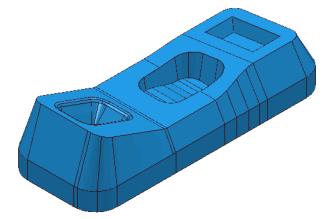
In some cases imported **surfaces** to be used in **Swarf Machining** could be of a poor quality. This would typically include such problems as *mis-matching edges* and/or *un-intentional curves* across the **surfaces**. These problems will undoubtedly result in part or complete failure to create a **Swarf Finishing** strategy.

One solution is to re-model the affected **Surfaces** (assuming the user has access to a suitable CAD system (eg **PowerSHAPE**)).

The other alternative is to create 2 separate **Patterns** that define both edges running along the area to be *swarf machined*. The user can then use the **Wireframe Swarf Finishing** strategy.

The **model** used in the following example contains a pocket in which part of the sidewall is **un-swarfable** due to being slightly convex between the top and bottom edges.

- 1 Select File > Delete All and Tools > Reset Forms.
- 2 Import the Model:
 -\PowerMill_Data\five_axis\swarf_mc\Wfrm-Swarf.dgk



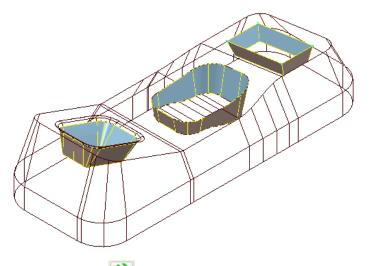
- 3 Select File > Save Project As:\COURSEWORK\PowerMill-Projects\Wframe-Swarf
- 4 Activate the **Workplane** named **Datum**.
- 5 Calculate a Block using *Defined by* Box and Type Model.
- 6 Create a Dia 5 End Mill (EM5) using the following dimensions:

Tool	Dia 5 Length 35
Shank	Lower Dia 5 Upper Dia 5 Length 25
Holder-1	Lower Dia 15 Upper Dia 25 Length 15
Holder-2	Lower Dia 25 Upper Dia 25 Length 15
Overhang 5	0

7 Calculate the Rapid Move Heights.



8 Select the *sidewall surfaces* on each of the 3 pockets in the component.



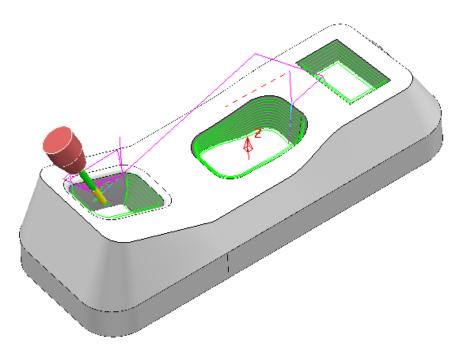
- 9 Select Toolpath strategies and from the Finishing tab select the Swarf Finishing option.
- **10** Enter the values into the 2 pages of the **Swarf Finishing** dialog exactly as shown.

P Swarf Finishing	? ×
Toolpath name	e EM5-SwarfPkts
 Workplane Block Tool Machine tool Machine tool Suraf finishing Swarf finishing Swarf finishing Gouge avoidance Multiple cuts High speed Automatic verification 	Swarf finishing Drive curve Surface side Outside Radial offset 0.0 Minimum fanning distance 0.0 Fan at end on planes Reverse axis Follow surface laterals
Point distribution Point distribution Tool axis Machine axis control Rapid Moves Leads and links Start point End point Feeds and speeds	Surface joining tolerance 0.3 Gouge avoidance Gouge check Degouge tolerance 0.3
History Notes and Description	Tolerance Cut direction 0.02 Climb
A A A A A A A A A A A A A A A A A A A	Thickness Imp 0.0 Preview Draw
	Calculate Queue OK Cancel



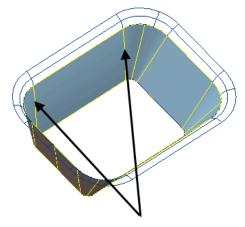
Swarf Finishing	? >
Toolpath n	ame EM5-SwarfPkts
Workplane	Multiple cuts
	Mode Merge 🗸
	Order by Region ~
Swarf finishing	Upper limit Top ~
	Workplane 🗸 🗸
	Offset 0.0
Automatic verification	Maximum number of cuts
Point distribution Tool axis	10
🧭 Machine axis control	Maximum stepdown
	3.0

- Mode Merge and Max Stepdown -3.0
- **11 Calculate** the toolpath.



The **Swarf Finishing** strategy has failed to machine one of the *selected surfaces* due to part of the sidewall being un-swarfable.

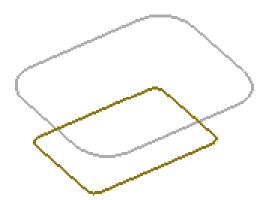




On closer inspection it is evident that some of the curves linking across the **sidewall surface** are convex and as a result make this area un-swarfable.

This problem will be fixed by creating separate **Patterns** along the upper and lower edges of the *sidewall surface* of the affected pocket. The 2 **Patterns** will then be used in a **Wireframe Swarf Finishing** strategy.

- 12 Select the **Surface** defining the angled sidewall of the left hand pocket (shown above).
- 13 Create a Pattern named Upper and right-click over it in the PowerMill explorer selecting Insert > Model from the local menu.
- 14 Select the lower **Pattern** segment.



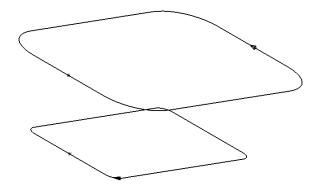
- 15 Right-click on the *Pattern* named **Upper** and from the local menu, select the option **Edit Copy Pattern (selected only)**.
- 16 *Rename* the new, copied **Pattern** as **Lower**.
- 17 Select and **Delete** the *lower segment* from the **Pattern** named **Upper**.

For Wireframe Swarf Finishing to function correctly the two Patterns must travel in the same direction.

It is not compulsory to align the **start points** on the upper and lower **Patterns**. It is the **first point** on the lower **Pattern** that defines the start position of the resultant toolpath.



18 To identify whether the two **Patterns** are suitable for use, right click each one in turn and select **Instrument** to display the start point and direction.





As can be clearly seen the two segments travel in opposite directions creating the need for one to be reversed.

In this case, to create a Climb milling strategy, the lower segment must <i>be reversed.

- **19** Select the lower **Pattern** segment and right mouse click on it to open the local menu.
- 20 From the local menu, select **Edit** > **Reverse Selected**.
- 21 Select the **Toolpath Strategies** and from the **Strategy Selector** > **Finishing** options, select **Wireframe Swarf Finishing**.
- **22** Enter the values into the dialog exactly as shown below:



Wireframe Swarf Finishing			?	×
- 🔃 🚺 To	oolpath name	EM5-WireframeSwarfPkt1	1	
Workplane Block Glock G		Ang	inishing Image: Second system Image: Second system	
		oouge avoidance	Gouge check Degouge tolerance 0.3	
User defined settings	~	Tolerance 0.02 Thickness 	Cut direction Climb	∽_ }_

- 23 Select **Component Thickness** to open the following dialog.
- 24 Select both the sidewall and fillet surface (flanked by the **Patterns**) and acquire them to a selected row (with the **Machining Mode** set to **Ignore**) in the **Component Thickness** dialog.

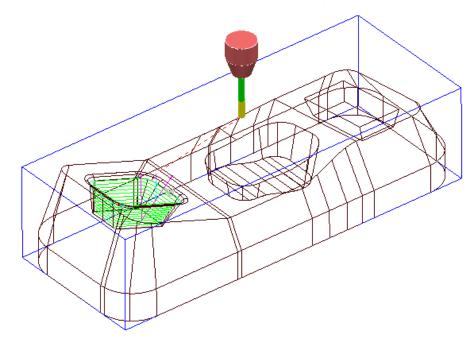
Com	ponent Thickn	ess					?	×
ourfaces	Verification	Surface Def	faults					
Entity	v 1		~	Clo	ne V		~	8
*	\mathbb{P}		Use Axial	Thickness			(<u></u>
~							_	
Machir	ning Mode			<u>Thickness</u>			_	~
Machir Ignore	_]		Į	
	_	Thickness		<u>Thickness</u>	Total Axial	#	Į	
lgnore	~			Thickness 0.0	Total Axial	# 0	ĺ	
lgnore Set	~ Mode	Thickness		Thickness 0.0 Total Thickness	Total Axial -			
lgnore Set	∨ Mode Machine	Thickness 0	Axial -	Thickness 0.0 Total Thickness 0	Total Axial - -	0	Į	

25 Apply the Component Thickness dialog.



P Wireframe Swarf Finishin	g			?	2
و الله الله الله الله الله الله الله الل	Toolpath name	EM5-WireframeSwarfPkt1			
Workplane	^	Multiple cuts			
Tool		Mode	Merge		~
		Order by	Region		~
□	ishing	Upper limit	Тор		~
	e	Workplane			~
			Offset	0.0	
Point distribution	cation	Maximum number of cuts	[10	
Machine axis contro Machine axis contro April Rapid Moves I Leads and links Art point	1	Maximum stepdown 3.0			

26 Calculate the Wireframe Swarf Finishing strategy.



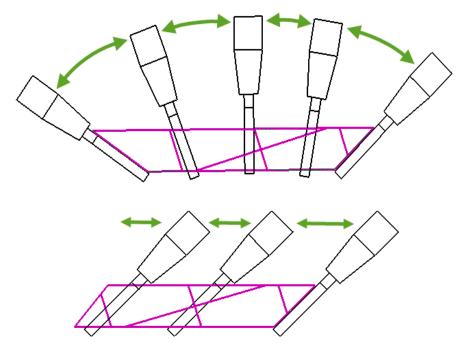
The new **Wireframe swarf finishing** strategy has successfully been applied between the **Upper** and **Lower Patterns**.

- 27 Select File > Save Project to update the Project:
 -\COURSEWORK\PowerMill-Projects\Wframe-Swarf

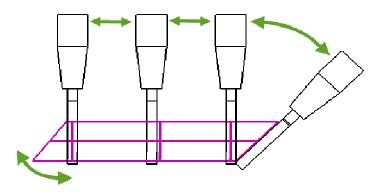


Swarfable Surface Design

When designing a component certain factors will dictate how successfully a **Swarf finishing** strategy can be applied to what appear to be visibly suitable **surfaces**. The fundamental rule is that **Swarf finishing** will only occur where the side of the tool can be in full contact from one side of a surface to the other (Linear). This works fine if the swarfable surfaces are twisting and turning and the tool is able to find a specific linear alignment at all times. If however a **surface** is totally planer then the linear tool alignment can occur at any angle across the swarfable edges.



A *tick box* option exists in the strategy to force the tool to **Follow surface laterals** (natural surface curves). For this to work it is likely that the existing planer swarfable surfaces will need to be re-modelled. This task has to be done using a suitable CAD software such as **PowerSHAPE**.



The above planer **surface** has been designed with the **laterals** aligned to match the required tool axis. The initial angular move is the required transition to or from the end of another selected swarfable **surface**.

7. Flowline Finishing

Flowline Finishing

Flowline Finishing is designed to machine multiple surfaces. The strategy uses 2 *drive curves* and either 1 (closed form) or 2 (open form) *end curves* to define a virtual surface area. Intermediate drive curves can be added to further control the flowline shape. This strategy provides evenly spaced tool passes, irrespective of the underlying geometry.

Advantages over existing toolpaths include:

- Multiple surfaces can be machined.
- Machining of undercut regions is possible.
- The toolpath passes are not determined by the surface parameterisation.
- The region being machined is not forced to be an entire surface or parametric box.
- The stepover is defined in 3D, giving total control over the maximum value.

Flowline Finishing Example

- 1 Select File > Delete All followed by Tools > Reset Forms.
- 2 **Open** the **Project**:

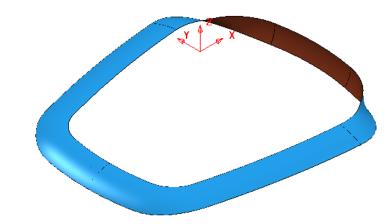
....\PowerMill_Data\five_axis\Flowline\Flowline_EX4-Start



- 3 Select File > Save Project As:
 -\COURSEWORK\PowerMill-Projects\Flowline-EX4



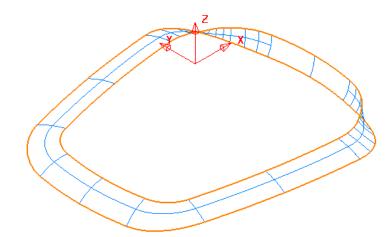
- 4 Activate the *Workplane* MC-Datum.
- 5 Activate the **BN12** tool.
- 6 Calculate a **Block** Using **Defined by Box** and **Type Model**.
- 7 Calculate the **Rapid Move Heights** using the default settings.
- 8 Select the following **5** surfaces and **Blank** the rest (**Ctrl K**).



- 9 Display the **Model** as **Wireframe** only.
- 10 Create a new (empty) Pattern 1.



11 With the above **Surfaces** selected, Right click on the **Pattern** and from the local menu select **Insert** – **Model**.





A Pattern extracted from a selection of surfaces will automatically become *Embedded* (Inherits the surface normals etc).





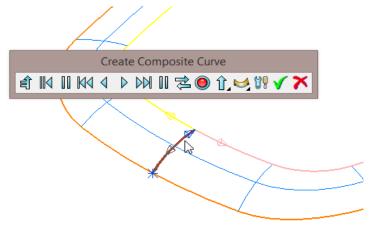
The Pattern symbol changes to identify it as being Embedded.



13 Select the **Composite Curve** option from the **Curve Editor** toolbar.

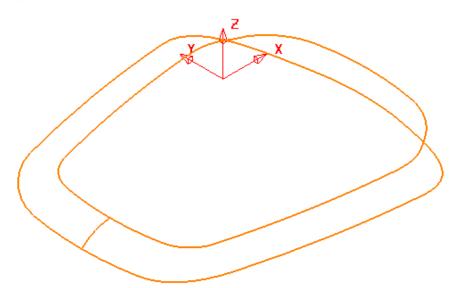


14 With the **Create Composite Curve** toolbar open click near to the upper end of the first surface lateral (As shown arrowed below).



15 In the toolbar select the **red disc** followed by the **green tick** to both *accept the new segment* and *close the toolbar*.

The new **Embedded Pattern** (1) is now made up of 3 segments (2 closed and 1 open).



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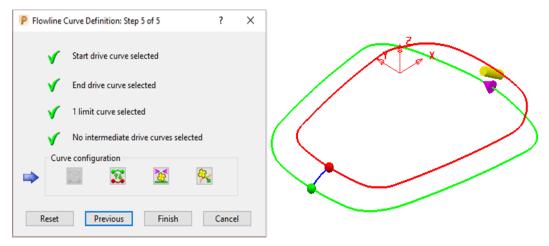


- **16** From **Toolpath Strategies** open the **Finishing** options and from the dialog select **Flowline Finishing**.
- 17 Enter data into the **main** page exactly as shown below.

P Flowline Finishing			?	2
	Toolpath name	Bn12-Flowline-FIN1		
Workplane Block Block Tool Kachine tool Kachine tool Kachine finist Flowline finist Devict distribution Calculation	ning verification	Flowline finishing Curves definition Embedded pattern T Status Valid	X \$ Z	2
Point distribut Tool axis Machine axis April Moves Leads and link Start point End point Feeds and spe	control cs	Sequence None Ordering Two way Surface joining tolerance 0.3	у	~ ~
Notes and Des User defined s		Tolerance 0.02		
				<u>/</u>

18 Still on the main page select the Interactively select pattern segments for





The options in the above form enable the toolpath ordering, directions, etc to be controlled before the toolpath is calculated. However, no changes are required in this instance.



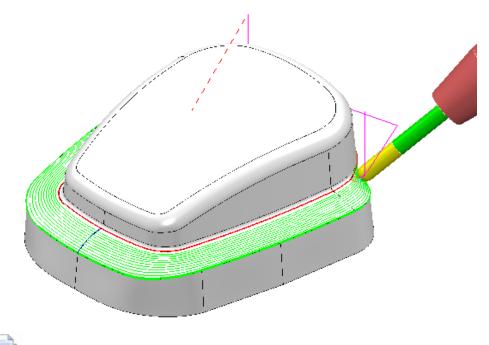
19 Select the **Tool axis** page and select the **Lead/Lean** option with both the **Lead** and **Lean** angles as **0**.

P Flowline Finishing	?	\times
Toolpath name	Bn12-Flowline-FIN1	
Workplane Block Jool Machine tool Kimit Stock engagement Flowline finishing Automatic verification	Tool axis Tool axis Lead/Lean Lead/Lean angles Lead 0.0	
Point distribution Iool axis Machine axis control	Mode Contact normal	-

20 Select **Calculate** to create the following **Flowline Finishing** toolpath.



If the Flowline Finishing toolpath should fail to calculate try to **Embed** *the* **Pattern** *again using* **Closest point** *with* **Distance 0.1** *and* **Tolerance 0.01**



For visual reasons the above toolpath has been created with a 2mm stepover.

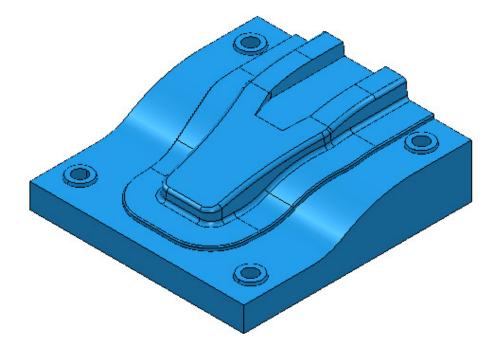
- 21 Right mouse click on the *toolpath* BN12-Flowline-FIN1 and from the local menu select Simulate from Start.
- 22 From the **Simulation** toolbar select *Play* and observe the **Flowline Finishing** process.
- 23 Select File Save Project.
- 24 Select File Delete All and Tools Reset Forms.



Exercise

The purpose of this exercise is to create a suitable **Embedded Pattern** and use *Five Axis* - **Flowline Finishing** to machine the *fillet surfaces* running around the upper edge of a component model form.

- a A single segment, **Embedded Pattern** will be directly created along the edges of the *fillet surfaces*.
- **b** The **Embedded Pattern** will then be split into 4 suitable segments using the **Curve Editor** options.
- **c** The user will then be asked to create a suitable **Flowline Finishing** strategy using the **Embedded Pattern**.
- 1 Import the Model:-
 -\PowerMill_Data\Models\Vortex2.dgk

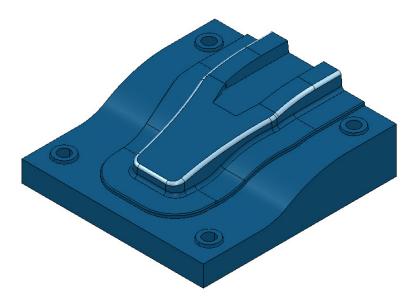


2 Select File > Save Project As:

...\COURSEWORK\PowerMill-Projects\FlowLineFillet-EX1

- **3** Select the whole of the **Model** and the select **Create and Orientate Workplane** – **Workplane** at **Top of Selection**.
- 4 Activate the new **Workplane**.
- 5 Create a *Dia* 8 *Ball Nose* Tool, named **BN8**.
- 6 Create a **Block** using **Defined by Box** and **Type Model**.
- 7 Calculate the **Rapid Move Heights** using the default settings.
- 8 Select all of the **Surfaces** that define the fillet along the upper edge of the main 3D form (As shown below).





9 In the **PowerMill** *explorer* right mouse click on **Patterns** and from the local menu select **Create Pattern**.

10 From the same menu select **Insert** – **Model**.



This will automatically become an **Embedded Pattern** as it inherits the required data from the edges of the selected **Surfaces**.



- 11 Select and **Blank** the whole of the **Model** and Un-draw the **Tool** and **Block**.
- 12 Right mouse click on the **Embedded Pattern** and from the local menu select **Curve Editor**.
- 13 Use Cut item to break the Pattern into separate segments at the four corners of the fillet form.





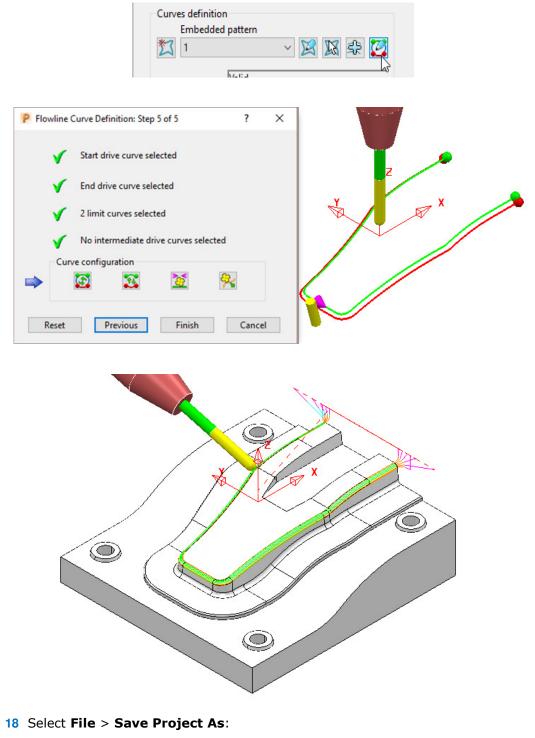
In this example the Embedded Pattern must consist of 4 segments that specifically define the 2 ends and 2 sides of the enclosed fillet.

14 If any of the drive or end curves contain multiple segments, select them and use Merge to reduce them to a single segment.





- **15** Accept the changes (**Green** tick) and return the **Embedded Pattern** from the **Curve Editor**.
- 16 Use the (4 segment) Embedded Pattern in a Flowline Finishing strategy to five axis machine (Tool Axis Lead/Lean 0 using Mode Contact normal) the enclosed surfaces of the fillet form.
- **17** Use the options in **Interactively select pattern segments for the strategy** to control the required toolpath order and direction.

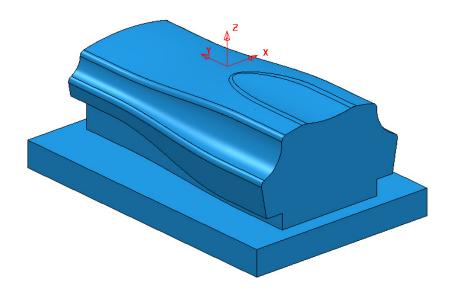


...\COURSEWORK\PowerMill-Projects\FlowLineFillet-EX1



Flowline with intermediate drive curves Example

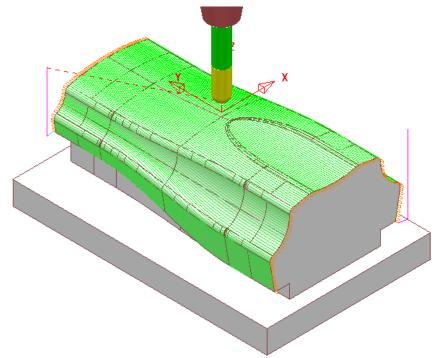
- 1 Select File Delete All followed by Tools Reset Forms.
- 2 Open the Project:
 - $....\PowerMill_Data\five_axis\Flowline\FlowLine-ExtraDriveCurves-Start$



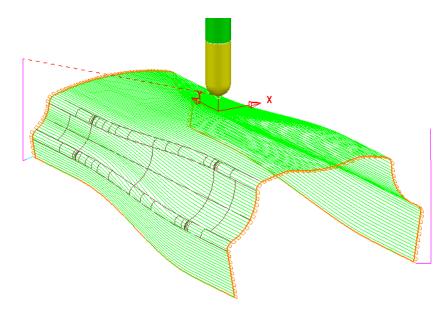
3 Select File - Save Project As:

....\COURSEWORK\PowerMill-Projects\FlowlineWithExtraDriveCurves

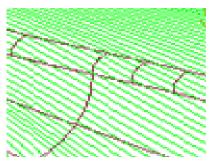
- 4 Select an **ISO 1** view.
- 5 Activate the toolpath **BN16-Flowline-4Curves-All**.







Note that this basic 4 segment, **Flowline** toolpath does not follow the intermediate flowlines of the variable fillet within the model form.



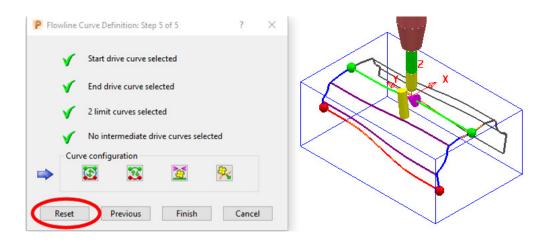
This can be changed if *intermediate drive curves* are included in the **Embedded Pattern**.

