ZW3D from Entry to Master Tutorial

4-5X Machining

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ZW3D[™] V2023 From Entry to Master CAM 4-5X Machining

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Foreword

In this tutorial, we provide various case studies, which are from easy to difficult and combine theory with practice. We hope to improve users' 3D CAD/CAM skills and techniques with ZW3D.

The tutorial bases on our technical engineers' years of experience in the industry and ZW3D, which is the fruit of a lot of efforts and wisdom. We sincerely hope that the tutorial will do help to you, and your precious advice on it is highly welcomed.

There are three series for this tutorial: *Primary Tutorial, From Entry to Master Tutorial*, and *Advanced Tutorial*. From easy to difficult, they offer a step-by-step learning process that can meet different user needs.

Primary Tutorial series is for users who have little or no prior 3D CAD/CAM experience. If you are green hands of 3D CAD/CAM software, or if you are a new user of ZW3D, we recommend that you get started with this tutorial. Here you can learn the basic knowledge and concepts of ZW3D, rapidly master the simple operations and workflows of ZW3D, and practice simple cases.

From Entry to Master Tutorial series is for users with basic know-how of 3D CAD/CAM software. If you have experience in 3D CAD/CAM software and want to master common functions of ZW3D, we suggest that you start with this series. Here you can dig deeper into the functions and master more operations of ZW3D.

Advanced Tutorial series is for users with practical experience in 3D CAD/CAM software. If you hope to have a comprehensive command of ZW3D and get the complicated operations done independently, you can choose to learn this series. Here you can learn to use the software more flexibly and get rich experience to increase your efficiency.

What you are learning is **ZW3D From Entry to Master CAM 4-5X Machining**, a master tutorial.

Thanks for being our user! The ZW3D Team

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1 4-5X Machining

Key Points:4X index milling

- ♦ 5X index milling
- ♦ 5X simultaneous movement operations

ZW3D CAM 5X module provides user 4X&5X indexing milling function and simultaneous movement function. With the indexing milling function user can easily mill multiple sides of a complicated part by one-time clamping. With the 4X/5X simultaneous movement operations user can deal with such tough jobs as the titled surface, undercut surface etc.

Notes:

This tutorial is based on ZW3D 2021 version, some functions or icons may not match the current version. All the tutorial models can be found in installation folder: ...training\5X machining model

1.1 4X Indexing Milling

Indexing milling function can position the tool axis in any direction by machine. Normally it includes 2 modes: one is for 4X indexing milling called as **3+1** mode. This means 3 linear axis plus 1 rotary axis, while the rotary axis is for positioning ; the other is for 5X indexing milling called "3+2" mode which means 3 linear axis plus 2 rotary axis, also the 2 rotary axis is for posisitioning. Open the practice file **4X_Indexing.Z3** as follows:

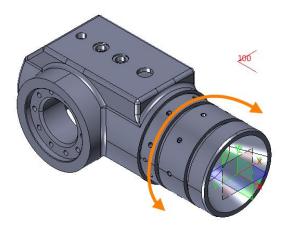
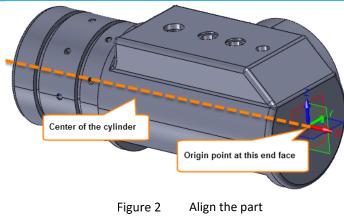


Figure 1 4X_Indexing milling part

Analysis: It is apparent that if we use the 3X milling tool, we are not able to finish all sides by one-time clamping. From the structure of the part it is easy to see that rotating the part around the cylinderical center line(as indicated in Figure 1) it is able to mill all sides by one-time clamping. So one rotary positioning axis is enough for this case, here let's suppose that the 4X machine 's rotating axis is A which is rotating around X axis and the part is a casting part. Then let's see how to achieve the 4X indexing milling in ZW3D CAM.

1.1.1 Align The Part

In order to make use of the A axis here we will align the part to make the default X axis colinear with the cylindrical center line as follows:

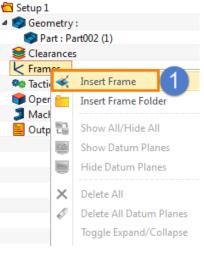


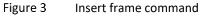
1.1.2 Create Sub Frame

After enter into CAM let'screate the sub frame as follows:

STEP 01 Create Sub frame for right side

I. Right click on Frames tab then we can get the Insert Frame command as follows:





II. Click on Insert Frame command then the definition form for Frame will pop up as follows

🖉 Frame 🖓 🖾							
Name	Frame 1						
Clear Z	100						
Head	none						
Auto Clear	10						
Fixture Offset							
Offset Register Auto							
Write ORIGIN in Output Define Frame Datum							
Create Datum Select Datum							
Frame Attribute							
Color							
Color							

Figure 4 Frame definition form

III. Then we can click *create datum* to create new frame as follows

4-5X Machining <////

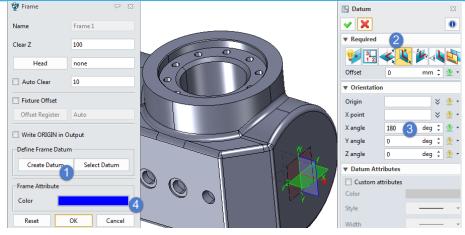


Figure 5 Create frame based on XZ plane

Notes: This process is the same as the process of creating datum in CAD level.

IV. Newly created frame will be as follows:

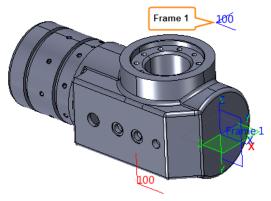


Figure 6 Finished Frame 1 for right side

STEP 02 Then create another frame for the bottom side as follow:

🐲 Frame	Ģ	23		🧏 Datum				23	2
Name	Frame2			✓ X ▼ Required	2			0)
Clear Z	100			3		1			5
Head	none			Offset	0	mm	\$	₫	Ŧ
Auto Clear	10			▼ Orientation					
Fixture Offset			100	Origin			¥	<u>*</u>	•
Offset Register	Auto		V7 1 100	X point			¥		Ŧ
		_		X angle	-180 (3	deg	÷	₫	*
Write ORIGIN in O	Output		XX	Y angle	0	deg	÷	₫.	*
Define Frame Datu	m		1.	Z angle	0	deg	÷	₫	*
Create Datum Select Datum				▼ Datum Attr	ibutes				
			dele	Custom at	tributes				
Frame Attribute 4				Color					
Color				Style		_	_		Ŧ

Figure 7 Create frame on Bottom side

Tips: In order to distinguish different frame especially in the same position you can choose different color to tell the differences.

Then we can get the following result with 2 newly created frames:

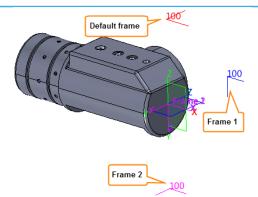


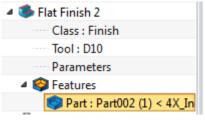
Figure 8 Finished local frames and default frame

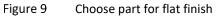
Next we can create toolpath based on these frames.

1.1.3 Create Toolpath Based On Each Frame

STEP 01 Create toolpath on top side: finish the top face based on default frame.

I. Let's choose 3X Flat Finish operation and choose the whole part as feature as follows. Then choose D10 flat end tool.





II. Set up frame for it : open the parameter form to set up which frame to be based on as follows:

Plat Finish 2 leave it bl	ank means use the d	lefault one 🔍 🖓 🖄
Type: Flat Finish	▼ Basic	
P Basic	Frame	
 Tolerance and Steps Limiting 	Speeds, Feeds	Flat Finish 2
Boundaries Interference Tool	▼ Tolerance and Thio	:k
뒔 Check	Path Tolerance	0.01
Filters	Surface Thick	0
▲ ≚ Link and Lead	Z Surface Thick	
Link	Flatness	0.01

Figure 10 Choose default frame

III. Set up the rest necessary parameters and then calculate the toolpath as follows:

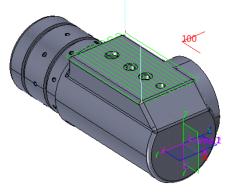


Figure 11 Toolpath for top side

Notes: since this process is the same as using 3X milling operation so here we will skip the details for creating the toolpath. And here we just use one opeartion to show indexing milling, for the rest necessary operations please finish by yourself.

Tips: In order to better manage the operations on each side , it is helpful to create operation folder and name it clearly. For example here we can name the folder for the operations in topside as "topside" and put all of the operations into this folder as follows:

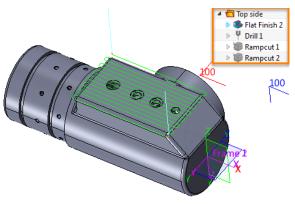


Figure 12 Operation folder for top side

STEP 02 Create toolpath based on Frame 1 on right side as follows:

I. In order to get a clear idea about the toolpath on the left side we can firstly rotate the part as follows:

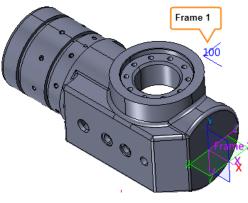


Figure 13 Rotated part

- II. Create a folder and name it as *Right side* and then go to add operations.
- III. Pick 3X *Flat Finish* operation. Then Open the parameter form to set up the work frame as follows:

Primary Frame Frame 1 Image: Speeds, Feeds Flat Finish 1 Image: Speeds, Feeds Filters	🍮 Type: Flat Finish 4 🏠 Primary	▼ Basic	
Limiting Speeds, Feeds Flat Finish 1 Fig Frame 1 Speeds, Feeds Flat Finish 1 Flat Flat	😗 Basic	Frame 2 F	rame 1
Reference Tool Fir Frame 1		Speeds,Feeds F	lat Finish 1
Fe Frame J	Reference Tool	Fir	
Path Setting	Filters	Fe Frame 1 3	

Figure 14 Set up work frame for Flat finish operation

IV. Then set up the Boundaries as follows:

🖗 Flat Finish 1			₽ 23
Type: Flat Finish A Primary	▼ XY		
Basic	Containment Type	Simple Box	•
म Tolerance and Steps	% Offset	0.0	
4 🔳 Limiting	3D Offset	No	.
Boundaries			
Reference Tool	Limit Lead Moves No		*
🚳 Check	▼ Z		
💹 Filters			
🧶 Path Setting	Тор	48	
Link and Lead	D	. ed	_
🚰 Link	Bottom	42	
📥 Lead In			

Figure 15 Set up bottom boundary

V. Add the whole part as feature and then calculate (other parameters are default) then we can get the toolpath as follows:

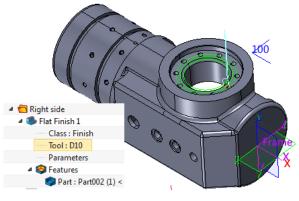


Figure 16 Flat finish based on Frame1

Next, use the same process to choose other operations to finish the inner wall as follows:

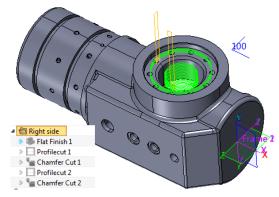


Figure 17 Finish toolpath based on frame 1

So far we have created tool path in different frames, next we can go to verify the toolpath in frame1 as follows:

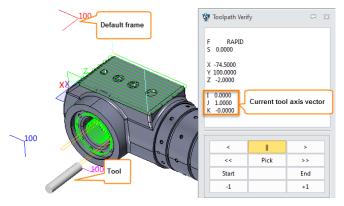


Figure 18 Verify the tool and toolpath

From the verified result we can find that now the tool axis has been tranformed. If we check the tool axis's vector we can find it is not (0,0,1) which is default Z axis, butit is (0,1,0), that means the tool has been rotated around X axis 90 degree.

So far the indexing milling from default frame to frame1 is almost finsihed.

But there still is a probem confusing us: How is the tool transformed to this position? And we always want to track this process. Actually the *Inter Path Move* operation can achieve this function. It will connect the end point of the last operation in previous operations and the start point of the first operation in next frame.

