ZW3D Advanced Tutorial

Full Machine Simulation

ZW3D™ V2023 CAM Full Machine Simulation

Printed in P. R. China.

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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 CAM Full Machine Simulation***, an advanced tutorial.

Thanks for being our user!

The ZW3D Team

Contents

Focusing on Full Machine Simulation in the CAM module of ZW3D, this tutorial will help you master the workflow and some specific operations of machine builder and machine simulation. Besides, it can help you better understand machine structure.

Key Points:

- ✧ Machine Structure Analysis
- ✧ Machine Building Workflow
- ✧ Machine Simulation Workflow
- ✧ Tool Compensation
- ✧ 5X RTCP Function

1 An Introduction to Full Machine Simulation Modules

1.1 Advantages of Full Machine Simulation

There is no doubt that safety is the top priority of CNC machining. Programmers need to ensure that not only the NC codes will not cause overcut, but also the toolpaths won't induce any collision between hardware, such as the cutting tools, fixtures, machine tables and other machine equipment, or over the machine's axis limits.

However, as the structure of parts becomes more complex and the number of machining procedures increases, verifying the correctness and effectiveness of the program, especially that for multi-axis machining, intuitively and effectively is a major challenge for programmers.

To help you overcome the challenge and ensure machining safety, the FMS (Full Machine Simulation) function of ZW3D provides machine builder and machine simulation. You can build the virtual machine and simulate the whole machining process on your computer intuitively, verify the correctness of the program and detect potential clash errors to ensure safe machining and improve work efficiency.

1.2 Full Machine Simulation Modules

FMS contains two modules: machine builder and machine simulation.

Machine builder allows you to define or edit the virtual machine structure by importing STL files, setting linear or rotary axes, etc. to complete the definition of virtual machine which is used for machine simulation.

Machine simulation allows you to load NC, part, stock and tools to the virtual machine and then simulate the whole machining process. It provides clash and part comparison which can help programmers to spot problems and ensure safe machining.

2 Machine Builder

In this chapter, you will learn the workflow of machine builder, which will be illustrated with the **5x_table_C_on_A.Z3** file.

2.1 Workflow of Machine Builder

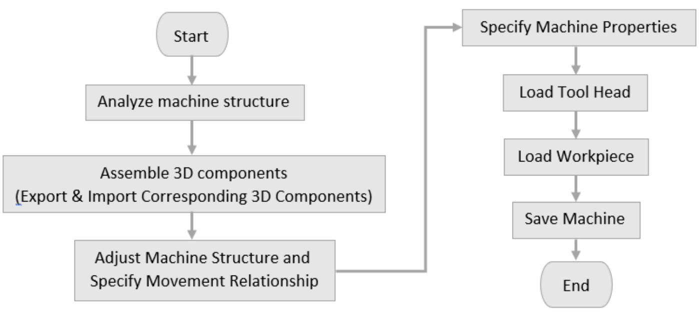


Figure 1 The Workflow of Machine Builder

To get the machine model that represents the real machine, you need to analyze the machine structure first. Take the **5x_table_C_on_A.Z3** file as an example, the model is as below.

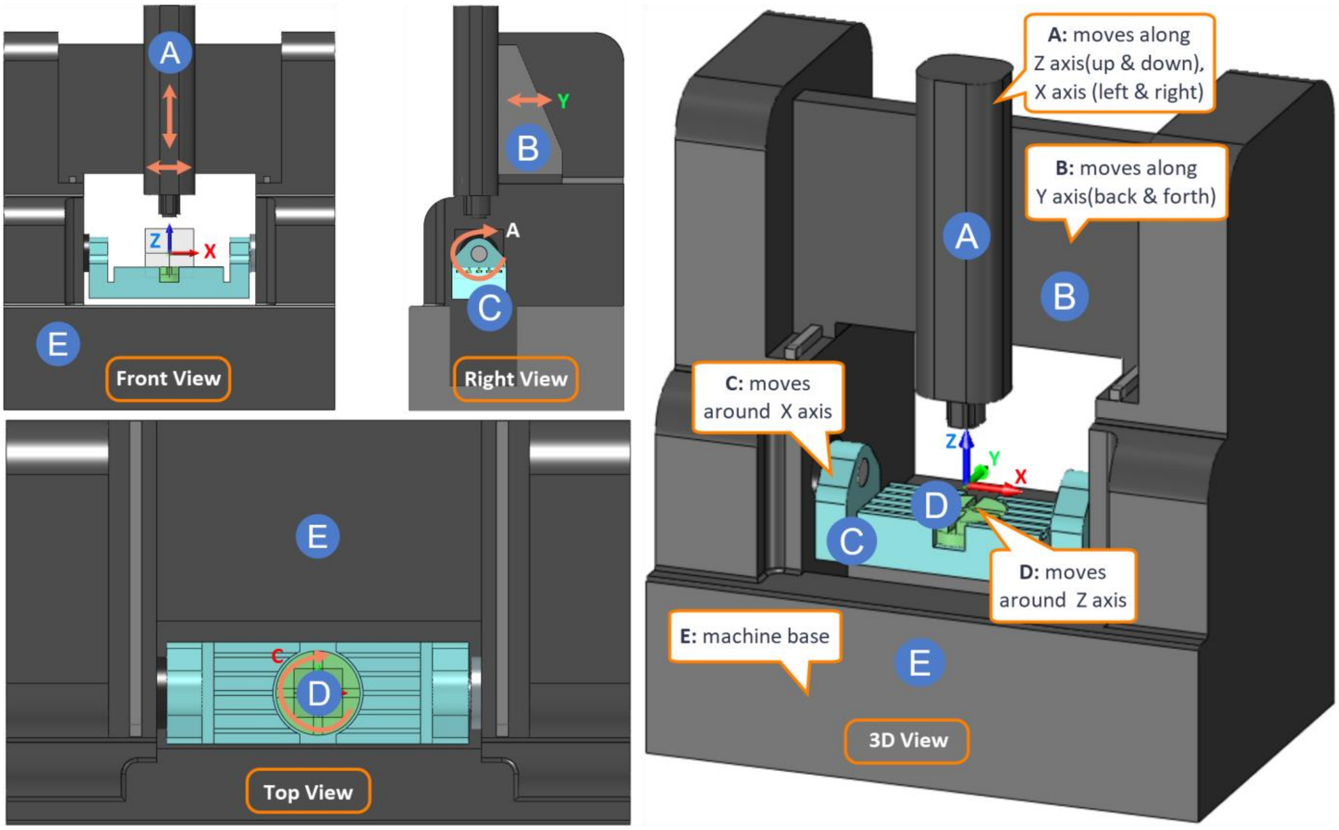


Figure 2 The Machine Structure

Here is the analysis: machines can be divided into fixed parts and movable parts. There are mainly two types of movable parts: one drives the tool movement and the other drives the workpiece movement.

According to the case above, the parts that drive the tool movement are X, Y, and Z axes. And according to the machine structure, the Z axis is based on the X axis, and the X axis is based on the Y axis. As for the parts that drive the workpiece movement, they are A and C axes, and the C axis is based on the A axis. Hence, the machine structure diagram should be as follows.

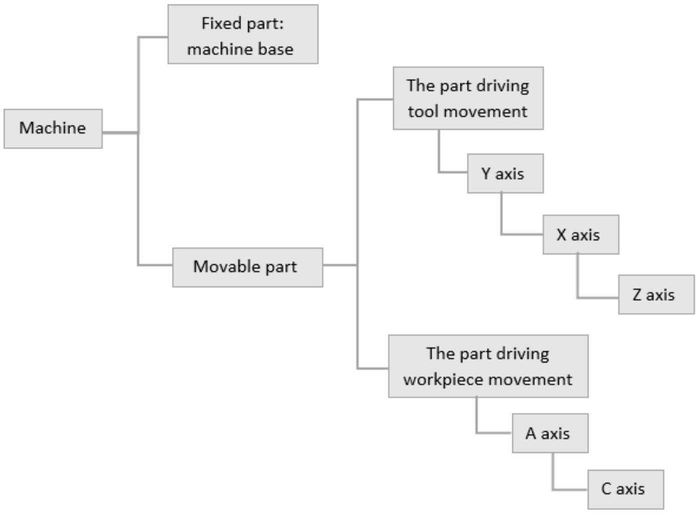


Figure 3 The Machine Structure Diagram

2.2 Assemble 3D Components

Currently, you can only use STL data to build the machine with FMS in ZW3D. So, you need to export STL files from a 3D machine model, and then import them to the machine builder for assembly.

2.2.1 Export STL files

STEP 01 Open the **5x_table_C_on_A. Z3** file in ZW3D.

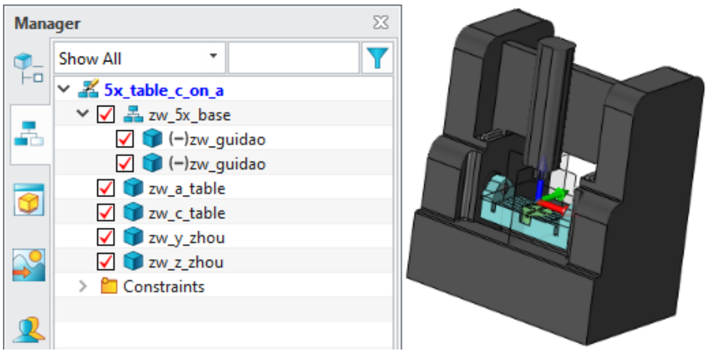


Figure 4 Opening the 5x_table_C_on_A. Z3 File

STEP 02 Double-click on a component, for example, **zw_5x_base**, to activate it and then export it to the STL file with the same settings as shown in the below figure. Repeat the same operation for each component.

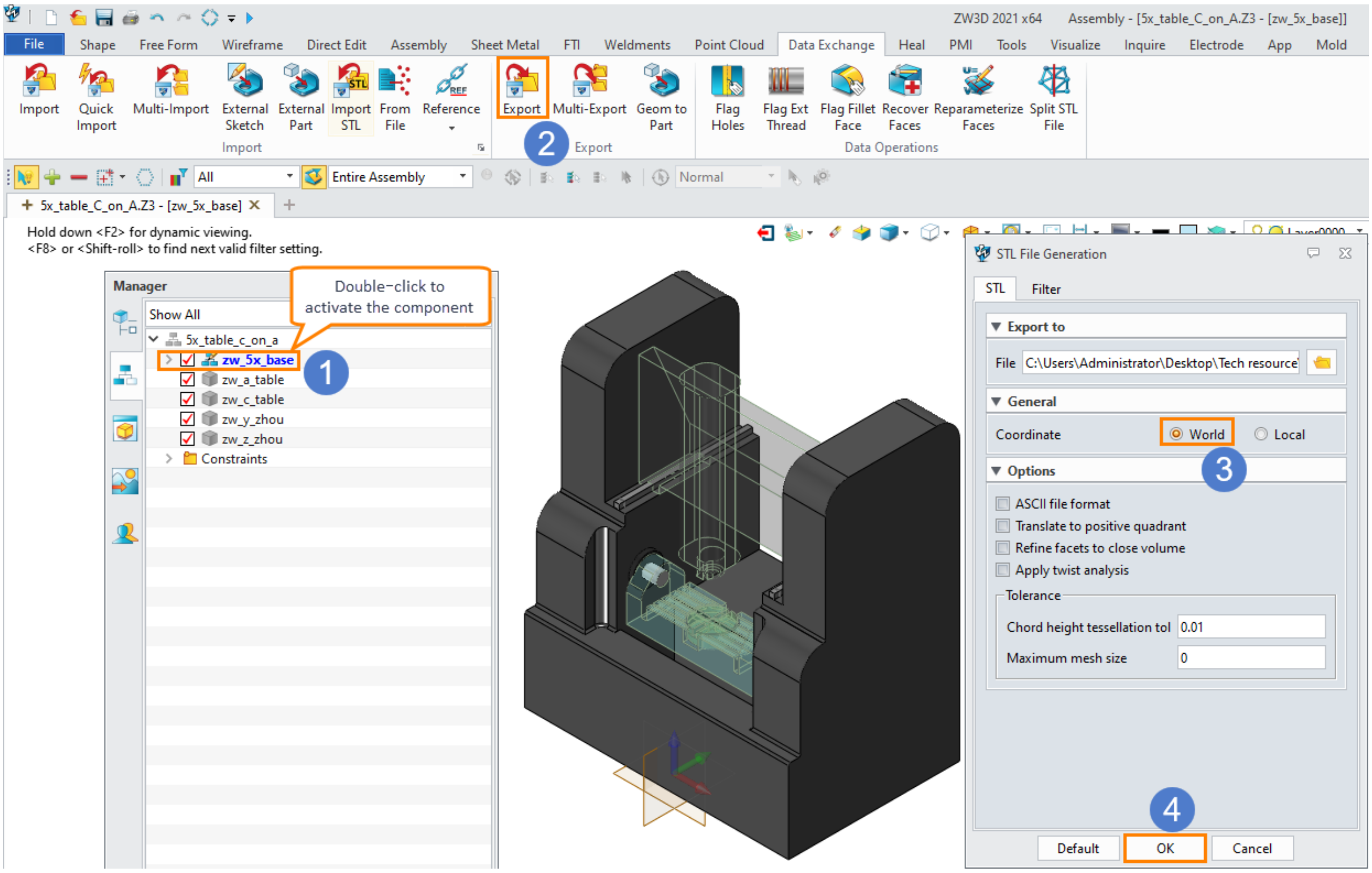


Figure 5 Exporting STL Files

STEP 03 To ensure that the exported components can be used to assemble a virtual machine in the machine builder correctly, it is suggested to create a new ***Part*** file to which you import all the STL files exported from STEP 02 at once. Follow the steps shown in the figure below and check if all the components are in the right position in the modeling environment.