- 6 Right mouse click on the active toolpath **BN16-Flowline-4Curves-All** and from the local menu select **Settings** to open the **Flowline Finishing** dialog.
- 7 Select the **Copy** toolpath **I** option and then rename the new toolpath as **BN16-LH-Flowline-ExtraCurves**.
- 8 In **Curves definition**, change the selected **Embedded pattern** to **9Segment**.

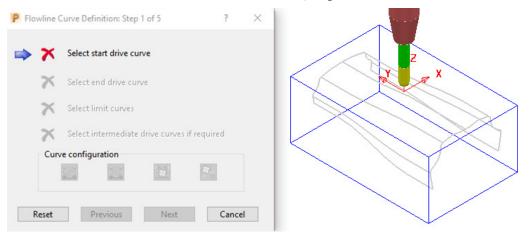
P Flowline Finishing		?	×
Toolpa	ath name BN16-LH-Flowline-ExtraCurves	5	
Workplane Block Tool Machine tool Stock engagement Flowline finishing Automatic verification	Flowline finishing Curves definition Embedded pattern 9Segment Status Valid		2



9 Select Interactively select pattern segments for the strategy.



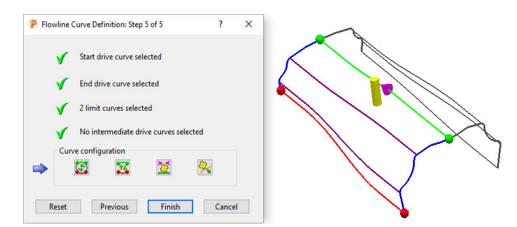
10 Select the **Reset** button to clear the default, segment selection.



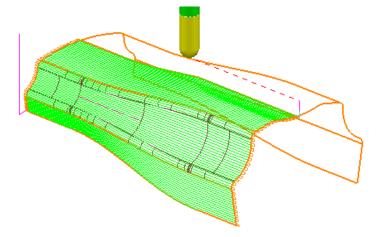
- **11** Select the upper central curve as the **start drive curve** (green)
- 12 Select the bottom left curve as the **end drive curve** (red).
- 13 Shift select the 2 end curves (blue).
- 14 Shift select the 2 nearest intermediate curves (purple).

P Flowline Curve Definition: Step 4 of 5	?	×	
Start drive curve selected			
Find drive curve selected			
2 limit curves selected			
2 intermediate drive curves selected			
Curve configuration	-		
		_	
Reset Previous Next	Cancel		

15 Select the **Next** button to return to the full preview stage.



- 16 Select the **Finish** button to return to the main Flowline finishing dialog.
- 17 Select **Calculate** to generate the new toolpath then select **Close**.

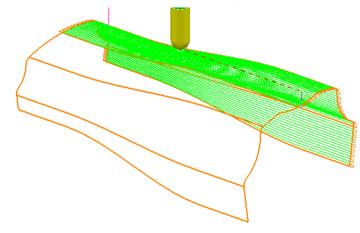


Note that this 6 segment, **Flowline** toolpath follows the intermediate flowlines of the variable fillet within the model form.

Exercise

人 AUTODESK.

18 Create a *Copy* of the above toolpath named **BN16-RH-Flowline-ExtraCurves** and modify to machine the RH side of the component form.



- **19** Select **File Save Project**.
- 20 Select File Delete All and Tools Reset Forms.

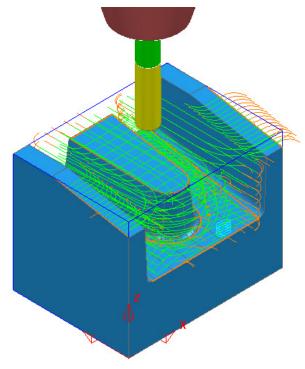


8. Auto Collision Avoidance

Introduction

Automatic Collision Avoidance can be applied to Vertical alignment operations in cases where the Shank would otherwise be rubbing on a sidewall and\or the Holder would clash with the component. If parts of the component still cannot be machined without a tool collision occurring then these areas will not be included as part of the toolpath. Note: Automatic Collision Avoidance is not applicable to Swarf Finishing.

- 1 Open the Project:
 - ...\PowerMill_Data\five_axis\CollisionAvoidance\AutoCollisionAvoid1_Start



- 2 Select File > Save Project as:
 - $... \verb|COURSEWORK\verb|PowerMill-Projects\verb|AutoCollisionAvoid_1|| \\$



The **Project** contains 3 toolpaths all of which have had **Collision Checking** applied with **Shank** and **Holder** clearances values of **1** and **2** respectively.



The Area Clearance strategy is Gouge and Collision safe while the two 3D

Offset finishing strategies although **Gouge** free are not **Collision** safe relative to the **Shank** and **Holder**.

- 3 In the **PowerMill** explorer, activate the toolpath **BN5-Walls-fin1**.
- 4 Right mouse click on the *toolpath* BN5-Walls-fin1 and from the local menu select **Settings**.
- 5 Select **Recycle** in the **3D Offset Finishing** dialog and select the **Tool Axis** page.



Note that the selected **Tool Axis** option is **Vertical**.

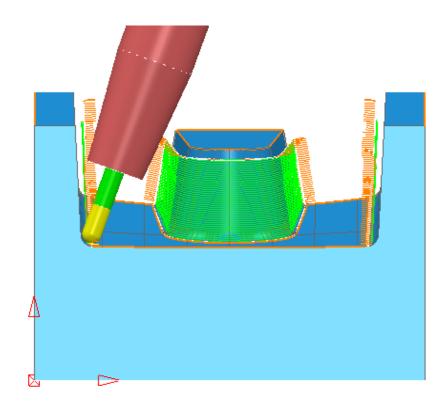
3D Offset Finishing		?	\times
Toolpath name	BN5-Walls-fin1		
 Workplane Block Tool Machine tool Limit Stock engagement 3D offset finishing Automatic verification Point distribution Tool axis Machine axis control Rapid Moves Leads and links 	Tool axis Tool axis Vertical ~		
	None 90.0 Rotary axis configuration Image: Configuration Tool path Image: Configuration Tool axis limite Image: Configuration avoidance Tool axis smoothing Image: Configuration Draw tool axis Image: Configuration avoidance]
	Calculate Queue OK Cancel		



6 Select the newly available **Collision Avoidance** page (Below **Tool axis**).

P 3D Offset Finishing		?	×
Toolpath name	BN5-Walls-fin1		
Workplane Block Tool Kachine tool Stock engagement Stock engagement Automatic verification Point distribution Tool axis Collision Avoidance Machine axis control	Collision Avoidance Tilt method Lean Tool clearances Holder clearance 2.0 Shank clearance 1.0 Smoothing distance 10.0		

- Input the *Tilt method* as Lean.
- Input Shank and Holder clearances of 1 and 2 along with a smoothing distance of 10.
- 7 Calculate the 3D Offset Finishing toolpath.
- 8 Select a **View from front** and **Simulate** the toolpath to observe the **Automatic Collision Avoidance** in action.



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- 9 In the **PowerMill** explorer, activate the toolpath **BN5-Floor-fin2**.
- 10 Right mouse click on the *toolpath* BN5-Floor-fin2 and from the local menu select **Settings**.
- 11 Select **Recycle** in the **3D Offset Finishing** dialog and select the **Tool Axis** page.

Note that the selected Tool Axis option is Vertical .	
---	--

P 3D Offset Finishing		?	\times
Toolpath na	me BN5-Floor-fin2		
 Workplane Block Tool Machine tool Limit Stock engagement 3D offset finishing Automatic verification Point distribution Point distribution Machine axis control Appid Moves Leads and links Start point Feeds and speeds History Notes and Description User defined settings 	Tool axis Tool axis Vertical Vertical None 90.0 Rotary axis configuration Tool axis limits Automatic collision avoidance Tool axis smoothing Draw tool axis		

12 Select the **Collision Avoidance** page.

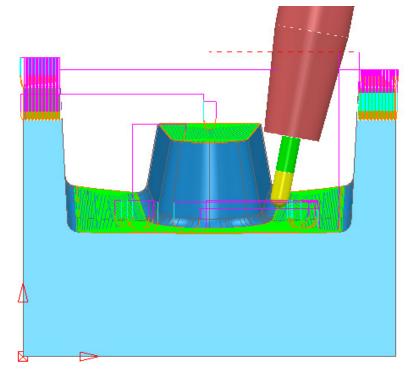
P 3D Offset Finishing		?	×
Toolpath name	BN5-Floor-fin2		
Workplane Block Tool Kachine tool Limit Stock engagement Stock finishing Automatic verification Point distribution Y Tool axis Collision Avoidance Wachine axis control	Collision Avoidance Tilt method Lean V Tool clearances Holder clearance 2.0 Shank clearance 1.0 Smoothing distance 10.0		

- Input the *Tilt method* as Lean.
- Input *Holder* and *Shank* clearances of 2 and 1 along with a smoothing distance of 5.
- 13 Calculate the 3D Offset Finishing toolpath.

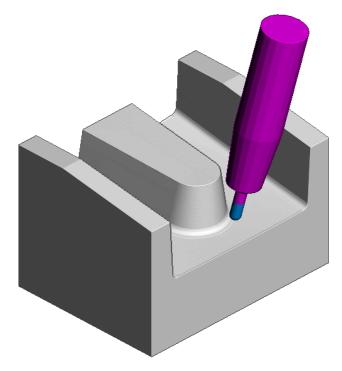




14 Select a **View from front** and **Simulate** the toolpath to observe the **Automatic Collision Avoidance** in action.



Vertical tool alignment is applied as default and the **Lean** angle is progressively changed as required in areas where a collision would otherwise occur.



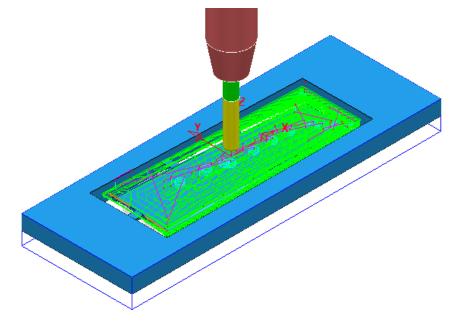
15 Select **File > Save Project**.



EXAMPLE 2

- 1 Select File Delete All and Tools Reset Forms.
- 2 **Open** the (read only) **Project**:

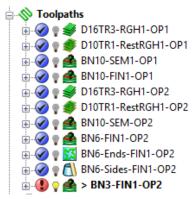
 $....\PowerMill_Data\five_axis\CollisionAvoidance\DashboardPanel-A1_Start$



3 Select **File > Save Project as**:

....\COURSEWORK\PowerMill-Projects\Dashboard-A1_EX1

The **Project** contains 11 toolpaths all of which have had **Collision Checking** applied with **Shank** and **Holder** clearances values of **1** and **2** respectively.



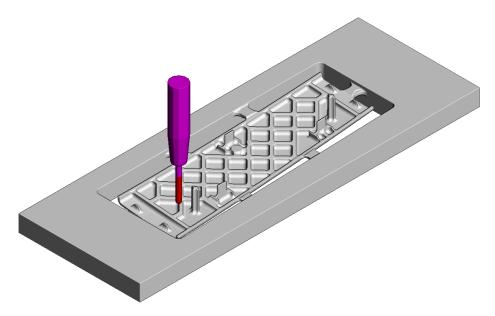
All have been confirmed to be safe with the exception of **BN3-FIN1-OP2**.

The toolpath is *gouge free* relative to the flutes but not *collision safe* relative to the **Shank** and **Holder**.

- 4 Activate the 5th toolpath, **D16TR3-RGH1-OP2** to reinstate the **OP2** setup.
- 5 Select an **ISO1** view.



6 Run a full **ViewMILL** simulation on both *NCPrograms* **OP1** and **OP2**.

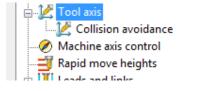


The final toolpath **BN3-FIN1-OP2** is not currently included in the **OP2** *ncprogram*. The above **ViewMILL** simulation displays the result of all toolpaths except **BN3-FIN1-OP2**.

- 7 Put **ViewMILL** on suspend and return the graphics area to the **PowerMill** page.
- 8 Activate the toolpath BN3-FIN1-OP2 and from the local menu select Settings.
- 9 Select **Recycle** in the **Steep and Shallow Finishing** dialog and select the **Tool Axis** page.
- **10** In the **Tool axis** page *tick* the box named **Automatic collision avoidance**.



The **Collision avoidance** page appears in the local **explorer**.

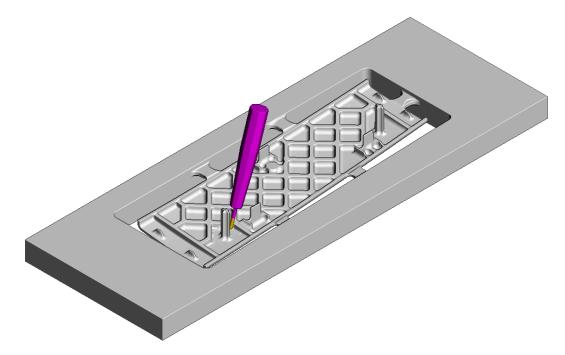


- **11** Select the **Collision avoidance** page.
- 12 Set *Tilt Method* to Lean with a *Holder clearance* of **2.0**, *Shank clearance* of **1.0**, and *Smoothing distance* **3.0**.



P Steep and Shallow Finishing		?	×
Toolpath name	BN3-FIN1-OP2		
 Workplane Block Tool Machine tool Limit Stock engagement Steep and shallow finishing Automatic verification Point distribution Tool axis Collision Avoidance Machine axis control 	Collision Avoidance Tilt method Lean Tool clearances Holder clearance 2.0 Shank clearance 1.0 Smoothing distance 3.0		<u>ل</u>

13 Select **Calculate** and note that the collision status of the toolpath **BN3-FIN1-OP2** (as displayed in the local explorer) changes from a *Red* to *Blue*.



14 Run a **ViewMILL** simulation on the toolpath **BN3-FIN1-OP2**.

If a potential collision situation is encountered the tool automatically *leans* away from the wall (as shown in the above image).

15 Save the **Project**.



9. Tool Axis Limits

Introduction

It is possible to control the rotary **Tool axis limits** of a machine tool within **PowerMill**. This enables the rotary working envelope of a specific machine not to be exceeded when creating multi-axis toolpaths. The angular limits are defined in terms of **Azimuth** and **Elevation** angles.

Azimuth and Elevation

The **Azimuth** is the angle from X 0° anticlockwise around the XY plane. The **Elevation** is the angle that is lifted upwards $(+90^\circ)$ or downwards (-90°) from the XY plane.



The **Tool Axis Limits** dialog is accessed from within the **Tool Axis** direction dialog. **Tool Axis** Limits are accessible if the **Tool Axis** box is ticked. This tick box will not be available if the Tool axis is set to **Vertical** or **Fixed Direction**.

P Tool Axis	?	×	P Tool Axis		?
Smoothing Machine	e axis control		Smoothing		Machine axis control
Definition Limits Col	lision avoidan	ce	Definition	Limits	Collision avoidance
Tool axis				Mode	Remove toolpath
Lead/Lean angles			Use machine to	of when poss	ible 🚺
Lead Lean 0.0			Orienta:	ion Manual	
Mode Contact n	ormal	~		Workplane	2
			Angle limits Azimuth angle		
Fixed Angle			Start 0.	0	End 360.0
None ~ 90	.0		- Elevation angle -		
Rotary axis configuration			Start -9	0.0	End 90.0
Toolpath Toolpati Toolpati Toolaxis limits Toolaxis smoothing Toolaxis smoothing Draw toolaxis					
			🗌 Project to plan		nping angle 3.0
			🗌 Draw limits —		
			Copy f	rom machine	tool
Accept Cance	21			Accept	Cancel



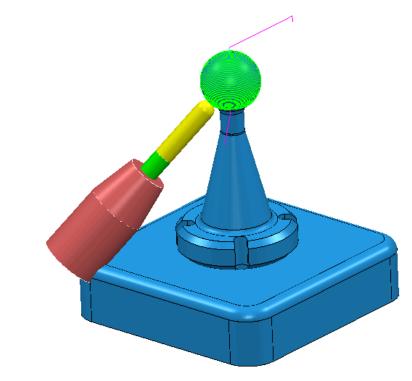
- 1 Select File Delete all and Tools Reset Forms.
- 2 Open the 'read only' Project:

....\PowerMill_Data\five_axis\Tool_Limit\JoyStick_Start

3 Select File > Save Project As:

....\COURSEWORK\PowerMill-Projects\JoyStick-Example

4 In the graphics area, right-click on the toolpath at the underside of the sphere, and from the local menu select, **Simulate from Here**.





Note that the tool is cranked over way beyond the rotational limits of the machine tool and the tool holder is visibly colliding with the base form.

To further illustrate the machining process exceeding the rotary limits, the strategy will be simulated using a **DMU50 Evolution** machine tool.

5 In the PowerMill explorer, right mouse click on the Toolpath BN16-NoToolAxisLimits and from the local menu select Simulate from Start.

This command will raise the **Simulation** toolbar (if it is not already open).



6 In the PowerMill explorer right mouse click on Machine Tools and from the local menu select Toolbar.

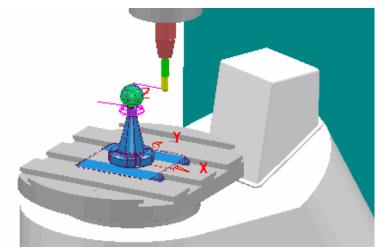


- 7 Select **Import the Machine Tool Model** and select the file:
 -\PowerMill Data\Machine Data\DMU\dmu50v.mtd



Impor	t Machine Tool					
	Look in:	DMU	Co 🎓 📂 🔜 •			
~	Name	^	Date modified	Туре	Size	
	dmu50v	,	24/11/2015 08:54	File folder		
\mathbf{i}	📇 dmu50v	.mtd	07/11/2003 15:20	MTD File		4 KB
2) 2)						
	File name:	dmu50v.mtd			~	Open
	Files of type:	Machine Tool Formats (*.			~	Cancel

8 Ensure the **Draw\Undraw** machine tool icon is on to display the machine tool model.



The current component datum (**Transform**) is matched to that of the Machine Tool model (Top - Centre of Table). As a result, the base of the component is currently embedded into the machine tool bed. To compensate for this, a new, suitably positioned Workplane is created. This new **Workplane** is then used in the **Machine Tool definition** toolbar.

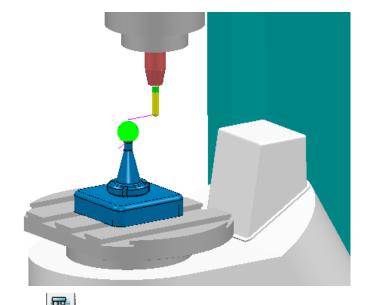
- 9 Create a new Workplane named MTD-datum and move it by Z-50.
- **10** Input the new **Workplane**, **MTD-datum** into the **Machine Tool definition** dialog.

It is not necessary to activate the new **Workplane**.



The component will immediately be repositioned, relative to the new **Workplane**.



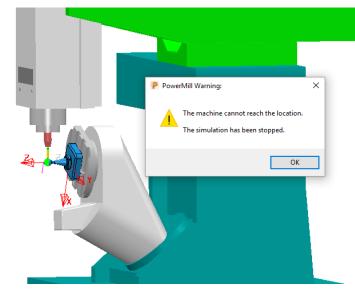


11 Select Floor View on the Machine Tool toolbar.

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12 Start the simulation \triangleright to observe the virtual machining of the component.

The **DMU50** angular limits are **X** \pm **90 Y** \pm **360** and this information is stored in the **MTD** file. This translates to **Azimuth Angle** limits of **0** to **360** and **Elevation Angle** limits of **0** to **90**. When the toolpath simulation attempts to go beyond this range an error message will be displayed indicating that the machine, **Tool Axis Limits** will be exceeded.





To allow for this appropriate **Tool Axis Limits** will be applied to the toolpath during calculation.



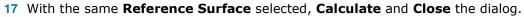
13 In the **PowerMill** explorer, Machine Tools folder right mouse click on dmu50v and from the local menu select Go Home to return the machine tool model to the home position.



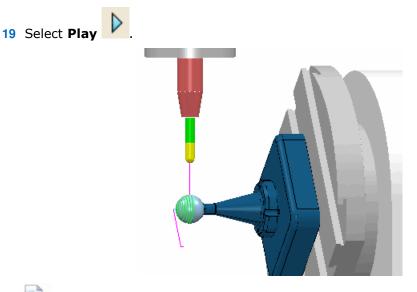
- 14 Make a **Copy** of the original toolpath and rename it as **BN16-LimitsSet**.
- 15 In the local explorer Tool Axis folder, select the Tool Axis Limits option to activate the **Tool Axis** Limits page.
- 16 Enter the values into the dialog exactly as shown (select Mode Remove toolpath and tick the Draw limits box).

Surface Projection Finishing	9				?	\times
٠	Toolpath name	BN16-LimitsSet				
🖳 Workplane 🛁 Block		Tool axis limits				
Tool		🗆 Ura mashina taal w	Mode	Remove tool	path 🕓	-
		Use machine tool w Orientation	Manual	ne		~
Pattern	tion	v	Vorkplane	1		~
Point distribution		Angle limits Azimuth angle <u>Start</u> 0.0		End 360.0		
 Machine axis control Rapid Moves U Leads and links Start point 		Elevation angle		End 90.0		
→→→ Start point →→ Feed point ⊕→ → →→ Feeds and speeds →→ → →→ <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td></td<>						
↑ <i>∕</i>	•	Project to plane	Damp	ing angle 3.0)	
		Draw limits Translucency	(percentag	ge) 0.0		
	Y					

The green area of the sphere represents the permissible angular alignment of the Tool Axis.



18 In the **PowerMill** *explorer* right-click the toolpath, **BN16-LimitsSet** and from the local menu select **Simulate from Start**.

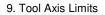


With **Mode** set to **Remove Toolpath** in the **Limits** dialog, only the portion of the surface within the rotary **Tool Axis Limit** range is machined.

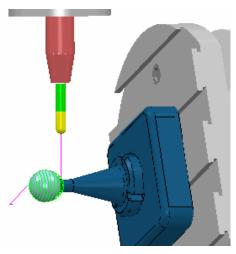
- 20 Right-click on the toolpath, BN16-LimitsSet, and select Settings to access the Surface Projection Finishing dialog.
- 21 Select recycle and in the **Tool axis** page select the **Tool axis limits** and enter the values into the form exactly as shown below (select **Mode Move tool axis**).

Surface Projection Finishing	? ×
Toolpath name	BN16-LimitsSet
Workplane	Tool axis limits
	Mode Move tool axis
Stock engagement	Orientation Manual
Pattern	Workplane 1
Point distribution Tool axis Tool axis limits Machine axis control	Angle limits Azimuth angle <u>Start</u> 0.0 <u>End</u> 360.0
 ■ ■ Rapid Moves ■ ↓↓ Leads and links ■ ↓↓ Start point 	Elevation angle <u>Start</u> 0.0 End 90.0

- 22 With the original reference surface selected, **Calculate** the toolpath.
- 23 Right-click the toolpath BN16-LimitsSet, in the PowerMill explorer and select Simulate from Start.
- 24 Select Play







With **Mode** set to **Move tool axis** in the **Limits** dialog, the surface is fully machined with the **Tool Axis** becoming fixed when it exceeds the maximum rotary Limit.

25 Select File > Save Project to update the stored data.

Defining Limits for a Multi-Axis Machine

The Tool Axis Limits option allows the user to control the angular limits of a tool while creating a multi-axis toolpath. The specified limits will differ in format depending on the type of rotary axis configuration. As a result they will have to be translated as universal Azimuth and Elevation angles to be compatible with PowerMill.

The configuration of the rotary axes varies widely, however the differences between many of these are relatively minor and there are really only three fundamentally different machine configurations:

- Table Table Both rotary axes move the table.
- Head Head Both rotary axes move the head.
- Head Table One rotary axis moves the head, the other moves the table.

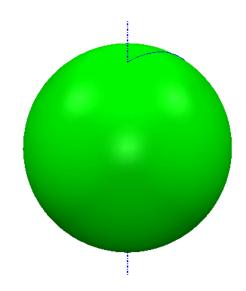
The next examples will show how to transpose angular limits of a machine tool into Azimuth and Elevation angles.

- 1 Select File Delete all and Tools Reset Forms.
- 2 Select the **Tool Axis** icon I from the **main** toolbar.
- 3 Define **Tool Axis** as **Lead****Lean** and set both the **Lead** and **Lean** angles to **0**.
- 4 Select the **Tool axis limits** option tab.
 Tool axis limits to activate the **Limits**
- 5 Open the Limits tab.
- 6 Select the **Draw Limits** option from the dialog.