STEP 03 Create link toolpath by Interpath operation:

I. Insert Interpath operation between Top side and Right side as follows:

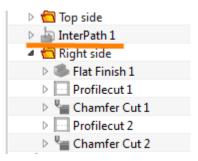


Figure 19 Insert Inter Path Move operaion

II. And then set up the interpath operation as follows:

Can input by manually or by picking point in

graphic area

💯 InterPath 1				X
Type: InterPath	▼ Basic			
Path Setting	Frame			
Display	Speeds, Feeds	InterPath 1		
Previous frame tool transfor option blank by default it wi operation will be the previo	II regard the fra us frame.	ame applied in previous		
Figure 20	Set up the	previous frame		
😨 InterPath 1		₩ X	2	
Type: InterPath	▼ Cutting Control			
Primary	Safety Distance	10		
Display	Max Rotate Angle	5		
	Home Point	0,0,100		
	Home Axis	0,0,1		
The Tool's home point				

Figure 21	Set up the Tool's information in previous frame
19410 51	set up the root's information in previous name

area

Tool's home Z axis in previous

frame, can be input manually or by picking direction in graphic

III. After calculating the InterPath operation we can get the following link toolpath :

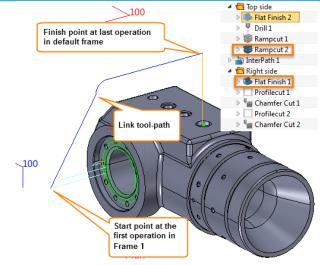
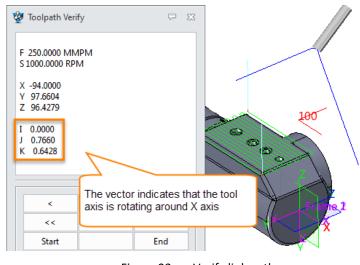
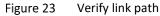


Figure 22 Link tool path for transforming

The link toolpath can clearly show how the tool transform from the default frame to Frame 1, so it is helpful to check if it is safe or not.

IV. Verify the InterPath as follows:





Notes: The Interpath operation's tool should be the same as the tool used by the first operation in next frame as follows:

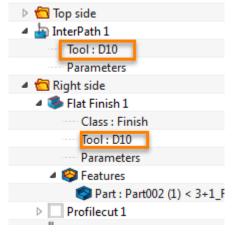


Figure 24 Tool for InterPath operation

STEP 04 Create the toolpath on the bottom side as follows:

I. Create toolpath based on the frame 2 as follows:

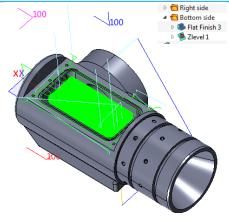


Figure 25 Tool path on bottom side

II. Insert Interpath operation and set up as follows:

Type: InterPath]			
Path Setting Frame Display Speeds Feeds InterPath 2		-			
leave it blank : transform from the frame applied in previous operation					

Figure 26 Set up Interpah operation

III.Calculate the Interpath operation we can get the link tool-path between right side and bottom side as follows:

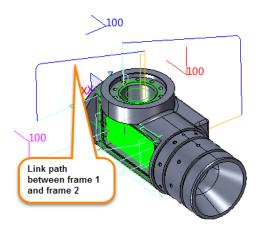


Figure 27 Link path beween right side and bottom side

So far we have finished the 4X indexing milling process for this part. Next we need to output the NC code for it. Before we output the NC code, we have to check some necessary setting such as machine type, controller, output space etc.

1.1.4 Set Up The Machine

Double click on the machine tab to activate the Machine Manager and set up as follows:

4-5X Machining <///

👰 Machine Manager			Π. Σ
Definition		Library	
Machine Name Machine 1		Machine	
Class 5-Axis M.C. 1			
Type Vertical 🔹			
Subtype	Rotating Head 🔻		
Post-Processor	ZWPost *	💯 List	≂ x
Post Configuration ZW_FANUC_4X_A XY Arcs Yes		MILL_5AXIS_HeiDH530_ACT MILL_5AXIS_SINMS840D_AC Okuma_3X_Inch	
YZ Arcs No ZX Arcs No Check MULTAX Yes MULTAX Yes 4		TNC426_3X_Heidenhain Turning_KND-2000TC YasnacBasic Yasnac_3000G_Inch	=
		Yasnac_MX3_Inch ZW_Fadal_3X ZW Fanuc_3X_IN ZW_FANUC_4X_A	
Accurate RAPIDs	No	ZW_FIYANG_3X ZW_FIYANG_4X_A ZW_FIYANG_5X	
Scale	1	ZW_GSK983M	▼
#.xxxx	5		
Rewind Yes *			
Increment 1			
CUTCOM None •		Dele	te
Offset Registers		-Options-	
NC Extension	.nc	Tool Changer	Rotary Axes and Offsets
Definition File	machine_all.mdf 📩	Parameters	Limits
Open Machine Definit	tion File Legacy Definition Files	Add To Library>	Apply Filter>

Figure 28 Set up machine

Here let's choose the **ZW_FUNAC_4X_A** as an example to output.

1.1.5 Set Up Output Space

Since here we have already defined different frames, it is necessary for us to specify on which frame to output the NC code.

STEP 01 Insert a new NC file as follows:

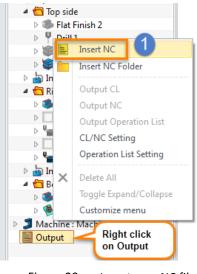


Figure 29 Insert new NC file

STEP 02 Add operation for output as follows:

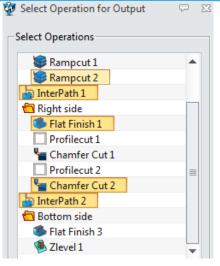


Figure 30 Add operations for output

Here we just want to verify if the NC code can correctly output the rotating angle, so we can just pick some connected operation as test.

STEP 03 Set up output space as follows:

	~					
	1+	Add	Operations			
⊿ 🧉	1 F	Outp	out CL			
Þ	•	Outp	out NC			
	10 m	Outp	out Operation Li	st		
⊳	- 🗋 🆓	Rena	me			
	<mark>i</mark> ×	Dele	te			
⊿ 🗧		Setti	ng (3)			
		Dupl	icate			
> 🎜 I	Ma	Cust	om CL Cmd			
a 📃 (Ou	Cust	omize menu			
Output Setting	₽ 13					
Select Machine						
Machine 1						
Create Edit						
Setting						
Part Id	NC					
Programmer	win7					
Toolpath Space	Machine	2	4			
Relation Frame	Machine					

Figure 31 Set up output space

1.1.6 Output NC Code:

Choose the first Inter-Path operation as an example to show:

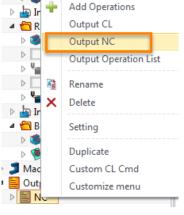


Figure 32 Output NC

Output NC code as follows, it shows how the tool rotates around X axis from the default frame to frame1.

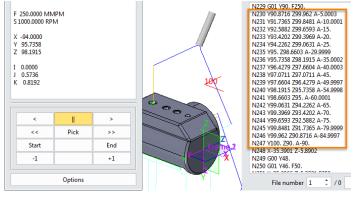


Figure 33 Output NC code

If you want to check more, please go through the whole NC code by yourself.

So far, we have finished the sample case for 4X indexing milling. From this process we can find that the key points for the indexing milling are as follows:

- 1) Align the part according to the machine structure
- 2) Create sub frame
- 3) Set up 4&5 X machine type
- 4) Set up the output Space

1.2 5X Indexing Milling

Last case we finished the 4X indexing milling. Now we can use the same way to finish the 5X indexing milling case. Following is a 5X indexing milling case we are going to finish:

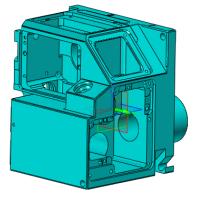


Figure 34 5X indexing milling case

Analysis: From this part we can find that if we want to finish all sides by one clamping, the machine needs to rotate the tool axis around different axis. Here let's suppose the 5X machine is AC type, which means rotating around X, Z. Besides here we just take the finished operation as an example to show how to

achieve in ZW3D CAM.

1.2.1 Align Part

Just as what we mentioned above, in order to make use of the default frame we can align the part in CAD level as follows, here the origin is located at the center of top.

STEP 01 Create a assistive stock for positioning part as follows:

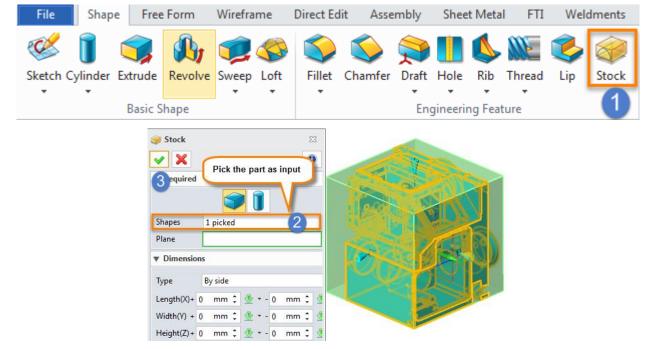
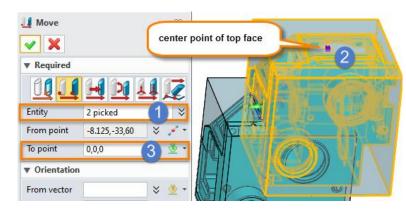


Figure 35 Create stock in CAD level



STEP 02 Move the part as follows:

Figure 36 Move the part and stock to origin point

STEP 03 Result will be as follows:

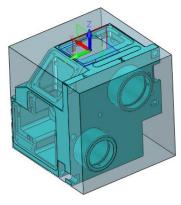
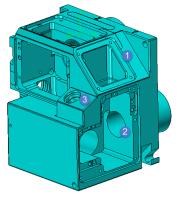


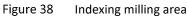
Figure 37 Aligned Part

Then we can delete or hide the stock.

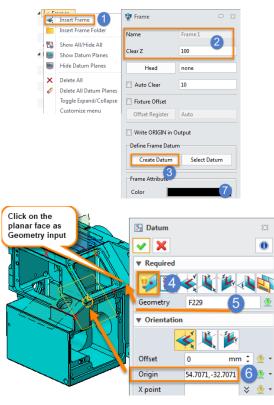
1.2.2 Create Sub-Frame For Multiple Faces

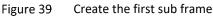
Here we will choose some faces as examples to show this detailed process which is as follows:





STEP 01 Create the first frame as follows:





Finished result is as follows:

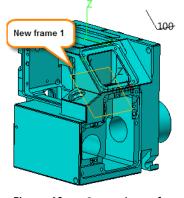


Figure 40 Created new frame 1

Notes : Here the sub frame is only used to define the tool axis's direction, so the sub frame's origin point can be located at any position. In order to show it clearly, here we chose an obvious position mentioned above.

STEP 02 Create other frames on area 2 and area 3 as follows:

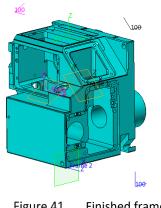


Figure 41 **Finished frame**

1.2.3 Create Toolpath Based On Different Frame

The process of creating 2X or 3X toolpath based on different frame is the same as 4X indexing milling, so here we will skip this process of creating toolpath and just show you the result as follows:

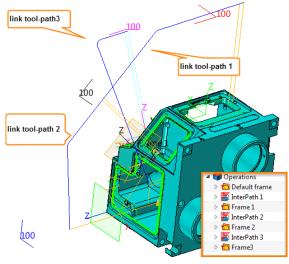


Figure 42 Finished toolpath

For your reference you can open the file **5X_indexing_With toolpath.Z3** directly.

But you are strongly recommended to finish it from beginning again by yourself.