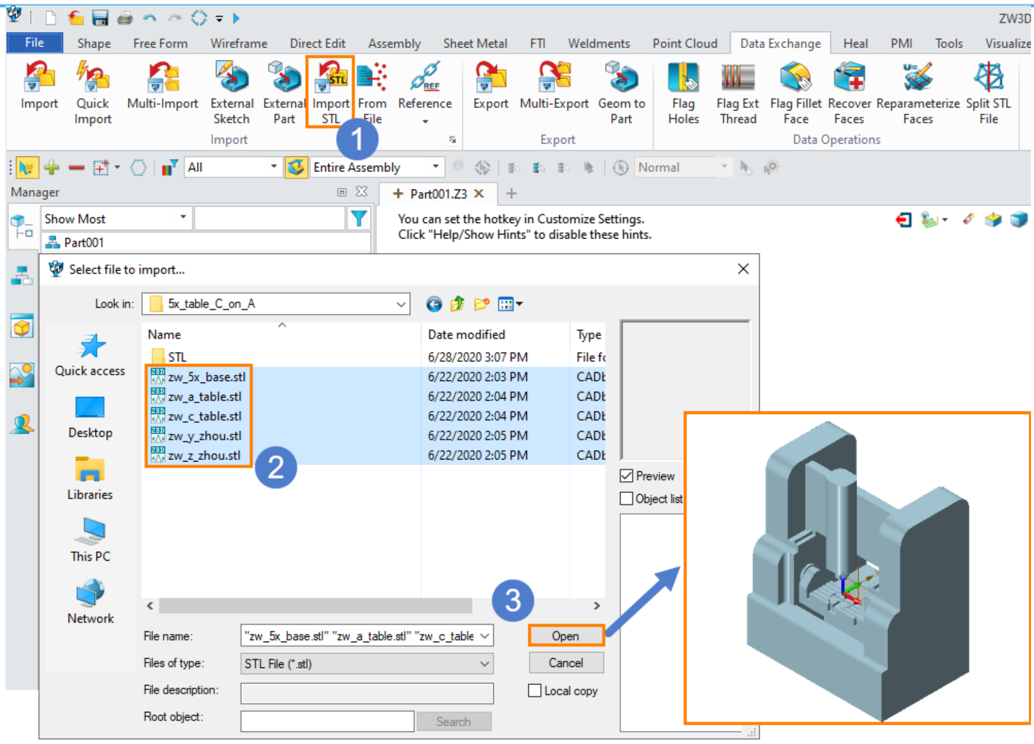


Figure 6 Verifying the Exported STL Files

Tip: *You can directly import the existing machine model (STL files) to the machine builder, then modify its origin and direction, and adjust the position of each component.*

2.2.2 Import STL Files

STEP 01 Create a new ***CAM Plan***, click the ***Full Machine Simulation*** button to enter the FMS environment, and then click the ***Machine Builder*** button to enter the machine builder environment.

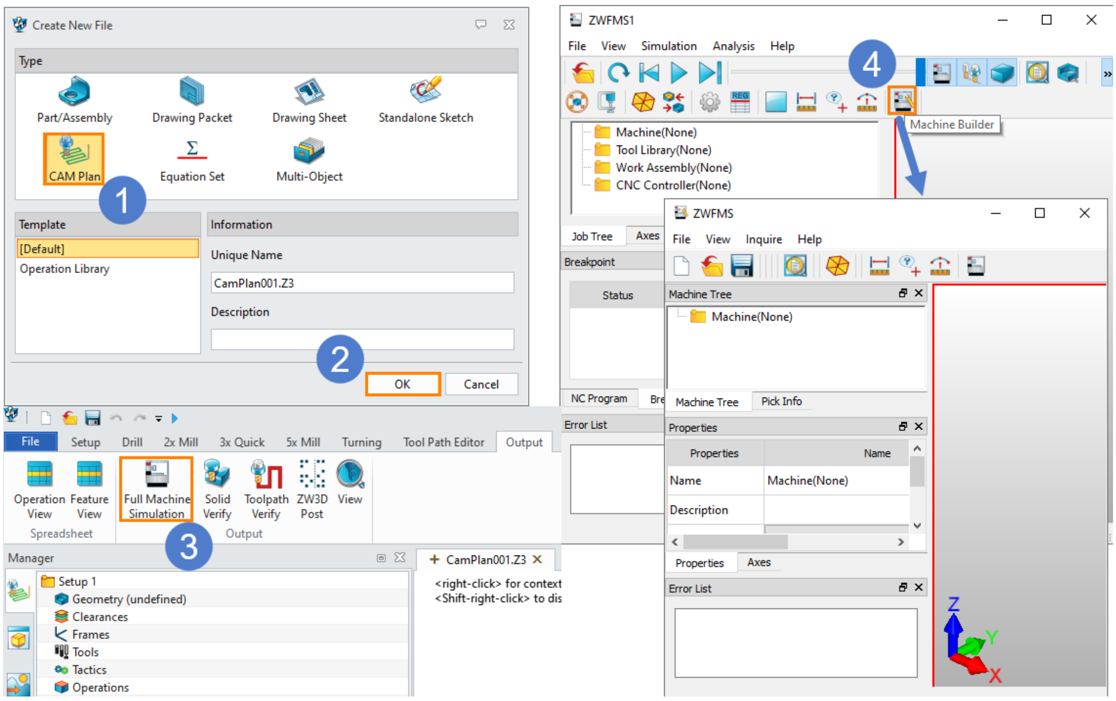


Figure 7 Entering the Machine Builder Environment

The machine builder environment includes:

Machine Tree (A): Display or adjust the machine structure.

Properties (B): Display or adjust the relevant properties of the selected component.

Pick Info (C): Display the geometric information of the selected object.

Axes (D): Display the axis information, including the maximum axis travel and initial values.

Error List (E): Prompt the error messages.

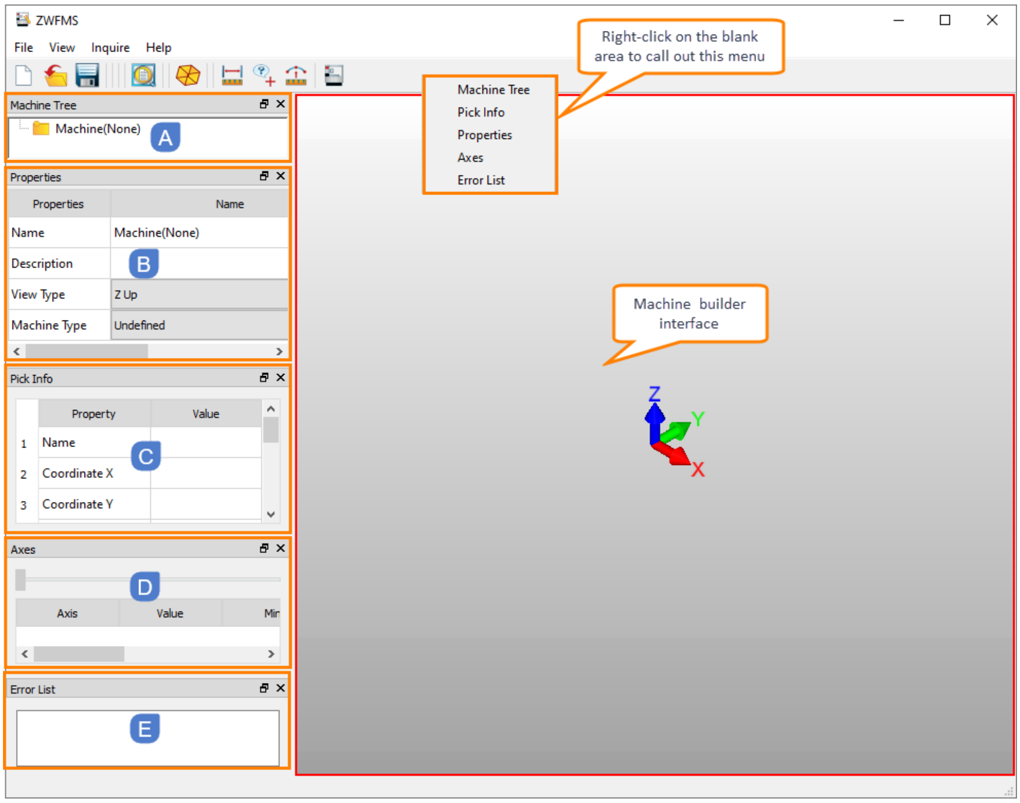


Figure 8 The Machine Builder Environment

STEP 02 ***Rename*** the machine folder and then right-click on it to create a new ***Assembly***.

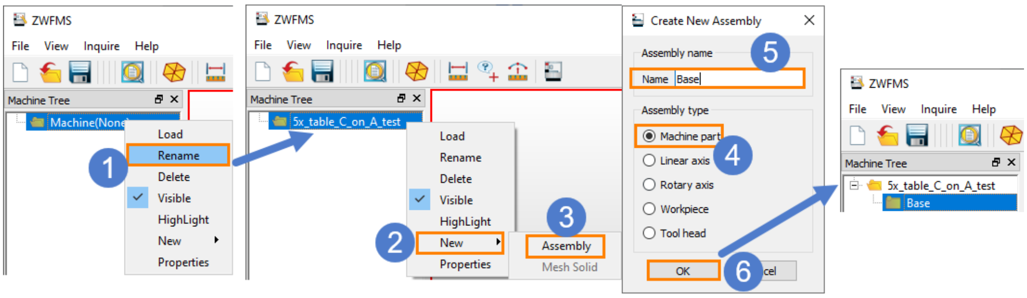


Figure 9 Creating a New Assembly

STEP 03 Right-click on the ***Base*** folder to create a new ***Mesh Solid***, and then import all the STL files to form the virtual machine as follow.

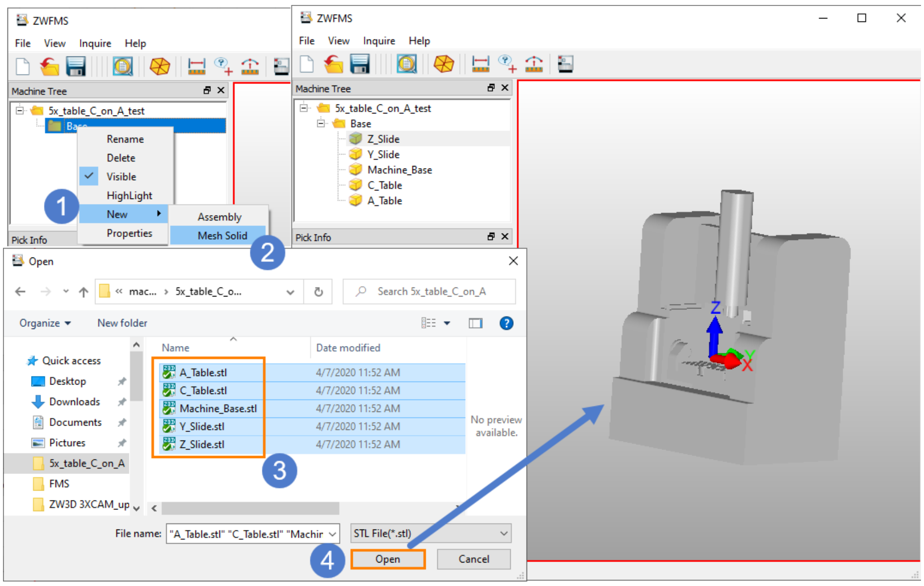


Figure 10 Importing STL files

2.3 Adjust the Machine Structure and Specify Movement Relationships

After importing STL files to the machine builder, you need to create the axes.

2.3.1 Insert Machine Axes

As we have analyzed in **Chapter 2.1**, this machine involves linear axes (X, Y, and Z) and rotary axes (A and C). So you need to insert these five axes following the step below.

STEP 01 Right-click on the ***Base*** folder to create a new ***Assembly***, and then insert the linear X, Y, and Z axes and rotary A and C axes, respectively.