🔽 Draw lim	nits
Translucen	cy (percentage)
0.0	



7 Select view **ISO 1**.

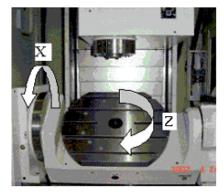


With the **Draw Limits** option selected a sphere will be displayed in the graphics window representing the angular machining limits available.

Green indicates a machinable portion and Red a non-machinable portion. With the default settings selected the total machining range is covered so the whole sphere will be Green.

Table – Table

Both rotary axes operate on a table.



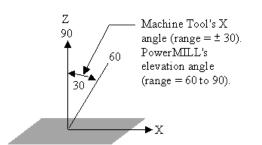
With the above **Table-Table** machine tool the angular limits are specified as:

X ± 30

Z ± 360

The machine tool **Y** limits are equivalent to the **Azimuth Angle** or the angular limits normal to the **XY** plane. The **Y** limit of \pm **360** translates to **Azimuth Angle** limits of **0** to **360**.

The machine tool **X** limits are equivalent to the **Elevation** angle above the **XY** plane. However they are not the same angle. This is best described using the diagram below. The machine tool measures the angular range relative to the **Z** Axis and **PowerMill** measures it relative to the **XY** plane, therefore the angle required for the limit in PowerMill is the complementary angle to the one given for the machine tool.



The X limit of ±30 translates to Elevation angle limits of 60 to 90.

1 Retain the default **Azimuth Angle** and modify the **Elevation Angle** values in the form as shown below to update the machining limits.

Angle limits	
Start	End
0.0	360.0
Elevation angle	
Start	End
60.0	90.0

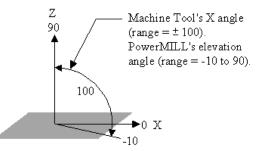
The $\ensuremath{\text{Tool}}$ $\ensuremath{\text{Axis}}$ Limits sphere has been visually updated with the modified values.

An Alternative **Table -Table** machine tool has the following angular limits:

$X \pm 100$

Y ± 360

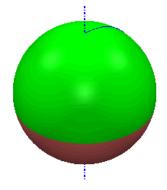
This translates to **Azimuth Angle** limits of **0** to **360** and **Elevation Angle** limits of **-10** to **90**.



- 2 Modify the **Elevation Angle** values (**-10** to **90**) in the **Angle Limits** dialog to update the machining limits (as shown).
- Copyright © Autodesk

🔼 AUTODESK.

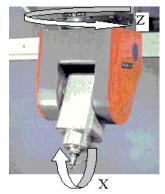




The **Tool Axis Limits** sphere has been visually updated with the modified values.

Head – Head

Both rotary axes move the head.



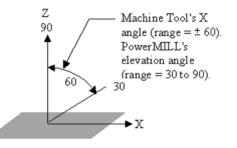
With the above **Head-Head** machine tool the angular limits are specified as:

X ± 60

Z ± 360

The machine tool **Z** limits are equivalent to the **Azimuth Angle** or the angular limits normal to the **XY** plane. In **PowerMill** the **Z** limit of **± 360** translates to **Azimuth Angle** limits of **0** to **360**.

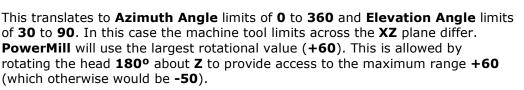
The machine tool **X** limits are equivalent to the **Elevation Angle** above the **XY** plane. The angular range of the machine tool is relative to the **Z** axis, however **PowerMill** measures it relative to the **XY** plane. Therefore the angle required for the limit in **PowerMill** is the complementary angle to the one given for the machine tool. The **X** limit of **± 60** translates to **Elevation Angle** limits of **30** to **90**.



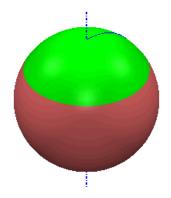
Alternative Head-Head machine tool angular limits:

X -50 to **+60**

Z ± 360



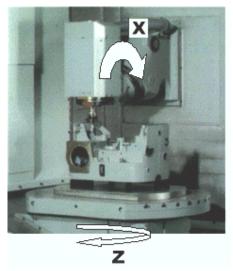
1 Modify the **Elevation Angle** values (**30** to **90**) in the dialog to update the machining limits as shown.



The **Tool Axis Limits** sphere has been visually updated with the modified values.

Head – Table

One rotary axis moves the head, and the other moves the table.



With the above **Head-Table** machine tool, the angular limits are specified as:

X ± 40

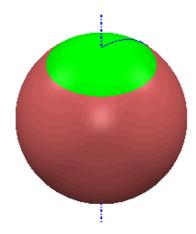
Z ± 360

The machine tool **Z** limits are equivalent to the **Azimuth Angle** or the angular limits in the **XY** plane. The **Z** limit of **±360** translates to **Azimuth Angle** limits of **0** to **360**.

The machine tool X limits are equivalent to the **Elevation Angle** above the XY plane. It is the complimentary angle to the **Elevation Angle**. The X limit of \pm 40 translates to **Elevation Angle** limits of 50 to 90.

1 Modify the **Elevation Angle** values (**50** to **90**) in the dialog to update the machining limits as shown below.

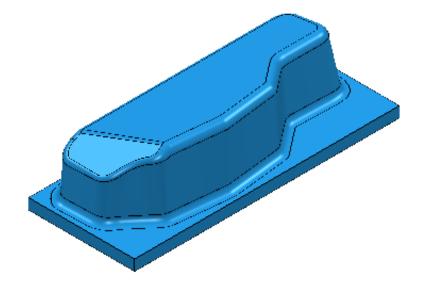




The **Tool Axis Limits** sphere has been visually updated with the modified values.

Applying tool Axis limits on a Steep Sidewall base Fillet

- 1 Select File Delete all and Tools Reset Forms.
- 2 Import the Model:
 - ...\PowerMill_Data\five-axis\punch2\punch2_insert.dgk



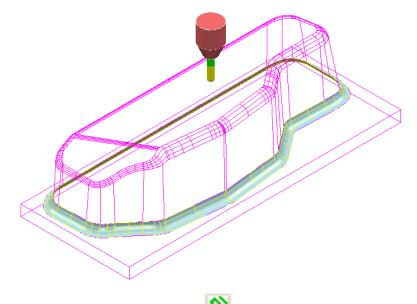
3 Select File > Save Project As:

...\COURSEWORK\PowerMill-Projects\Punch2-ToolAxisLimits

- 4 Create a Diameter 20 Ballnose tool Length 50 named BN20.
- 5 Add a Shank component Upper Dia 20 Lower Dia 20 Length 40
- 6 Add a Holder component Upper Dia 70 Lower Dia 40 Length 40
- 7 Add a Holder component Upper Dia 70 Lower Dia 70 Length 60 Overhang 80
- 8 Calculate a Block using Defined by Box and Type Model.
- 9 Calculate the **Rapid Move Heights** using the default settings.



10 Select the fillet running around the base of the main component sidewalls.



- 11 Select the **Toolpath Strategies** icon and in the **Strategy Selector Finishing** options select **Surface Finishing**.
- **12** Input data into the **Surface Finishing** dialog exactly as shown:

P Surface Finishing	?	×
Toolpath name	BN20-Fillet-FIN	
Workplane Block B	Surface finishing Surface Surface side Outside Surface units Degouge tolerance 0.3 Tolerance 0.02 Thickness 0.0 Stepover (Distance) Image: Window Constraints Image: Outside Constraints Image: Outsi	

- Toolpath name: **BN20-Fillet-FIN**
- Stepover: 0.5

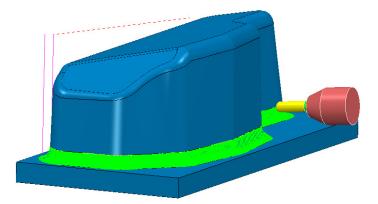


P Surface Finishing			? >
Toolpath name	BN20-Fillet-FIN		
Workplane Block	Pattern		
U Tool 	Pattern Patter	n direction U	~
→ Stock engagement		Sp	oiral 🗹
Pattern Automatic verification	Ordering	One way	~
Point distribution	Start corner	Min U min V	~
Cool axis Machine axis control	Sequence	None	~

- Pattern Direction: U
- Spiral: *Ticked*

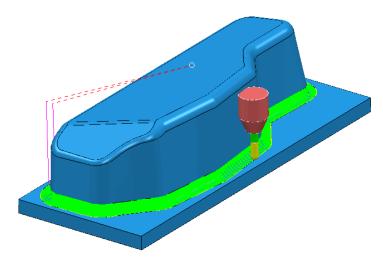
P Surface Finishing		?	\times
Toolpath name	BN20-Fillet-FIN		
Workplane Image: Source of the second sec	Tool axis Lead/Lean Lead/Lean angles Lead Lead 0.0 0.0 Mode	al	

13 Select **Calculate** to create the **Surface Finishing** toolpath.



- The Tool Holder is in Collision with the Base.
- 14 From the local toolpath menu, select **Verify Toolpath** to open the **Toolpath** Verification dialog.
- 15 Un-tick both **Split Toolpath** and **Adjust Tool**.
- **16** Then check for **Collisions** using a **Shank Clearance** of **1** and a **Holder Clearance** of **2**.



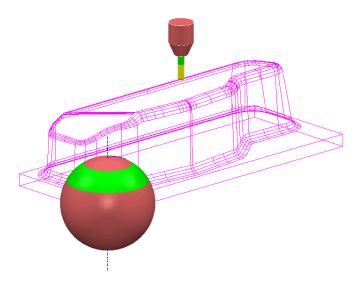


- The **Tool Holder** is also in collision with the Sidewall.
- During Projection Surface Finishing the tool (BN20) is aligned normal to the Fillet Surface (if default Lead Lean 0 is applied). This is creating a Collision situation with both the sidewall and the base. Tool Axis limits will be applied to prevent this immediate problem as well as to keep the tool alignment within the machine tool rotary limits.
- 17 In the **PowerMill** *explorer*, right-click the toolpath, **BN20-Fillet-FIN**, and select **Settings** to re-open the **Surface Finishing** dialog.
- 18 In the **Surface Finishing** dialog select **12** to create a 'copy' and enter the toolpath name **BN20-Fillet-FIN-LIM30**.

Surface Finishing					?	\times
 3 4 5 5 6 7 7	foolpath name	BN20-Fillet-FIN_LIM30				
Workplane		Tool axis limits				
			Mode	Move tool axis		~
- Machine tool		🗹 Use machine tool w	hen possil	ble	(
Stock engagement		Orientation	Manual			~
Pattern	tion	v	Vorkplane			~
Point distribution		Angle limits				
Tool axis		Azimuth angle Start 0.0		End 360.0		
Rapid Moves		Elevation angle		End 60.0		5
Start point						
🗄 🚡 Feeds and speeds						

- **19** Tick **Tool Axis limits** and move to the **Tool axis limits** page.
- 20 In Mode, select Move tool axis and for Elevation angle input:- Start 30 and End 60.
- 21 Select **Calculate** to create the new toolpath.

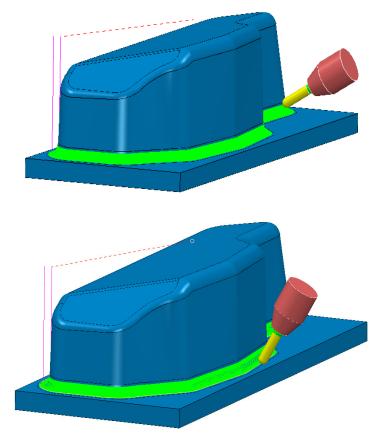




With the **Tool Axis Limits** applied the alignment will be restricted to operate between 30 and 60 degrees (**Elevation Angle**) relative to the **XY** plane. The sphere displaying the **Tool Axis** alignment limits (shaded green and pink) becomes visible when the box labelled **Draw Limits** is ticked.



The two illustrations below show the toolpath with the tool attached on the upper and lower tracks and the effect of the specified limits.

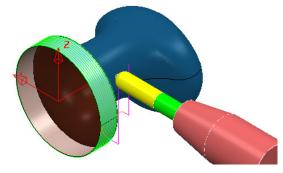


• The **Tool Holder** is no longer in collision with the Base or Sidewalls.

22 Save the Project.

Applying Tool Axis limits to maintain a 4-Axis toolpath.

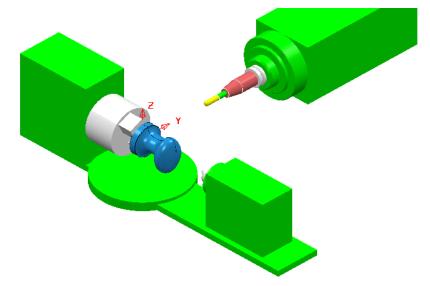
- 1 Select File Delete all and Tools Reset Forms.
- 2 **Open** the 'read only' **Project**:
 -\PowerMill_Data\five_axis\Tool_Limit\FixTo4Axis_Start



- 3 Select File > Save Project As:\COURSEWORK\PowerMill-Projects\FixTo4Axis-example1
- 4 If not already displayed, from the main pull down menus select **View Toolbar** and tick **Machine Tool**.
- 5 In the **PowerMill** *explorer* open the **Machine Tools** folder and activate the **RotaryMachine** (double left click the icon ^{III}).



- 6 Input **workplane 1** as the **Machine Tool** output datum.
- 7 Select an **ISO 2** view.

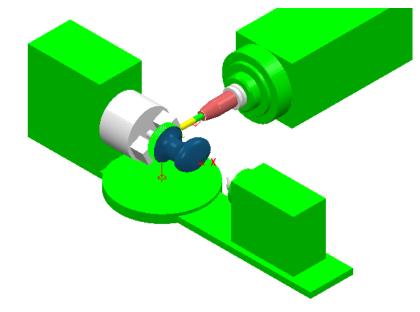


The **Project** contains a model of a 4-Axis Rotary Machine and two toolpaths.

The first toolpath is inherently 4 Axis while the second toolpath is 5 Axis.

The Rotary Machine is unable to produce the **Tool Axis** moves required by the second **Five Axis** toolpath. This toolpath can however easily be converted to **4-Axis** using the appropriate **Tool Axis Limits** options.

- 8 In the **PowerMill** explorer, right mouse click on the toolpath **BN16-Base-SEM1** and select **Activate** followed by **Simulate from Start**.
- 9 Click the **Play** button and the simulation successfully runs all the way to the end.



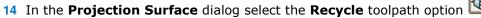
- 10 In the **PowerMill** *explorer*, right mouse click on the toolpath **BN16-Form-SEM2** and select **Simulate from Start**.
- 11 Click the **Play** button and the simulation immediately fails to proceed with the following message being displayed.

P Powe	rMill Warning:	×
	The machine cannot reach the location. The simulation has been stopped.	
	ОК	

As the toolpath is fully *Five Axis* it impossible for the **Rotary Machine** to perform a **simulation**.

- **12** Abandon the simulation.
- 13 Right mouse click on the toolpath BN16-Form-SEM2 and from the local menu select Activate it before selecting Settings to open the Projection Surface dialog.

🐧 AUTODESK.



15 In the local **explorer** select **Tool axis** and tick the **Tool axis limits** box.



The **Tool axis limits** page will become available in the local **explorer**.

16 Select the **Tool axis limits** page and enter data exactly as shown below.

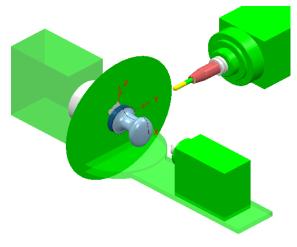
Surface Projection Finishing				? ×
Toolpath name	BN16-Form-SEM2			
Workplane	Tool axis limits			
	vvpi pis u s	Mode	Move tool axis	~
🔞 Limit	Use machine tool w	hen possik	ole	
Stock engagement	Orientation	Manual		~
Pattern	W	Vorkplane		~
	Angle limits			
E- Maria	Azimuth angle			
Machine axis control	Start 0.0		End 360.0	
Rapid Moves	Elevation angle			
	Start 0.0		End 65.0	
			0310	
🔚 🗞 User defined settings				
	Project to plane			
•	\sim	Damp	ing angle 0.0	
1		-		
	Draw limits		ae) 0.0	1
	Translucency	percentag	ge) [0.0	
	Copy f	from mach	ine tool	
-	Calculate Queue	OK	Cancel	

With **Project to plane** ticked the **Tool axis limits** are flattened to create a 4 axis limit (about the global transform in this case). A zero **Damping angle** will ensure that the 4 axis alignment is fully maintained.

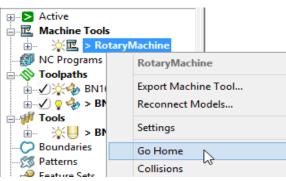




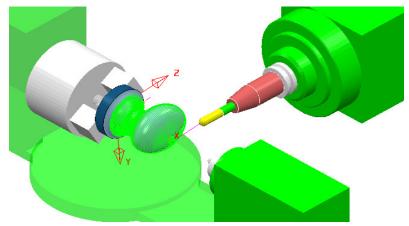




- 17 In the Tool axis limits page, un-tick Draw limits.
- **18** With the 3D form, **surface** selected **Calculate** the new 4-Axis toolpath.



- **19** In the local **explorer**, right mouse click on **Rotary Machine** and from the local menu select **Go Home**.
- 20 From the **PowerMill** *explorer*, right mouse click on the new toolpath **BN16-**Form-SEM2 and from the local menu select **Simulate from Start**.
- 21 Click the **Play** button and the 4-Axis toolpath simulation successfully runs all the way to the end.

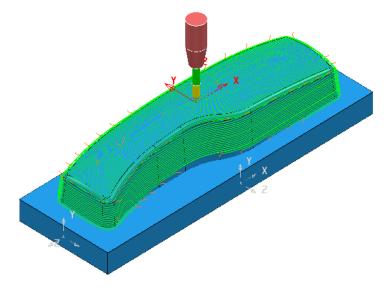


22 Save the Project.



Exercise 1

- 1 Select File Delete all and Tools Reset forms.
- 2 **Open** the 'read only' **Project**:
 -\PowerMill_Data\five_axis\Punch3\Punch3_Start



3 Save Project As:-

....\COURSEWORK\PowerMill_Projects\Punch3_EX1

The Project contains a **Steep and Shallow Finishing** toolpath **BN16-StpShlw** with a **Tool Axis** set to **Vertical**. The **Tool** is too short to safely machine some areas of the sidewalls. These potential collisions are avoided by the using **Automatic verification (Shank clearance 1** and **Holder clearance 5**).

The upper base surface is set with **Machining Mode** as **Collision** with a **Thickness** value of **0.5**.

Steep and Shallow Finishing	? ×
Toolpath name	BN16-StpShlw
Workplane Block Tool Example Wachine tool Wachine tool Wachine tool Steep and shallow finishing Automatic verification Point distribution Tool axis Machine axis control Rapid Moves	Automatic verification Head clearance 600.0 Automatic collision checking Collision checking against Model Holder clearance 5.0 Shank clearance 1.0 Machine maximum stock

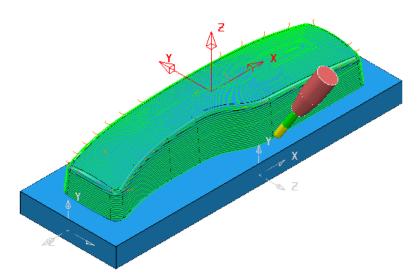
The object of the exercise is to create 2 copies of the existing toolpath the first with a suitable **Toward Point** - **Tool Axis alignment** applied and the second that is further limited to being **4 Axis** only (applied about the X axis).

人 AUTODESK.

- 4 Activate the toolpath **BN16-StpShlw** and from the local menu select **Settings** to re-open the strategy dialog.
- 5 Create a **Copy** of the toolpath and rename it as **BN16-StpShlw_TwdPt**.
- 6 Select the Tool Axis page and select the option, Towards Point with the X Y Z positional values as 0 50 -350.

Steep and Shallow Fin	ishing		?	×
	Toolpath name	BN16-StpShlw_TwdPt		
Workplane Block Jool Machine tool Mit With the tool We Limit Stock engageme Steep and shallo		Tool axis Tool axis Towards point Point 0.0 50.0	X Z	
Automatic ve Automatic ve Automatic ve Automatic ve Automatic ve Point distribution Automatic ve Tool axis OMachine axis cor Apid Moves Automatic ve Automatic ve	erification n	Mode Toolpath	~	
	s	None v 90.0 Rotary axis configuration		
History Notes and Description Set defined settings	Toolpath Tool axis limits Automatic collision avoidance Tool axis smoothing			
		Draw tool axis		

7 **Calculate** the new toolpath.



With a suitable **Toward Point** - **Tool Axis alignment** applied the **Tool** is now angled away from the sidewalls providing collision free access to the deeper areas.

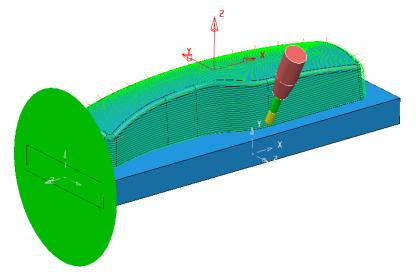
8 Activate the toolpath **BN16-StpShlw_TwdPt** and from the local menu select **Settings** to re-open the strategy dialog.



- 9 Create a **Copy** of the toolpath and rename it as **BN16-StpShlw_TwdPt_4Axis**.
- **10** Select the **Tool Axis** page and tick the **Tool axis limits** box.
- 11 Select the newly appeared **Tool axis limits** page in the local **explorer** and input the data into the dialog exactly as shown below.

Steep and Shallow Finishing	? ×
Toolpath name	BN16-StpShlw_TwdPt_4Axis
 Workplane Block Tool Machine tool Limit Stock engagement Steep and shallow finishing Automatic verification Point distribution Point distribution Tool axis Tool axis limits Machine axis control Rapid Moves Leads and links Start point Feeds and speeds History Notes and Description User defined settings 	Mode Move tool axis Use machine tool when possible Image Orientation Manual Workplane X-Direction Angle limits Image Azimuth angle Start Start -90.0 Elevation angle Start Start -90.0
	Project to plane Damping angle 3.0 Draw limits Translucency (percentage) 0.0

12 Calculate the new toolpath.



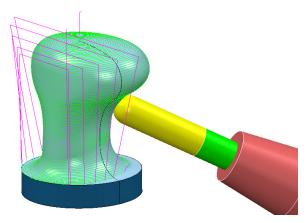
This strategy is limited to operate as 4 Axis only.

13 Save the **Project**.



Exercise 2

- 14 Select File Delete all and Tools Reset forms.
- 15 Open the 'read only' Project:
 -\PowerMill_Data\five_axis\joint_5axismc\JointAxisLimits_Start

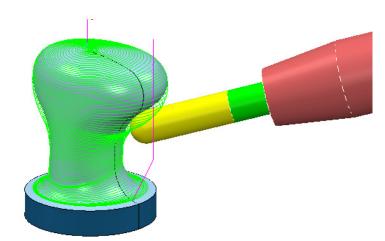


16 Save Project As:-

....\COURSEWORK\PowerMill_Projects\JointAxisLimits-EX1

The **Project** contains a **Surface Finishing** toolpath with a **Tool Axis** setting of **Lead 0** and **Lean 0**. This causes the **Tool** to be aligned to the **surface normals** at all points on the toolpath adjacent to the selected surface. The tool alignment is not prevented from exceeding the machine tool, rotary limits or to clear overhanging areas of the model.

- 17 Recycle the Surface finishing toolpath using Tool axis limits between Elevation Angles of 15 and 65 degrees using Mode Move tool axis.
- Perform a toolpath Simulation followed by a full Gouge and Collision (Shank Clearance 2 – Holder Clearance 3) check on the modified Surfacing Finishing toolpath.



19 Save the **Project**.



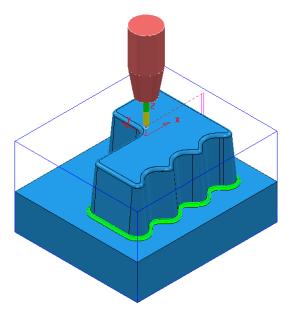
10. Tool Axis Editing

Introduction.

In some applications the type of **Tool Alignment** option applied to a **Five Axis** strategy can result in unnecessary, exaggerated rotary movements while the cutter runs along a toolpath.

In some cases, these exaggerated movements can result in **Tool Holder** or **Machine Tool** collisions. To reduce this, it is possible to edit the toolpath to have an alternative **Tool Alignment** within a user defined, area.