1.2.4 Set Up Machine and Output Space

STEP 01 Set up the machine and choose the post processor **ZW_FUNAC_5X** :

🐲 Machine Manager					
Definition					
Machine Name	Machine 1				
Class	5-Axis M.C 1				
🗌 Туре	Vertical 🔻				
Subtype	Rotating Head 🔹				
Post-Processor	ZWPost 💌				
Por 2nfiguration	ZW_FANUC_5X				
XY Arcs	Yes 🔻				
YZ Arcs	No				
ZX Arcs	No				
Check MULTAX	Yes •				
MULTAX	Yes 3 •				
Accurate RAPIDs	No •				
Scale	1				
#.xxxx	5				
Rewind	Yes •				
Increment	1				
СИТСОМ	None •				

Figure 43 Set up post processor

STEP 02 Set up the machine structure as AC type by the post Processor editor as follows:

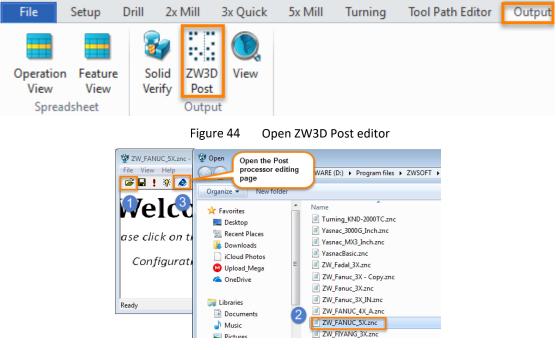


Figure 45 Load the related Post Processor

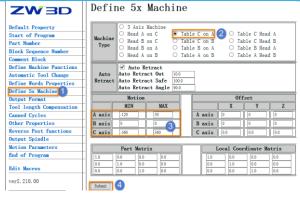


Figure 46 Set up 5X machine type and rotary axis's limitation



STEP 03 Set up Output space as Machine as follows:

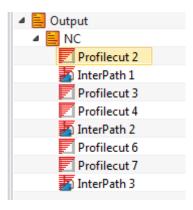
🐉 Output Setting					∇	23
Select Machine						
Cre	ate		Edi	t		
Cre	ate		Edi	t		
	ate NC		Edi	t		
Setting			Edi	t		
Setting Part Id	NC win7		Edi	t		

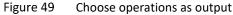
Figure 48 Set up output space

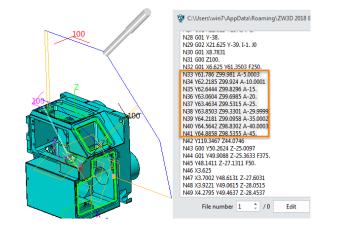
1.2.5 Output NC Code

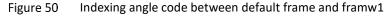
Here just choose the connected operation to output the NC code and check it as follows:

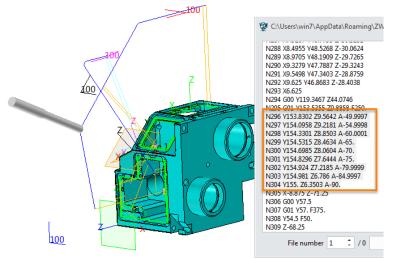
STEP 01 Choose the connected operation as output:

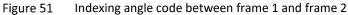












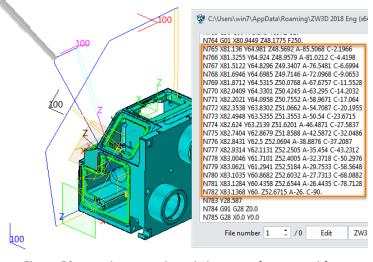


Figure 52 Indexing angle code between frame2 and frame3

1.3 5X Silmutaneous Movement Operations

Next we will learn how to use the 5X operations as follows:



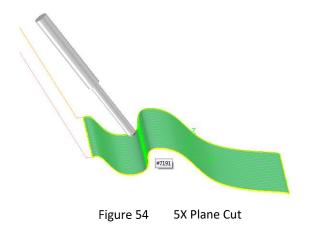
Figure 53 5X Simultaneous Movement Operations

Among those operations we have introduced the InterPath Move operation, so we can skip it. As for the **Interactive** operation, since it is not used very often, it will be not introduced in this chapter, if you are interested in it then you can check the help document.

ZW3D CAM 5X simultaneous movement operations integrate both 4X and 5X functions together. Therefore, it is able to switch the 5X simultaneous operation to 4X simultaneous operation by the tool axis control parameter.

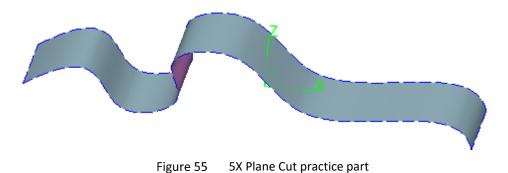
1.3.1 5X Plane Cut Operation

Philosophy: The 5 axis plane cut creates a cutting pattern based on parallel cuts at a user-specified angle with respect to the frames X axis. This cutting pattern can be used to control the tool tip or the contact location of the tool on the part. It is possible to constrain the tool axis to a plane (for 4 axis milling) or to a specific orientation (for 3 axis milling).



1. How to run 5X plane operation

5X Plane operation works on general surface, so it only requires that the general part surface can create toolpath. Next Let's open the practice file **"5X Plane Cut**.Z3" as follows:



Then we shall use this part to show you how to create 5X Plane Cut tool path on it:

I. Define a general surface as follows:

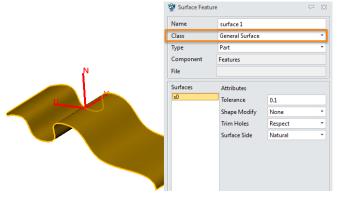


Figure 56 Define general surface for 5X plane cut

II. Calculate operation by default parameter to get toolpath as follows:

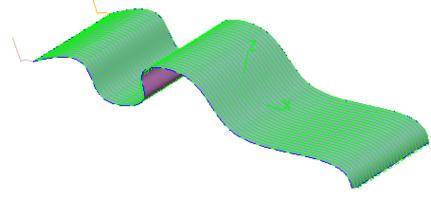


Figure 57 5X Plane Cut toolpath

2. Set up 5X Plane Cut parameter:

I. Primary parameters:

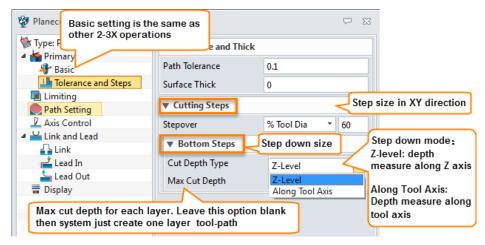
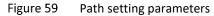


Figure 58 Primary parameters

II. Path setting parameters:

🐲 Planecut 1		Ģ	23
👹 Type: Planecut 4 🍆 Primary	▼ Cutting Control		Can specify, by default
P Basic	Cut Angle	0,0.707107,-0.707107	is the default X axis
Tolerance and Steps	Path Pattern	Zigzag	direction
Limiting	Stepover Link	Straight	• Whether or not the
Path Setting	Stepover Link	Straight	trimed hole in surface
Axis Control	Trim Holes	Respect 🛛 🧹	will be ingored
Link and Lead	Allow Undercutting	No	▼
Link			
🛁 Lead In	Point Setting		If cut the undercut region
Sead Out	Tool Home Start		In cut the undercut region
Display	Iool Home Start		
	Tool Home End		



III. Axis control parameters:

🖗 Planecut 1		⊽ ⊠
 Type: Planecut Primary Basic Tolerance and Steps Limiting Path Setting 	▼ Axis Control Axis Control Lead Angle Roll Angle	Contact Control Fixed Axis Tip Control Contact Control
Axis Control	Max Tilt Angle Max Rotate Angle	4X Tip Control 4X Contact Control 5
Link Lead In Lead Out		

Figure 60 Axis control parameters

• Fixed Axis: The tool axis will be determined by lead and roll angles along the cutting direction and relative to the Z axis of the frame. Actually, you can think it is the frame's Z axis, since by default the Lead and Roll angle are all 0. As follows:

Figure 61 Fixed Axis tool.

• **Tip Control**: The local contact data determines the cutter orientation while the cutter tip point is kept within the cutting plane. Actually, when the Tip of Tool is in the cutting plane then the tool axis is the surface's normal way.

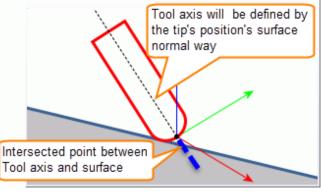


Figure 62 Tool tip

• **Contact Control**: The local contact data determines both the cutter orientation and tip point. It uses the local contact point as reference and the normal way of this point together to determine the tool axis's position.

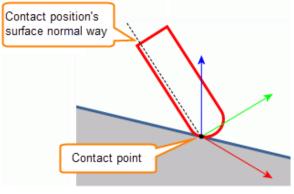


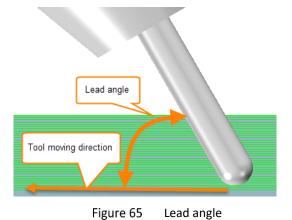
Figure 63 Contact control case

• **4X Tip Control:** Tip contol option work in 4X mode, and you need to specify 4X plane as follows:

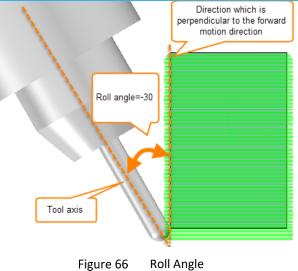
Axis Control				
Axis Control		4X Tip Control	•	
Four Axis Plane		0,1,0		
Lead Angle 0				
Roll Angle	Click	this icon to Sot		
Max Tilt Angle Up the 4X plane				
Max Rotate Angle				

Figure 64 Specify 4X plane

- **4X Contact Control**: Contact control option work in 4X mode, you also need to specify 4X plane.
- Lead angle: The angle of the tool axis will be tilted toward the movement direction



• **Roll angle** : The angle of the tool axis will be tilted to the direction which is perpendicular to the forward motion direction. A positive value will tilt the tool to the right, negative to the left.



1.3.2 5X Swarf Cut

Philosophy: The 5 axis Swarf Cut operation uses **Control surfaces** to calculate the tool path. The tool axis is controlled by **Drive surfaces** with which the side of the tool maintains contact. The bottom of the tool (contact point) is controlled by **Part surfaces**.

Open the practice file **5X_SwarfCut_Practice.Z3** as follows:

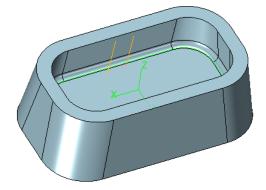


Figure 67 5X Swarf Cut practice file

From the part structure we can find that it is not able to cut the side wall and radius on the bottom face by 3X tool path since the wall is titled. So here we hope the tool axis can title following side wall and keep tangent to the side wall as follows:

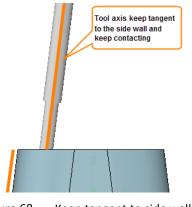


Figure 68 Keep tangent to side wall face

Next let's show how to create 5X swarfCut tool path on this part as follows:

1. How to run Swarf Cut operation:

STEP 01 Define drive surface : the drive surface will be used to control the tool axis by maintaining contact with the side of tool

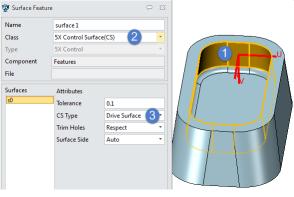


Figure 69 Define drive surface

STEP 02 Define Part surface: the part surface actually is the target that will be cut as follows:

💯 Surface Featur	e		~	23
Name	surface 2			
Class	5X Control Surfac	e(CS) 2		•
Туре	5X Control			-
Component	Features			
File				
Surfaces	Attributes			
s0	Tolerance	0.1		
	CS Type	Part Surface	3	7
	Trim Holes	Respect	-	•
	Surface Side	Auto		•

Figure 70 Define Part surface

STEP 03 Choose a ball end tool with diameter of 6 mm, and calculate the operation by default parameter. Then we can get toolpath as follows:

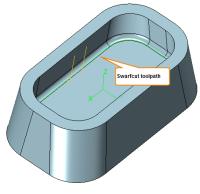


Figure 71 Swarfcut toolpath

Swarf cut parameters

Next let's take a look at the main parameters of Swarfcut operation as follows:

1. Primary parameters

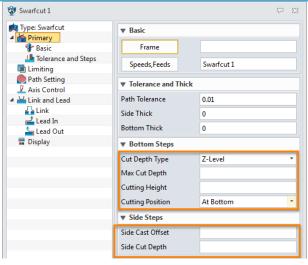


Figure 72 Swarfcut primary parameters

For the Basic and Tolerance related parameter actually, every operation is the same meaning. So here let's skip it. Here are some new parameters we need to explain

- Cut depth Type: depth measurement direciton.
- Z-Level: means that depth is measured along working frame's Z axis
- Along tool: means that depth is measured along tool axis
- **Max Cut depth**: if we create multiple layers toolpath then this value is the maximum depth for each layer. If we leave it blank then it means only 1 layer toolpath will be created.