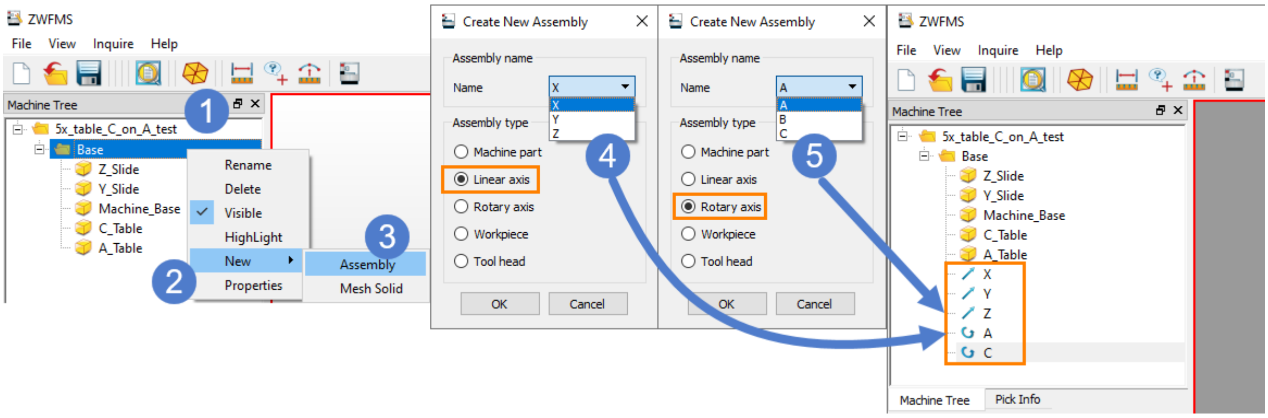
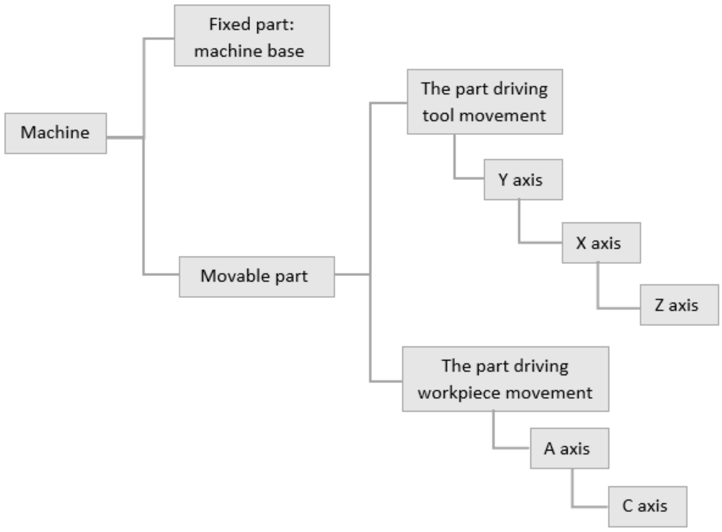


Figure 11 Inserting Axes

2.3.2 Adjust the Machine Structure

After importing all the geometries representing equipment and creating the corresponding axes, you can start defining the parent-child relationship between the axes and the components according to the analysis in **Chapter 2.1** so that the virtual machine works correctly.



STEP 01 Assign the components to their corresponding axes.

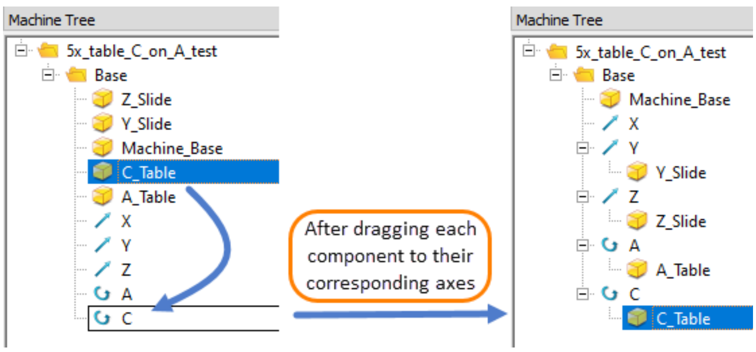


Figure 12 Assigning Components

STEP 02 Adjust the axis structure.

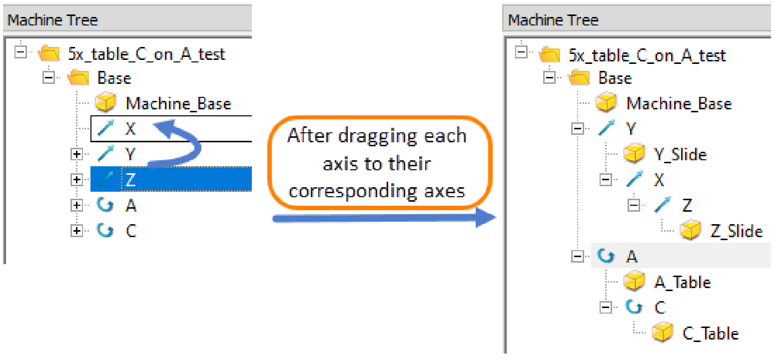


Figure 13 Adjusting the Axis Structure

***Note:** In CNC machines, the tool will be loaded along the Z axis, which is at the bottom of the machine axis structure. So, in this case, the Z axis is under the X axis.*

2.4 Specify Machine Properties

Machine properties include the machine type, axis direction, axis travel limitation, color of components, etc. You need to specify these properties to make the virtual machine work correctly and clearly.

2.4.1 Specify the Machine Type

As regards the machine View Type, it is normally “Z Up” in milling machines and “Y Up” in lathe machines. So the View Type in this case is “Z Up”. And the Machine Type is “Table_C_on_A”.

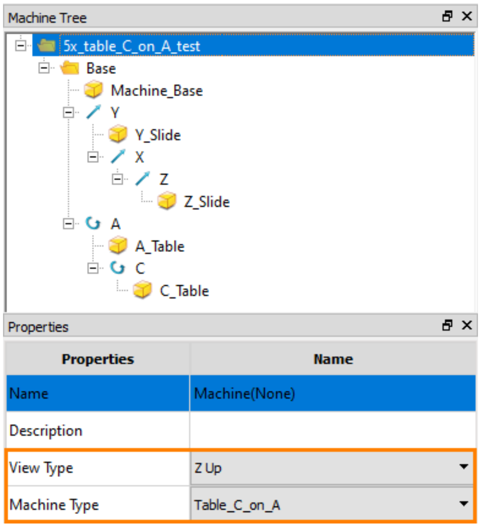


Figure 14 Specifying the Machine Type

2.4.2 Adjust the Position of Components

You can also adjust the **Position and Orientation** of each component. For example, in this case, you can move the origin of the Z component (Z_Slide) 100 mm upwards.

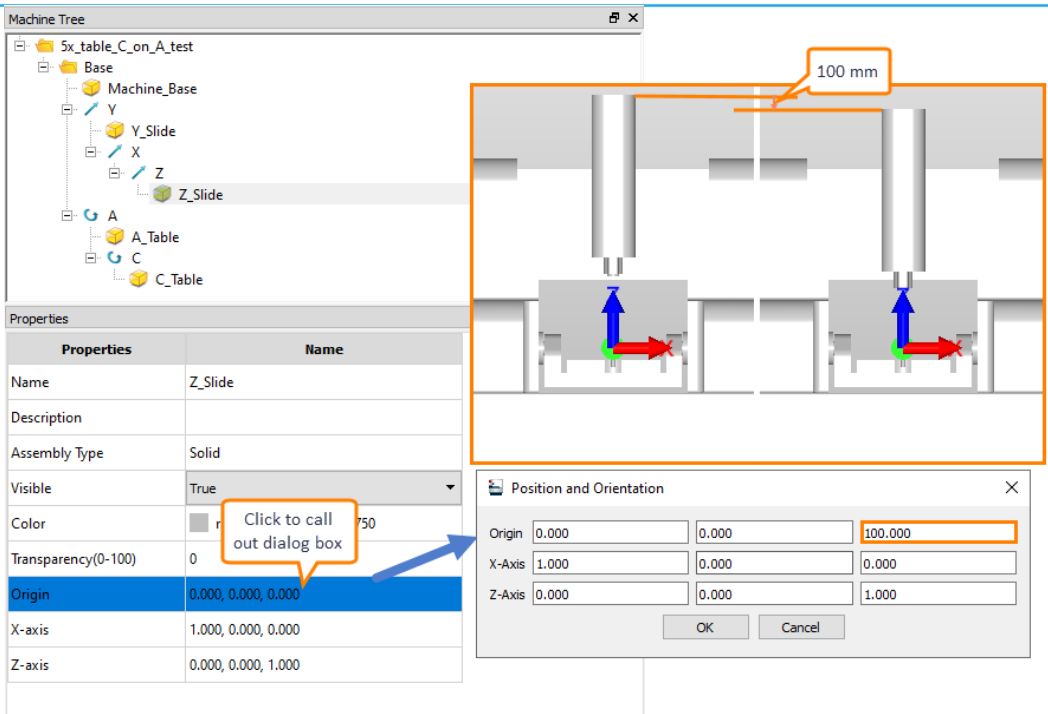


Figure 15 Adjusting the Position of Components

2.4.3 Specify the Axis Direction & Maximum Axis Travel

Generally speaking, the axis vectors should be positive to drive the tool movement directly if they belong to the tool movement section, while those that belong to the workpiece movement section, need to be negative. As it is analyzed, the vectors of the X, Y and Z axes are positive, while those of the A and C axes are negative. The axis limitations are set based on the physical limitations of the machine. In this case, the corresponding parameters will be set as shown below.

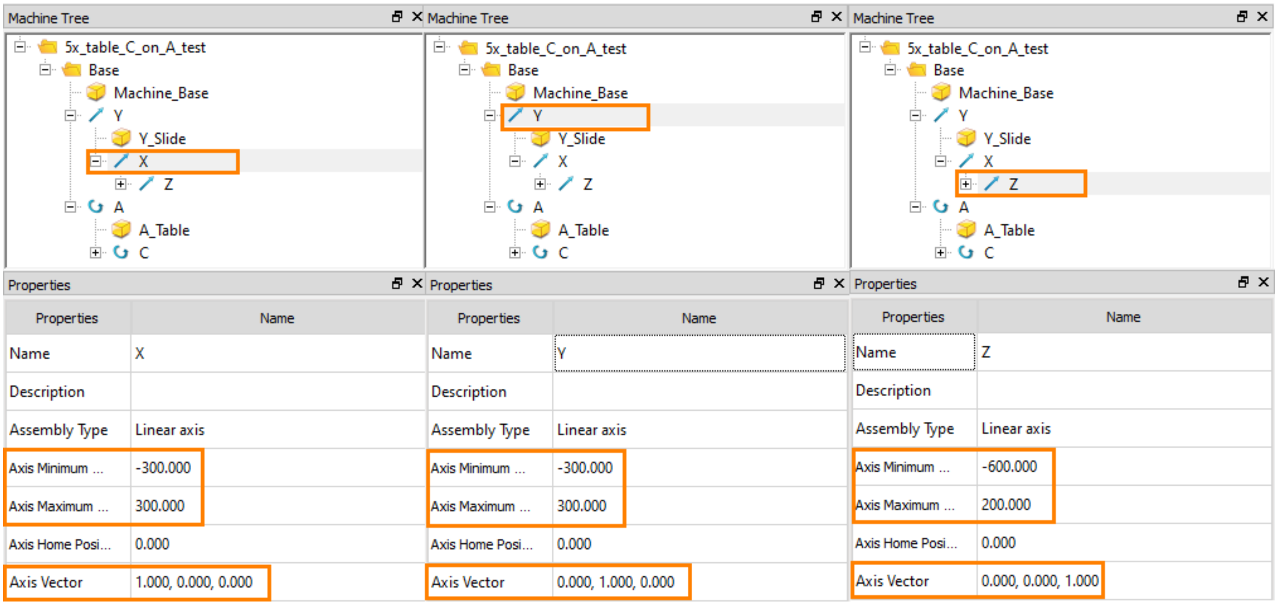


Figure 16 The Directions and Axis Travel Limitations of the X, Y, and Z Axes

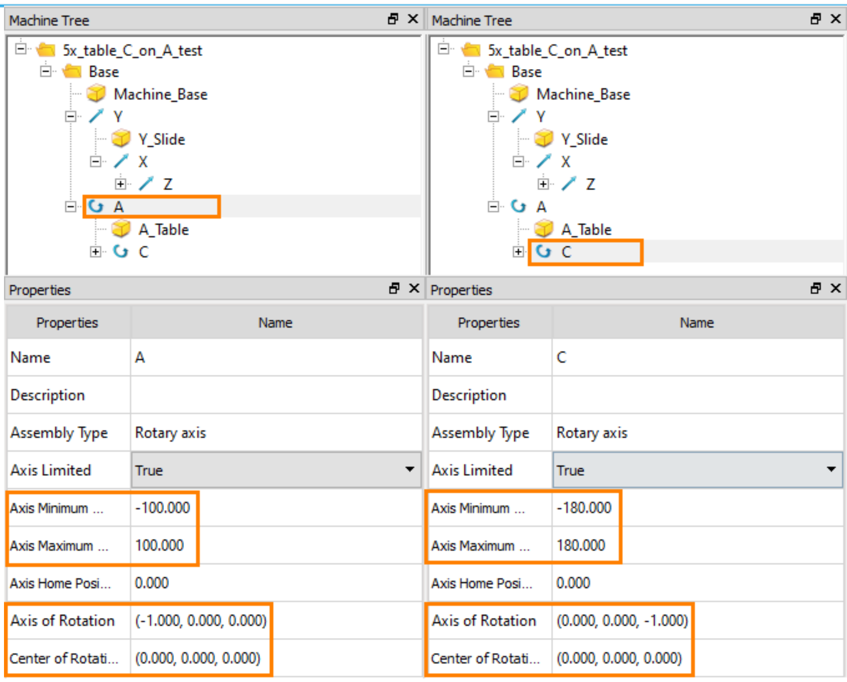


Figure 17 The Directions and Axis Travel Limitations of the A and C Axes

***Tip 1:** When the rotary axis of the machine component is inconsistent with the world coordinate system, you can set the **Center of Rotation** value in the **Properties** panel, so that components can rotate along the correct rotary axis.*