- 1 **Open** 'read only' the **Project**:
 -\PowerMill_Data \five_axis\ToolAxisEditing\EditToolAxis_Start



The **Project** contains a **Corner Along** strategy created using a **Dia 5 Ball Nosed** tool with a **Lean Angle** of **45** Degrees applied.

2 From the **main** pulldown menus select **File** > **Save Project as**:

....\COURSEWORK\PowerMill-Projects\EditToolAxis

3 In the main pull down menus select View > Toolbars > Machine Tool to raise the Machine Tool definition toolbar.

📰 🛐 🔌	~ 🔀 🖳 🦉	~ 🔊 ×
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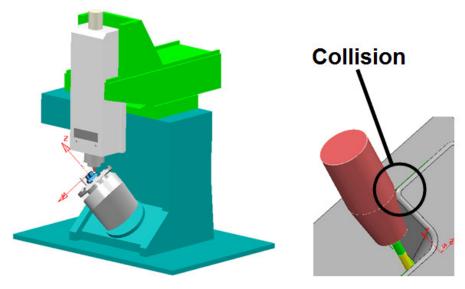
4 Click on the Import Machine Tool Model icon and from the\PowerMill_Data\MachineData directory, select the file dmu50v.mtd.



- 5 Input the workplane Base as the datum for the Machine Tool Simulation.
- 6 Ensure the **Draw\Undraw** machine tool icon is selected to display the machine tool.
- 7 Select an **ISO 1** view and zoom the machining area.
- 8 Select Floor View from the Simulation toolbar.
- 9 Right-click on the toolpath BN5-Rest-Lean45 and from the local menu, select Simulate from Start.



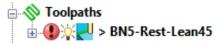
10 Move the simulation speed, *slider* to a slow setting and then click the *Play* icon and observe the machine tool movement.



In addition to there being an excessive amount of table rotation while the undulating sidewall is machined there is also a **Tool Holder collision** on the sidewall internal corner (see above right graphic).

- 11 From the local **BN5-Rest-Lean45** *toolpath* menu, select **Verify Toolpath** and in the dialog, un-tick both **Split Toolpath** and **Adjust Tool**.
- 12 Select *Check* Collisions, with a Shank Clearance 1 and Holder Clearance 2 and Apply the dialog.

The **Toolpath** is now displayed red in the **PowerMill explorer** confirming that the **Shank** and/or **Holder** are colliding with the model.





The 2 issues will be fixed by applying localised Tool Axis alignment modifications on the toolpath. To enable normal viewing while the changes are made, the Machine Tool model will temporarily be removed from the Machine Tool Simulation toolbar. 13 In the Machine Tool Simulation toolbar select None to remove dmu50v.mtd from the selection input box leaving it blank. F 🖥 19 Base B 呕 ¥. × 14 Select a **View from top** ready for snapping the corners of a **polygon** to define the first area of the toolpath to undergo **Tool Axis Editing**. **15** On the keyboard select **Ctrl H** to display the **Cross Hair** on the cursor position. 16 In the PowerMill explorer, right-click on the toolpath BN5-Rest-Lean45 and select Edit > Edit Within Region from the local menus to access the following dialogs. 17 In the (default) Select Region dialog set Define Region By - Polygon and Side - Inner (as shown below left). 🦻 Edit Toolpath Within Region 2 \times P Edit Toolpath Within Region ? \sim Select Regions Specify Changes Select Regions Specify Changes Define Region By Polygo Type of Editina Plane New Axis Definition \sim Type PlaneX **Retary Axis Configuration** Point Toolpath R. 0.0 -45.0 0.0 Normal **Tool Axis** 0.0 0.0 1.0 Tool A Fixed Direction Boundary Boundary Orientation 12 Free Projection Plane Active Workplane Point Distribution nner Туре Tolerance And Keep Arcs ♦ Save Selection Blend Distance 5.0 **Clear Selection** Unde Cancel Apply Cancel Apply

18 Select the Specify Changes tab, and set Tool Axis as Fixed Direction and input a Blend Distance of 5, before selecting the Tool Axis icon .



P Tool Axis			?	×
Smoothing Definition	Limits	lachine axis c Collision a		ce
Tool axis Fixed direction	~			
Direction 0.0	-1.0	1.0		
 ☐ Tool axis limits ☐ Automatic col ☐ Tool axis smoot ☑ Draw tool axis 	lision avoidance			
	Accept	Cancel		

19 Input values into the Direction vector (Along the tool axis) as:-

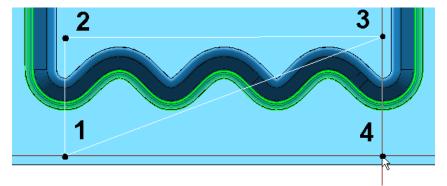
I 0.0 J -1.0 K 1.0

- 20 In the **Tool Axis** dialog, tick the **Draw Tool Axis** box before selecting **Accept** (to return to the **Edit Toolpath Within Region** dialog).
- 21 From the **main** pulldown menus select **Draw** > **Cursor** > **Cross Hair**.



This will display **cross hairs** running through the **cursor position**, to assist visual alignment when 'snapping' points.

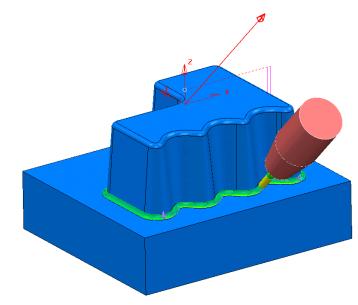
- 22 Click on the **Select Regions** tab to access the original options.
- 23 Left-click to snap 4 corners of the Polygon inside where the Tool Axis Edit is to occur, and click Apply.



The above illustration is at the stage where the user is ready to **snap** the **4th** and final point on the **Polygon** (Cross hairs are mid grey).



24 Select an **ISO 1** view and **simulate** the toolpath to observe that the **Tool Axis Alignment** is no longer performing a series of rotary movements along the undulating sidewall.

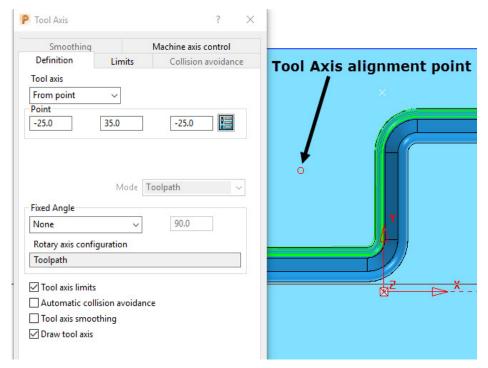


- 25 Select a View from top.
- 26 In the PowerMill explorer, right-click on the toolpath BN5-Rest-Lean45 and select Edit > Edit Within Region to open the Edit Toolpath Within Region dialog again.
- 27 In Select Regions select Polygon with *Side* Inner, and then click the Specify Changes tab.

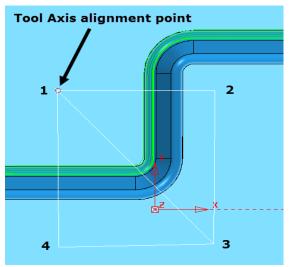
P Edit Toolpat	h Within Region	? ×	🦻 Edit Toolpath Within Region 🛛 💡 ?
Select Regions	Specify Changes		Select Regions Specify Changes
Define	Region By Polygon	v	Type of Editing
Plane			New Axis Definition
Point	Type Plane X	×	Rotary Axis Configuration
0.0	0.0 -45.0	X X	Toolpath
Normal			Tool Axis
1.0	0.0 0.0	T.	Tool Axis
	n Plare Active Work	cplane v	From Point Orientation Free
	Side Inner	~	Point Distribution Type Tolerance And Keep Arcs
	Save Selection		Blend Distance 5.
	Apply Canc	el	Apply Cancel

28 Set *Tool Axis* - From Point with the coordinate values X-15 Y 25 Z-25, and then tick the box labelled Draw Tool Axis before selecting Accept.





29 This time snap 4 corners of the polygon to form a square, aligned as close as possible to the **Tool Axis Alignment** point, and click **Apply**.



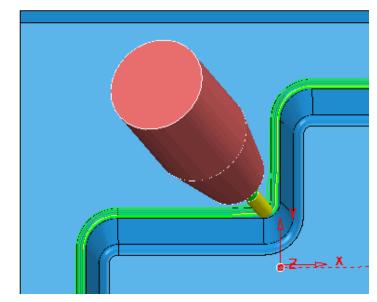
- 30 Select an ISO 1 view.
- 31 From the local **BN5-Rest-Lean5** toolpath menu, select **Verify Toolpath** and in the dialog, un-tick both **Split Toolpath** and **Adjust Tool**.
- 32 Select *Check* Collisions, with a Shank Clearance 1 and Holder Clearance 2 and Apply the dialog.
- 33 Select Check Gouges and Apply the dialog.

The **Toolpath** is now displayed green in the **PowerMill explorer** confirming that the toolpath is free of both **Gouges** and **Collisions**.

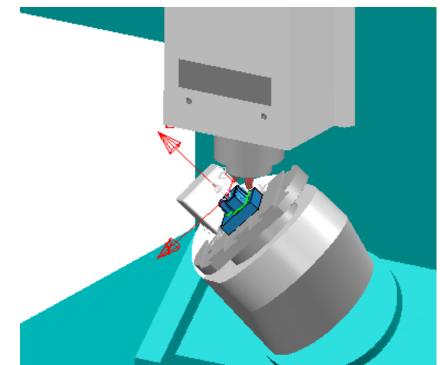




34 Simulate the toolpath to observe that with the new **Tool Axis Alignment** the tool holder is no longer in a *collision* condition with the sidewall internal corners.



35 Perform a **Machine Tool Simulation** again using the **DMU50V** with the **Floor View** selected.



This time the unnecessary, 'rocking' movements about the rotary axis are minimised and the **Tool Holder collision** removed.

36 Select **File - Save Project**.





11. Machine Tool Simulation and Verification

Introduction

The ability to check for potential **Machine Tool** - **Component collisions** is an essential requirement for **Five Axis** applications. To provide this capability **PowerMill** contains an additional **Machine Tool** toolbar for use with the toolpath **Simulation** options.



The standard **Machine Tool Simulation** is purely visual and it is the user's responsibility to identify collisions. An additional, 'cost option' is available where the **Machine Tool Simulation** will stop if a collision situation is identified. At this point a warning box will be displayed. The tool along with the affected parts of the **Machine Tool model** will turn red, and once acknowledged (by clicking **OK**) all moves in a collision condition will be registered in a list.

The individual component parts of a **machine tool** (eg; Main Body, Head, Rotary Table, Cradle, etc) are stored as a set of individual triangle models. These are registered within an **mtd** file that controls the **orientation** and **position** of the individual triangle models during a **simulation**.

Three basic, multi-axis **Machine Tool Simulation** (.mtd) files are supplied within the **PowerMill** installation data. A typical location for a **C** drive install:

C:\Program Files\Delcam\PowerMill13.0.06\file\examples\MachineData

A further selection of sample **mtd** files, based on actual **machine tools** are located on the training PCs in:

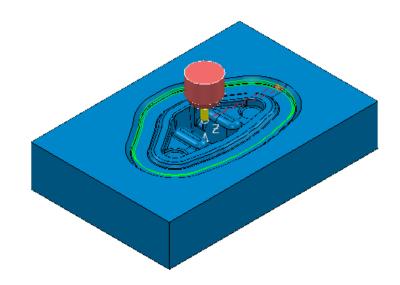
....\PowerMill_Data\MachineData

It is essential that all models along with controlling moves and limits used in a **Machine Tool Simulation** (.mtd) file are an accurate copy of the actual Post-Processor and machine tool in use. Due to design variations, different set up criteria, and tolerance issues, each **Machine Tool Simulation** (.mtd) file and associated models must be tailor made and fine-tuned for each individual application.

1 Select File - Delete all and Tools - Reset forms.



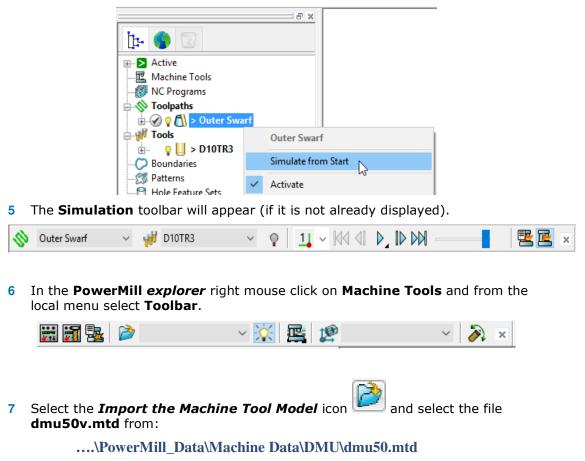
- 2 **Open** the read only **Project**:
 -\PowerMill_Data\five_axis\Collision_Simulation\Swarf_check



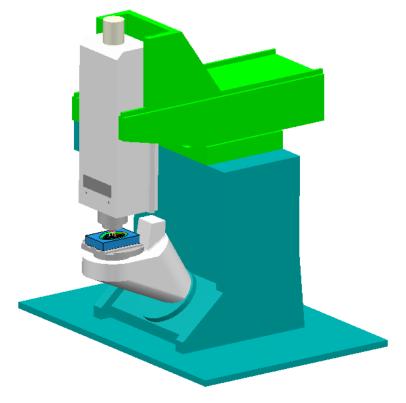
3 Select File - Save Project As:

....\COURSEWORK\PowerMill-Projects\MCTool-simulation

4 In the **PowerMill** *explorer*, right mouse click the toolpath **Outer Swarf** and select **Simulate from Start**.







The **MTD** file contains the **Positional** and **Rotational** details for the individual, **Machine Tool**.

It is normal practice to create the **machine tool model**, with the global datum (Transform) positioned at the Top - Centre of the table.

The active cutting **Tool** is automatically positioned in the machine tool head.

- 8 Ensure the **Draw\Undraw** machine tool icon is selected to display the machine tool.
- 9 Select an **ISO 1** view and zoom into the machining area.
- 10 Select the Floor View icon from the Simulation toolbar.
- 11 Select **Display the simulation issues** The from the **Simulation** toolbar.

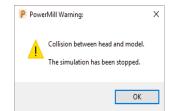
During a toolpath **Simulation**, the **Simulation Issues** dialog will display information on collision positions.

With the **Position** tab selected machine tool positions will be displayed. The values on the left hand side refer to the **Axis Address Letters** and their associated values.

This machine tool has five axes, **A** and **B** are rotary with **X**, **Y** and **Z** as linear.

12 Start the **Simulation** to observe the virtual machining of the component.





A collision has been detected and a **PowerMill Warning** message displayed.

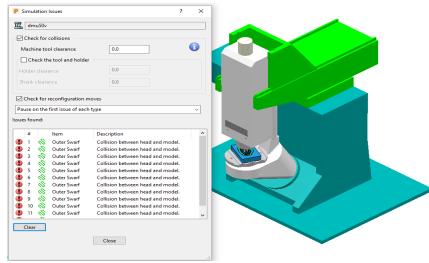
The warning message is only displayed for the first collision.

13 Select **OK** to close the **PowerMill Warning** dialog.

P Simulation Issues		? ×
Check for collisions		
Machine tool clearance	0.0	
Check the tool and holder		
Holder clearance	0.0	
Shank clearance	0.0	
Check for reconfiguration mov	ves	
Pause on the first issue of each ty	/pe	~
sues found:		
 # Item 1	Description Collision between head and mode	el.
Clear	Close	

The first collision move is registered and displayed in the **Issues found** pane. At present only the first collision is displayed until the **Simulation** is continued.

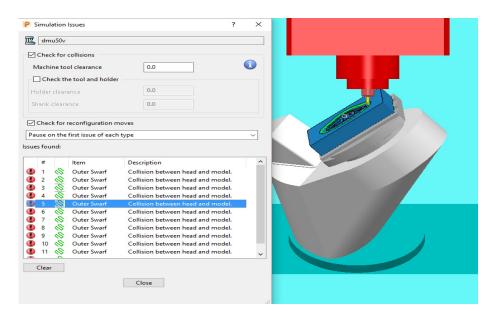




On completion of the simulation the machine tool is displayed in the normal colour scheme.

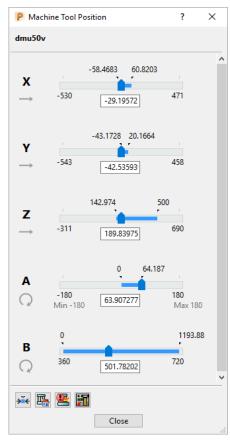
15 Select a *Collision Move* from the list.





The **simulation** will move directly to the selected position in the form so that the collision (top right corner of component) can be viewed.

16 Select *View and adjust the Machine Tool position* from the **Simulation** toolbar.

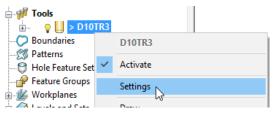


The current positional values are displayed in the **Machine Tool Position** dialog.



With a clear view of the collision, the user can assess how best to make the appropriate changes to avoid it. In this case, substituting the cutter with one with increased Tool Length would be the easiest solution.

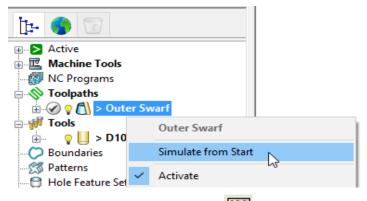
17 In the **PowerMill** *explorer* right mouse click on the tool **D10TR3** and select **Settings**.



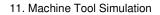
18 Select the **Holder** tab on the tool dialog and modify the **Overhang** to **50**.

P Tip radiused	tool	?	×
Tip Shank	Holder Holder profile Cutting data User Defined Settings	Description	
Components	Tool assembly		
	Holder name dummy toolholder name Q 100%	/	-
	~ 🕅 🕅		
	+♥ ₩ ₩ KA		
	Upper diameter		
	Lower diameter		
i	Length		
	Ignore 🗌		
	Overhang 50.0		
	Gauge length 90.0	J	
	Connection		
	×	XX ×F [Y.
	Close		

19 Close the dialog and in the **PowerMill** *explorer* select **Simulate from Start** on the **toolpath** named **`Outer Swarf**'.



- 20 Select *Switch on the Machine Tool Display* in from the Simulation toolbar.
- 21 Select the Collisions tab on the dialog.
- 22 Select **Clear** on the dialog to clear any existing collisions.





23 Start the Simulation **b**.

P s				
IĽ.	dmu50v			
	Check for	collisions		
Ν	/lachine to	ol clearance	2.0	
6	Check th	ne tool and hold	ler	
н	older clear	ance	2.0	
Sł	hank cleara	ance	1.0	
2	Check for	reconfiguration	mover	
		first issue of ea		
	s found:			
ue	is round:			
	#	ltem	Description	
	Clear			
	Clear			
	Clear		Close	

The **Machine Tool Collisions** dialog remains blank indicating that no collisions have been detected.

- 24 Select File > Save Project.
- 25 Select File Delete All and Tools Reset Forms.

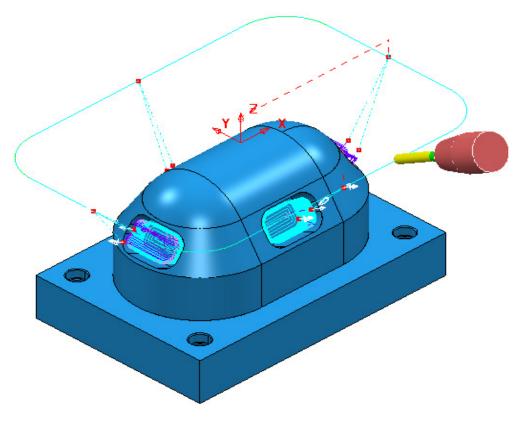


NCProgram Verification (Including a Machine Tool Model)

It is possible to **Verify** the whole contents of an **NC Program** including an option to collision check a *Machine Tool Model*.

1 **Open** the read only **Project**:

....\PowerMill_Data\five_axis\Collision_Simulation\AnglePockets-FullVerify_Start



Select File - Save Project As:

....\COURSEWORK\PowerMill-Projects\AnglePockets-FullVerify

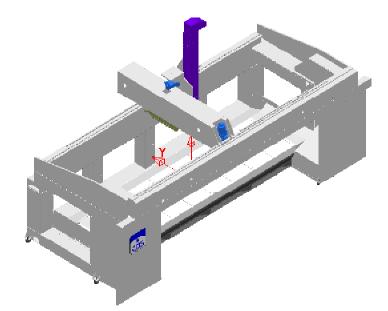
2 In the **PowerMill** *explorer* right mouse click on **Machine Tools** and from the local menu select **Toolbar**.



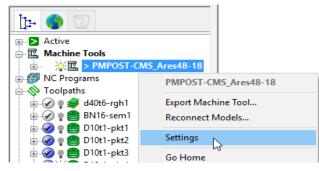
3 Select the *Import the Machine Tool Model* icon *PMPOST-CMS_Ares48-18.mtd* from:

....\PowerMill_Data\MachineData\CMS\.....

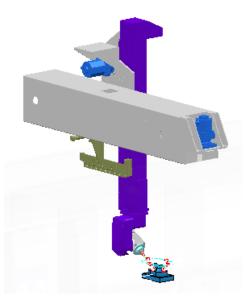




4 In the **PowerMill** *explorer* right mouse click on the **Machine Tool** *PMPOST- CMS_Ares48-18* and fro the local menu select **Settings**.



- 5 In the dialog, select **Part** and move the **Opacity** slider fully to the left to make the static machine tool parts almost invisible.
- 6 Apply and Accept the dialog.

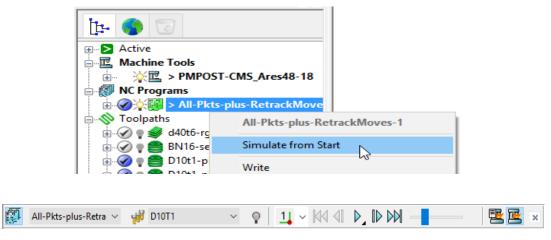




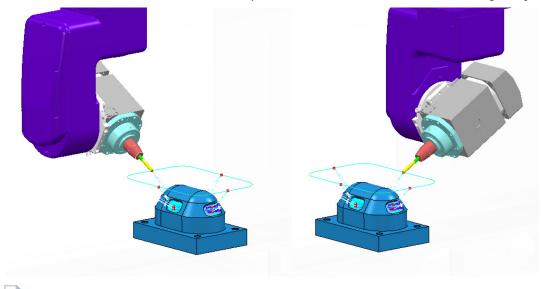
7 In the Machine Tool toolbar select the Workplane MC-Table-location.



8 In the **PowerMill** *explorer*, right mouse click the **NC Program** named **All-Pkts-plus-RetrackMoves-1** and from the local menu select **Simulate from Start**.



9 In the **simulation** toolbar set the speed slider to medium before selecting **Play**.



Observe that the total CMS machine's Head rotation (C Axis) is currently 450 degrees (This CMS has a maximum C axis rotation limit of 360 degrees).

- 10 Right mouse click on the NC Program *All-Pkts-plus-RetrackMoves-1* and from the local menu select **Settings** to open the NC Program dialog.
- 11 In the *Machine Tool* box select the **PMPOST-CMS_Ares48-18** and for *Model Location* select **MC-Table-location**.



P NC Program : All-Pkts-plus-	RetrackMoves-1					?	×
12 Name	All-Pkts-plus-Retra	ackMoves-1					8
Output File	C:\Temp\NCProgr	ams\{ncprog	ram}				0
Machine Option File	C:\dcam\config\P	MPOST\CMS	Head-He	ad_Fanu	:31i_5ax	dis_J ~	2
Machine Tool	PMPOST-CMS_ ~		Model L	ocation	MC-Ta	ble-loca	• ~
Output Workplane	None> Image: Second	-CMS AresA	8-18	Name	1		
Program Number		cm5_mc34	3	l Value	Тір		~
Automatic Tool Ali	1			Moves	Move,	Rotate	~
Toolpath Num Di				Thi	ckn	Axial T	^
Pkt4-Pkt1-C 1 10	×			0			
D10t1-pkt1 (1) 10	1 130	70	0.01	0			
Pkt1-Pkt2 (1) 10) 1 130	70	0.01	0			
D10t1-pkt2 (1) 10) 1 130	70	0.01	0			~
<						>	

- 12 At the base of the dialog select **Apply** followed by **Accept**.
- 13 In the PowerMill explorer right mouse click on the NC Program

All-Pkts-plus-RetrackMoves-1 and from the local menu select Verify.