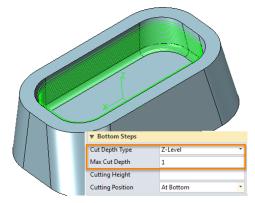


Figure 73 Multiple layers swarf cut toolpath along Z level

• Cutting height : It is a limitation for depth and only work for At Top option as follows

Tolerance and Thick		
Path Tolerance	0.1	
Side Thick	0	
Bottom Thick	0	
▼ Bottom Steps		
Cut Depth Type	Z-Level	
Max Cut Depth	0.5	
Cutting Height	3	
Cutting Position	At Top 🔹	
▼ Side Steps		

Figure 74 Cutting height of swarf cut

• **Cutting position:** we can regard it as a measurement reference for depth, starting from top or from bottom. If we only create one toolpath then it is used to specify where to cut top or bottom.

- Side cast offset: it is used to set up the side thickness of cast part which needs to be removed.
- **Side cut depth**:something like the stepsize in XY.

Tolerance and Thick		
Path Tolerance	0.1	
Side Thick	0	Side wall Offset
Bottom Thick	0	value
▼ Bottom Steps		
Cut Depth Type	Z-Level 🔹	
Max Cut Depth	0.5	
Cutting Height	3	
Cutting Position	At Top 🔹	
▼ Side Steps		
Side Cast Offset	7	Side cut depth
Side Cut Depth	3	

Figure 75 Side steps

2. Path setting parameters

💯 Swarfcut 2		⊽ ⊠
Type: Swarfcut	▼ Cutting Control	
▲ Mainter America	Path Pattern	Zigzag 🔹
Interance and Steps	Cut Order	Side First 🔹
Path Setting	Fan In	5
🖉 Axis Control	Fan Out	5
▲ Link and Lead ↓ Link	Cut Overlap	5
Link Lead In	Cut Direction	Climb 🔻
🖕 Lead Out	Cutting Order	Automatic 🔹
冒 Display	Corner Radius	Respect 🔹
	▼ Point Setting	
	Start Point	
	Start Axis	
	Tool Home Start	
	Tool Home End	

Figure 76 Path setting parameters

- Path pattern: set up if use one way or Zigzag pattern
- **Cut order**: This determines the depth cut order. This can be applied to both Base Depths and Side Depths. (Normally used under the condition of side cast offset)
 - Bottom First: Cut down to base (part) surfaces first for each side cut.
 - Side First: Cut sides first on each level.
- Fan In: A distance from a corner seam (edge) at which the tool will begin to lessen the influence of the drive surfaces on the tool axis so that it can assume the optimal orientation on the corner.
- **Fan Out**: A distance the tool may traverse while transitioning from the optimal orientation in a corner to have the tool axis controlled by a drive surface.
- **Cut Overlap:** This is a re-cut distance to obtain smooth part surface when **cutting closed loops.** This distance is added at the end of the cut (retracting the beginning of the cut) at the **cut** feed rate.
- **Cut Direction:** This determines the direction of cut, which are Clime and Conventional.
- Corner Radius: Fillet the cut with this radius.

3. Axis control pararmeters:

💯 Swarfcut 1		₽ %
🙀 Type: Swarfcut 4 🏠 Primary	▼ Axis Control	
Basic	Axis Option	Automatic 🔹
Tolerance and Steps	Four Axis Plane	Ruled Lines Ruled Line Interp
Path Setting	Max Tilt Angle	Vertical Automatic
Axis Control	Min Tilt Angle	
Link	Max Rotate Angle	5
📥 Lead In	Skew Angle	
Sead Out		

Figure 77 Axis control parameters

Axis Option:

- **Ruled lines**: The tool axis always follows the ruling direction of a drive surface for ruled surfaces, it is used for the ruled drive surface.
- Vertical: The tool axis is both tangent to the drive surface and vertically tilted.

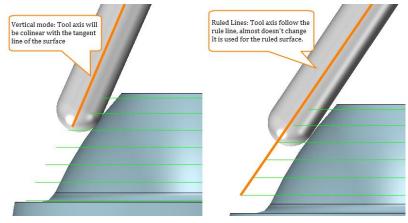


Figure 78 Tool axis options

 Automatic: The tool axis follows *ruled lines* for curved ruled drive surfaces and will be vertical for other types of drive surfaces including flat ones.

Real case study

Next we will use 2 real cases as examples to show how to apply the swarf cut operation to real work.

1. Case 1: "5X_Impeller.Z3"

Let's open the real case " 5X_impeller.Z3 " file as follow:

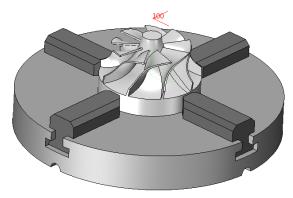


Figure 79 5X_Impeller file

Then we will create swarf cut toolpath to cut the blade as follow:

STEP 01 Define the 5X control surface as follow:

🐲 Surface Feat					
Name	surface 1				
Class	5X Control Surface(CS		•		
Туре	5X Control		-		
Component	Impeller				
File	5X_Impeller.Z3				E
Surfaces	Attributes				
SU	Tolerance 0.				
			•		
		·			
		Fig	ure 80 ,⊂ ∞	Define 5X Drive Surface	
-	eature surface2	Fig		Define 5X Drive Surface	
Name				Define 5X Drive Surface	
Vame Class	surface2			Define 5X Drive Surface	
Surface Fe Name Class Type Component	surface2 5X Control St 5X Control			Define 5X Drive Surface	
Name Class Type Component	surface2 5X Control S 5X Control Impeller	rface(CS)		Define 5X Drive Surface	
Vame Class Type Component File	surface2 5X Control S 5X Control Impeller 5X_Impeller	rface(CS)		Define 5X Drive Surface	
Name Class Type Component File Surfaces	surface2 5X Control S 5X Control Impeller	rface(CS)		Define 5X Drive Surface	
Name Class Type Component File Surfaces	surface2 5X Control S 5X Control Impeller 5X_Impeller	rface(CS)		Define 5X Drive Surface	
Name Class Type Component File Surfaces	surface2 5X Control So 5X Control Impeller 5X_ Impeller.2 Attributes Tolerance	rface(CS) 3		Define 5X Drive Surface	
Name Class Type	surface2 5X Control So 5X Control Impeller 5X_ Impeller Attributes Tolerance CS Type	rface(CS) 3 0.1 Part Su	(7) (2) (7) (7) (7) (7) (7) (7) (7) (7) (7) (7	Define 5X Drive Surface	
- Name Class Type Component File Surfaces	surface2 5X Control So 5X Control Impeller 5X_ Impeller.2 Attributes Tolerance	rface(CS) 3	r x	Define 5X Drive Surface	

Figure 81 Define 5X Part Surface

STEP 02 Set up tool size and operation parameters

Here we assume that the corner radius is 2 mm so that we can choose the ball end mill with the radius of 2 mm. Then set up operation parameters as follows:

Type: Swarfcut	▼ Tolerance and Th	ick
Primary Basic	Path Tolerance	0.1
La Tolerance and Steps	Side Thick	0
Limiting Path Setting	Bottom Thick	0
Axis Control	▼ Bottom Steps	
Link and Lead Link	Cut Depth Type	Along Tool Axis
💾 Lead In	Max Cut Depth	2
Lead Out	Uniform Depth	Yes 🔻
冒 Display	Cutting Height	
	Cutting Position	At Bottom 🔻
	▼ Side Steps	
	Side Cast Offset	
	Side Cut Depth	

Figure 82 Define Primary parameters

Type: Swarfcut	▼ Cutting Control		
Primary Basic	Path Pattern	Zigzag	
Tolerance and Steps	Cut Order	Bottom First	
Path Setting	Fan In Fan Out Cut Overlap Cut Direction	5 5 5 Climb	
Axis Control			
 Link and Lead Link Lead In Lead Out 			
	Display	Corner Radius	Ignore
	▼ Point Setting		
	Start Point		
	Start Axis		
	Tool Home Start		

Figure 83 Define Path setting parameters

💯 Swarfcut 1			₽ Ж
Type: Swarfcut	▼ Axis Control		
4 🍲 Primary 🌮 Basic	Axis Option	Ruled Lines	*
Interance and Steps	Four Axis Plane		
Limiting Path Setting	Max Tilt Angle		
Axis Control	Min Tilt Angle		
	Max Rotate Angle	5	
📥 Lead In	Skew Angle		
Lead Out			
冒 Display			



Define Axis Control

▼ Lead In		▼ Lead Out		
Lead In Type Normal 🔹		Lead Out Type	Normal *	
Start Angle In		Start Angle Out		
End Angle In	0	End Angle Out	0	
Radius In	0	Radius Out	0	
Ramp Length In	1.5	Ramp Length Out	1.5	
Ramp Angle In	0	Ramp Angle Out	0	

Figure 85 Lead in and lead out

For the rest parameters keep their default setting.

STEP 03 Calculate toolpath as follows:

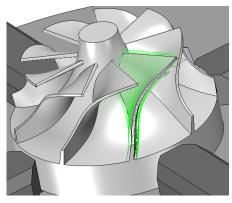


Figure 86 Swarf cut toolpath

STEP 04 Pattern the toolpath by transforming function and setting up the pattern parameters as follows:

Type: Transform	▼ Xform Control		
Path Setting	Xform Method	Circular Array 🔹	
Link and Lead	▼ Circular		
Display	Origin	0	
	Axis	0,0,1	
	Angular Spacing	40	
	Number of Copies	9 ‡	
	Create Copy at Original		

Figure 87 Pattern the swarf cut toolpath around Z axis

The finished result is as follows:

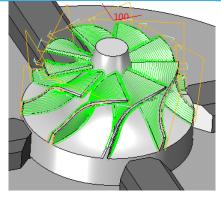


Figure 88 Finished swarf cut for impeller blade

Verify the toolpath movement by verifying function as follows:

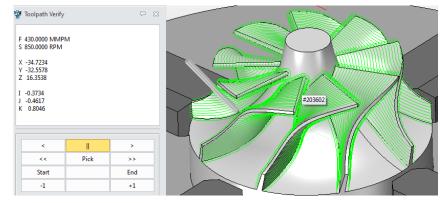


Figure 89 Verify swarf cut toolpath

After saving the file. From the result we can find that actually the blade part has been finished. We will keep on creating toolpath on this impeller file by other operations and finally when we finished the tutorial the impeller model also will be finished.