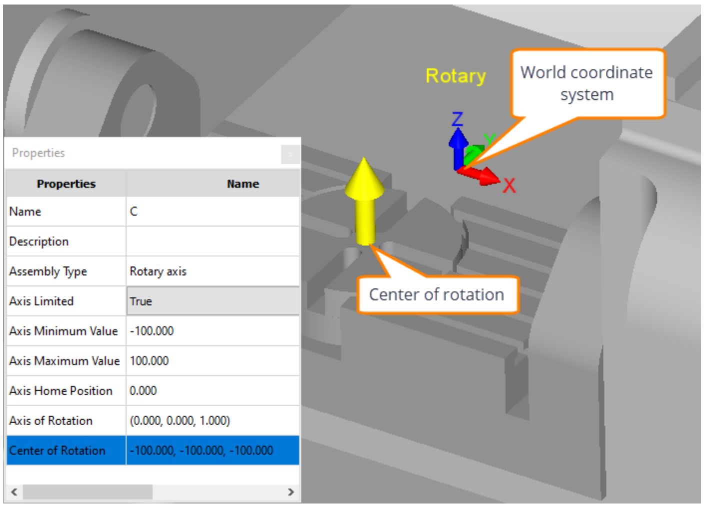


Figure 18 Center of Rotation

***Tip 2:** After setting the axis direction and axis travel limitation, you can drag the slider in the **Axes** panel to check if the movement of the corresponding component is correct.*

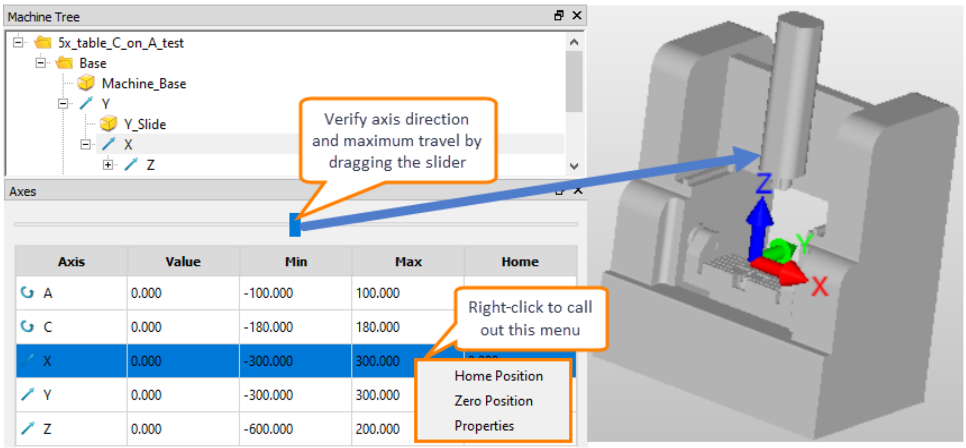


Figure 19 Verify the Axis Direction and Maximum Travel

2.5 Load the Tool Head

The tool head must be loaded to the bottom center point of the spindle (Z_Slide) directly. In other words, you need to get the coordinates of that point as the location of the tool head. The steps below will show you how to get the coordinates of the bottom center point of spindle and insert the tool head.

STEP 01 Right-click on the Z axis to create a new ***Assembly***, and then insert the tool head.

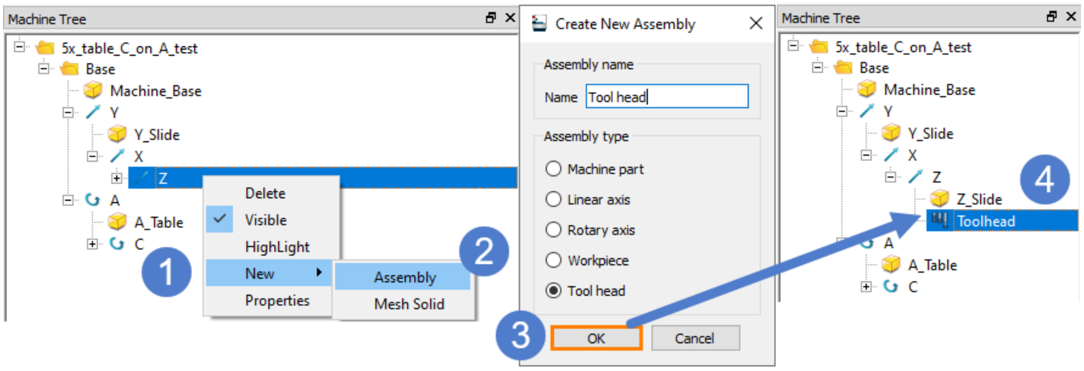


Figure 20 Inserting the Tool Head

STEP 02 Double-click on the bottom face of the spindle (Z_Slide) to get the coordinates of the center point.

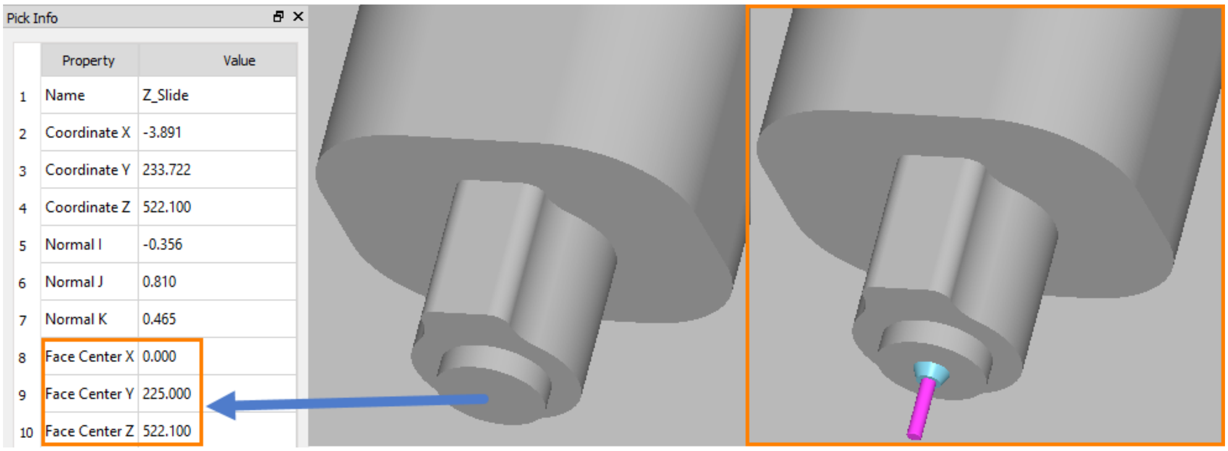


Figure 21 Getting the Coordinates of the Bottom Center Point of the Spindle

STEP 03 Use the coordinates defined in STEP 02 as the origin of the toolhead.

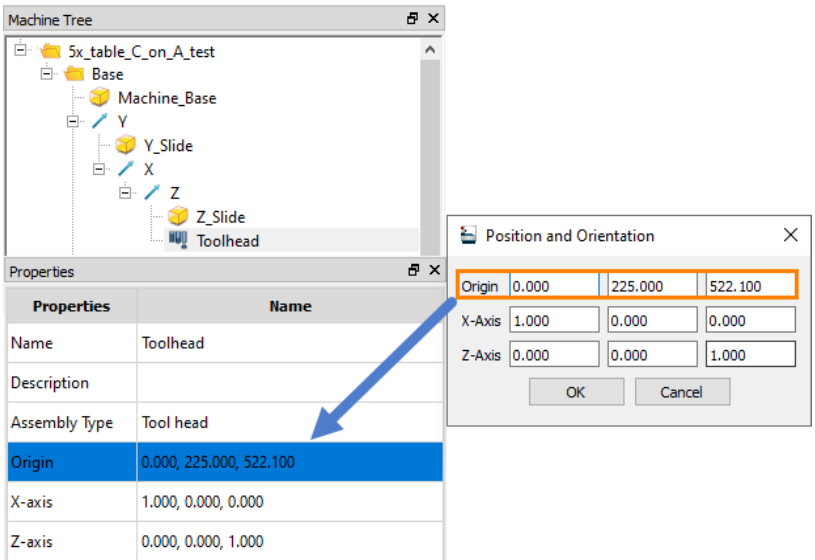


Figure 22 Inputting the Origin of the Tool Head

Note: *As the comparison in Figure 21 shows, when running FMS, the tools are loaded to the bottom center point of the spindle.*

2.6 Load the Workpiece

Workpiece here means the placement point of the workpiece. When loading the workpiece onto the machine, the origin of workpiece programming coordinate system will coincide with this placement point, which is based on the real machining situation. In this case, let's set the top center of C_Table as the workpiece placement point. The steps below will show you how to insert the workpiece.

STEP 01 Right-click on the ***C*** axis to create a new ***Assembly***, and then insert the workpiece.

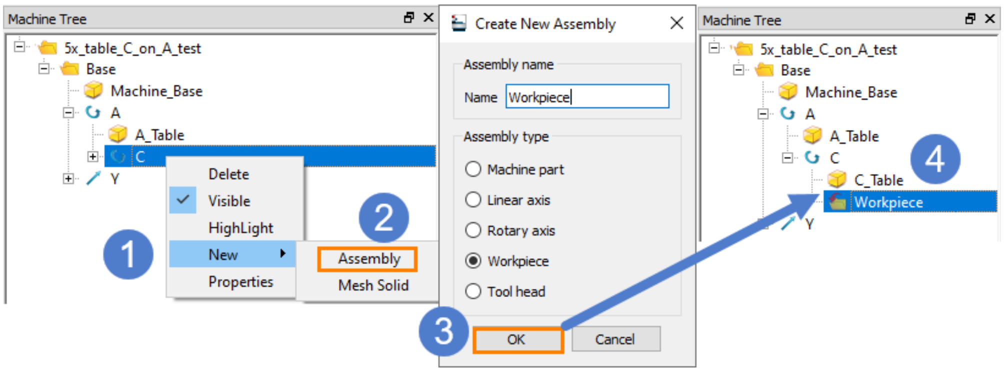


Figure 23 Inserting the Workpiece

STEP 02 Double-click on the top face of C_table to get the coordinates of the center point.

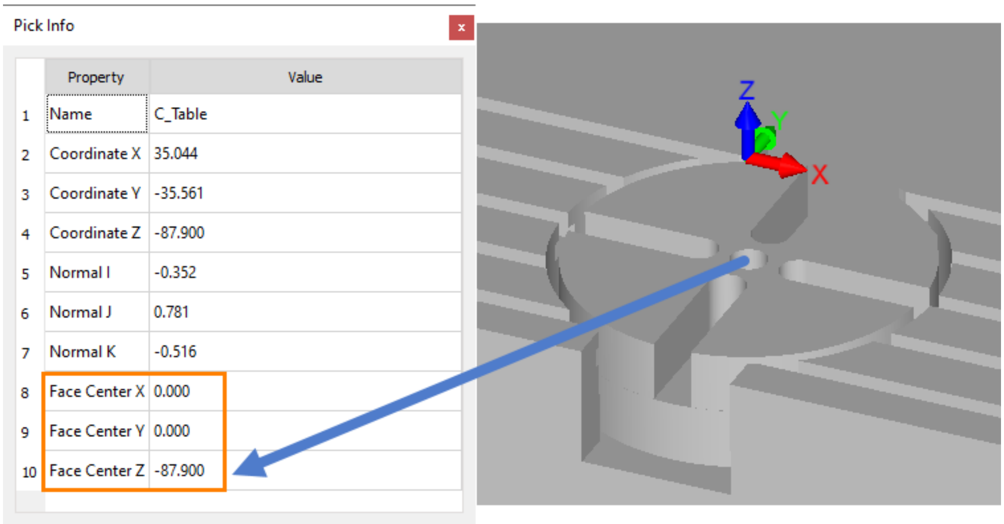


Figure 24 Getting the Coordinates of the Top Center Point of C_Table

STEP 03 Use the coordinates defined in STEP 02 as the origin of the workpiece.