14 In the NC program verification dialog input the Machine Tool, Holder, Shank clearances as 5, 2 and 1 respectively before selecting the Verify tab.

P NC program verification	? ×
All-Pkts-plus-RetrackMov	∧ × 🐯
PMPOST-CMS_Ares48-1	8 IP MC-Table-location
Verify the machine tool	Verify toolpaths 🗹
	Verify connection moves 🗹
	Machine tool clearance 5.0
Verify the tool against the mo	odel Verify toolpaths ✓
K	Keep existing toolpath clearances
	Holder clearance 2.0
	Shank clearance 1.0
Verified. Potential issues for the second	ound.
# NC item	Description
 2 1 0 2 0 2 0 9 kt4-Pkt1-C 	NC program's machine tool and the option file's machine tool differ: The transforms on the linear axes differ A retract and reconfigure is required.
	· · · · · · · · · · · · · · · · · · ·
<	(
¥22	Load issue
	Verify Close

In the above **NC Program** dialog it has been reported that one of the toolpaths is causing the rotary limits to be exceeded. This CMS machine tool can only perform a total of one 360 Degrees rotation about the C axis. The total of C Axis rotation currently required by the **NC Program** is 450 Deg.



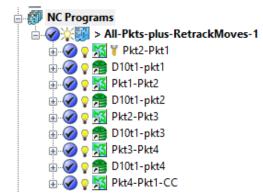


This can be fixed by using different positional move toolpaths at the ends of the **NC Program** that will start well within the main machining areas and then re-track the tool back to the original start position.

15 In the **PowerMill** explorer right mouse click on the **NC Program**

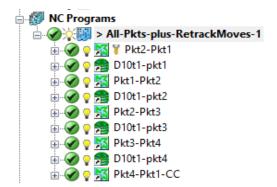
All-Pkts-plus-RetracMoves-1 and from the local menu select **Clear Verification**.

16 In the NC Program All-Pkts-plus-RetracMoves-1 replace the common first and last positioning toolpath (Pkt4-Pkt1-C) with Pkt2-Pkt1 and Pkt4-Pkt1-CC respectively.



The replacement toolpaths preform repositioning with counter clockwise rotation about the C axis. This will keep the total C rotation moves well within the CMS machine limits.

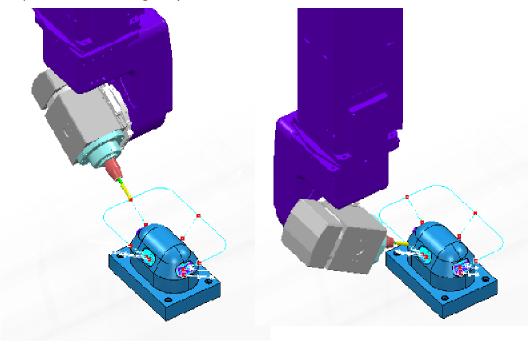
17 In the PowerMill explorer right mouse click on the updated NC Program All-Pkts-plus-RetracMoves-1 and from the local menu select Verify.





This time all toolpaths are displayed with a green verification status ' and no issues are reported in the **NC program verification** dialog. The green status also confirms that within the **NC Program** the **Machine Tool** is collision safe in addition to the included, gouge free **toolpaths**.

18 Run another **NC Program** simulation and observe that this time the whole process is now contained within a total C axis rotation of 270 degrees (max permissible 360 degrees).



- **19** Select **File > Save Project**.
- 20 Select File Delete All and Tools Reset Forms.



12. Machine Axis Control

Introduction.

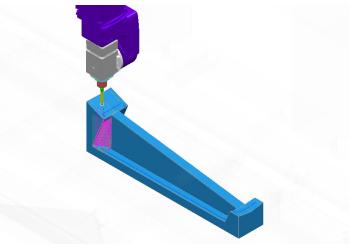
The **PowerMill verification** options will ensure collision safe, toolpaths relative to the **Tooling components**. However, In 5 Axis applications it is also essential to check that the actual moving parts of the **Machine Tool** are also collision safe. For this to work effectively, a suitable machine tool model (**MTD** file) is required in the **simulation** process. If a collision between the component part and machine tool model is detected then the user can **recycle** the strategy with appropriate **Machine Axis Control** options applied.

Machine Axis Control options allow the user to avoid collisions by controlling the *orientation/movement* of the independent parts of a machine tool within the machining strategy.

Machine Axis Control is not just used for collision avoidance but can also be used to enable an oversized component to be machined by applying **Polar** to force the use of a *rotary axis* in preference to a *linear axis*. This option can also be used in cases where it is simply more efficient for a specific machine tool to use a rotary axis in place of a linear axis.

Tool Axis Control - Re-Orientation - Example

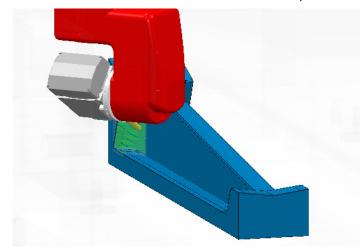
- 1 **Open** 'read only' the **Project**:
 -\PowerMill_Data \five_axis\MachineAxisCtrl\CMS-AxisControl_Start



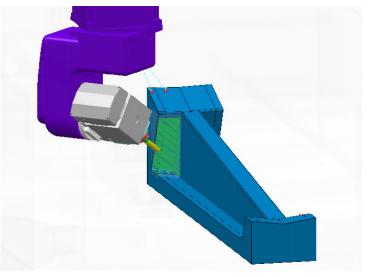
2 From the main pull down menus select File > Save Project as:\COURSEWORK\PowerMill-Projects\ CMS-AxisControl-ex1



The **Project** contains 2 **NC Programs** that contain the same machining toolpaths. If the **NCProgram** *No-OrientationMoves* is run in a *machine tool simulation* the Machine Tool Head clashes with the component.



If the **NCProgram** *With-External-OrientationMoves* is run in a *machine tool simulation* there are no collisions between the machine tool parts and component. This is due to the addition of repositioning toolpaths inserted as necessary to provide machine tool head **re-orientation**.



Although the last **NC program** provides an acceptable collision free solution the method is labour intensive and dependant on the user correctly creating and inserting positional move toolpaths in the correct order.

- 3 Select an **ISO 2** view.
- 4 In the **PowerMill** *explorer* right mouse click on **Machine Tools** and from the local menu select Toolbar.
- 5 Input **Base-Centre** in the *workplane* input box of the **Machine Tool** toolbar.
- 6 In the Machine Tool toolbar input the machine tool model:-

....\PowerMill_Data\MachineData\CMS\PMPOST-CMS_Ares48-18.mtd





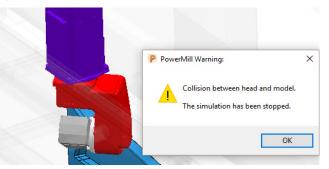
- 7 In the **PowerMill** *explorer*, right mouse click **Machine Tools** > **PMPOST-CMS_Ares48-18**, to open the local menu.
- 8 In the local menu select **Settings**.

	res48-1	8	
In the second secon	P	MPOST	-CMS_Ares48-18
🖅 🛛 💡 🔛 WithExternal-Orien		kport Ma	achine Tool
	R	econnec	t Models
	S	ettings	2
 · · · ·			

9 In the dialog select the item, named **Part** and then move the **Opacity** slider to make the static part of the machine tool model, translucent.

P Machine Tool		? ×	
Machine Tool PMPOST-CMS_Ares48-18	piedini DarkSi carena Gainst base DimGr < Opacity =	ateGrey ateGrey poro	
Apply	Accept Cancel		

- 10 Accept the Machine Tool dialog.
- 11 In the **PowerMill** *explorer*, right mouse click on the **NC Program** named **No-Orientation Moves** and from the local menu select **Simulate from Start**.
- 12 Select the **Play** button in the simulation toolbar.



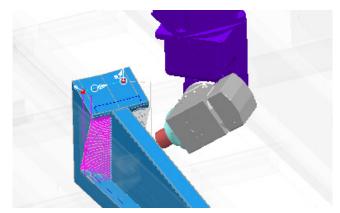
After several passes the machine tool head is in collision with the component. The machine tool head changes colour to **red** and a **PowerMill Warning** box appears as soon as the first collision is detected.

13 Select **OK** and the simulation will continue even though the head is still colliding (The head will change colour to red during each collision).



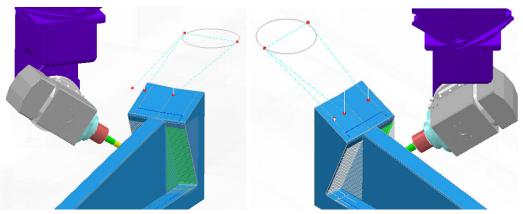
Collision checking and reporting to a Machine Tool Model simulation is a cost option.



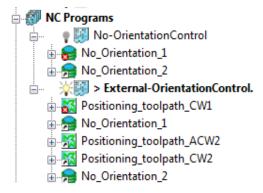


When the **NC Program simulation** moves to the other side of rib, the machine tool head happens to be in a collision safe, orientation relative to the component. This is not easily predictable and could easily change to a collision situation on switching the order or inserting new toolpaths into the **NC Program**.

14 In the PowerMill explorer, right mouse click on the NC Program WithExternal-OrientationMoves and from the local menu select Simulate from Start.



This time the machine tool head is collision safe throughout the simulation.



In this case, drive curve toolpaths have been inserted as required into the **NC Program** to force appropriate re-orientation moves to occur.

The only problem is that these moves are added retrospectively and as mentioned earlier, will be unpredictable if the toolpath order is changed or additional toolpaths are inserted into the **NC Program**.

A more efficient and direct method to apply machine tool head alignment within an individual strategy is to use the **Machine axis control** dialog.



- 15 Ensure that neither **NC Program** is active.
- 16 Activate the toolpath No_Orientation_1 and then select Settings from the local menu.
- 17 In the **Constant Z Finishing** dialog, select **Make a Copy** and rename the new toolpath as **Orientation_AZ180**.
- 18 Select the Machine axis control page in the dialog and select the Orientation type as Orientation vector, the Orientation vector as Fixed direction, and input a Direction Azimuth 180.

Constant Z Finishing	?	×
Toolpath nam	No_Orientation_AZ180	_
2. Workplane	Machine axis control	
Tool	Orientation type	
	Orientation vector 🗸 🚺	
	Orientation vector Offset angle	
- 🤤 Constant Z finishing F High speed	Fixed direction V 0.0	
Automatic verification	Direction	
Point distribution	Azimuth Elevation	
<u>14</u> Tool axis Ø Machine axis control	180.0 0.0	
🗄 🚽 Rapid Moves	Components	
	-1.0 -0.0 0.0	

By changing the default **Orientation type** from **Free** to **Orientation vector** the machine head alignment will now be controlled directly within the strategy. The **Machine axis control** will cause the head to be rotated by **180** Degrees about the **Z** axis compared with the original toolpath.

- 19 Select **Calculate** to create the new toolpath and close the dialog.
- 20 Activate the toolpath No_Orientation_2 and then select Settings from the local menu.
- 21 In the **Constant Z Finishing** strategy dialog, select **Make a Copy** ^[42] and rename the new toolpath as **Orientation_AZO**.
- 22 Select the **Machine axis control** page in the dialog and enter data exactly as shown below but this time with **Direction Azimuth 0**.

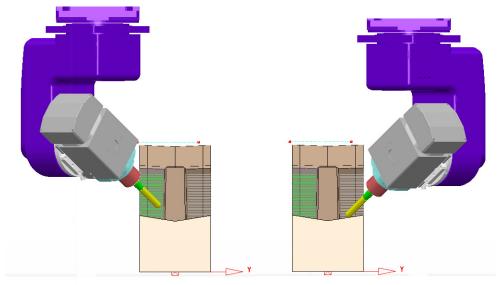
P Constant Z Finishing	? ×
Toolpath nar	me No_Orientation_AZ0
	Machine axis control
	Orientation type
🖾 Machine tool 🔞 Limit	Orientation vector 🗸 🚺
	Orientation vector Offset angle
E Constant Z finishing	Fixed direction v 0.0
Automatic verification	Direction
Point distribution	Azimuth Elevation
	0.0 0.0
🗄 🚽 Rapid Moves	Components
🕀 🔰 Leads and links	1.0 0.0 0.0

The Machine axis control will use the default values for an Orientation Vector of Azimuth 0 and Elevation 0.

23 Select **Calculate** to create the new toolpath and close the dialog.

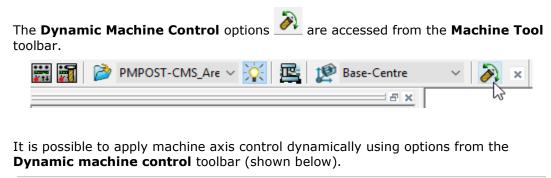


- 24 Create a new NC Program named Internal-OrientationControl containing the 2 new toolpaths Orientation_A180 and Orientation_A0.
- 25 With the machine tool model, **PMPOST-CMS_Ares48-18** still active, run a full simulation on the new **NC Program** and check that the head movement is collision free throughout.
- 26 Reverse the order of the toolpaths in the NC-Program named Internal-OrientationControl and run the full simulation again and check that the head movement is collision free throughout.



The application of **Machine axis control** directly in the strategies has eliminated the need for the additional positioning toolpaths. As shown in the above illustration, the **machine axis control** is now independently controlled within the 2 new strategies.

Dynamic Machine Control (Requires VeriCL - The Advanced Simulation cost option)



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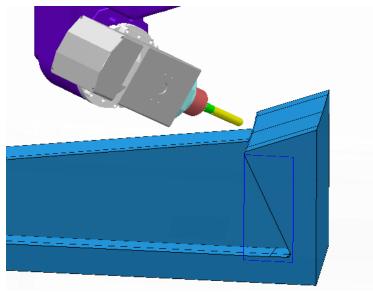


Visual checking for Machine Tool accessibility

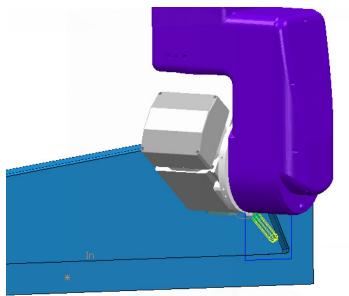
The active **Tool** and **Machine Tool** head can be dynamically moved around the part to visually check for accessibility relative to the current orientation

- 1 In the **PowerMill** *explorer* right mouse click on the toolpath **No_Orientation_2** and select **Simulate from start**.
- 2 **Jog** the tool to the start of the fixed machining alignment position and then from

the Machine Tool toolbar select Dynamic Machine Control.

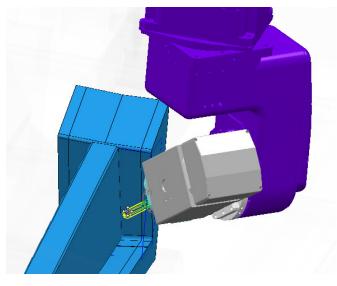


- 3 In the Dynamic machine control toolbar select use tool positioning graphics.
- 4 Left click on the tip of the tool and then dynamically move it down the angled model, undercut towards the base of the recess.

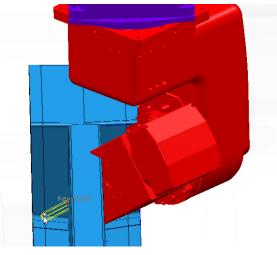




5 Rotate the view to observe the new position from different angles.



6 Dynamically drag the tool to a '*key point*' on the opposite side of the model.



If any part clashes with the model the $\ensuremath{\textbf{machine tool head}}$ will change colour to red.

7 Select the green tick **Y** at the end of the **Dynamic machine control** toolbar to exit with the tool still displayed in the final position.

The above final **Tool** position is cancelled if a new **Toolpath simulation** is selected, or if **Go Home** is selected in the **Machine Tool** menu.



If the **red cross** *is* selected then the tool will be positioned as it was before the **Dynamic machine control** toolbar was opened.

8 Right mouse click on the machine tool model, **PMPOST-CMS_Ares48-18** and from the local menu select **Go Home**.

Dynamic Machine Tool re-orientation applied to a Toolpath.

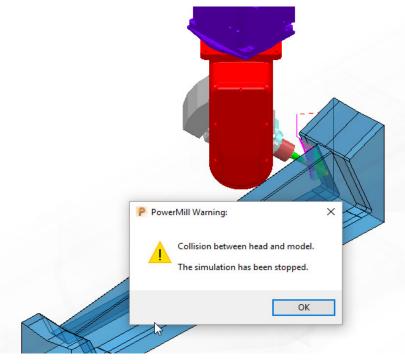


The default setting in the **Dynamic machine control** toolbar is **Use machine tool graphics**.

The rotary axis components of the machine tool can be dynamically reorientated and applied retrospectively to the active toolpath.

Other options include:-

- a **Use machine tool graphics** Applies dynamic rotation and linear moves relative to the Machine Tool model datum (Default).
- **b** Active workplane graphics mode 2 Applies dynamic rotation and linear moves relative to the active workplane.
- **c** Lock tool axis direction **·** This locks the current rotary axis orientation, allowing only dynamic linear axis, moves to take place when used with **a** or **b** above.
- From the local PowerMill explorer Toolpaths, right mouse click on No_Orientation_1 and from the local menu select Edit - Copy Toolpath.
- 2 Rename the new toolpath as **Dynamic_Orientation_1**.
- 3 Activate the new toolpath and run a **Machine Tool simulation** until the collision with the **Head** is first detected.



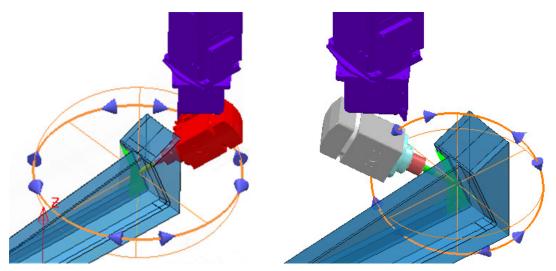
4 Select **OK** in the **PowerMill Warning** dialog.



5 On the Machine Tool, toolbar select Dynamic machine control



6 Use the default Use machine tool graphics option



- 7 Use the upper circular handle to rotate the head to the above left, alignment, followed by the lower circular handle to re-orientate the tool to the above right alignment.
- 8 Once a suitable Machine Tool Orientation has been achieved select the

Update Toolpath 🚞 option.

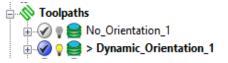
9 Select the green tick to accept the changes and close the **Dynamic machine** control toolbar.



The toolpath is now displaying **gouge** and **collision** status as **Unknown**.



10 Verify the modified toolpath Dynamic_Orientation_1 for both Gouges and Collisions (Clearances:- Holder 2 and Shank 1).



The **Toolpath** is now confirmed to be both **Gouge** and **Collision** safe relative to the **Tool** assembly.



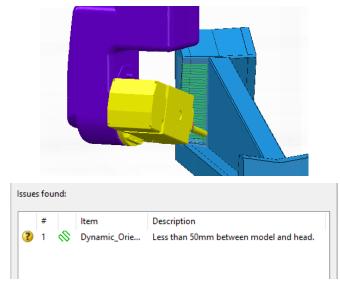
11 Right mouse click on the machine tool model and from the local menu select **Issues** to open the following dialog.

P Simulation Issues		? ×				
PMPOST-CMS_Ares48-18						
Check for collisions						
Machine tool clearance	5.0					
Check the tool and holder	$\overline{\mathbf{a}}$					
Holder clearance	2.0					
Shank clearance	1.0					
Check for reconfiguration moves						
Pause on the first issue of each	Pause on the first issue of each type $\qquad \lor$					
Issues found:						
# Item	Description					
Clear						
	Close					

- **12** In the dialog input a suitable clearance value for the machine tool head (eg **5**).
- 13 Clear the issues found, list and perform further machine tool simulation to confirm that the *head assembly* is also collision safe (The Holder and Shank clearances (eg 2 and 1) can also be included in the same dialog).



During a simulation the machine tool **Head** will change colour yellow if a collision situation is identified and it will also be registered in the above dialog.

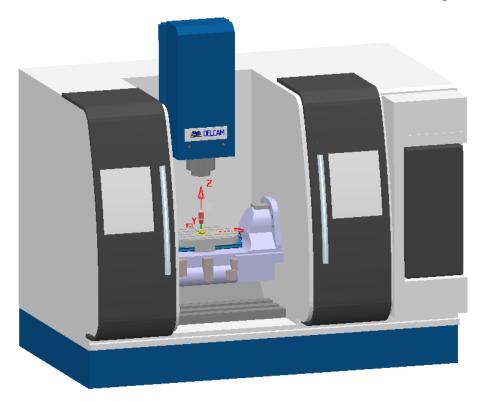


- 14 Save the Project.
- 15 Select File Delete All and Tools Reset Forms.

Tool Axis Control - Polar - Example

The start up **Project** contains a **BN16** tool, 3 Axis **toolpath**, Mazak Variaxis **Machine Tool** model, and component **model**. The component model has a length dimension that exceeds the **X axis** and **maximum Y**, travel limits for the Mazak machine. However the model could be machined in 4 stages if the longest dimension, is controlled to align within the **minimum Y** axis travel limits. This will be achieved by applying the **Tool Axis Control** – **Polar** options to convert all **X** linear moves to **C Axis**, rotary moves (about the Z Axis).

- 1 **Open** 'read only' the **Project**:
 - ...\PowerMill_Data \five_axis\MachineAxisCtrl\Mazak-OversizeCompt_Start



- 2 From the main pull down menus select File > Save Project as: ...\COURSEWORK\PowerMill-Projects\ Mazak-OversizeCompt-ex1
- 3 In the **PowerMill** *explorer* Machine Tools area, activate the machine tool model, **PMPOST-Mazak_Variaxis_630PSA**.
- 4 From the **main** pull down menus select **View Toolbar** and from the resultant menu ensure that the **Simulation**, and **Machine Tool** options are all ticked.
- 5 In the **Machine Tool** toolbar, input the machine tool named **PMPOST-Mazak_Variaxis_630PSA** and the **workplane** named **TableDatum**.

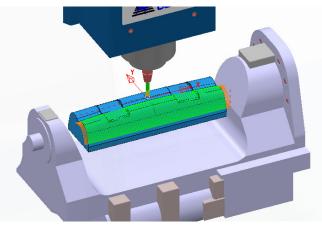




6 In the **PowerMill** explorer right mouse click on the **Machine Tool** - **PMPOST-Mazak_Variaxis_630PSA** and from the local menu select **Settings**.

Machine Tool		?	×	
B Machine Tool PMPOST-Mazak_Variaxis_6: Part A A Lable X B-Y Lable X b-Y head	Axis MachineDNA Part name Movement <u>Static</u>			
	Filename swarf-gutter door-handles doors main-casing base	Colour DarkGrey Lavender DarkSlateGrey White Teal		
Apply	Accept Cancel	acity	>	

- 7 In the dialog, select A and move the *Opacity* slider to the left until the moving parts can be clearly seen behind the opaque, static parts of the Machine Tool Model.
- 8 From the **PowerMill** *explorer*, right mouse click on the existing **toolpath** and from the local menu, select **Simulate from Start**.



9 In the **Simulation** toolbar, select the **Play** button and immediately the following *PowerMill Error* dialog will open.

P PowerMill Warning:	×
Machine X needs to get to -341.34, minimum is -315. The simulation has been stopped.	
ОК	

The **X** co-ordinates at the ends of the above **toolpath** are outside the **X** axis, travel limits. Note, the travel limits are included in the **machine tool model** definition.

- 10 In the **PowerMill explorer**, right mouse click on the existing toolpath and from the local menu select **Activate** followed by **Settings** to open the dialog.
- 11 In the Line Projection Finishing dialog select the 'make a copy' option
- 12 In the dialog, Rename the new toolpath as BN16-Vert-Orientation-Polar_A.
- **13** In the local explorer, select the **Machine axis control** page and input data as shown below.

P Line Projection Finishin	g		?	×
وي ال	Toolpath name	BN16-Vert-Orientation-Polar_A		
Workplane Block Block U Tool Kachine tool Kachine tool Kachine tool Kachine projection Kachine projection Kachine axis cont Kachine axis	fication	Machine axis control Orientation type Polar Rotation centre Lock Axis Offset X Output Use complementary angle Image: Complementary angle Image: Complementary angle Image: Complementary angle Image: Complementary angle		

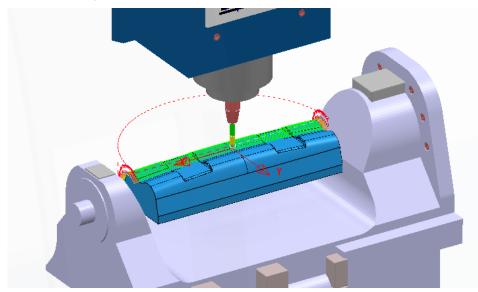
14 In the above dialog select it to change to the **Rapid Moves** page and then tick the box, **Use polar links** as shown below.