2. Case 2: SwarfCut_A.Z3

Please open the case file *Swarfcut_A.Z3* as follows:

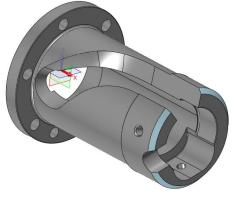


Figure 90 Swarfcut_A file

Task: finish the highlighted surface as follows:

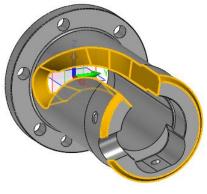
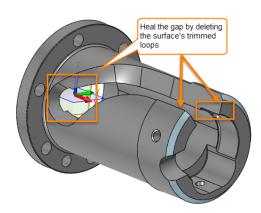


Figure 91 cutting required faces

- STEP 01 Heal the highlighted surface Since this file is an imported file and the swarfcut operation has strictly requirements for geometry quality, so it is better to heal the file first before programming. Details are as follows
 - I. Delete loops



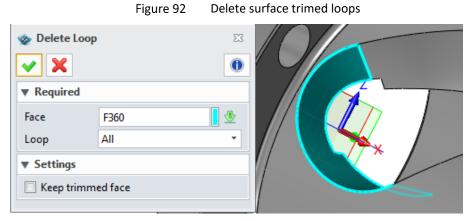


Figure 93 Delete loops operation 1

🔹 Delete Loop		×	
▼ Required			
Face	F358	_ ₹	
Loop	All	•	
▼ Settings			
Keep trimm	ed face		
Keep trimm	ed face		

Figure 94 Delete loops operation2

	🔹 Delete Loop		23	
▼ Required				
	Face	F314	- 🕹	
	Loop	Selected	*	
	Edges	4 picked		
	▼ Settings			
Keep trimmed face				



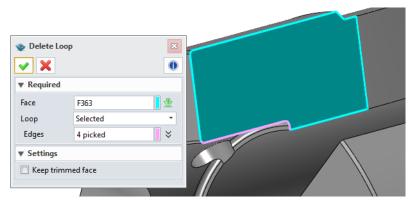
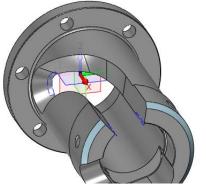
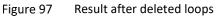


Figure 96 Delete loops operation 4

II. After deleting the loops, we can get the following result:





STEP 02 Modify surface: Trim the surface to curve as follows:

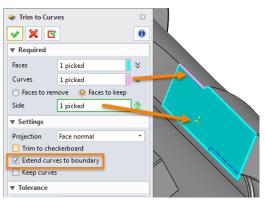


Figure 98 Trim surface_right side

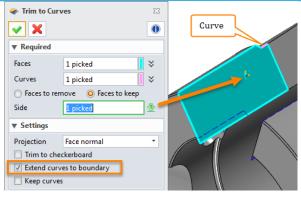
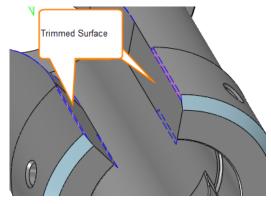


Figure 99

Trim surface_left side

Finally we can get the result as follows:





STEP 03 Ensure that the trimmed surface can be tangent to the adjacent surface by **Match Tangency** Tool as follows:

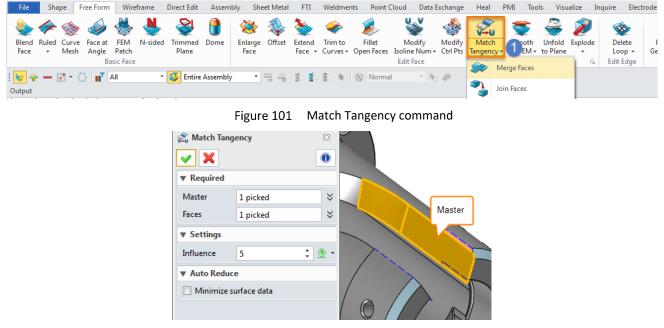


Figure 102 Match trimed surface tangency to adjacent surface

Please use the same way to match the trimmed surface tangency on the both right and left side

- STEP 04 After healing the surface we can go back to CAM and create swarfcut toolpath for the target surface as follows:
 - I. Define the drive surface:

🐉 Surface Feat	ure	ç	7 23	
Name	surface 1			
Class	5X Control Surfa	ice(CS)	-	
Туре	5X Control		-	
Component	AX			
File	Swarft_A_Withto	olpath.Z3		101
Surfaces	Attributes			
sO	Tolerance	0.1		N N
	CS Type	Drive Surface	-	
	Trim Holes	Respect	-	
	Surface Side	Natural	-	2 /0/

Figure 103 Define drive surface

Here we will cut the drive surface to define a drive surface as feature input.

- II. Set up tool size : Use 10 mm flat end mill.
- III. Set up parameter as follows:

😵 Swarfcut 1				23
鰔 Type: Swarfcut 4 🎽 Primary	▼ Tolerance and Thick			
Basic	Path Tolerance	0.01		
Interance and Steps	Side Thick	0		
Limiting Path Setting	Bottom Thick	0		
Axis Control	▼ Bottom Steps			
Link and Lead	Cut Depth Type Along Tool Axis			Ŧ
🚢 Lead In	Max Cut Depth	1		
Lead Out	Uniform Depth	Yes		•
Display	Cutting Height			
	Cutting Position	At Bottom		•
	▼ Side Steps			
	Side Cast Offset			
	Side Cut Depth			

Figure 104 Primary parameters

Cutting Control		
Path Pattern	Zigzag	
Cut Order	Bottom First	-
Fan In	5	
Fan Out	5	
Cut Overlap	5	
Cut Direction	Climb	•
Cutting Order	Automatic	•
Corner Radius	Ignore	•
▼ Point Setting		
Start Point		
Start Axis		
Tool Home Start		
Tool Home End		

Figure 105 Path setting parameters

▼ Link		
Short Link Type	Z Lift Up 🔻	,
Long Link Type	Automatic 🔹	·
% Short Link Limit	300.0	
Max Link Rotate Angle	10	
Safe Distance	5	

Figure 106 link

▼ Lead In		▼ Lead Out	
Lead In Type	Normal *	Lead Out Type	Normal 🔻
Start Angle In		Start Angle Out	
End Angle In	45	End Angle Out	45
Radius In	1	Radius Out	1
Ramp Length In	0	Ramp Length Out	0
Ramp Angle In	0	Ramp Angle Out	0

Figure 107 Lead in and out

IV. After calculating the toolpath we can get the following result:

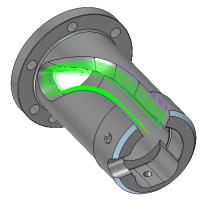


Figure 108 Finished Swarfcut toolpath for pocket

Now we can check the toolpath by verifying as follows:

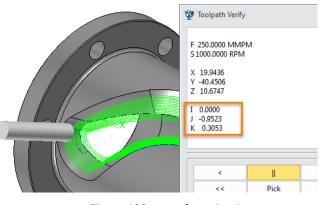


Figure 109 Verify toolpath

we can find that actually this is 4X milling simultaneous movement toolpath. So let's look at the Four Axis Plane option as follows:

4-5X Machining <<<<</>

🖗 Swarfcut 1		⊽ ⊠
烕 Type: Swarfcut	▼ Axis Control	
Primary Pasic	Axis Option	Automatic 🔹
Limiting	Four Axis Plane	
Path Setting	Max Tilt Angle	
Axis Control	Min Tilt Angle	
Link and Lead	Max Rotate Angle	5
💾 Lead In	Skew Angle	
🖕 Lead Out		

Figure 110 Define 4X plane for swarfcut operation

4X Plane option actually is used to force the toolpath to a 4X Tool path. By default the system will automatically create the toolpath according to the surface's situation. Here the 4X tool path is enough to finish the pocket so even without setting up the Four Axis Plane system can automatically create the 4X toolpath for it. But the end chamfer surface will be different. In order to make a better toolpath here we can modify the part again to the following result:

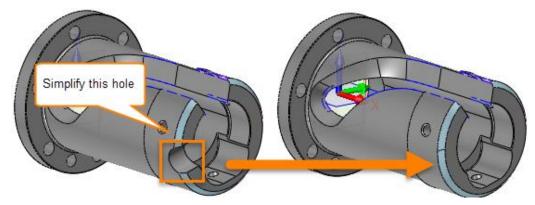
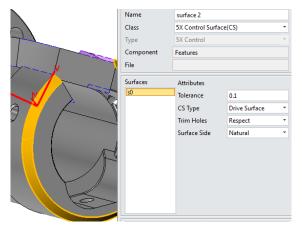
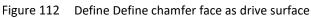


Figure 111 Simplify hole in end

Next we will go to create toolpath on the chamfer face by the four axis plane option or without it seperately.

STEP 01 Define the chamfer face as drive surface:





STEP 02 Set up parameters and choose the same tool (D10) as follows:

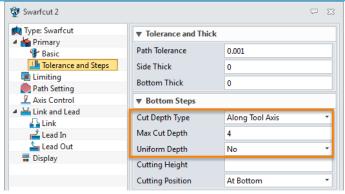


Figure 113 Primary cutting parameter for cutting chamfer face

STEP 03 Create toolpath without 4X plane option:

🖗 Swarfcut 1			$\overline{\nabla}$	23
対 Type: Swarfcut 4 🏠 Primary	▼ Axis Control			
Basic	Axis Option	Automatic		•
Tolerance and Steps	Four Axis Plane			
Limiting Path Setting	Max Tilt Angle			
Axis Control	Min Tilt Angle			
Link and Lead Link	Max Rotate Angle	5		
🛃 Lead In	Skew Angle			

Figure 114 Axis control setting

The toolpath is as follows:

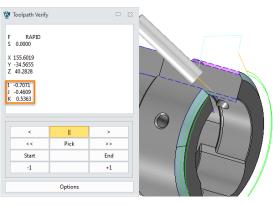


Figure 115 Swarf cut toolpath without 4X plane option

From the result you can find that now actually it is a 5X toolpath not 4X simultaneous toolpath. So it will conflict with your machine. How to solve it? By 4X plane option as follows:

STEP 04 Set up the 4X plane according to real condition (here let's choose A)

😨 Swarfcut 1		₽ %
📩 Type: Swarfcut 🔺 🏠 Primary	▼ Axis Control	
Basic	Axis Option	Ruled Lines 🔹
Tolerance and Steps	Four Axis Plane	1,0,0
Limiting Path Setting	Max Tilt Angle	
Axis Control	Min Tilt Angle	
▲ ≚ Link and Lead	Max Rotate Angle	5
Link	2	5
Lead In	Skew Angle	

Figure 116 Set up 4X plane

STEP 05 After calculation we can get another toolpath as follows:

<	 Toolpath Verify F RAPID S 0.0000 X 154.2532 Y -33.7106 Z 39.9928 I 0.0000 J -0.6518 K 0.7584 		
Start End	<	I	>
	<<	Pick	>>
	Start		End
-1 +1	-1		+1

Figure 117 4X swarf cut with Flat end mill tool

If we use ball end mill tool and create more toolpath then we can get a better 4X toolpath for finishing this chamfer face as follows:

 Toolpath Verify F 250.0000 MMPN S 1000.0000 RPM 	И	2
X 160.3475 Y -22.3836 Z -35.9803 I 0.0000 J -0.5282 K -0.8491		
<		>
 <<	Pick	>>
Start		End
-1		+1

Figure 118 4X Swarf cut toolpath with ball end mill tool

1.3.3 5X Drive Curve Cut

Philosophy: The 5 axis **Drive Curve Cut** uses 3D driving curves to calculate the tool path. The cutter is driven along these curves and respects the surface geometry to be cut. This operation shares the same Axis Control capability as the 5 Axis Plane Cut operation. The remaining parameters are also similar.

Open the Z3 file *DriveCut_ISOCut_HelicalGear.Z3* as follows:

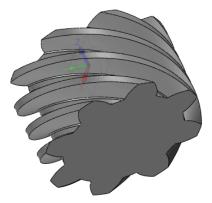


Figure 119 DriveCut_ISOCut_HelicalGear file

Next, we will use this file to introduce how to run the **Drive Curve** cut operation and Guide Surface ISO operation. First, let's look at drive curve cut operation.

1. How to run Drive Curve Cut operation

STEP 01 Create the drive curve:

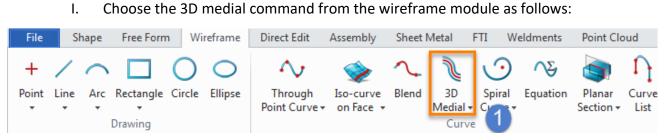


Figure 120 3D Medial command

II. Pick the edges on bottom surface of any tooth socket as input as follows:

🐧 3D Medial		Σ	3	
🖌 🗙			D	
▼ Required				
1st curve	E121	2	₫	
2nd curve	E118	8	₫	
▼ Settings				
Method	Equidistant-I	Viddle end	4	
Tolerance	0.02	mm 🗘 🔮	-	
Number	1	\$	•	

Figure 121 Input curves for creating 3D medial curve

After creating the 3D medial curve then enter into CAM let's create Drive curve cut toolpath.