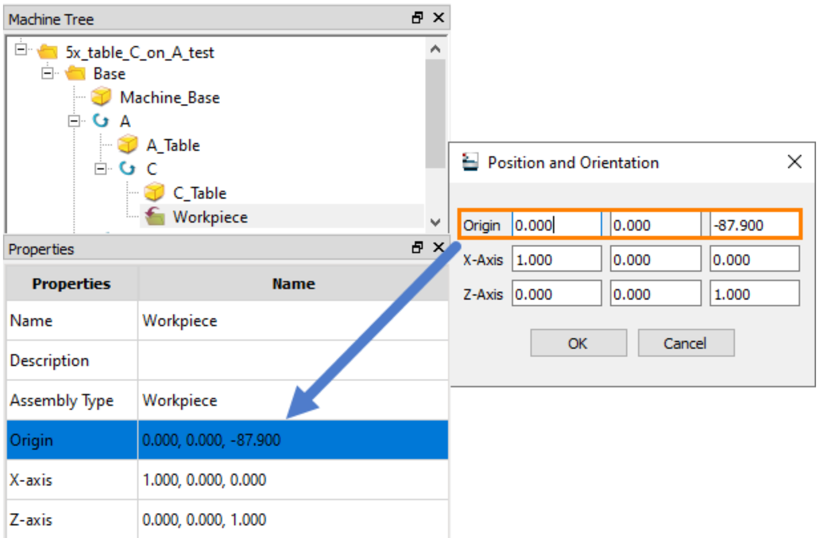


Figure 25 Inputting the Origin of the Workpiece

2.7 Save the Machine

After finishing all the settings, you can save the machine file (.mch) under the same folder of the STL files. Then, put the whole folder under the installation path, **…:\ZW3D2022\languages\language version\resource\machine_library**. You can name the folder after the .mch file, for example, 5x_table_C_on_A_test.

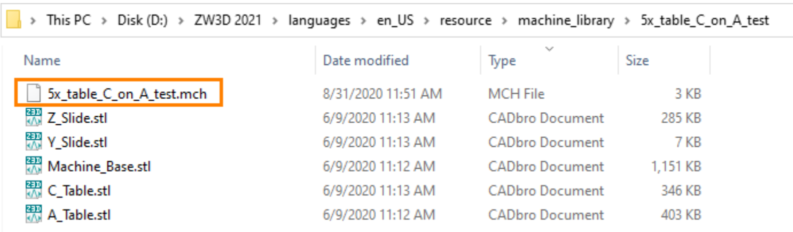


Figure 26 Saving the Machine File

***Note:** When running FMS, ZW3D will read the machine library in the corresponding language folder in the installation path. Therefore, the machine file must be saved under the corresponding language folder.*

3 Full Machine Simulation

With the virtual machine ready, you can start working on the machine simulation.
Full machine simulation is to load the stock and tools onto the machine and to simulate the movement of the machine. The clash check and part comparison during the simulation can help programmers pinpoint problems and ensure safe machining.

3.1 The Interface and Parameters

You can enter the machine simulation environment through the following steps:

METHOD 01 Create a new ***CAM Plan***, click the ***Output*** tab-click and then the ***Full Machine Simulation*** button.

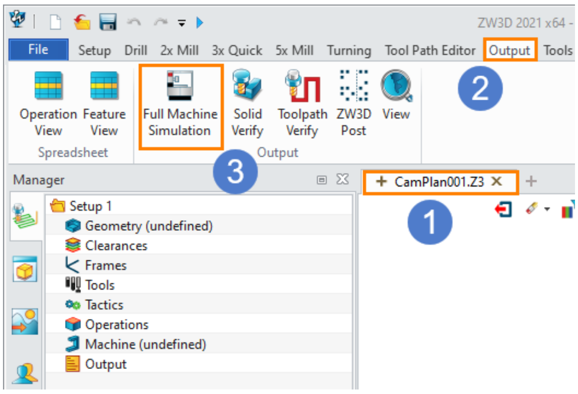


Figure 27 Entering the Machine Simulation Environment (Method 1)

METHOD 02 Select and right-click on a certain operation in the CAM Manager, and then click the ***Full Machine Simulation*** button.

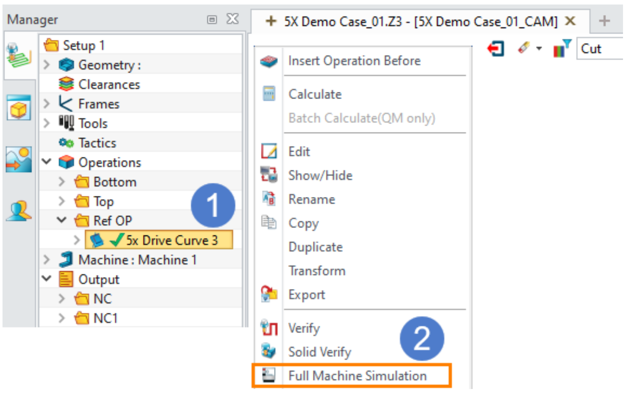


Figure 28 Entering the Machine Simulation Environment (Method 2)

After that, the FMS environment should be as shown below.

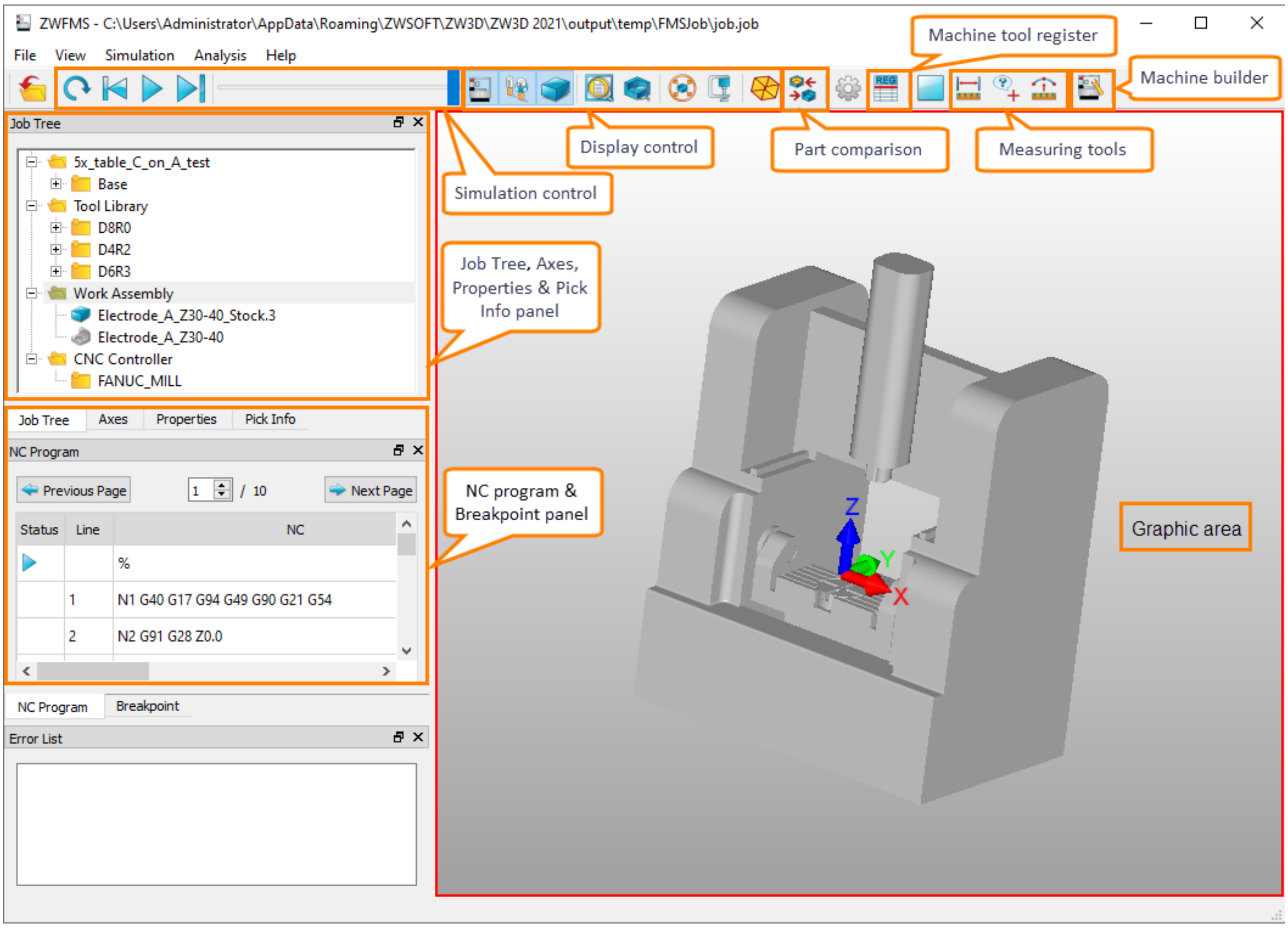


Figure 29 The FMS Environment

3.1.1 An Introduction to Panels

Job Tree: The structure of each machine component, tool library, work assembly and controller.

Axes: Axis information including the maximum axis travel and initial values.

Properties: Display the properties of the selected component.

Pick Info: Double-click to select and display the position information of the surface selected by double-clicking in the graphic area.

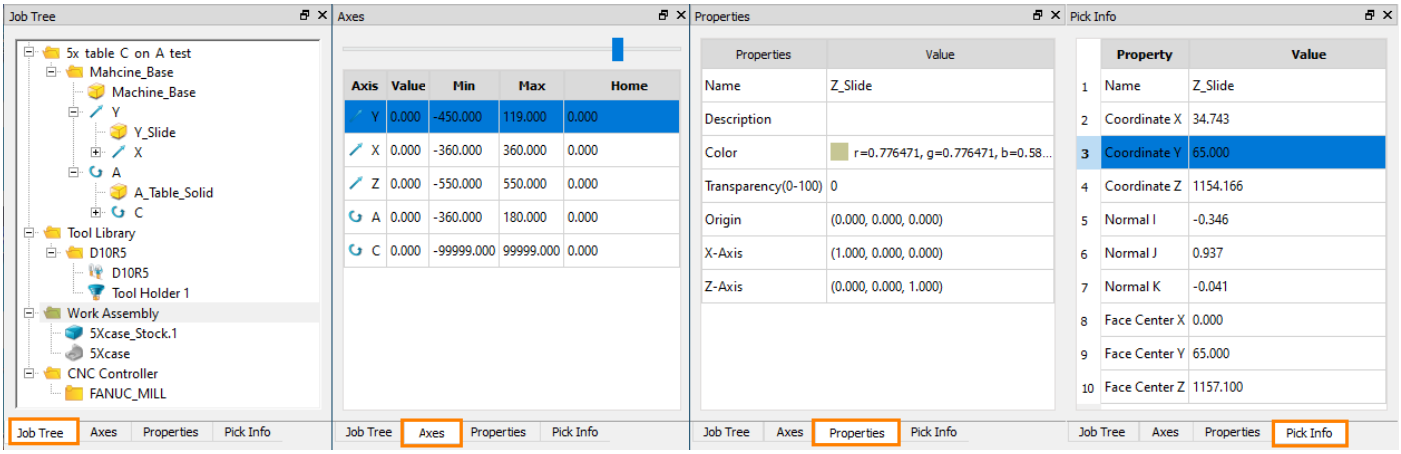


Figure 30 The Job Tree, Axes, Properties and Pick Info Panels

NC Program: Display the NC codes in FMS and toggle breakpoints by clicking the Status column. The NC codes are generated with the post configuration file **ZW_FMS_5X.znc** (post processing can only be configured through this file currently) and based on the default coordinate system.

Breakpoint: Display the information of the breakpoints. You can click the Status column of a specific line in the NC program to set the breakpoints and then check them.

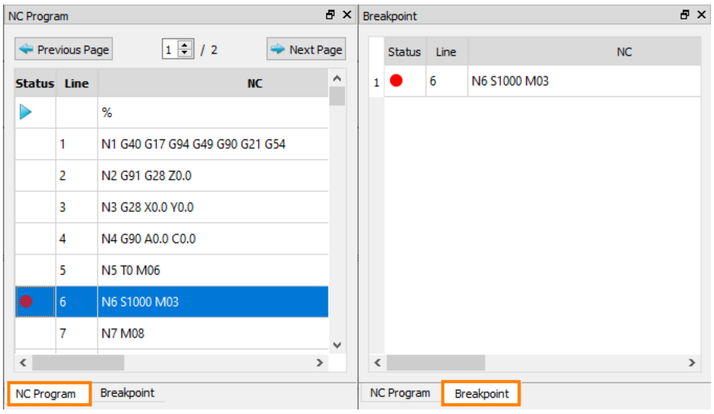


Figure 31 The NC Program and Breakpoint Panels

3.1.2 An Introduction to Options

Simulation Control: Restart, step forward, step backward or run FMS.

Figure 32 Simulation Control

View Machine: Display or hide the machine.

View Tool: Display or hide the tool.

View Workpiece: Display or hide the workpiece and stock.

Zoom All: Zoom all.

Zoom to Workpiece: Zoom to the workpiece.

Workpiece Static: Control whether to move the workpiece when simulating.

Workpiece Important: Highlight the workpiece.

Auxiliary: Top, bottom, left, right, back, front, and auxiliary view.

Part Comparison: Compare the simulation result with the actual part.