P Line Projection Finishing	? ×
Toolpath na	me BN16-Vert-Orientation-Polar_A
Workplane	A Rapid Moves
Block	Safe area
Tool	
Machine tool	Type Plane ~
🕅 Limit	Workplane MCdatum ~
Stock engagement	incutani
Line projection	
Pattern	
Automatic verification	Normal
Tool axis	
Machine axis control	0.0 0.0 1.0
Rapid Moves	
Moves and clearances	Rapid height 9.998021
Leads and links	Plunge height 4.998021
Lead in	Use polar links 🗸
ULead out	
First and last leads	Calculate dimensions
Lead extensions	Measured from Block and Model 🗸
	Rapid clearance 10.0
Point distribution	
J Start point	Plunge clearance 5.0

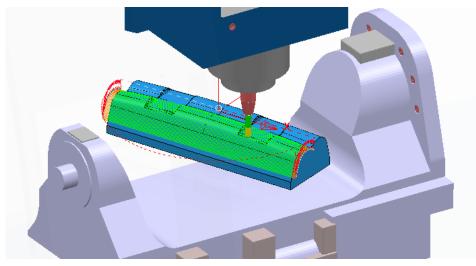
15 Calculate the dialog to create the new toolpath.



16 From the **PowerMill** *explorer*, right mouse click on the new toolpath and from the local menu, select **Simulate from Start**.



17 In the **Simulation** toolbar, select the **Play** button and this time the strategy will successfully run from start to end.



All the **X-Axis** cutting moves in the original toolpath have been converted to **C-Axis** rotary moves in the new toolpath. This has resulted in tool moves being confined to the area from the *table centre* towards the **min Y** travel limit.

18 Select File - Save Project.

Exercise

- 1 Create a copy of the above toolpath named **BN16-Vert-Orientation-Polar-B**.
- 2 Calculate after inputting the appropriate data to finish machine the other half of the component model keeping within the Tool Axis limits for the Mazak machine tool.
- 3 Select File Save Project.



13. Machine Tool Models

Introduction.

The **PowerMill** toolpath **simulation** process can be expanded to include a **Machine Tool Model**. This capability becomes extremely important for multi-axis applications.

First of all **triangle** models (eg **dmt** or **stl** format) need to be obtained of all the independent moving parts of the machine tool. It is essential that the user obtains accurate dimensions along with any other details relating to the setup of a specific machine tool.

These separate **Triangle** files are stored in a folder adjacent to a *Machine Tool Simulation* schema file (mtd)

To create a new **mtd** file it is easier to modify a copy of an existing one based on a machine tool of similar configuration.

It is essential that the kinematics of a **Machine Tool Simulation model**, is the same as the relevant **Post-Processor** output.

How to configure a Machine Tool for simulation

The first stage is to create the separate component models (ideally in **PowerSHAPE**) for each moveable axis for the machine tool. These must be exported as individual **triangle** models to be compatible for use in an **mtd** file. For the following example the models have already been created and are ready to be registered to a new **mtd** file.

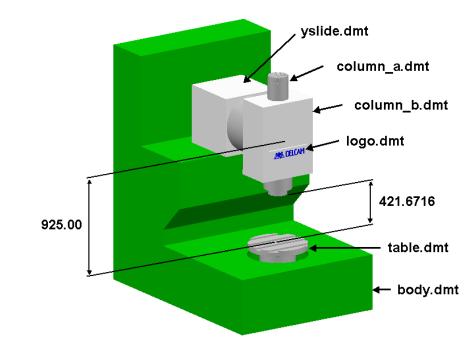
An **mtd** file contains information that describes the kinematics of a particular machine.

For **mtd** files to work, they must be accompanied in the same folder by the *schema* file, **pmillmt.xsd**.

In the same location, a *sub-folder* must exist that contains separate **triangle** models **dmt** of all the necessary *static* and *moving* machine tool components.







Machine Tool Model for a dmu80t Five Axis

The above illustration identifies 6 separate **triangle** models that form a *dmu80t* five axis machine tool. Also shown are the vertical distances from the top of the *table* to the base of the *head* (**421.6716**), and the centre of the *rotational axes* (**925.00**).

machine_part

The **mtd** file is made up of objects called **machine_part**. There are 2 compulsory **machine_part** objects which must be identified as "**head**" and "**table**". Note; their names in the **mtd** file must be in lower case.

In the above machine tool the **X**, **Y**, and **A** axis (rotation about Y) are controlled on the "**head**", and the **Z** and **B** axis (rotation about Z) are controlled on the "**table**".

Linear Axis Controls

X, **Y**, and **Z** must exist and only right handed axis systems are supported.

These can be in any orientation as long as they are orthogonal.

Type of axis that can be configured is:-

Simple_linear:- The definition requires *direction*.

Rotary Axis Controls

Rotary controls are typically defined by **A**, **B**, or **C** and ideally should be selected to match the same output as output in the associated *Post-Processor*. Note; where applicable, angular limits can be assigned to an individual rotary axis.

Type of axis that can be configured is:-

simple_rotary:- The definition requires *position* and *direction*.



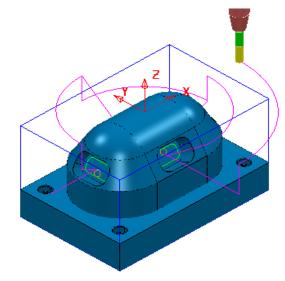
MTD file initial state

Although all the separate **triangle** models are correctly positioned relative to the assembled machine tool model, it is still required to input key dimensions into the mtd file. In this example, these include the 'gauge' distance from the top of the table (**0 0 0**) to the base of the head (**0 0 421.6716**), and the coordinates of the centre of the rotary axes (**0 0 925**).

EXAMPLE:- MTD file for a Mazak five axis machine

1 Select File - Open Project:-

....\PowerMill_Data\five_axis\MachineToolModels\MTD-Mazak-Ex1_Start



2 Select File - Save Project As:-

....\COURSEWORK\PowerMill_Projects\MTD-Example1

A **Machine Tool Model** will be loaded into the above **Project** that correctly defines:-

- a The position of all the separate machine tool components.
- b The direction of rotation for the 2 rotary and +/- movement for the 3 linear axes.
- c The max/min travel limits for each of the 5 axes.
- 3 From the main pull down menus select View Toolbar Machine Tool to open the Machine Tool toolbar (Or alternatively right click on Machine Tools in the PowerMill explorer and from the local menu select Toolbar).

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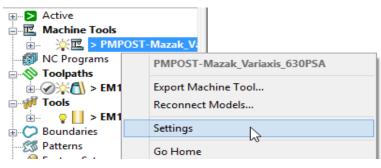
4 In the Machine Tool toolbar select the Import Machine Tool Model option. 人 AUTODESK.

5 In the dialog select the Machine Tool Model file:-

....\PowerMill_Data\five_axis\MachineToolModels\PMPOST-Mazak_Variaxis_630PSA.mtd



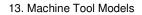
- 6 Select Workplane 2 as the Current Model location point.
- 7 In the PowerMill explorer right mouse click on the Machine Tool Model name PMPOST-Mazak_Variaxis_630PSA and from the local menu select Activate followed by Settings.



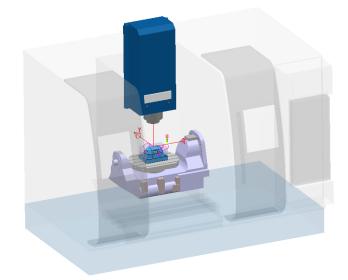
8 In the Machine Tool dialog select Part.

P Machine Tool		?	×
Machine Tool PMPOST-Mazak_Variaxis_6: Part A C table X table Y head	Axis MachineDNA Part name Movement Static	<u>.</u>	
	Filename swarf-gutter door-handles doors main-casing base	Colour DarkGrey Lavender DarkSlateGrey White Teal	
< >			
Apply	Accept Cancel		

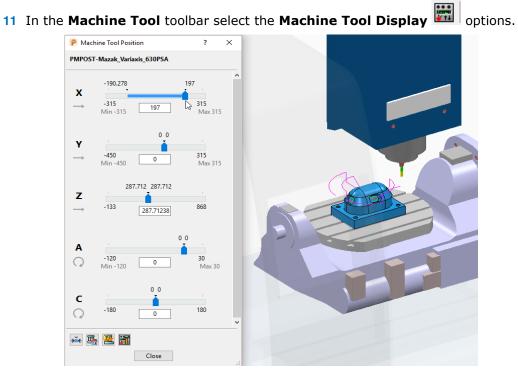
9 Move the **Opacity** slider to the left until the **Machine Tool Body** is almost invisible.







10 Right mouse click on the toolpath **EM12-FinPkts** and from the local menu select **Simulate from Start**.

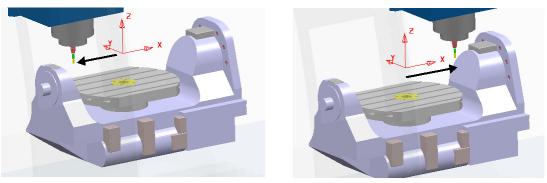


12 To test the X-Axis travel, select the Cursor on the X row slider and drag it to the left, and/or use the LH/RH keyboard *arrow* keys for exact 0.5 incremental moves.

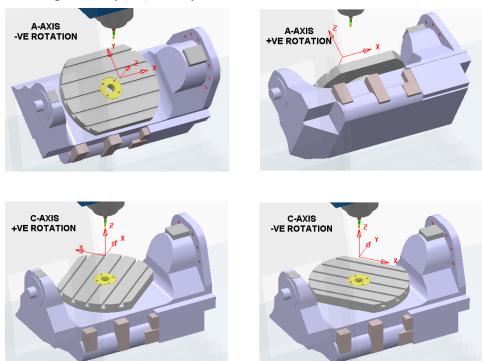




13 On the keyboard hold while holding down the Shift key, press the left hand arrow key to perform continuous, incremental -ve X moves on the machine tool model.



- 14 While holding down the Shift key, press the RH keyboard arrow key to perform a +ve X move on the machine Tool Model.
- 15 On the keyboard press the downward, **arrow** key to move down to the next row (or simply click on the **Y** row, cursor).
- 16 As before visually check both the -ve and +ve Y moves on the Machine Tool Model.
- 17 Systematically move down the rows and check out the movement of the remaining 3 axes (**Z**, **A**, and **C**) on the **Machine Tool Model**.

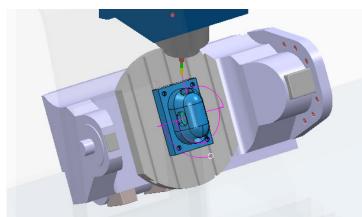


The above movements are exactly the same as on the actual **Mazak** machine tool to which the **MTD** file relates.

A full **simulation** will provide a visual confirmation of the all moves performed on the toolpath. It is also possible to check for **Machine Tool** component collisions (if an additional <u>cost option</u> is purchased).



18 Close the *Machine Tool Position* dialog and then perform a full **Simulation** on the toolpath **EM12-FinPkts**.



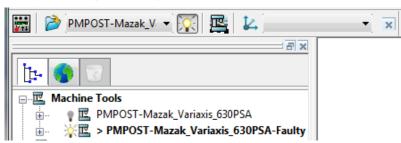
19 In the **PowerMill** *explorer* right mouse click on the machine tool, *PMPOST-Mazak_Variaxis_630PSA* and from the local menu select **Go Home**.

Correcting a faulty MTD File:-

- 20 In the Machine Tool toolbar select the Import Machine Tool Model option.
- 21 In the dialog select the Machine Tool Model file:-

....\PowerMill_Data\five_axis\MachineToolModels\PMPOST-Mazak_Variaxis_630PSA-Faulty.mtd

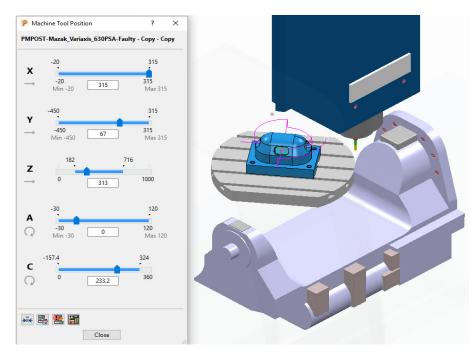
- 22 As before open the **Settings** dialog from the local menu and turn down the **Opacity** of the non-moving parts of the **Machine Tool Model**.
- 23 In the dialog select Open to import the new Machine Tool Model.



The newly imported **Machine Tool Model** file should perform exactly as the existing one. However the **MTD** file contains some incorrect values which need to identified and fixed. The user will need to systematically check the linear and rotary axis movements and the relative location of the trunnion and rotary table.

- 24 In the Machine Tool toolbar select the Machine Tool Display
- 25 Use the Jog options to check the +ve and -ve movement of all 5 axes (They should be the same as the Machine Tool Model imported with the original Project).





The following C-Axis faults are exposed in the currently active MTD file:-

- a The +ve/-ve rotational moves for the *Rotary Table* C Axis are reversed compared with the Machine Tool Model imported with the original Project.
- **b** The **Rotary Table** rotational centre (**C-Axis**) is incorrectly aligned.
- **c** The **-ve X Axis** moves are incorrectly limited to just beyond the table centre.
- 26 From the Desktop open a File Explorer dialog and browse to the folder:-

....\PowerMill_Data\five_axis\MachineToolModels

27 Create a copy of the mtd file:- PMPOST-Mazak_Variaxis_630PSA-Faulty.mtd and rename it as:- PMPOST-Mazak_Variaxis_630PSA-Update.mtd



If an MTD file of the same name already exists overwrite it.

28 Open the new copy of the mtd file in Wordpad and look for incorrect data in the section of the mtd file that defines the Rotary Table – C-Axis.

```
<machine_part>
<axis>
<control_info ADDRESS="C" />
<simple_rotary X="0" Y="250" Z="0" I="0" J="0" K="-1" />
</axis>
<model_list>
<dmt_file>
<path FILE="Mazak_Variaxis_630/table.dmt" />
```



<rgb R="200" G="200" B="200" />

The previous row that defines the C-Axis requires the XYZ position to be in the centre of the table, and the +ve/-ve rotation directions to be reversed.

29 Modify the above incorrect values to those shown below:-

<simple_rotary X="0" Y="0" Z="0" I="0" J="0" K="1" />

30 Save the updated mtd file (but do not close it).

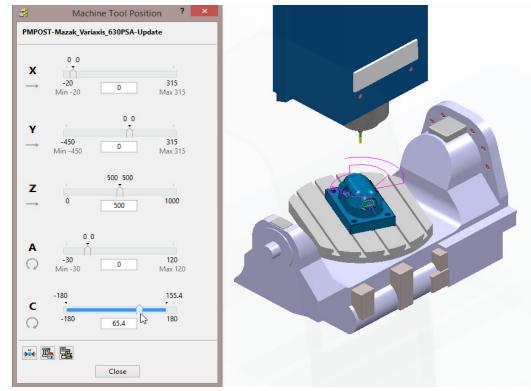


This latest update will now be tested in the **PowerMill Project**.

- 31 In the Machine Tool toolbar select the Import Machine Tool Model
- 32 In the dialog select the Machine Tool Model file:-

....\PowerMill_Data\five_axis\MachineToolModels\PMPOST-Mazak_Variaxis_630PSA-Update.mtd

- **33** Turn down the **Opacity** on the static parts of the **Machine Tool model**.
- 34 In the Machine Tool toolbar select the Machine Tool Display 📰 option.
- 35 Use the Jog options to check the +ve and -ve movement of the Rotary Table
 C-Axis.



The updated **Rotary Table** – **C-Axis** movement is now exactly the same as in the original **Machine Tool Model** (*PMPOST-Mazak_Variaxis_630PSA*).

The next stage is to use a **Simulation** to check that all of the **linear** and **rotary** travel limits on the **Machine Tool Model** are correct.

36 Right mouse click on the toolpath **EM12-FinPkts** and from the local menu select **Simulate from Start**.

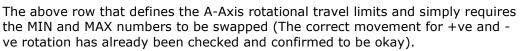
37	On the Simulation toolbar se	lect t	ne Play 🔽 button.		
	And	P Powe	rMill Warning:	×	
			Machine X needs to get to -190.28, minimum is -20. The simulation has been stopped.		
			OK		

The **Simulation** has immediately stalled due to one of the defined **X** axis the travel limits being exceeded.

- 38 Press the Play button again to allow the Simulation to continue but note that the A axis trunnion has been able to incorrectly rotate well beyond its 30 deg limit towards the back of the machine.
- 39 Return to the file in Wordpad and look for incorrect data in the section of the mtd file that defines the Table A-Axis.

```
<!-- The table -->
<machine_part>
<axis>
<control_info ADDRESS="A" MIN="-30" MAX="120" />
<simple_rotary X="0" Y="0" Z="50" I="-1" J="0" K="0" />
</axis>
<model_list>
<dmt_file>
<path FILE="Mazak_Variaxis_630/Trunion1.dmt" />
<rgb R="210 " G="210" B="255" />
```

🔼 AUTODESK.



🔼 AUTODESK.

40 Modify the above incorrect values to those shown below:-

<control_info ADDRESS="A" MIN="-120" MAX="30" />

41 Save the updated mtd file (but do not close it).

This latest update will now be tested in the **PowerMill Project**.

42 In the **PowerMill** *explorer* right mouse click on the machine tool *PMPOST-Mazak_Variaxis_630PSA-Update* and from the local menu select **Delete**.

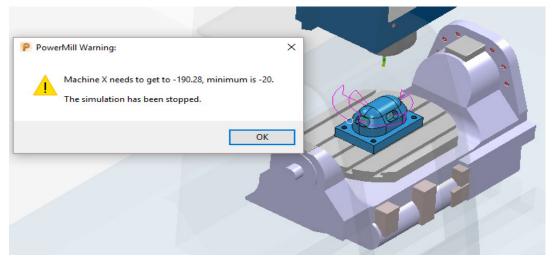


It is necessary to re-import the updated **MTD** file into the **Project**.

- 43 In the Machine Tool toolbar select the Import Machine Tool Model
- 44 In the dialog select the Machine Tool Model file:-

....\PowerMill_Data\five_axis\MachineToolModels\PMPOST-Mazak_Variaxis_630PSA-Update.mtd

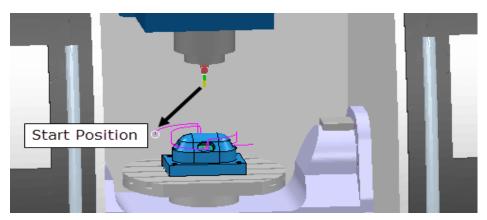
- 45 Turn down the **Opacity** on the static parts of the **Machine Tool model**.
- 46 Right mouse click on the toolpath EM12-FinPkts and from the local menu select Simulate from Start.
- 47 On the **Simulation** toolbar select the **Play I** button.



The **Simulation** immediately stalls and the **PowerMill Error** dialog is displayed informing that the current minimum limit for **X** is **-20**.

48 Select **OK** in the **PowerMill Error** box.





Note that the head is currently unable to move to the **-ve X** start position.

- 49 Continue to **Step Forward** and observe that the **Machine Tool Model** is only performing moves that exist from **X-20** to **X315**.
- 50 Return to the file in **Wordpad** and look for incorrect data in **'The head**' section of the **mtd** file that defines the **X** axis travel limits.

```
<!-- The head -->
<machine_part>
<axis>
<control_info ADDRESS="X" MIN="-20" MAX="315" />
<simple_linear I="1" J="0" K="0" />
</axis>
<machine_part>
<axis>
<control_info ADDRESS="Y" MIN="-450" MAX="315" />
<simple_linear I="0" J="1" K="0" />
</axis>
<machine_part>
```

The above row defining the MIN **X** travel limits contains an incorrect value of "-20". This value must be changed to "-315".

- 51 Modify the above incorrect value to that shown below:-<control_info ADDRESS="X" MIN="-315" MAX="315" />
- 52 Save the file.

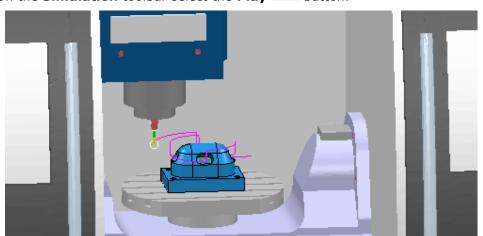
This final update will now be tested in the **PowerMill Project**.

53 In the **PowerMill** *explorer* right mouse click on the machine tool **PMPOST-**Mazak_Variaxis_630PSA-Update and from the local menu select **Delete**. It is necessary to re-import the updated MTD file into the Project.

- 54 In the Machine Tool toolbar select the Import Machine Tool Model
- 55 In the dialog select the Machine Tool Model file:-

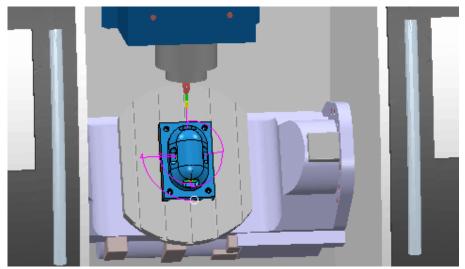
....\PowerMill_Data\five_axis\MachineToolModels\PMPOST-Mazak_Variaxis_630PSA-Update.mtd

- 56 Turn down the **Opacity** on the static parts of the **Machine Tool model**.
- 57 Right mouse click on the toolpath **EM12-FinPkts** and from the local menu select **Simulate from Start**.



58 On the **Simulation** toolbar select the **Play** button.

The simulation will now successfully runs from start to finish without stalling. All linear and rotary moves should be an exact match compared with the original **mtd** file, **PMPOST-Mazak_Variaxis_630PSA**.



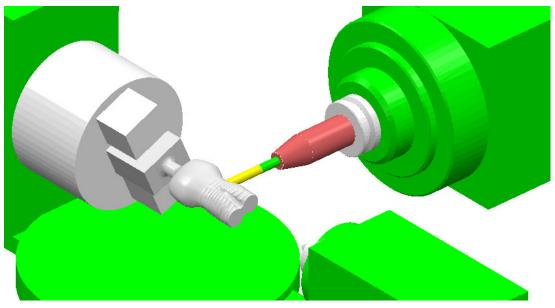
59 Select File - Save Project



14. Four Axis Rotary Finishing

Introduction.

This **Finishing** strategy is designed for machining a component mounted on a single, programmable **Rotary Axis**. During milling, the component rotates around the rotational **X-axis** while the cutter performs simultaneous **3-Axis** movements.



The main options are summarised below.

X Limits

The **X Limits** define the absolute limits of the finishing path along the rotational, X-axis. These can be manually defined, or automatically set to the limits of the block.

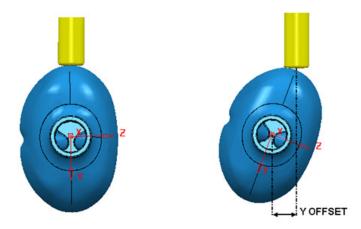
Pattern

This enables the cutting method to be specified for rotary milling either **Circular**, **Line**, or **Spiral**.



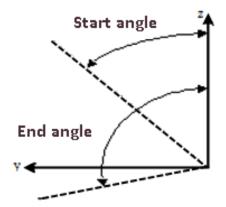
Y Offset

A **Y Offset** distance can be specified to avoid cutting with the tip of the tool. This view along the X-axis shows how the **Y Offset** (if active) is applied to the Rotary form:



Angular Limits

The **Angular Limits** section of the dialog is only available when using the **Style** as **Circular** or **Line**. The **Angular limits** are defined between a **Start** and **End** angle.



The angular limits are measured in an anti-clockwise direction when viewed along the positive X-axis. The area machined is between the start and end angles.

Cut Direction

This option determines whether **Climb**, **Conventional**, or **Any** milling directions are used.

Stepover

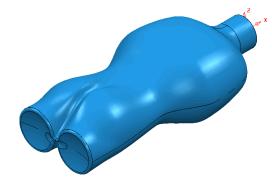
In the case of **Circular** and **Spiral** this is defined as the pitch for each programmed revolution of the component. For **Line** this is defined as the angular, stepover between adjacent tool tracks.



Circular Rotary Machining

In this example a model of a bottle with its centre along the X-axis will be used. Using the **Style** as **Circular**, the job rotates with the tool aligned to a fixed direction. While the component rotates, the tool moves back and forth along its axis to generate the sectional form. The tool then steps over by the **Pitch** value and the rotational machining process is repeated.