STEP 02 Define dirve curve and part surface

🐲 Profile Featur	e		$\overline{\nabla}$	23	
Name	Profile				
Class	general				
Туре	Part			•	
Component	Features				
File					
Profiles	Attributes				
p0	Tolerance	0.001			
	Offset	0			
	Open / Close	Open		•	
	Join Method	Linear		•	
	Reverse Dir	No		•	
	Part Side	Left, Tangent		-	X

Figure 122 Define profile for Drive curve cut

💯 Surface Featur	re		₽ 23	
Name	Part face1			
Class	General Surface		•	
Туре	Part		•	
Component	Features			
File				
Surfaces	Attributes			
s0	Tolerance	0.01		
	Shape Modify	None	•	
	Trim Holes	Respect	-	
	Surface Side	Auto	•	

Figure 123 Define part surface

STEP 03 Customize a taper tool

Name R0.5 T	ype I	Mill × S	Subtype End	× (Add to Lib	Load from l
		Tool Len (L)	5			
		Flute Len (FL)	5			
	Ť	Angle (A)	3			
	L	Flutes (F)	4			
F FL		Radius (R)	0.5		Υ	
	•	Cutter Dia (D)	1			

Figure 124 Customize taper tool

STEP 04 Set up parameters:

Since most of the parameters are similar to the previous introduced PlaneCut and SwarfCut operations so here we just take some special and different parameter to explain the meaning. For others we just show the setting as follows:

I. Primary parameters:

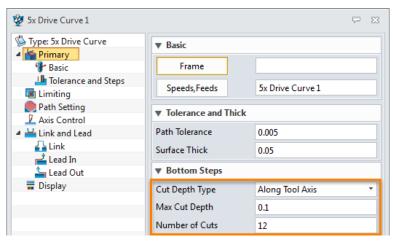


Figure 125 Primary parameter of 5X Drive Curve

- Number of Cuts: means how many cutting layers in depth way.
 - II. Path setting parameters:

🐲 5x Drive Curve 1		۵ ک	23
🖄 Type: 5x Drive Curve 🔺 🏠 Primary	▼ Cutting Control		
Basic	Allow Undercutting	No	
Limiting	Project Direction		
Path Setting	Cutting Order	Automatic 🔹	1
Axis Control	Tool Side	On 🔻	
Link and Lead Link	▼ Point Setting		٦
📥 Lead In 🆕 Lead Out	Start Point		
T Display	Tool Home Start		
	Tool Home End		

Figure 126 Path setting parameters of 5X Drive Curve

- **Tool side**: includes ON, Left/Right/Center of ball as follows:
 - On: The curve offset defined in any profile feature will be ignored.
 - Left/Right: The cutting tool follows the corresponding left (or right) side of each driving curve when looking down from the z-axis. The left or right offset equals the sum of the curve

offset of the profile feature and the tool radius.

• Center of ball : means the center of ball end mill will locate on the drive curve, it is the same function as the On if tool is not ball end.

III. Axis control parameters:

😨 5x Drive Curve 1			₽ 33
🕼 Type: 5x Drive Curve	▼ Axis Control		
4 🍲 Primary	Axis Control	AV Tin Control	
🏰 Basic	Axis Control	4X Tip Control	· ·
म Tolerance and Steps	Four Axis Plane	0,0,1	
🔄 Limiting			_
🧶 Path Setting	Axis Directions		
🖉 Axis Control	Lead Angle	0	
Link and Lead	Lead Angle	U	
Link	Roll Angle	0	
📥 Lead In	Max Tilt Angle		
🖕 Lead Out	-	-	
Display	Max Rotate Angle	5	

Figure 127 Axis control parameters of Drive Curve

IV. Link, lead in and lead out parameters:

Stype: 5x Drive Curve	▼ Link			
Primary Basic	Short Link Type	Automatic -		
Tolerance and Steps	Long Link Type	Automatic -		
Limiting Path Setting	% Short Link Limit	300.0		
Axis Control	Safe Distance	20		
Link and Lead	Max Plunge Len			
Lead In	▼ Lead In			
Lead Out	Lead In Type	Normal		
冒 Display	End Angle In	10		
	Radius In	1		
	Ramp Length In	0		
	▼ Lead Out			
	Lead Out Type	Normal		
	End Angle Out	10		
	Radius Out	1		
	Ramp Length Out	0		

Figure 128 Link, lead in and lead out parameters of 5X Drive Curve

STEP 04 Calcualte toolpath as follows:

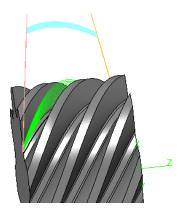


Figure 129 5X Drive Curve toolpath

So far we finished the 5X drive curve toolpath for the tooth socket. But as we can see that we had left some material over, so it is necessary to use another operation to finish the whole tooth socket. Then let's take a look at 5X GuideSurface ISO Cut operation as follows:

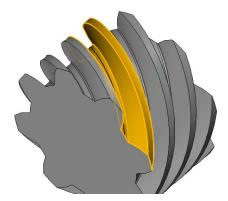


Figure 130 Finish required region for the tooth socket

Phylosophy :

1) Each 5 axis **Guide Surface Iso Cut** operation must have **drive surface(s)** selected in its feature list with general surfaces input as the cutting target.

2) The guide surface defined by a drive surface forces tool axis to follow its normals along the isolines.

3) If the field *Cut Drive Surface* is toggled as *Yes*, the drive surfaces will serve as the cutting target in addition to other general surfaces in the feature list. If *No*, the drive surfaces will be ignored. The iso direction will be either U-isolines or V-isolines,, conventional or climbing.

Therefore it is easy to know if we want the tool axis to follow a normal way along a special pattern we still need a drive surface as follows:

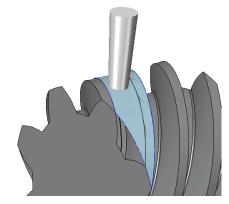


Figure 131 Tool axis normal to drive surface and move along the isoline

Next let's create the toolpath as follows:

STEP 01 Create drive surface

I. Copy the origial part file and rename it as auxilairy face as follows:

Man	ager					(o X3						
Filter	All		•	Preview	Off		•						
Find				in	Name		-						
	Name	-	-	Туре	Modifie	d	L	Man	ager				
Gear	CAM		Cam	Plan			2/14/2		-				
Gear			Dart				2/14/2	Filter	All		*	Preview	Off
		7	Edi	t		Г							
		1	Rer	name				Find				in	Name
		6	Del	lete					Name	-	-	Туре	Modified
		8	Cut	t									mounicu
		B	Rel	ated cut				Gear	_CAM		Cam	Plan	
		3	Co	ру 🌔	1			Gear	r		Part		
		3	Rel	ated copy	-			Αυχί	liary face		Part		2
		en en	Dad	-to				, and	inary race		. are		

Figure 132 Copy original gear part

- II. Enter into the new Auxiliary face part file and create surface as follows:
- 1) Create a blend curve at one end as follows:

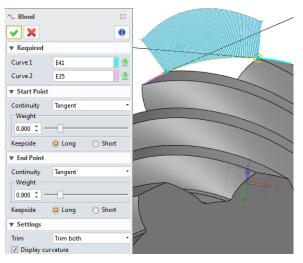


Figure 133 Create a blend curve between 2 edges

2) Then make use of the curve to create a surface by "Bi Rail Loft" command as follows:

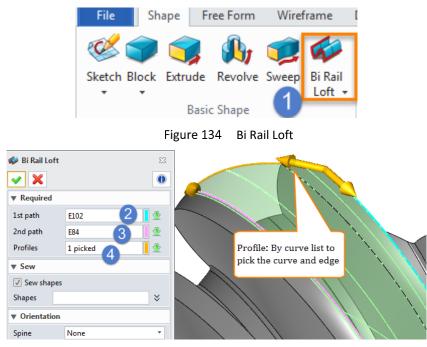


Figure 135 Create Surface by Bi Rail Loft command

3) Then delete the gear shape and just leave the surface alone as follows:

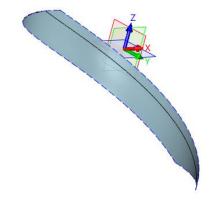


Figure 136 Leave the created surface only

4) Merge the surfaces together as follows:

🐲 Merge Face	s	23	
🗸 🗙 🖸	ł	0	
▼ Required			
Faces	2 picked	\approx	\checkmark
▼ Settings			
Normals	Outer	-	
Sample	Face	-	
Specify same	nple density		
U-direction		* 生 -	
Angle tol	2	‡ 垫 🔹	

Figure 137 Merge the surface together

STEP 02 After finishing the drive surface, go back to CAM and add the auxiliary face into as follows:

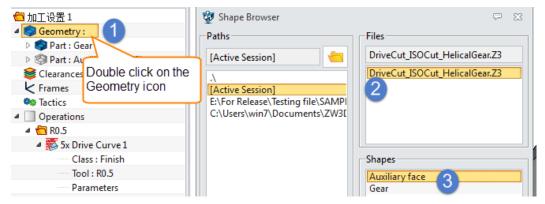


Figure 138 Add auxiliary face into CAM

STEP 03 After defining the auxiliary face as drive surface, define the cutting region as part surface as follows:

💯 Surface Feat	ure		Ţ	23	
Name	Drive Surfac	e			
Class	5X Control S	urface(CS)		-	
Туре	5X Control			-	
Component	Part : Auxilia	ry face (2)			
File					
Surfaces	Attributes				× I
sO	Tolerance	0.1			N
	CS Type	Drive Surface		-	
	Trim Holes	Respect		-	
	Surface Side	e Natural		•	
Modify A	Attributes	Apply Attribut	es		
Add Su		Remove Surfac			
	ОК	Cancel			

Figure 139 Define drive surface

🦉 Surface Feature	!			$\overline{\nabla}$	23	
Name	Part face1					
Class	General Sur	face			•	
Туре	Part				•	
Component	Features					
File						
Surfaces	Attributes					
sO	Tolerance		0.001			
	Shape Mod	lify	None		٠	
	Trim Holes		Respect		•	
	Surface Sid	e	Auto		-	
Modify Attr	ibutes		Apply Attribute	25		
Add Surfa	ices		Remove Surface	es		

Figure 140 Define part surface for 5X Guide Surface ISO Cut

STEP 04 Choose the same tool used in drive curve operation and then set up the parameters as follows:

I. Primary parameters:

😨 5x Isocut 1			\overline{a}	23	
Type: 5x Isocut	▼ Basic				
😵 Basic	Frame				
Limiting	Speeds, Feeds	5x Isocut 1			
Path Setting	▼ Tolerance and Thick				
🔺 💾 Link and Lead	Path Tolerance 0.005				
Link	Surface Thick 0.05				
🖕 Lead Out	▼ Cutting Steps				
冒 Display	Stepover	Absolute *	0.05	;	
	▼ Bottom Steps				
	Cut Depth Type	Z-Level		•	
	Max Cut Depth				

Figure 141 Primary parameters of 5X IsoCut

- **Stepover**: can choose differnet type, including Absolute, %Tool Dia, Scallop, Num of Cuts etc. It is the same menaing for the Absolute, %Tool Dia, Scallop, options with what in 3X milling operations.
- **Num of Cuts** means how many toolpath layer you can determine to cretae, which will fill the whole part face.

II. Path setting parameters:

😨 5x Isocut 1		∞ ∞
W Type: 5x Isocut	▼ Cutting Control	
Basic	Cut Drive Surface	No *
Interance and Steps	Path Pattern	Zigzag 🔹
Limiting Path Setting	Stepover Link	Straight 🔹
Axis Control	Iso Direction	V-Isoline 🔻
Link and Lead	Cut Direction	Climb
Link	▼ Point Setting	
⊾ Lead Out ∎ Display	Start Point	
	Tool Home Start	
	Tool Home End	

Figure 142 Path setting parameters of 5X IsoCut

- **Cut Drive Surface**: if we choose yes then the drive surface will serve as milling target at the same time. If No, then it will ignore it, and only use the drive surface to guide the tool axis.
- StepoverLink: Straight or Round
- **ISO direction**: if along the U direction or V direction of drive surface
- III. Axis Control parameters

😨 5x Isocut 1			₽ %
🧊 Type: 5x Isocut 🔺 🍆 Primary	▼ Axis Control		
Basic	Max Tilt Angle		
Interance and Steps	Max Rotate Angle	5	
 Limiting Path Setting 	Four Axis Plane		
📕 Axis Control			
🔺 📥 Link and Lead			

Figure 143 Axis Control parameters of 5X IsoCut

Here the four axis plane will affect your output, you can set up according to the real machine's structure.