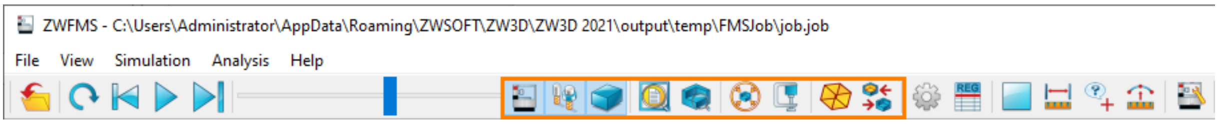


Figure 33 View Options (from Left to Right Are the Options Listed above)

Settings: Specify the simulation options, analysis settings, background color and 5X control.

Machine Tool Register: Set the tool compensation and work coordinate system.

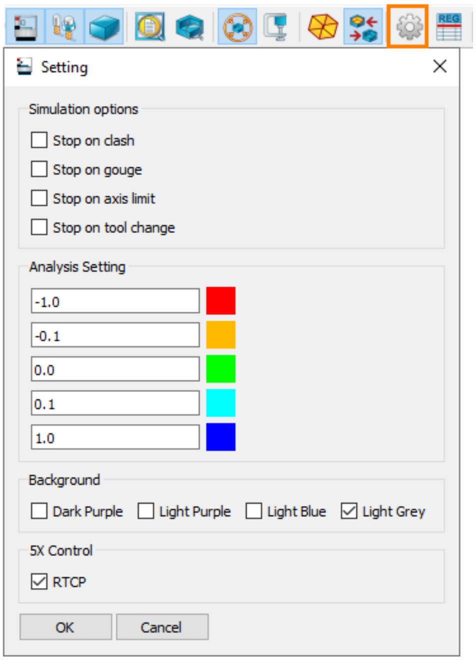


Figure 34 Settings

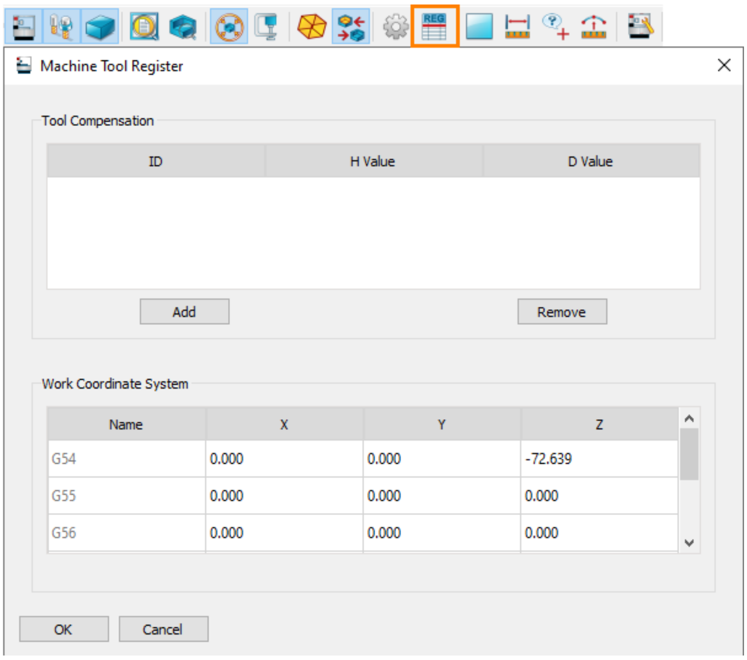


Figure 35 Machine Tool Register

Machine Builder: Create a new machine or edit the existing machine.

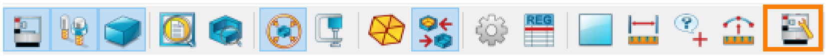


Figure 36 Machine Builder

3.2 Workflow

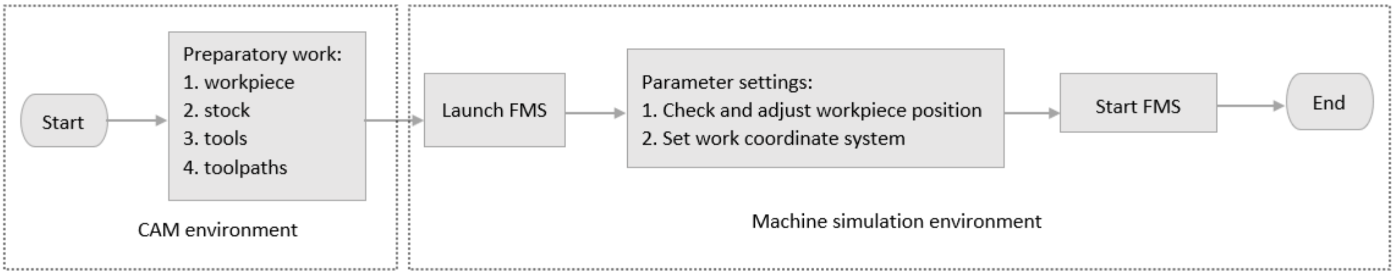


Figure 37 The Workflow of Full Machine Simulation

3.3 Machine Simulation on a 3X Program

The **Electrode_A_Z30-40_CAM** in **FMS case.Z3** will be the example to illustrate the workflow of FMS.

3.3.1 Preparatory Work

STEP 01 Open **FMS case.Z3** and then double-click on it to open **Electrode_A_Z30-40_CAM.**

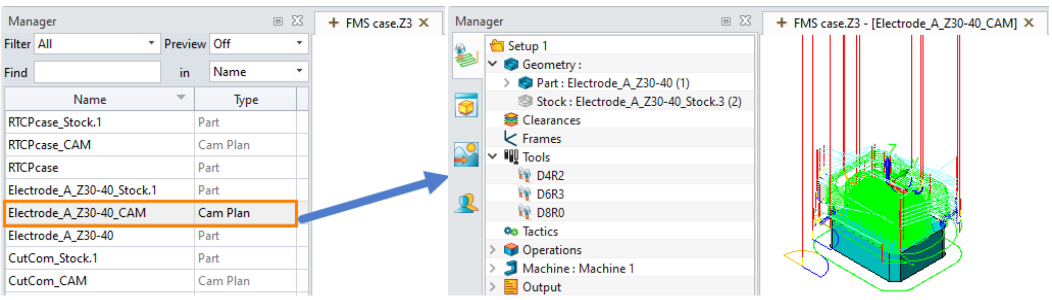


Figure 38 Opening the Sample File

STEP 02 Check the relevant preparation work including the workpiece, stock, tools and toolpaths.

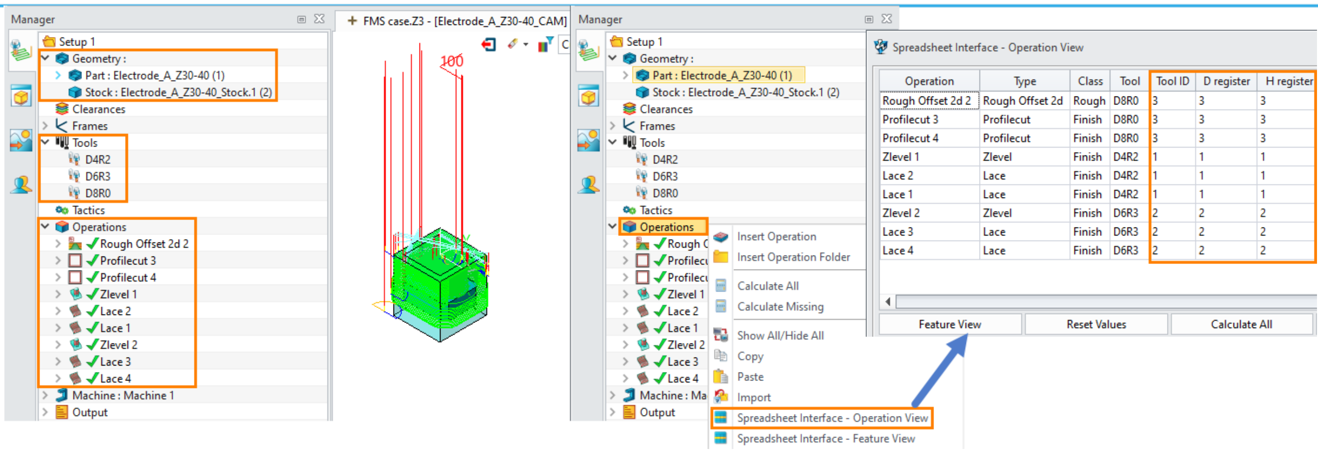


Figure 39 Check the relevant preparation work

***Note:** Since the machine will change tools and implement length or radius compensation according to the T, H, and D numbers in NC files, you need to set the Tool ID, Radius compensation number (D register) and Length compensation number (H register) for tools. Before you enter the FMS* environment*, ZW3D will automatically check whether there is a same Tool ID and remind you to modify the tools.*

3.3.2 Launch FMS

STEP 01 You can select all the operations, right-click on it and choose Full Machine Simulation, or go to ***Output*** tab, and then click the ***Full Machine Simulation*** button.

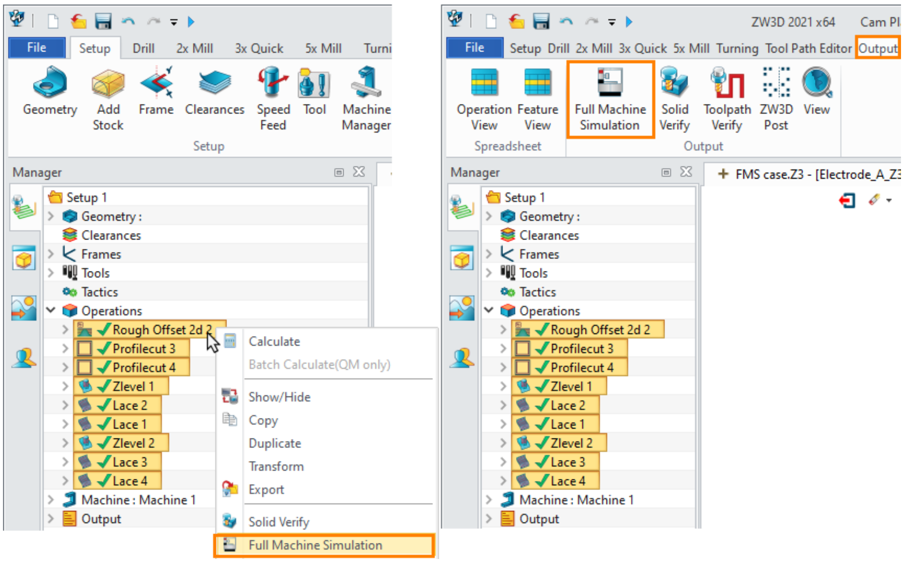


Figure 40 Entering the FMS Environment

STEP 02 After the ***Stock*** and ***Target Part*** are automatically recognized, click the ***Machine*** and ***Controller*** buttons to finish the FMS settings step by step, then click ***OK*** to enter the FMS environment (If there are multiple stocks or workpieces in the CAM file, you may select the proper stock or target part from their context menu.)

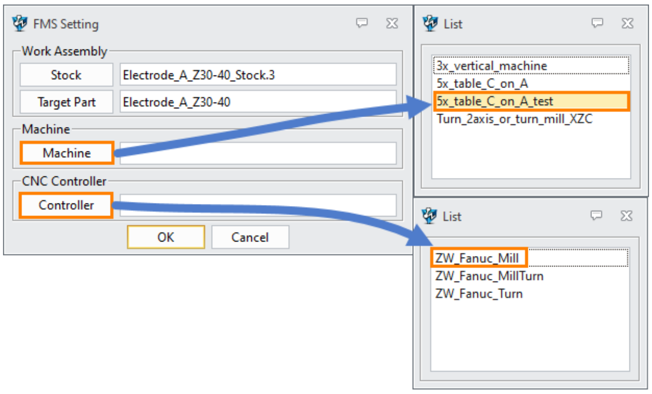


Figure 41 FMS Settings

3.3.3 Parameter Settings

STEP 01 Check the position of the workpiece. After entering the FMS environment, the position of the workpiece may not be correct, so the first step is to check its position. In this case, the workpiece is 28 mm (the total height of the workpiece is 28mm) below in the Z direction. So, you need to move it up by 28 mm.

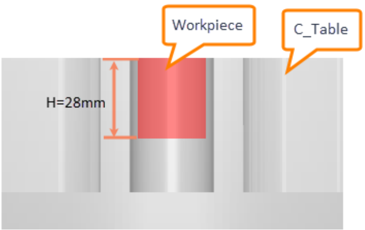


Figure 42 Checking the Position of the Workpiece (Front View)

STEP 02 Adjust the position of the workpiece. In the Job Tree panel, right-click on ***Workpiece*** to invoke the ***Workpiece Frame Setting*** dialog box. After you move it up by 28 mm in the Z direction, the Attach Point will go from (0,0,-87.9) to (0,0,-59.9).