- 1 Select **Delete All** and **Reset forms**.
- 2 **Import** the **Model**:
 - ...\PowerMill_Data\Models\rotary_bottle.dgk

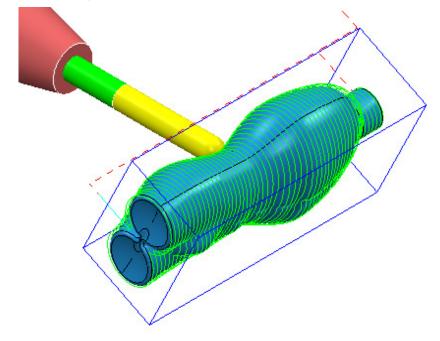


- 3 Calculate the Block using *Defined by* Box and Type model.
- 4 Create a Dia 10 Ball nosed tool named BN10.
- 5 In the **Rapid Move Heights** dialog select **Calculate**.
- In the Start and End Point dialog Use Absolute using the coordinates 20 0
 40.
- 7 Set the *Short/Long* Links to Skim and *Default* Links to Incremental.
- 8 In the Strategy Selector \bigotimes select Finishing > Rotary Finishing.

Rotary Finishing	?)
Toolpath name	BN10-Rotary-Circular
Workplane Block Tool Tool Kotary finishing Automatic verification Point distribution Machine axis control	X limits Start -115.067 End 0.0 Pattern Style Circular Y offset 0.0
ar ➡ Rapid Moves ar ↓ Leads and links ar ↓ Leads ar ↓ Leads and links ar ↓ Leads ar	Angular limits Start 0.0 End 360.0 \$
Fireds and speeds Firstory Notes and Description User defined settings	Tolerance Cut direction 0.02 Climb Thickness Image: Constraint of the second s
	Stepover



- Enter Name: BN10-Rotary-Circular
- Click on Defines X limits as block limits.
- Set Style: Circular
- Select Cut Direction: Climb
- Input Stepover: 2
- 9 Select **Calculate** to create the toolpath then **Cancel** the dialog.
- 10 Right mouse click the toolpath **Rotary1_BN10** and from the local menu select **Simulate from Start** to open the **Simulation** Toolbar.
- 11 Select the **Play** button on the **Simulation** toolbar





By applying **Tool view** point the rotation of the component is simulated (As if viewing the actual machine tool).

In the above example each section is machined in the same **Climb** milling direction. The entire length of the job is machined since the **X Limits** are set to the **Block** limits. Selecting **Conventional** will produce tool tracks travelling in the reverse direction and **Any** will produce alternate **Climb** and **Conventional** tool tracks along the job.

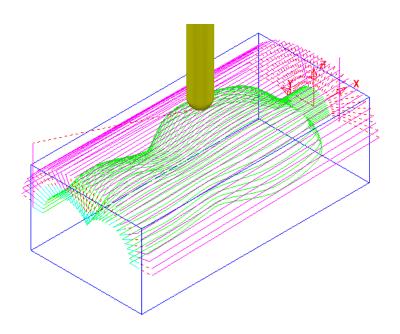
- 12 **Recycle** the toolpath, select **Any** for the **Cut direction** and select **Calculate** to create the toolpath before selecting **Cance**I to close the dialog.
- **13 Simulate** the **toolpath** as before to observe the effect of the toolpath reversing direction with every new section machined.



Line Rotary Machining

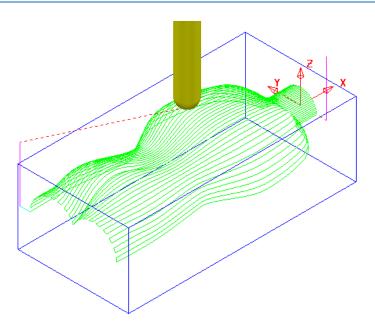
Using the **Style** as **Line**, the tool feeds in the X direction following the component form. At the end of each pass the tool retracts and moves above the start of the next pass. At the same time the rotary axis indexes by the angular stepover and the tool then leads onto the next machining move.

- 14 Make a Copy of the previous toolpath named BN10-Rotary-Line and select Style Line using Cut Direction > Climb milling.
- 15 For Angular Limits Start Angle, enter 90 and End Angle, enter -90.
- 16 From the main toolbar select Leads and Links and set all of the Links to Skim.
- 17 From the same dialog, select **Moves and Clearances** and set the **Axial clearance** to **20**.
- 18 Click on **Calculate** and **Close** the dialog.



- **19 Simulate** the new, uni-directional toolpath (shown above with a larger step over).
- 20 Make a Copy of the previous toolpath and name it as:-BN10-Rotary-Line-2way.
- 21 Change the **Cut Direction** to **Any**.
- 22 Apply the dialog and **Simulate** the new, bi-directional toolpath.

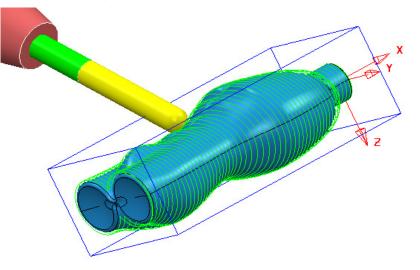




Spiral Rotary Machining

Using the **Spiral** technique, a continuous toolpath is generated around the form as the tool advances along the X-axis. To ensure a clean finish the toolpath starts and finishes with a constant X position, sectional pass. Due to a **Spiral** toolpath being a single, continuous track the cutting direction will be either **Climb** or **Conventional** milling. For the same reason the **Angular Limits** option is not viable and as a result is blanked out.

- 23 Make a Copy of the previous toolpath and name it as BN10-Rotary-Spiral and select Style Spiral using Cut Direction > Climb milling.
- 24 Click on **Calculate** to produce the toolpath shown below.



- 25 **Simulate** the new toolpath.
- 26 Save the Project as:-
 -\COURSEWORK\PowerMill_Projects\ Rotary_Bottle-EX1



15. Port Machining

Introduction

In the **Strategy Selector** the **Ports** option provides 3 specialist strategies, designed for machining cylinder head, inlet/outlet ports.

P Strategy Selector		? ×
🔌 🔶 🔀	Q]
★ Favourites	Cont Area Clearance	Preview
3D Area Clearance	 ☆ M Port Plunge Finishing ☆ M Port Spiral Finishing 	
Curve Machining	🟫 🖑 Port Spiral Finishing	
Feature Machining		
🦯 Finishing		
Drilling		Sel 1
Drilling Methods		
🥒 Ports		
🗱 Blisks		
Ribs		
Turning		
🧭 MyStrategies		
	< >>	
	OK Cancel	

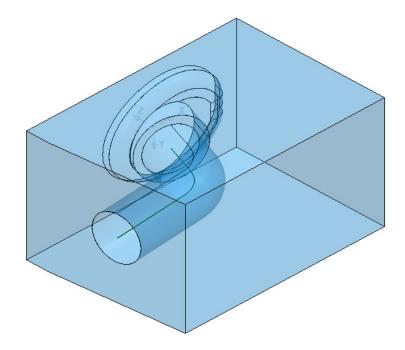
The **Port Machining** options automatically provide multi-axis, tool alignments where this is possible. A warning will be displayed if impossible alignment limits are reached and the port is not fully machined.





Basic Single Port Example

- **1 Open** the 'read-only' **Project**:
 - ...\PowerMill_Data\five_axis\Ports\SinglePort1-Start



- 2 Save Project As:-
 - ...\COURSEWORK\PowerMill-Projects\SinglePort1-ex1



The **Project** already contains all required cutting **Tools**, and preliminary **3Plus2** toolpaths.

The following section will take the user through the specialist **Port Area Clearance** and **Port Spiral Finishing options**.

A **Pattern** (1) is included running down the centre of the **Port**. This is required to control the extent and alignment of the **Port Machining** strategies.

- **3** Activate the existing **Toolpath 1** to reinstate all the settings.
- 4 Activate the BN10 tool.
- 5 In **Toolpath Strategies** select **Ports** > **Port Area Clearance** and fill in the 3 pages of the dialog exactly as shown below.



P Port Area Clearance	? ×
Toolpath	name BN10-PortAreaClear
Workplane Block Tool Cool Cool Cool Cool Cool Cool Cool	Port area clearance Pattern 1 1 Coll clearance 0.5 Cut direction Climb Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb Cut direction Climb
	Preview Draw Calculate Queue OK Cancel

- a Insert Pattern: 4
- b Input Tool Clearance: 0.5

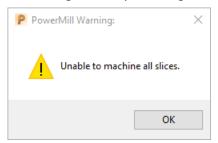
Workplane	Ramping
Tool	Ramping
	Slope angle 10.0
Port area clearance	Ramp diameter (TDU) 0.3
Ramping	
- 2 Workplane	Order
Block	Order
Machine tool	Machine Maximum from start \sim
Port area clearance	Spiral 🗹
Workplane limits	Partial slices
Order	

a Tick Spiral.

b Untick **Partial slices**.



6 Calculate and note the following advisory warning message:



The message is advising that the **Tool** is unable to fully machine the form to the current settings.

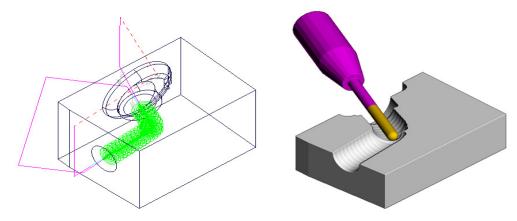
Later a visual check with **ViewMILL** will show that enough material has been removed to allow the finishing strategies to run.

- 7 Select **OK** to the message and wait for the toolpath to finish processing.
- 8 **Close** the dialog.
- 9 Activate Toolpath 1.
- 10 Right mouse click on toolpath 1 and from the local menu select **Simulate from start**.
- 11 Open the **Block** dialog and change the **Max Z** value from **40** to **0** before selecting **Accept**.



By defining the Block to be half the height of the model it will be possible to visualise the lower half of the port being machined.

12 Select an **ISO 2** view and run a **ViewMILL** simulation on all of the remaining toolpaths in sequential order.



13 Activate the SPHR12.5 tool.

14 In **Toolpath Strategies** select **Ports** > **Port Spiral Finishing** and fill in the two featured pages of the dialog exactly as shown below.



P Port Spiral Finishing	? ×
Toolpath name	Sphr12_5-PortSpiral
Workplane Block Machine tool Machine tool Machine finishing Merge Automatic verification Point distribution Tool axis Machine axis control Rapid Moves Leads and links Start point	Port spiral finishing Pattern 1 Tool clearance 0.02 Thickness 0.0 Stenover
End point Feeds and speeds History Solution Viser defined settings	Stepover 2.0 Stepdown $\underbrace{\raiset 0.3}$ Preview Draw
	Calculate Queue OK Cancel
Workplane Block Tool Machine tool	Merge Merge 50.0

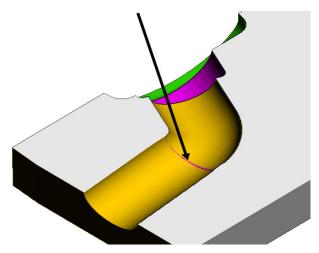
Tool	Merge
	Merge point 50.0
🔞 Limit	
🚊 🔏 Port spiral finishing	Lift start 10.0
- 💹 Workplane limits	
Merge	Overlap 10.0
🔓 Automatic verification	Lift height 0.0
	Lift height 0.0

The above **Merge** settings enable the **thickness** to gradually increase as it merges into the areas previously machined from the first end. This is to compensate for the cutter tending to dig in when the loading decreases.

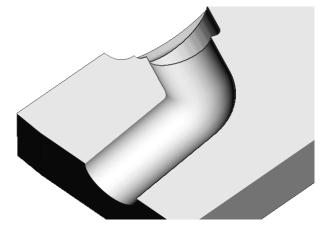
In this case a *Lift height* of **0** has been applied.

- **15** Select **Calculate** and once the toolpath has been created select Cancel.
- 16 Perform a ViewMILL simulation on the latest toolpath, Sphr12_5-PortSpiral.





Note the **0.3mm** step where the machining from the second end of the port has gradually moved away from the form over the last **10mm** to the blend point.



If the **Lift Height** is **0** then there will not be a visible step appearing on the toolpath running from the second end.

There is however a high risk of the **Tool** digging into this area if this **Toolpath** was to be run on the machine tool.

17 Select File > Save Project.

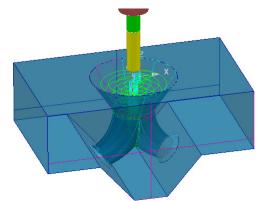


Twin Port Example

Only one Port at a time can be processed within the Port machining strategies. For this example, 2 reference surfaces have been created to blank access to the extra port while applying the **Port machining** strategies to the remaining *single Port* setups.

- 1 Select File > Delete All and Tools > Reset Forms.
- 2 **Open** the read only **Project**:

...\PowerMill_Data\five_axis\Ports\DualPort_Start



3 Save Project As:

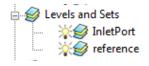
...\COURSEWORK\PowerMill-Projects\DualPort-ex1

- 4 Activate the existing toolpath **RghPort-3Axis** to reinstate all the settings.
- 5 Activate the BN16 tool.
- 6 **Calculate** a new Block to the full **Model** dimensions.
- 7 In **Toolpath Strategies** select **Ports** > **Port Area Clearance** and fill in the pages of the dialog exactly as shown below.

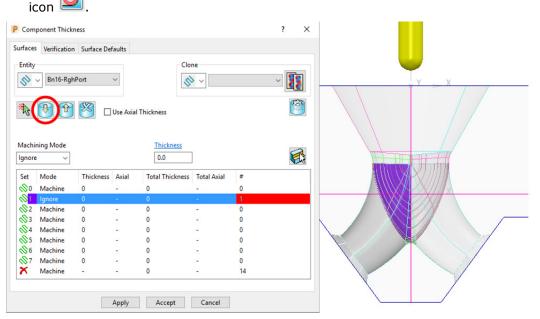
P Port Area Clearance		?	×
٠	Toolpath name	Bn16-RghPort	
Workplane Block U Tool Machine tool With Limit Workplane Workplane		Port area clearance Pattern X Image: Second	
Ramping - M Order - M Automatic - M Automatic - M Coll axis - M Automa axis c - M Achine axis c - M Automatic - M Aut	on	Cut direction Climb	
Start point Content of the second se	cription	Stepover 5.0 Stepdown 5.0 5.0	
		Preview Draw	



8 Switch on the Level named reference.



9 From the **Port Area Clearance** main page, select the **Component Thickness**



- 10 In the Component Thickness dialog, select and acquire the left hand reference surface (Shaded purple above right) to a row with the Machining Mode set to Ignore.
- **11 Apply** the dialog.

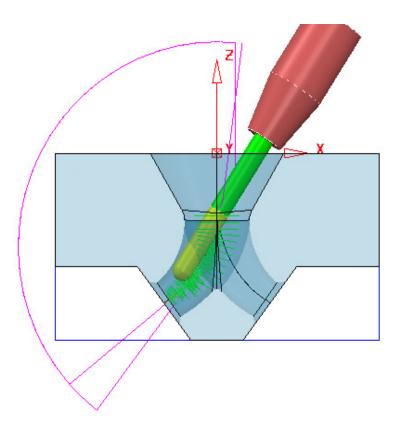
Workplane Block Tool Machine tool Minit Ort area clearance Morkplane limits Morkplane limits	Ramping Slope angle 10.0 Ramp diameter (TDU) 0.3
Workplane Block Tool Limit Ort area clearance Workplane limits Morkplane limits Morkplane limits	Order Order Machine Maximum from end Spiral Partial slices

12 In the **Order** page tick **Spiral**.



Workplane 🔨	Rapid Moves			
Block				
Tool	Safe area			
Machine tool	Type Cylinder 🗸			
🕅 Limit				
Port area clearance	Workplane TOP-CENTRE ~			
	Position			
	0.0 -85.0 -70.000326			
Automatic verification	Direction			
	0.0 1.0 0.0			
Machine axis control	Rapid radius 153.26564			
Rapid Moves				
	Plunge radius 148.26564			
Moves and clearances	Polygonisation tolerance 0.2			
🖶 🛄 Leads and links	Calculate dimensions			
	Measured from Block and Model V			
	Measured from Diock and Model			
🖶 🚡 Feeds and speeds	Rapid clearance 10.0			
	Plunge clearance 5.0			
	Plunge clearance 5.0			
🚬 🚴 User defined settings 🛛 🗡				
	Calculate			
Draw rapid surf				
	Draw plunge surface			
	Calculate Queue OK Cancel			

13 Calculate the Port area clearance dialog.





- 14 Activate the SPHR25 tool.
- 15 In **Toolpath Strategies** select **Ports** > **Port Spiral Finishing** and fill in the pages of the dialog exactly as shown below.

P Port Spiral Finishing	? ×
Toolpath name	Sphr25-FinPort
 Workplane Block Tool Machine tool Limit Workplane limits Workplane limits Workplane limits Merge Automatic verification Point distribution Tool axis Tool axis Machine axis control Rapid Moves Leads and links Start point Freeds and speeds History Notes and Description User defined settings 	Port spiral finishing Pattern Image: Constraint of the second state of the
	Preview Draw
 ✓ Workplane ✓ Block ✓ Tool ✓ Machine tool ✓ Limit ✓ Port spiral finishing ✓ Workplane limits 	Merge Merge <u>50.0</u> Lift start 10.0

16 From the **Port Area Clearance** main page, select the **Component Thickness** icon

🔏 Merge

🛅 Automatic verification

🔖 Point distribution

10.0

Overlap

Lift height 0.3

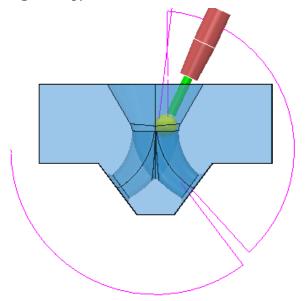




17 As shown in the following diagram, *Clone* the **Component Thickness** settings from the previously created toolpath **BN16-RghPort**.

Com	ponent Thick	ness					?	×
urfaces	Verification	Surface De	faults					
Entity	∽ Sphr25-Fi	nPort	~		ne > ∨ BN16-R	ghPort	~ 2	
*	1		Use Axia	l Thickness				<u></u>
Machi	ning Mode			Thickness				
Ignore	• ~			0.0			K	1
Set	Mode	Thickness	Axial	Total Thickness	Total Axial	#		
∞0	Machine	0	-	0	-	0		
<⊗1	Ignore	0	-	0	-	1		
<∞2	Machine	0	-	0	-	0		
≪3	Machine	0	-	0	-	0		
∕⊗4	Machine	0	-	0	-	0		
<∞5	Machine	0	-	0	-	0		
∞6	Machine	0	-	0	-	0		
-∞7	Machine	0	-	0	-	0		
×	Machine	-	-	0	-	14		
			Apply	Accept	Cancel			

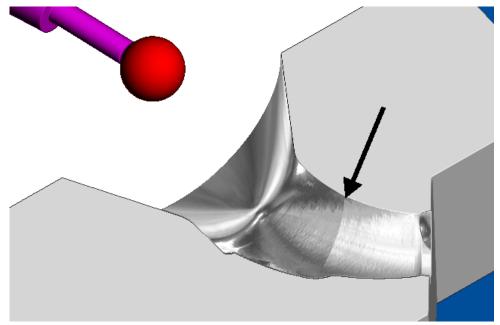
18 Apply and Accept the Component Thickness dialog, and then Calculate the Port spiral finishing strategy.



- 19 Activate Workplane mc-OUTPUT.
- 20 Activate Boundary 1.
- 21 Calculate a Block Defined by Boundary and Type Model.



- 22 Change the Max Z value to -75.0.
- 23 Select an **ISO 3** view, open and run a **ViewMILL simulation** of all the toolpaths.



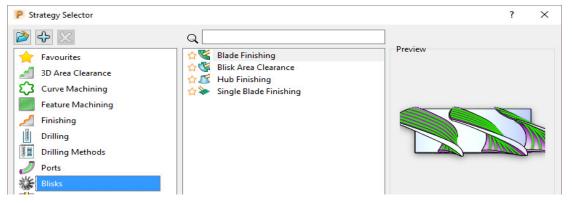
- 24 Note the **0.3mm** step where the machining from the second end of the Port has gradually moved away from the form over the last **10mm** to the blend point.
- 25 Select File > Save Project.



16. Blisks

Introduction

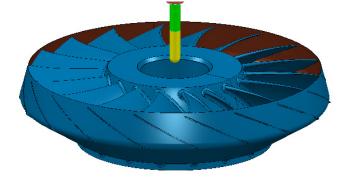
In toolpath strategies, the ${\bf Blisks}$ option provides 4 specialist strategies for machining Impellers.



Impeller Example

- 1 Select File > Delete All and Tools > Reset Forms.
- 2 **Open** the 'read only' **Project**:

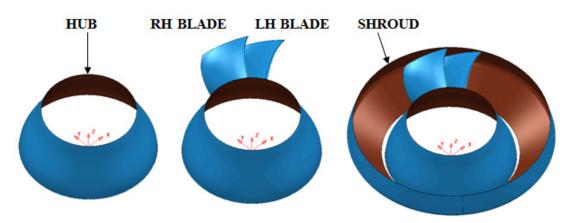
...\PowerMill_Data\FiveAxis\Blisks\BliskSimple_Start



- 3 Select File > Save Project As: ...\COURSEWORK\PowerMill_Projects\FiveAxis\Blisks\Blisk_Example
- 4 Activate **Workplane 1**.
- 5 Create a *Cylindrical* Block to the Model dimensions.

- 6 Calculate the Rapid Move Heights.
- 7 Set both Start and End Points to First/Last Point Safe.
- 8 In the Leads and Links dialog, set 1st and 2nd choice, Links to Short/Long Skim and Default Incremental.

To be able to apply the **Blisk** machining options the component surfaces must first be acquired to a series of specifically named levels. In this example the surfaces in the imported model are already acquired to appropriate levels.



9 Activate the existing Ball Nosed tool named **BN25**.

10 From the main toolbar, select **Default Thickness** and in the **Thickness Preferences** dialog, select the **Surface Defaults** tab.

THICK	mess Preferen	ces		?	×	
rfaces	Verification	Surface De	efaults			
				Clone	23	
/lachii	ning Mode] Use Axia	Thickness Thickness		
Ignor				0.0		
Set	Mode	Thickness	Axial	Components		
-		0	-	1		
	Ignore					
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∯1 ∯2	Machine Machine	0 0	-	0		
© 1 © 2 © 3	Machine Machine Machine	0 0 0	-	0 0		
口 口 口 口 口 2 口 3 口 3 口 4	Machine Machine Machine Machine	0 0 0	-	0 0 0		
021 022 023 024 025	Machine Machine Machine Machine Machine	0 0 0 0	-	0 0 0		
02 02 03 04 05 06	Machine Machine Machine Machine Machine Machine	0 0 0 0 0	-	0 0 0 0		
☆1 ☆2 ☆3 ☆4 ☆5 ☆6 ☆7	Machine Machine Machine Machine Machine Machine Machine	0 0 0 0 0 0		0 0 0 0 0		
☆0 ☆1 ☆2 ☆3 ☆4 ☆5 ☆6 ☆7 ×	Machine Machine Machine Machine Machine Machine	0 0 0 0 0	-	0 0 0 0		
 菜1 菜2 菜3 菜4 菜5 菜6 菜7 	Machine Machine Machine Machine Machine Machine Machine	0 0 0 0 0 0		0 0 0 0 0		

- 11 Select the single **Shroud Surface** and acquire 🕅 it to the first row in the above dialog.
- 12 Set the first row to **Machining Mode Ignore** and **Apply** the settings, before closing the dialog by clicking **Accept**.
- 13 In the Leads and Links options input Moves and clearances set the Axial clearance to 15, and set Planar skim moves to *Plane* Safe Area.



- 14 For both Lead in and Lead out, input 1st choice Extended move 10 and 2nd choice Surface normal arc Angle 90 and Radius 5.
- 15 In the **Toolpath Strategies** dialog, select **Blisks** and from the four available options, select **Blisk Area Clearance**.
- **16** Enter data exactly as shown below with the **Fillets** and **Splitter Blade** options left blank.