IV. Leak and lead parameters:

Type: 5x Isocut	▼ Link	
Primary Basic	Short Link Type	Automatic
Interance and Steps	Long Link Type % Short Link Limit	Automatic 300.0
Path Setting	Safe Distance	5
Link and Lead	Max Plunge Len	
崖 Lead In	▼ Lead In	
Lead Out Display	Lead In Type	Normal
Display	End Angle In	10
	Radius In	1
	Ramp Length In	0
	▼ Lead Out	
	Lead Out Type	Normal
	End Angle Out	10
	Radius Out	1
	Ramp Length Out	0

Figure 144 Link and lead parameters

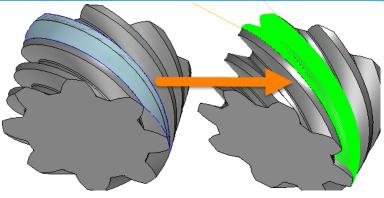


Figure 145 5X Guide Surface ISO Cut toolpath

1.3.5 5X Flow Cut

Philosophy: The 5 axis Flow Cut operation requires either a 5 axis Swarfcut or a 5 axis Drive Curve Cut as a reference operation that contains two separated cuts. These two cuts will be used as flowing curves. The Swarf cut or Drive Curve Cut can also have multiple depths. ZW3D CAM will select the two bottom cuts as flowing curves. It is very useful for machining areas between two tilted walls (turbine blades for example).

So let's open the file **5X_Impeller.Z3** again, when introducing the swarf cut operation we have created the swarf cut toolpath to finish the blade as follows:

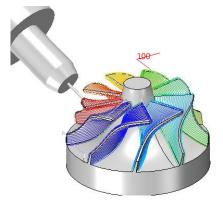


Figure 146 5X impeller with Swarf cut toolpath

Here we will make use of the part to introduce 5X Flow Cut operation. Now we need to create toolpath for the areas between blades and the out surface of the blade as follows:

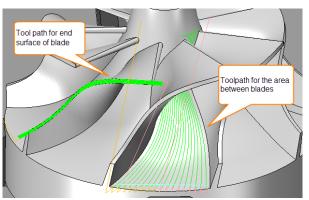


Figure 147 Tool path for impeller

Next we will use both introduced swarf cut operation and drive curve operation as reference separately to create the 5X flow toolpath on the desired areas.

1. Reference to Swarf Cut operation

STEP 01 Create another swarf cut toolpath on the root of blade as follows:

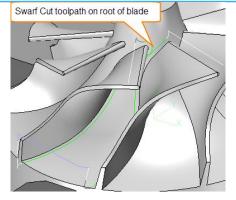


Figure 148 Swarf cut toolpath on root of blade

STEP 02 Create 5X flow cut reference to the swarf cut as follows:

I. Define part surface for 5X flow cut as follows:

🐲 Surface Feature	2		₽ 23	Pick these face as	
Name	surface 3			part surface	
Class	General Surface		*	7	
Туре	Part		*		
Component	Features			G	
File					
Surfaces	Attributes				
sO	Tolerance	0.1			2 3
	Shape Modify	None	-		
	Trim Holes	Respect	-		
	Surface Side	Auto	•		
				4	

Figure 149 Define part surface for 5X flow cut

II. Choose swarf cut as reference operation as follows:

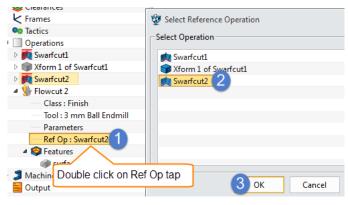


Figure 150 Pick swarfcut2 as reference

- III. Choose Tool : 3 mm Ball End Mill
- IV. Set up pararmeters

🐲 Flowcut 2		₽ %
Type: 5x Flowcut	▼ Basic	
😗 Basic	Frame	
Langle Tolerance and Steps	Speeds Feeds	Flowcut 2
Axis Control	▼ Tolerance and Thick	
Link	Path Tolerance	0.1
Lead In	Surface Thick	0
Display	▼ Cutting Steps	
	Stepover	Absolute • 2.8

Figure 151 Primary parameters

😨 Flowcut 2		⊽ ⊠
W Type: 5x Flowcut	▼ Cutting Control	
Primary Basic	Flow Pattern	One Way 🔹
	Flow Type	Spiral Outward 🔹
Path Setting	Collision Check	Yes 🔹
Link and Lead	Point Setting	
Link	Start Point	PNT#116327
Lead Out ■ Display	Tool Home Start	
	Tool Home End	

Figure 152 Path setting parameters

- **Collision check**: choose yes to check if the toolpath will collide with stock
- **Start Point**: it is allowed to set up the start point as follows:

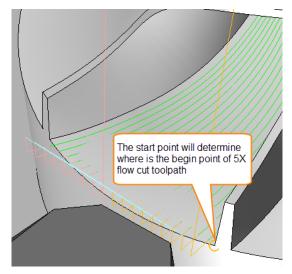


Figure 153 Strat point for 5X flow cut

💯 Flowcut 2		⊽ ⊠
Type: 5x Flowcut	▼ Axis Control	
Primary Primary Pasic	Max Tilt Angle	
Tolerance and Steps	Max Rotate Angle	0
Path Setting Axis Control		

Figure 154 Axis control parameters

😨 Flowcut 2		₽ 🛛
W Type: 5x Flowcut	▼ Link	
Primary Basic	Short Link Type	Automatic *
Tolerance and Steps	Long Link Type	Automatic 🔹
Path Setting	% Short Link Limit	300.0
4 💾 Link and Lead	Safe Distance	5
Link	Max Plunge Len	
Lead Out	▼ Lead In	
Display	Lead In Type	Normal 🔹
	End Angle In	0
	Radius In	0
	Ramp Length In	5
	▼ Lead Out	
	Lead Out Type	Normal 🔻
	End Angle Out	0
	Radius Out	0
	Ramp Length Out	5

Figure 155 Link and lead

STEP 03 Calculate the toolpath and we will get the following result:

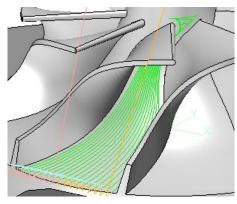


Figure 156 5X Flow Cut toolpath

2. Reference to 5X Drive Curve operation

Here we will create 5X flow cut toolpath on the end face of blade as follows:

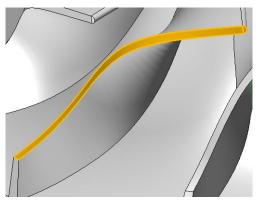


Figure 157 End face of blade

In order to make the toolpath that can fully cover the whole end surface, it is necessary to create an auxiliary surface to help create the toolpath. As follows:

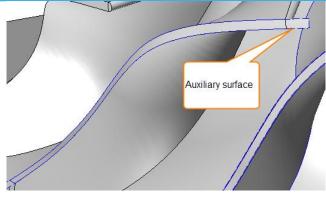


Figure 158 Auxiliary surface for 5X flow cut

Here we will not introduce how to create the auxiliary surface again, you can find it in the file of "5X_impeller" as follows:

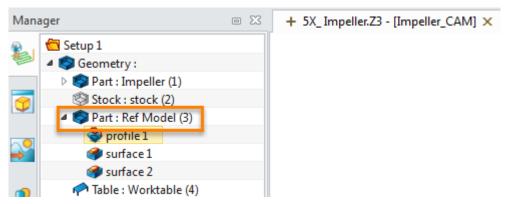


Figure 159 Auxiliary surface mode for 5X Impeller

Next let's make use of the existing auxiliary surface to create the toolpath

STEP 01 Define the surface as part surface and choose the profile as drive curve as follows :

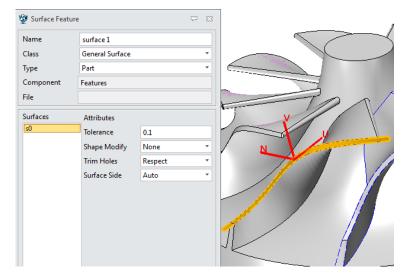


Figure 160 Define the auxiliary surface as part surface for drive curve operation

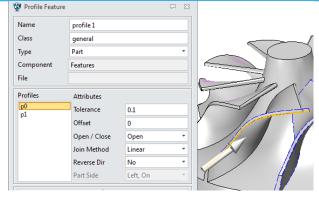


Figure 161 Define profile for drive curve

STEP 02 Choose ball end mill of 3 mm and set up parameters to create toolpath as follows :

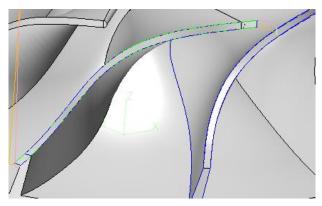


Figure 162 5X Drive curve toolpath

STEP 03 Create 5X flow cut as follows:

I. Set up the feature and reference operation

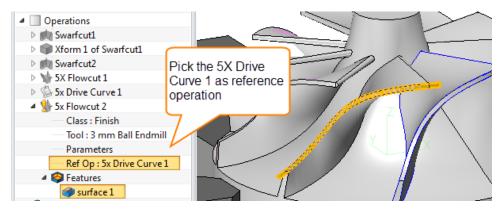


Figure 163 Reference to 5X Drive Curve to create Flow cut toolpath

II. Set up parameters

🐲 5x Flowcut 2		⊽ ⊠
Type: 5x Flowcut	▼ Basic	
P Basic	Frame	
Interance and Steps	Speeds Feeds	5x Flowcut 2
Axis Control	▼ Tolerance and Thick	
Link and Lead	Path Tolerance	0.1
Lead In	Surface Thick	0
Sead Out	▼ Cutting Steps	
	Stepover	Absolute * 0.2

Figure 164 Primary parameters

😨 5x Flowcut 2			₽ %
Type: 5x Flowcut	▼ Cutting Control		
Primary Primary Pasic	Flow Pattern	Zigzag	-
Tolerance and Steps	Flow Type	Along	•
Path Setting Axis Control	Collision Check	No	-
Link and Lead	▼ Point Setting		
Link	Start Point		
Lead Out	Tool Home Start		
	Tool Home End		

Figure 165 Path Setting parameters

Type: 5x Flowcut	▼ Link	
Primary Primary Pasic	Short Link Type	Automatic
Tolerance and Steps	Long Link Type	Automatic
Path Setting	% Short Link Limit	300.0
Link and Lead	Safe Distance	5
Link	Max Plunge Len	
📥 Lead In 🆕 Lead Out	▼ Lead In	
冒 Display	Lead In Type	Normal
	End Angle In	90
	Radius In	1
	Ramp Length In	0
	▼ Lead Out	
	Lead Out Type	Normal
	End Angle Out	90
	Radius Out	1
	Ramp Length Out	0

Figure 166 Link and Lead parameters

III. Calculate and get the result as follows:

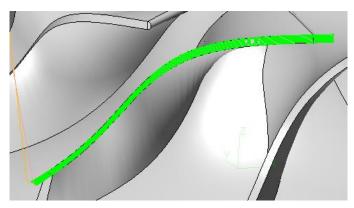


Figure 167 5X Flow Cut Toolpath on end face of blade

Then we can use the transform function to pattern the toolpath, finally we can get the following result :

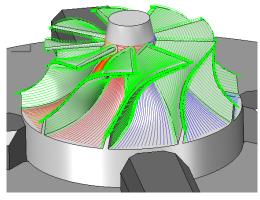


Figure 168 Toolpath for the impelle

After finishing these steps please hide the auxiliary part and then save the file. Next let's take a look at the last operation of 5X, side cut.

1.3.6 5X Side Cut

Philosophy: The **5** axis **Side Cut** operation accepts parts or general surface features as geometric inputs. Based upon different axis control options, it allows you to position the cutter in various orientations including normal or side tangent to the part with lead, roll and skew angles. This operation is a good choice for turbine top machining or complex pocket finishing with point control.