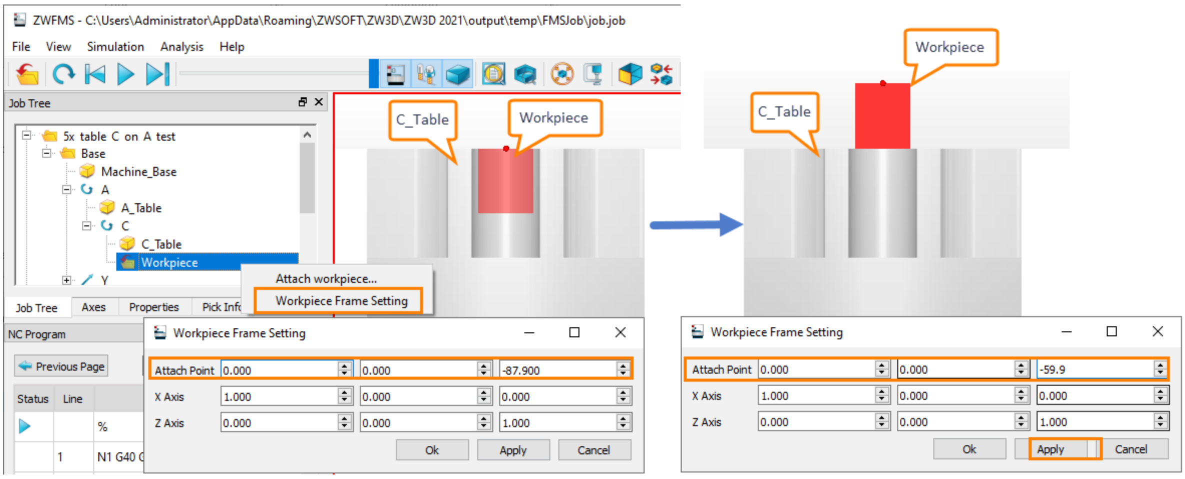


Figure 43 Adjusting the Position of the Workpiece (Front View)

STEP 03 Set the work coordinate system, making sure that the origin of the workpiece and the origin of the work coordinate system are the same. In this case, you need to set G54 to (0,0,-59.9) in ***Machine Tool Register***.

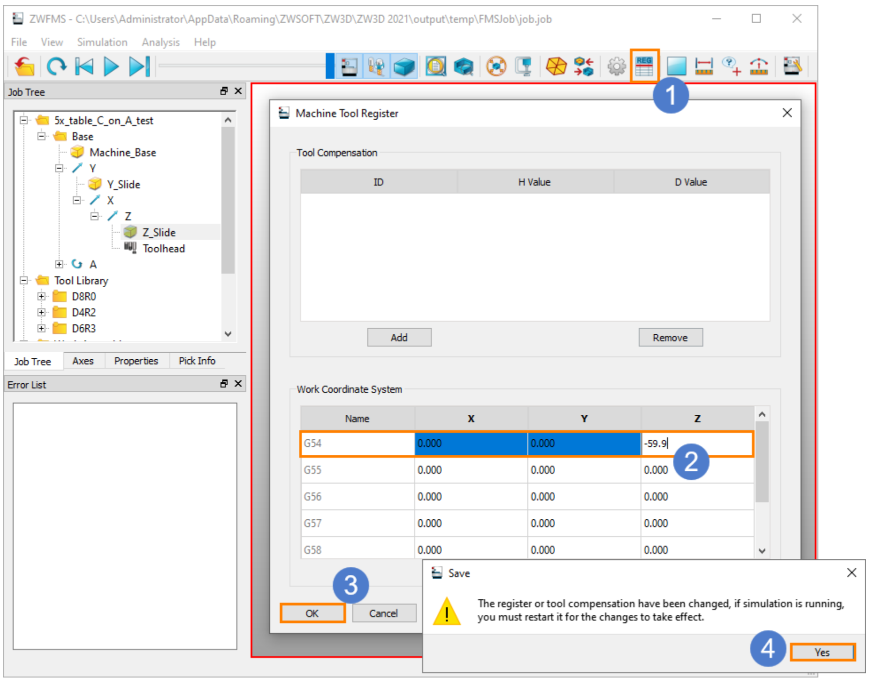


Figure 44 Setting the Work Coordinate System

Tip: *In STEP 01, you can measure the height of the workpiece in the CAD environment or right-click on C_table to hide it and measure the height of the workpiece.*

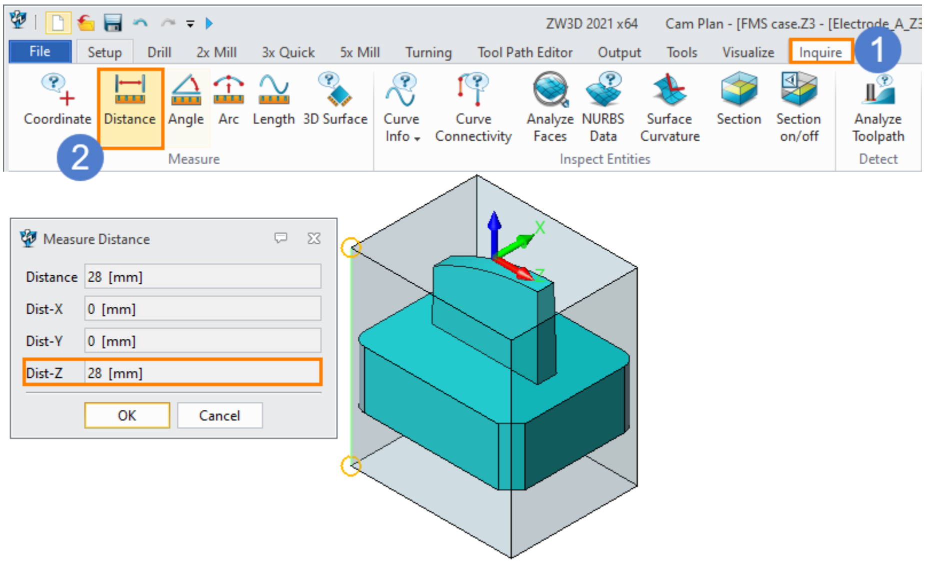


Figure 45 Measuring the Height of the Workpiece in the CAD Environment

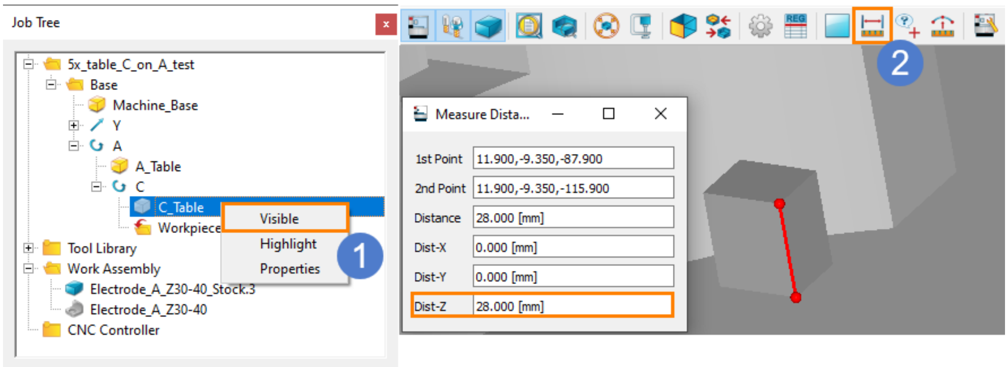


Figure 46 Measuring the Height of the Workpiece in the FMS Environment

3.3.4 Run FMS

After finishing all the parameter settings, you can adjust the perspective, then click the ***Run*** button to observe the simulation process.

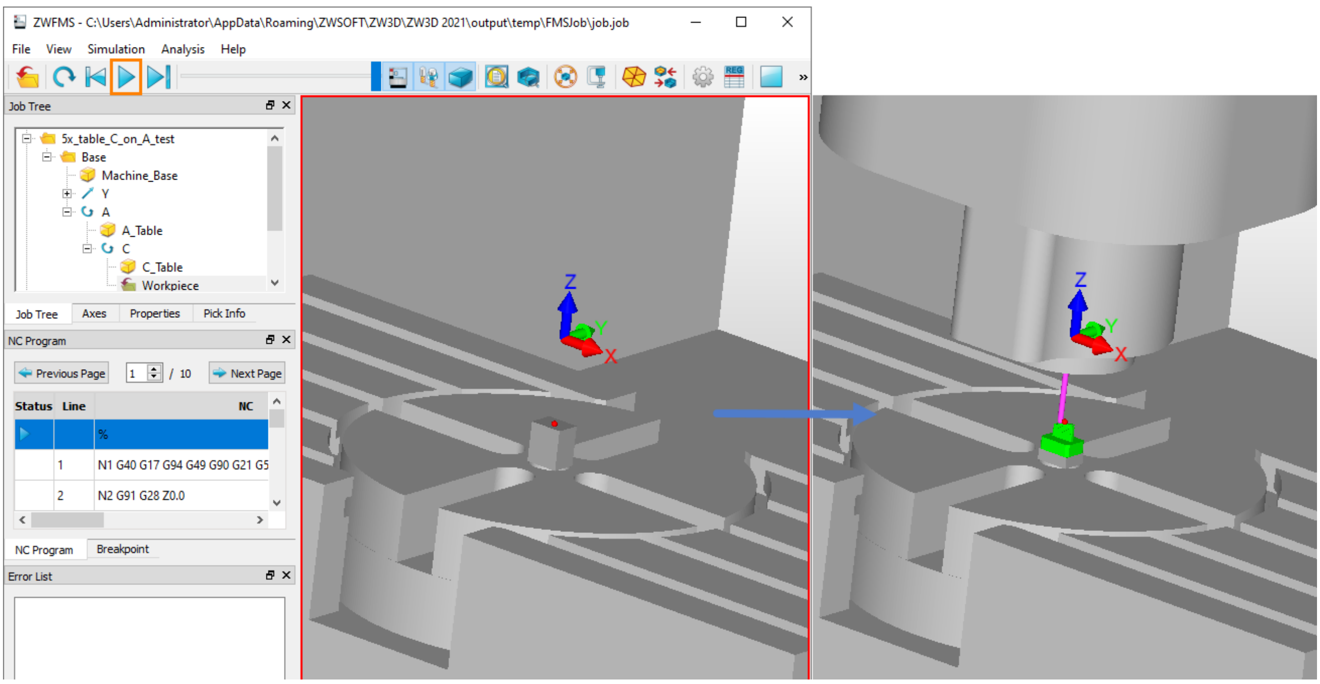


Figure 47 Running FMS

After that, click ***Part Comparison*** to compare the simulation result with the designed part. You can click the ***Setting*** option and customize tolerance bands.

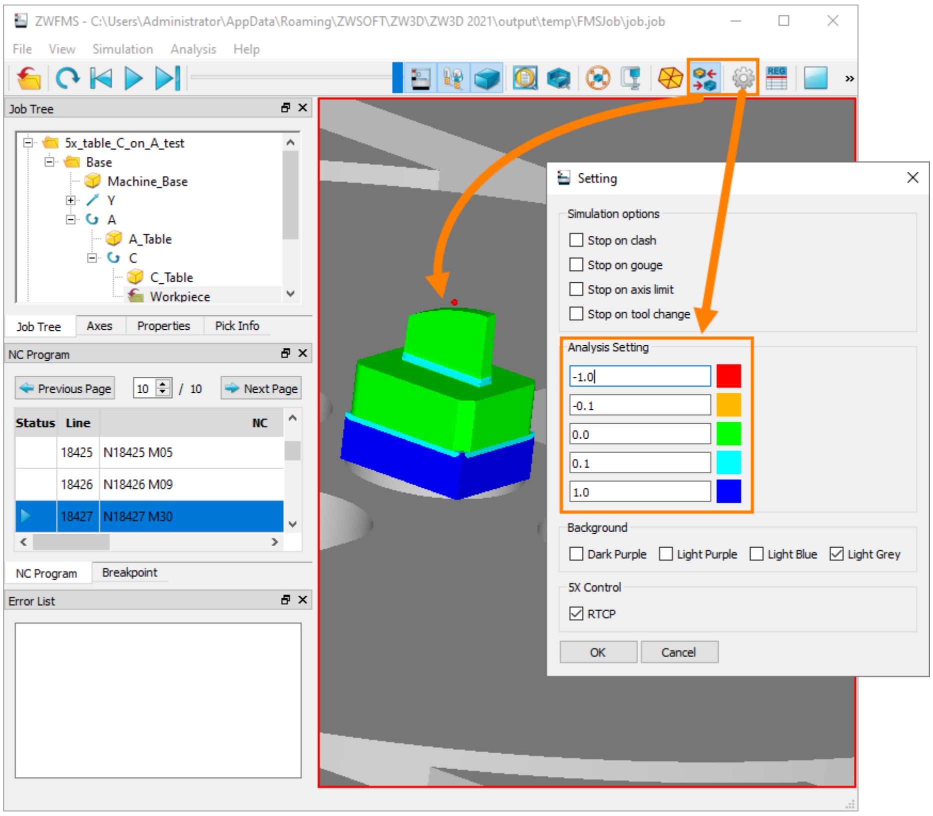


Figure 48 Comparison between the Simulation Result and Part

Besides, you can perform clash and gouge checks during the simulation. Just check the ***Stop on clash*** and ***Stop on gouge*** options before you run FMS.