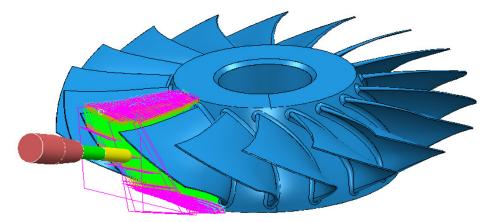
P Blisk Area Clearance					?	×
الله الله الله الله الله الله الله الله	Toolpath name	BN25-RGH-a1				
Workplane		Blisk area cl	earance			
		Blisk definitio		Hub	~	/
			Shroud	Shroud	~	-
🛛 🥳 Tool axis elevati		Blades	Fillets		~	1
Machining	ication	Diddes	Left blade	Left Blade	~	
Point distribution			Right blade	Right Blade	~	
	bl		Splitter blade Machine	One blade	~	
Use June 2018 Use and links Use and links Use and links		To	otal number 0	C	alculate	
End point		Tolerance				
	on	0.1 Thickness				
ber defined setting	js	0.5			<u></u>	5
		Stepover				
		5.0				
		Stepdown 5.0				
-OV	mg	Calculate Q	ueue OK	Cance	l	

Workplane	Tool axis elevation				
	Tool axis elevation Average hub normal Angle 0.0				
Machining					

Workplane Block	Machining					
	Machining					
	Cut direction	Climb ~				
🖃 😽 Blisk area clearance	Offset	Offset up 🗸				
	Method	Parallel ~				



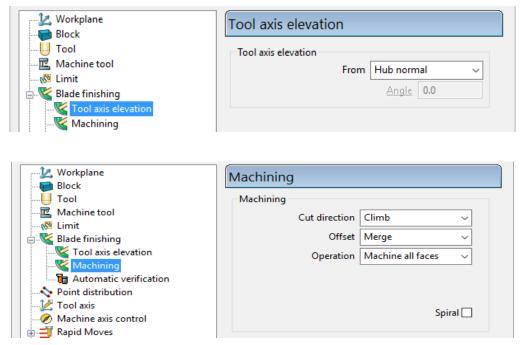
17 Select **Queue** in the dialog to commence background toolpath processing.



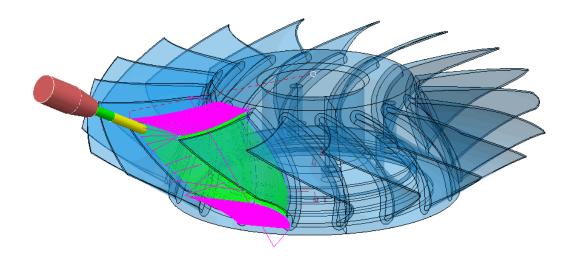
- 18 Activate the existing **Ball Nosed** tool named **BN15**.
- **19** In the **Toolpath Strategies** dialog, select **Blisks** and from the three available options, select **Blade Finishing**.
- 20 Enter data into the pages of the dialog exactly as shown below with the **Fillets** and **Splitter Blade** options left blank.

P Blade Finishing	? ×
Toolpath name	BN15-FIN-a1
Workplane Block Tool Machine tool Slade finishing Tool axis elevation Machining Automatic verification Point distribution Tool axis Machine axis control Rapid Moves	Blade finishing Blisk definition Hub Hub Shroud Shroud Fillets Blades Left blade Left Blade Right blade Splitter blade Machine One blade V
Leads and links Start point End point Feeds and speeds History Notes and Description User defined settings	Total number 0 Calculate Tolerance 0.02
	Calculate Queue OK Cancel





21 Select **Queue** in the dialog to commence background toolpath processing.



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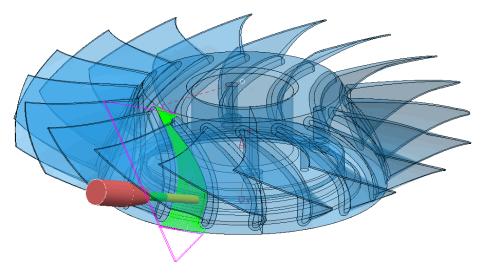
- 22 In the **Toolpath Strategies** dialog, select **Blisks** and from the four available options, select **Hub Finishing**.
- 23 Enter data exactly as shown below with the **Fillets** and **Splitter Blade** options left blank.

P Hub Finishing		? ×
Toolpath name	BN15-FINhub-a1	
Workplane Block Block Wachine tool Kachine tool Kachining Automatic verification Kapid Moves Kapid Mov	Fillets Blades Left blade Right blade Splitter blade Machine Total number 0 Tolerance 0.02 Thickness	Shroud ~ Shroud ~ Left Blade ~ Right Blade ~ One blade ~ Calculate
	0.0 Stepover Stepdown 0.5 Calculate Queue OK	لللل المراجع ا المراجع المراجع

Workplane Block	Tool axis elevation
	Tool axis elevation
- 🖓 Limit	From Average hub normal V
Hub finishing	Angle 0.0
<u>F</u> Tool axis elevation	
- 🗽 Workplane - 😝 Block	Machining
U Tool 	Machining Cut direction Climb ~
Hub finishing 	

24 Select **Queue** in the form to commence background toolpath processing.





The next stage is to perform a full **ViewMILL** simulation of all 3 toolpaths.

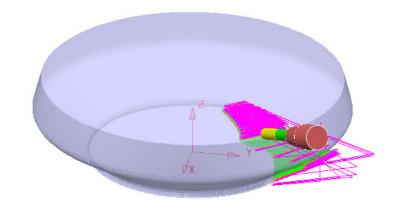
Before running **ViewMILL** it is necessary to define the **Block** as a *Triangle* model of the pre-turned, Shroud for an accurate representation of the material prior to milling.

- 25 Activate and right mouse click on the toolpath **BN25-RGH-a1** and from the local menu select the option **Simulate from Start**.
- 26 Before starting the Simulation, open the Block dialog and select Defined By > Triangles followed by select the Load block from file icon.

🛃 Block			? ×
Defined by	Triangles	•	🖻 🖪 %
Coordinate System	m		
Active Workpl	ane 🔻		▼
Limits			

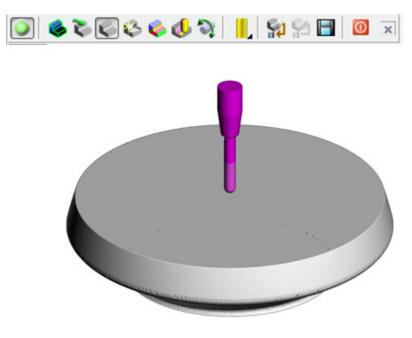
27 Browse and select the **Triangle** file:

...\PowerMill_Data\FiveAxis\Blisks\TurnedShroud.dmt

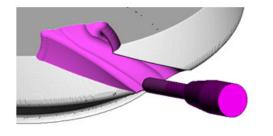


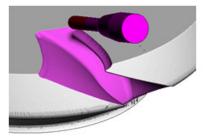
28 With the complex **Block** active, switch on a **ViewMILL** simulation.



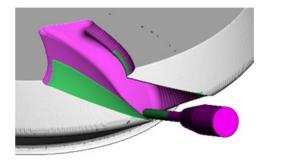


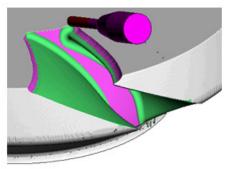
29 Select the **Play** button in the toolpath simulation toolbar and observe the machining process for the toolpath **BN25-RGH-a1**.





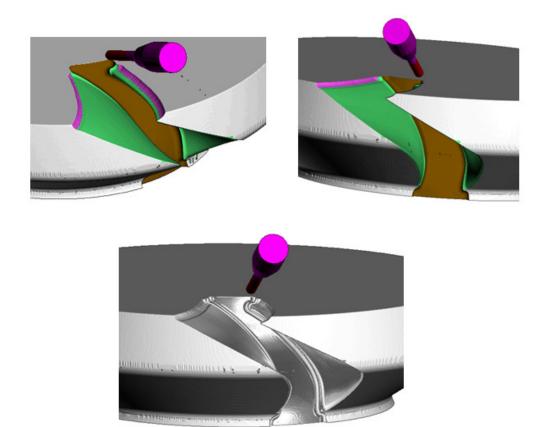
30 Continue the ViewMILL simulation on toolpath BN15-fin-a1.



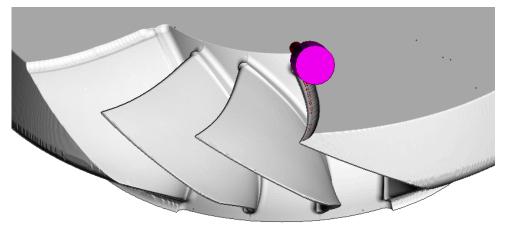


31 Continue the ViewMILL simulation on toolpath BN15-finHUB-a1.





The final image (below) shows the result of a **ViewMILL** simulation including 17 copies of the **toolpaths** rotated by **20 Degree** increments around **Z**.

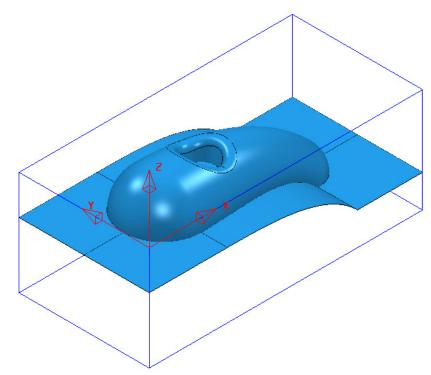






17. Five Axis-Tutorial

- 1 Select File > Delete All and Tools > Reset Forms.
- 2 Open the (read-only) Project:-....\PowerMill_Data\FiveAxis\Cowling\Cowling-5Axis-Start.dgk



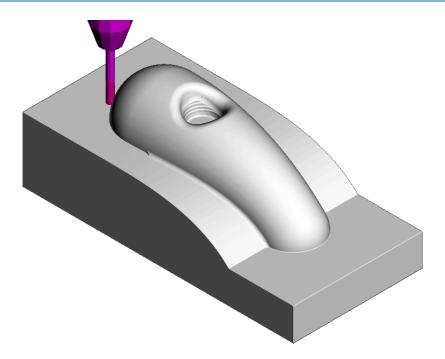
- **3** Save Project As:
 -\COURSEWORK\PowerMill_Projects\Cowling-5Axis

The **Project** currently contains 8, 3-Axis Toolpaths.

This has left remaining areas that are either more suited to, or can only be machined using 5-Axis strategies.

- 4 Select an **ISO2** view.
- 5 Activate the toolpath **D16TR6-RGH1_step** to restore the **Block** used in the strategy.
- 6 Perform a full **ViewMILL** simulation on the **NC Program** named **1**.





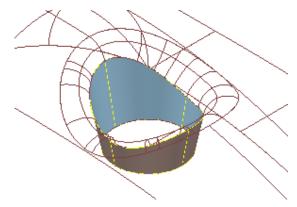
The remaining areas that require Five Axis machining include the central pocket (Swarf Machining), and the intersection between the main form and the 3D run-off (Embedded Pattern and Surface Finishing).



7 Select the **ViewMILL No-Image** display option to disconnect it from the simulation process.

Central Pocket

8 Activate the tool **EM12**.



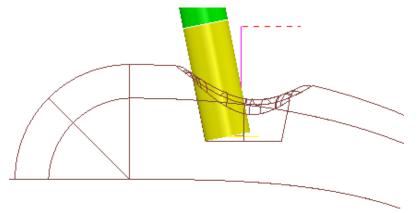
- 9 Select the pocket wall.
- 10 Select the **Toolpath Strategies** dialog \bigotimes select the **Finishing** tab.
- 11 From the list of strategies select **Swarf Finishing** and then **OK**.



Swarf Finishing		?	;
وي ال	Toolpath name	EM12-SwarfPktWall-FIN1	
Workplane	^	Swarf finishing	
		Drive curve	-
Machine tool		Surface side 🛛 🗸 🗸]
🕅 Limit		Radial offset 0.0	í
	nt		
⊡ <mark>∬</mark> Swarf finishing 		Minimum fanning distance 0.0	
Gouge avoida	ince	Fan at end on planes 🗹]
Multiple cuts		Reverse axis	
🐺 High speed		Follow surface laterals]
🔚 Automatic ve			
Point distribution		Surface joining tolerance	
Machine axis con	trol	0.3	
🗉 🚽 Rapid Moves		с	
🗄 🔰 Leads and links		Gouge avoidance Gouge check ✓	1
			1
		Degouge tolerance 0.3	
History		Tolerance Cut direction	
Notes and Descri		0.01 Climb ~	1
🛄 🤱 User defined setti	inas 👻		1
		Thickness	
4-17			
HALA			
		Preview Draw	
	V	Calculate Queue OK Cancel	

12 In the **Swarf Finishing** dialog enter data exactly as shown below:

13 For both the Lead in and Lead out input Surface normal arc with Angle 180 and Radius 2, then Calculate the toolpath.



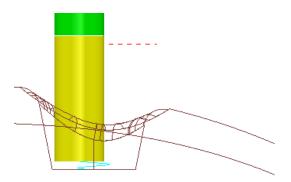
The **Swarf Finishing** strategy is created as *Five Axis* by default (The **Tool axis** option is set to **Automatic**). As shown in the above image this results in a wedge of material remaining on the flat base of the pocket. This can be removed with a second **Swarf Finishing** toolpath but this time with the **Tool Axis** set to **Vertical**.



14 Make a copy of the Swarf Finishing strategy named EM12-SwarfPktBase-FIN2 but this time set the Tool Axis to Vertical before selecting Calculate.

P Swarf Finishing		?	×
Toolpath name	EM12-SwarfPktWall-FIN2		
Workplane Block Good Wachine tool Stock engagement Stock engagement Swarf finishing Swarf finishing Multiple cuts	Tool axis Tool axis Vertical		
	Fixed angle None \checkmark 90.0		

15 Change the *1st choice*, Lead in move onto this toolpath to a circular Ramp with Angle 4, Circle Dia (TDU) 0.65 and Ramp Height 2.

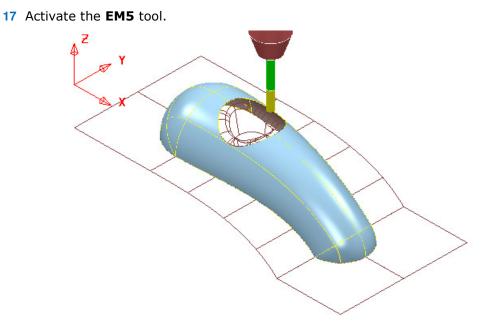


The Pocket is now fully machined.

16 Save (but do not close) the **Project**.



Main Form – Base Intersection



- **18** Select the main form surface (as shown in the above image).
- **19** Select the **Toolpath Strategies** dialog Select the **Finishing** tab.
- 20 From the list of strategies select **Surface Finishing** and then **OK**.
- 21 In the **Surface Finishing** page enter data exactly as shown in the image below.

Surface Finishing					?	×
Toolpat	h name EM5-M	lainForm-FIN1				
Workplane Block Machine tool Machine tool Machine tool Machine tool Machine tool Machine as control Machine axis control	Dego 0.3 Toleo 0.0	Surface	ce units	0.212132		
		Preview		raw		



22 Select the **Tool Axis** page and again enter data exactly as shown in the image below.

Surface Finishing			?	×
	Toolpath name	EM5-MainForm-FIN1		
Workplane Block Tool Machine tool Stock engagement Stock engagement		Tool axis Tool axis Lead/Lean Lead/Lean angles Lead 0.0		
Automatic verific Automatic verific		Mode Contact normal	~	,

23 Select the **Pattern** page and again enter data exactly as shown in the image below.

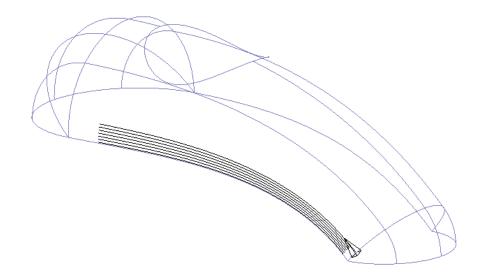
P Surface Finishing		?	×
Toolpath name	EM5-MainForm-FIN1		
Workplane Block Block Kooling Block Kooling Block Kooling Block Kooling Kooling Block Kooling Kooling Kooling Block Kooling K	Pattern Pattern Pattern Pattern direction Ordering One way Start corner Max U max Sequence None Limits (Distance) Limits (Distance) Limits (Distance) Limits (Distance) Limits (Distance) Preview Draw	J ~ Spiral [/ ~	

The values shown in the above page were finally arrived at after a trial and error process. The actual values are unit distance along and across the surface, curve network (U V).

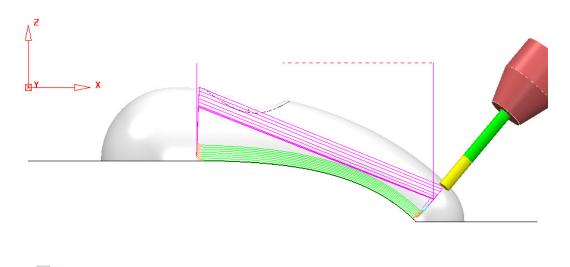
24 Select **Preview** to visualise the defined pattern on the surface.



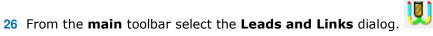




25 Select **Calculate** to process the toolpath.



To help visualisation the above images show the preview with a larger area and stepover than specified in the instructions.



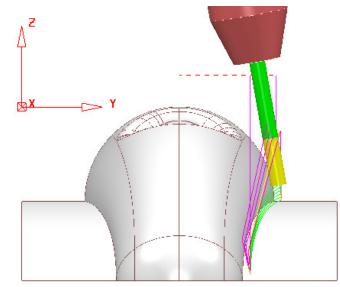
27 For both Lead in and Lead out, apply 1st choice as Vertical arc - Angle 90 - radius 2 and 2nd choice as Vertical arc - Angle 90 - radius 0.5.



28 Make a copy of the **Surface Finishing** toolpath and rename it as **EM5-MainForm-FIN2**.

P Surface Finishing	? ×
Toolpath name	EM5-MainForm-FIN2
Workplane Block Tool Machine tool Mit Limit Stock engagement	Pattern Pattern Pattern U ~
Surface finishing Pattern Automatic verification Point distribution Coloration Machine axis control Rapid Moves	Spiral Ordering One way Start corner Min U min V Sequence None V
	Limits (Distance) U V Start 60.0 92.3 End 167.5 94.8 Preview Draw

29 Modify the original settings in the **Pattern** page and select **Calculate** to perform the same strategy on the other side of the main form.





The last 2 Surface Finishing strategies deliberately stop just short of the run-off surfaces. A more accurate, final pass will be created normal to the run-off surfaces using a separate **Embedded Pattern Finishing**.

30 Save (but do not close) the **Project**.



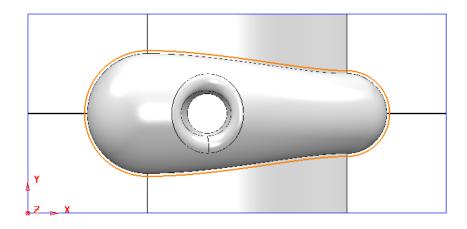
- **31 Activate** the **EM3** tool.

32 Select the main form and pocket **surfaces** (as shown in the above image).

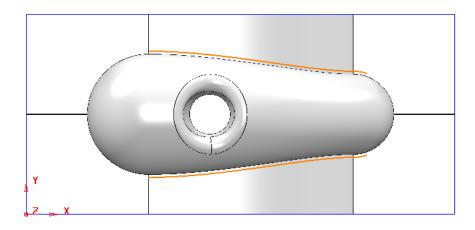
Selected Sur	face Boundary ? ×
Name	EM3-SeleSurf
Top Roll Over Tolerances <u>Tolerance</u> 0.01 <u>Thickness</u> 0.0 Axial Thickness 0.0	Limit Boundary Inside Outside
Use Axial Thickness	Automatic Collision Checking Holder Clearance 0.0 Shank Clearance 0.0
	Block Limit 🧃 🗸
Private	
Allow boundary to be private	0
Edit History Apply edit history on calculation	0
Apply Queue	Accept Cancel

- 33 Create a Selected Surface Boundary (with Roll Over ticked).
- 34 Create an empty **Pattern** and insert the above **Boundary** segment into it.
- **35** Delete the **Boundary**.





36 Use the **Curve Editor** to trim the **Pattern** into 2 segments (**Merge** if required) suitable for an **Embedded Pattern Finishing** strategy.



- **37 Reverse** the **Pattern** segments as required to produce a **Climb Milling** direction (Material to the right of the tool feed direction).
- 38 Right mouse click on the new Pattern and from the local menu select Edit Embed.

P Embed Pattern	?	×
Method	Drop	
Wiethou	ыор	<u> </u>
	Distance 0.1	
	Tolerance 0.01	
Apply	Cancel	

39 In the above dialog select **Method** as **Drop** with a **Tolerance** of **0.01** before selecting **Apply**.

A copy of the original **Pattern 1** is projected down Z onto the model as an **Embedded Pattern 1_1** (contains the surface normal).

- **40** Select the **Toolpath Strategies** dialog Select the **Finishing** tab.
- 41 From the list of strategies select **Embedded Pattern Finishing** and then **OK**.



42 In the **Embedded Pattern Finishing** page enter data exactly as shown in the image below.

P Embedded Pattern Finishing	? ×
Toolpath name	EM3-FIN1
 Workplane Block Tool Machine tool Limit Stock engagement Gouge avoidance Multiple cuts Multiple cuts Automatic verification Point distribution Tool axis Machine axis control Start point Start point Feeds and speeds History Notes and Description User defined settings 	Embedded pattern finishing Drive curve I_1 I_1 Lower limit Axial offset Gouge avoidance Gouge avoidance Gouge check Degouge Degouge tolerance 0.01 Thickness 0.0

43 Open the **Component Thickness** dialog and acquire the **Main Form surface** to one of the rows.

urface	s Verification	Surface Def	faults					
Entity				Clo	ne			
11	V EM3-FIN1		~	\$	> ~		~ 💈	į
*			Use Axial	Thickness				
Machi	ning Mode			Thickness				
Ignor				0.0]		<u>s</u>	
ignon	-							
Set	Mode	Thickness	Axial	Total Thickness	Total Axial	#		
		Thickness 0	Axial -	Total Thickness	Total Axial	# 0		
Set	Mode		Axial - -		Total Axial -			
Set	Mode Machine	0	Axial - -	0	Total Axial - - -	0		
Set	Mode Machine Machine	0 0	-	0 0	Total Axial	0		
Set ⊗0 ⊗1 ⊗2	Mode Machine Machine Machine	0 0 0	- -	0 0 0	-	0 0 0		
Set ⊗0 ⊗1 ⊗2 ⊗3	Mode Machine Machine Machine Ignore	0 0 0 0	-	0 0 0	-	0 0 0		
Set ©0 ©1 ©2 ©3 04	Mode Machine Machine Machine Ignore Machine	0 0 0 0 0		0 0 0 0	-	0 0 0 1 0		
Set © 0 © 1 © 2 © 2 © 4 © 5	Mode Machine Machine Machine Ignore Machine Machine	0 0 0 0 0 0		0 0 0 0 0 0	-	0 0 0 1 0 0		

44 Set the selected row to **Machining Mode Ignore** and **Apply**.

The main form **surface** is set to be ignored as it would otherwise result in the toolpath to fragment. This in turn will result in the tool very marginally gouging the main form **surface**. If checked both visually and using the gouge checking options the actual results will be negligible.



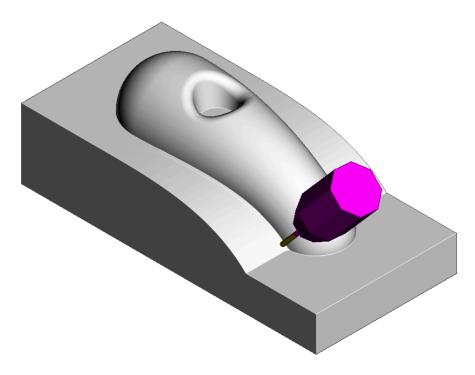
45 Back in the main **Embedded Pattern Finishing** dialog, open the **Tool Axis** page and select **Lead/Lean** both with a **0** angle.

P Embedded Pattern Finishing		?	×
Toolpath name	EM3-FIN1		
···· ¹ / ₂ Workplane ···· ¹ Block ···· ¹ Tool ···· ¹ Machine tool ···· ¹ Limit ···· ³ Stock engagement	Tool axis Tool axis Lead/Lean Lead/Lean Lean Lead		
Embedded pattern finishing Gouge avoidance Multiple cuts Automatic verification Yoint distribution Yoint axis	0.0 0.0 O.0 Mode Contact normal	~	
Machine axis control	Fixed angle		

46 Set all Link moves (1st choice/2nd choice/Default) to Incremental.

This is to prevent the toolpath from linking straight through the main cowling surface (Component Thickness set to Ignore).

- 47 Calculate the Embedded Pattern toolpath.
- 48 Run a full **ViewMILL simulation** (Final **EM3-FIN1** toolpath show below).



49 Save the Project.