First we can take the **5X_Impeller.Z3** file as an example again to show how to use the side cut operation. Now we need to cut the top region, the final result will be as follows:



Figure 169 5X side cut for the top region of impeller

Next let's create the toolpath step by step as follows:

STEP 01 Choose 5X Side Cut operation and define the general surface

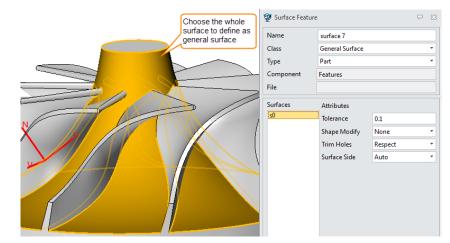


Figure 170 Define general surface for 5X side cut

Normally a general surface is enough to create the toolpath of 5X side cut.

STEP 02 Next let's set up the parameters:

I. Primary parameters:

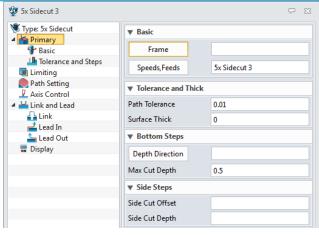


Figure 171 Primary parameters

II. Limit parameters:

💯 5x Sidecut 3			₩ 23			
😻 Type: 5x Sidecut	▼ Z					
4 🛉 Primary						
🗣 Basic	Тор	68.5				
Limiting	Bottom	55.5				
Path Setting						
🖉 Axis Control						
4 💾 Link and Lead				ut the value here	Bottom:	55.4174
🚹 Link			means th	e default Z value		·
📥 Lead In					7 /	
🆕 Lead Out				/		
冒 Display						

Figure 172 Set up the top and bottom point

III. Path setting parameters:

🐲 5x Sidecut 3		₽ 🛛
🖲 Type: 5x Sidecut 🖌 🏠 Primary	▼ Cutting Control	
😵 Basic	Cut Overlap Shift Start Point	0
Path Setting	Allow Undercutting	No
Axis Control	Path Pattern	Zigzag 🔹
Link and Lead	Cut Direction	Climb *
Lead In	Cutting Regions	All Regions 🔹
Sead Out	Z Progress	Top to Bottom
T Display	Enable Spiral	Yes *
	End Over Mill	Yes *
	▼ Point Setting	
	Start Point	
	Tool Home Start	
	Tool Home End	

Figure 173 Path setting parameters

- Allow Undercutting: If there is undercut need to cut, choose this option to allow tool axis to rotate
- Cutting Regions: Includes All Regions, Pockets Only, Outside Only,
- All regions: means all of the region in the target surface or part will be taken into account
- **Pockets Only**: Just cut the pocket, need to combinate with the option of *Control Point* in Axis control.
- **Outside Only**: just cut the outside of surface or part.
- Enable Spiral: If we allow the toolpath move as spiral pattern or not.

IV. Axis control parameters:

🐲 5x Sidecut 3		⊽ ⊠
🖲 Type: 5x Sidecut 🔺 🏠 Primary	▼ Axis Control	
Basic	Axis Type	Tip Sidecut 🔹
Tolerance and Steps	Skew Angle	0
Limiting Path Setting	Max Tilt Angle	5
Axis Control	Control Point	
 Link and Lead Link 	Max Rotate Angle	5
📥 Lead In	Cutting Height	
Lead Out	▼ Axis Guide	
	Guide Type	None 🔻

Figure 174 Axis control parameters

- Axis Type: besides the introduced types in this operation there are 2 more different types :
 - **Tip SideCut**: Tool Tip determine the tool axis's orientation and then cutter side will be tangent to the part tangent plane.
 - **Contact SideCut**: Tool's contact point determine the tool axis's orientation and then cutter side will be tangent to the part tangent plane
- Control Point

This parameter is used to **machine pockets**. If defined, the control point overwrites the Axis Control parameter so that the tool axis passes through the control point.

• Axis Guide

In 5x sidecut, Axis Guide tries to define a few types of primitive surfaces as the guide surface by using the same concept as the guide surface does in 5x isocut. It is used mainly to machine pockets or porting (like driving curve).

For more details about the axis guide function we will use some cases to explain it in details. Here let's skip it first, and choose none.

STEP 03 For the rest parameters please refer to the previous introduction to finish by yourself and then calculate the toolpath as follows:

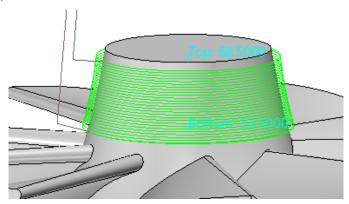


Figure 175 5X side Cut toolpath on the top region of impeller

After saving the file. So far actually we have finished the toolpath for the impeller.

Next, we will take another example to show how to use the axis guide function to solve some problems:

1. Statue Case: Open the Statue Cut case file Statue_SideCut.Z3 as follows:

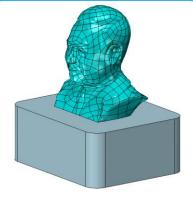


Figure 176 Statue_SideCut case

STEP 01 Enter into CAM and create 5X Side Cut operation and then add the general surface as follows:

💯 Surface Featu	ure		×	and the second second
Name	surface 1			ACCEDED.
Class	General Surface		•	
Туре	Part		•	
Component	Features			
File				Marrie Marrie V
Surfaces	Attributes			
s0	Tolerance	0.1		
	Shape Modify	None	*	
	Trim Holes	Respect		
	Surface Side	Natural		

Figure 177 define the statue part as general surface

In oder to let the tool stop at the bottom of statue we can define the bottom face as Start check surface as follows:

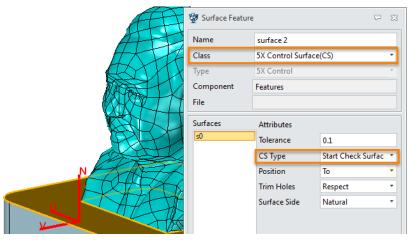


Figure 178 Define Start Check Surfac

STEP 02 Set up the parameter according to the above introduction as follows:

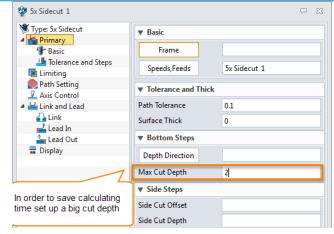


Figure 179 Primary parameters for statue cut

💯 5x Sidecut 1				
Type: 5x Sidecut	▼ Cutting Control		Set up start point to let tool cut	
Primary Primary Pasic	Cut Overlap	0	from this side	
Tolerance and Steps	Shift Start Point		Atro Th	
Limiting Path Setting	Allow Undercutting	No	Start P	aint.
Axis Control	Path Pattern	One Way		
4 💾 Link and Lead	Cut Direction	Climb	- # + + + + + + + + + + + + + + + + + +	ay cause
Link	Cutting Regions	All Regions		
Lead In	Z Progress	Top to Bottom	· .	
Display	Enable Spiral	No		
	▼ Point Setting			
	Start Point	PNT#50495		
	Tool Home Start			

Figure 180 Path setting parameters

🖲 Type: 5x Sidecut	▼ Axis Control	Original point is the frame's 0			
A Primary Basic Tolerance and Steps Tolerance and Steps Limiting Path Setting Law Scontrol Link and Lead Link Link Lead In Lead In Lead Out	Axis Type Lead Angle Roll Angle Max Tilt Angle Control Point Max Rotate Angle	Tip Control 0 0 80 5	point		e star
Display	Guide Type Origin Normal Guide Radius Guide Side Guide Side	Cylinder 0,0,0 0,0,1 200 From Outside Guide Norma		_	

Figure 181 Axis control parameters

Now let's stop here and calculate the toolpath to check what we will get. Following is the result:

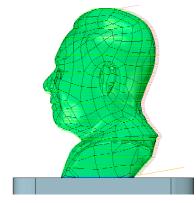


Figure 182 5X Side Cut toolpath for the statue

Next let's make use of the created toolpath to explain axis guide parameters, as follows:

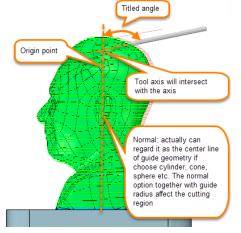
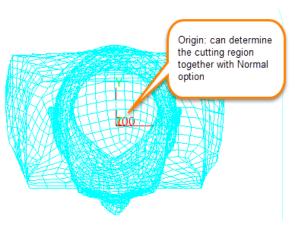
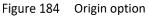


Figure 183 Explanation for axis guide parameters

- **Guide type**: normally use the cylinder, cone, sphere and drive curve. For drive curve we will use another case to show how to use it.
- **Origin:** Can be regarded as the center point of section profile in XY as follows, the picked normal way will pass this origin.





- **Normal**: if choose Cylinde, Cone, Sphere etc type, regard it as the center line of the guide geometry. which will affect the cutting region together with guide radius.
- **Guide Radius**: It is the section profile's radius of guide geometry which depends on the guide type.
- Guide Side: If cut the outside or Pocket.
- Guide Rule: if the tool axis guide by guide geometry normal or cutting part's normal.
- **Origin Deflection**: if deflect the origin to allow the tool to engage into the small corner.

Now that most of the pameters are illustrated, let's use another case to explain how to use the drive curve type guide and control point together to do the porting cut.

2. Porting cut Case: Open the file 5X PortingCut.Z3 as follows:

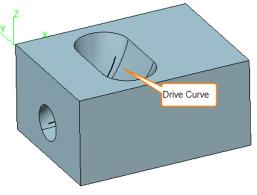


Figure 185 5X porting cut case

In this file a drive curve had been created for reference. So in this case we will skip the jobs on how to create the drive curve. Next let's create toolpath for the port shape step by step:

STEP 01 Define profile for drive curve:

Name	profile 1			
Class	general			
Туре	Part		*	
Component	Features			
File				
Profiles	Attributes			
p0	Tolerance	0.1		
	Offset	0		
	Open / Close	Open	+	
	Join Method	Linear	*	
	Reverse Dir	Yes	*	
	Part Side	Left, On	-	

Figure 186 Define drive curve by profile

STEP 02 Define cutting surface as general surface:

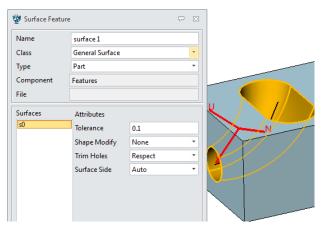


Figure 187 Define general surface

Note: it is important to make sure the surface's direction is positive.

STEP 03 Define a lollipop tool as follows:

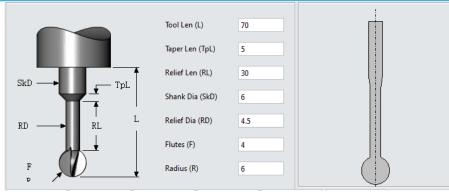


Figure 188 Define lollipop tool

STEP 04 Set up parameters:

Here we will skip the Primary parameters and Path setting parameter and just focus on axis control parameter as follows:

▼ Axis Control			
Axis Type	Tip Sidecut	•	
Skew Angle	0		
Max Tilt Angle			
Control Point	PNT#2076		
Max Rotate Angle	5		
Cutting Height			ntrol Pe
▼ Axis Guide			.0005
Guide Type	Drive Curve		
Origin			
Guide Radius			
Guide Side	From Inside		
Guide Rule	Part Normal	$\overline{}$	

Figure 189 Set up axis control parameters

Because here used the drive curve as the guide geometry: the tool axis will be guided by the drive curve's tangent way, so the guide radius makes no sense for this situation, just leave it blank.

STEP 05 After finishing setting up parameter, calculate the operation Toolpath as follows.

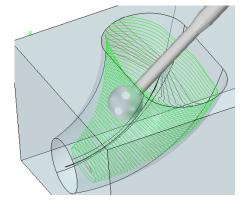


Figure 190 Porting cut toolpath by 5X Side Cut operation

2 Summary

We have introduced how to achieve the 5X indexing milling by sub frame and Interpath function. And with the practical examples, we have introduced how to run 5X simultaneous movement operations and apply these operations to the real case.

Notes:

This tutorial is based on ZW3D 2021 version, some functions or icons may not match the current version. If you have any suggestions or questions about this tutorial, please contact us at

ZW3D Global Website: <u>https://www.zwsoft.com</u>

ZW3D Support Team: sales@zwsoft.com