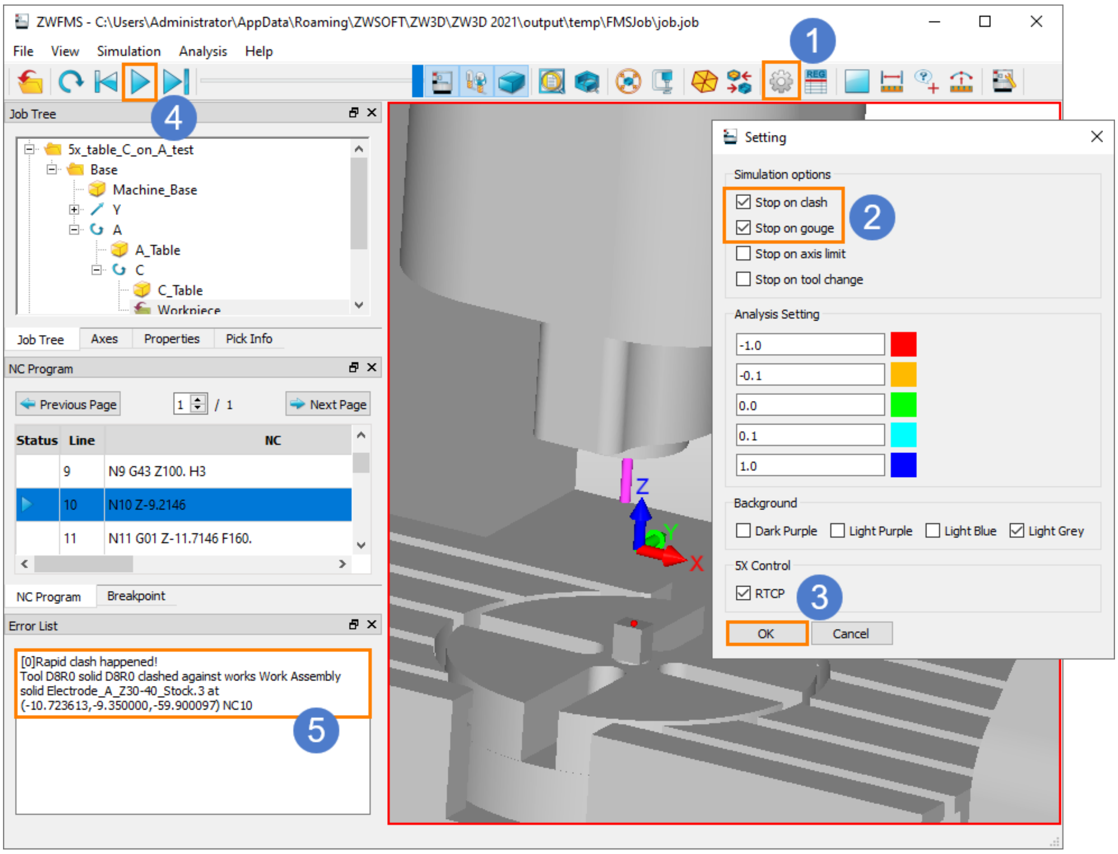


Figure 49 Stop on Clash and Stop on Gouge Options

3.3.5 Tool Compensation

Tool compensation includes length and radius compensations, which should be identical with the CAM program setting so that you get the correct simulation result. Let's take ***Tool_compensation_CAM*** in ***FMS case.z3*** as an example and see how to set the radius compensation.

STEP 01 Open **FMS case.Z3** and double-click on it to open **Tool_compensation_CAM.** Profilecut 1 is an operation with radius compensation, and the tool ID, D register and H register have been set to 1.

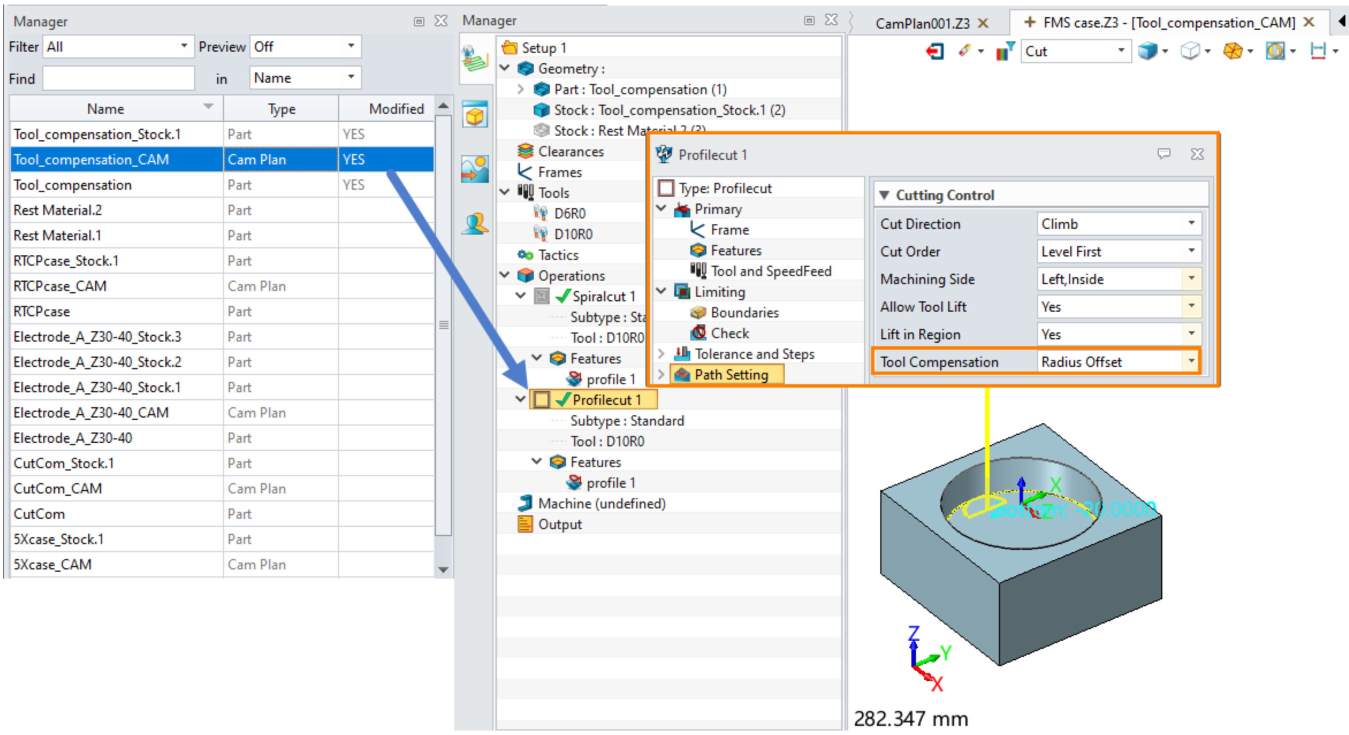


Figure 50 Opening Tool_compensation_CAM

As the figure above shows, the toolpaths were generated with radius compensation. However, the radius compensation has not been set in FMS. As a result, the simulation is not running according to the toolpaths, causing the overcut.

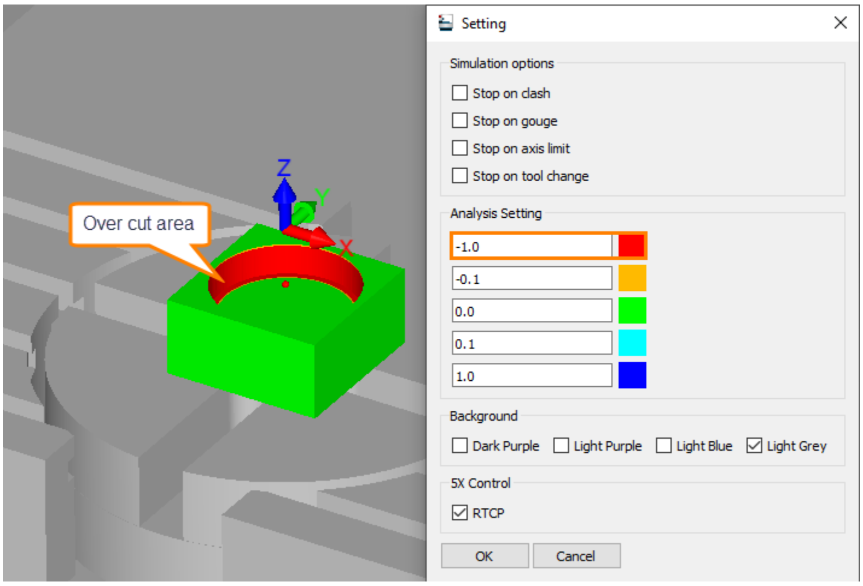


Figure 51 The Simulation Result without Tool Compensation

STEP 02 Set the tool compensation in FMS in terms of the CAM program (the radius compensation is 5 mm since the radius compensation toolpath is generated by "D10flat end_mill"), and then set the D Value of the tool compensation in FMS to 5 to be consistent with the CAM settings.

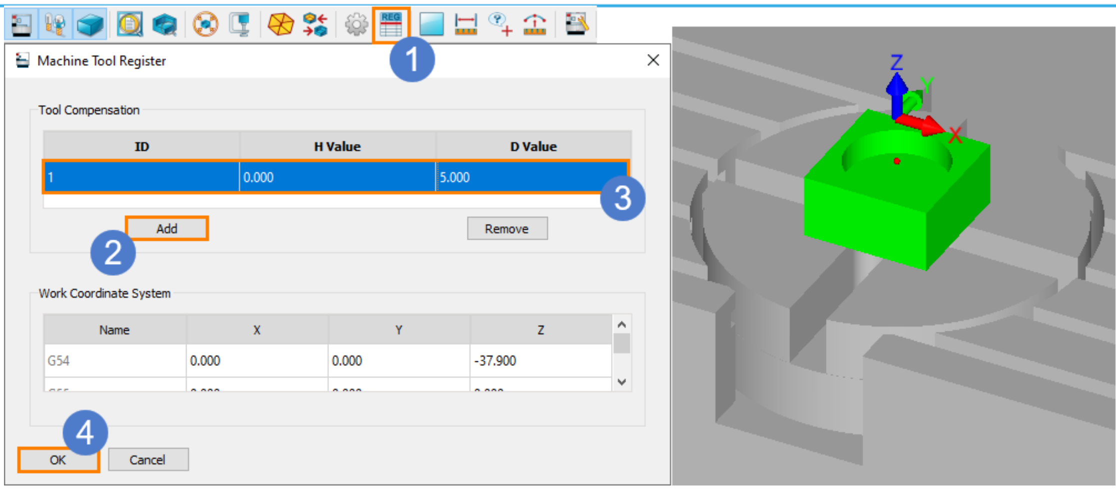


Figure 52 The Simulation Result with Tool Compensation

3.4 Machine Simulation on a 5X Program

You will learn about simulation with and without RTCP through case studies in this chapter.

In the ZW3D FMS modules, the RTCP switch option allows you to decide whether to simulate machines with the RTCP function. If you choose to stimulate the machine with RTCP, it is necessary to turn on RTCP when the software generates the NC codes, so that the codes can match the machine and you get the correct simulation result. In ZW3D, you can decide whether or not the output NC has RTCP with the "SYS.MX_RTCP_ON" function of the ZW_FMS_5X.znc file (under the installation path, ...:\ZW3D 2022\ZWPostConfigs).
When SYS.MX_RTCP_ON = 1, the output NC has RTCP and it can run in the machine with the RTCP function.
When SYS.MX_RTCP_ON = 0, the output NC does not have RTCP and it does not match the machine with the RTCP function.

ZW_FMS_5X.znc

```
SUB __INIT()
    DIM SYS.TOOLNO_ARRAY
    DIM SYS.TOOLNO_CYCLE_ARRAY
    DIM SYS.PART_MATRIX
    DIM SYS.LOCAL_COORDINATE_MATRIX
    SYS.RAPID_EVALUATION = 1
    SYS.PASS1_EXECUTION = 1
    SYS.MX_RTCP_ON = 1
    SYS.FIRST_SPINDL = 1
    SYS.MX_PIVOT_LEN = 0
    SYS.EMULATE_BREAK = 0
    SYS.RUN_AUTO_RETRACT = 0
    SYS.COORDINATE = ""
```

Figure 53 Function SYS.MX_RTCP_ON

***Note:** RTCP (Rotated Tool Center Point), also known as TCPM, TCPC or RPCP, refers to the function maintaining rotary axes at a constant angle between the tool and the surface to be machined. In 5-axis machining, the additional motion of the tool point is generated due to the rotary motion following the tool point path and the angle between the tool and the workpiece. Since the control point of a CNC system is often not consistent with the tool point, the CNC system should automatically correct the control point to ensure that the tool point moves according to the given trajectory.*

3.4.1 Simulation with RTCP

Let's take **Impeller_CAM** in **5X_case.Z3** as an example.

SYS.MX_RTCP_ON = 1 is the default setting in the **ZW_FMS_5X.znc** file, which means that the output NC matches the machine with the RTCP function by default. The following steps will show you how to stimulate the machining of the impeller with RTCP.

STEP 01 Open **5X_case.Z3** and double-click on it to open **Impeller_CAM**.

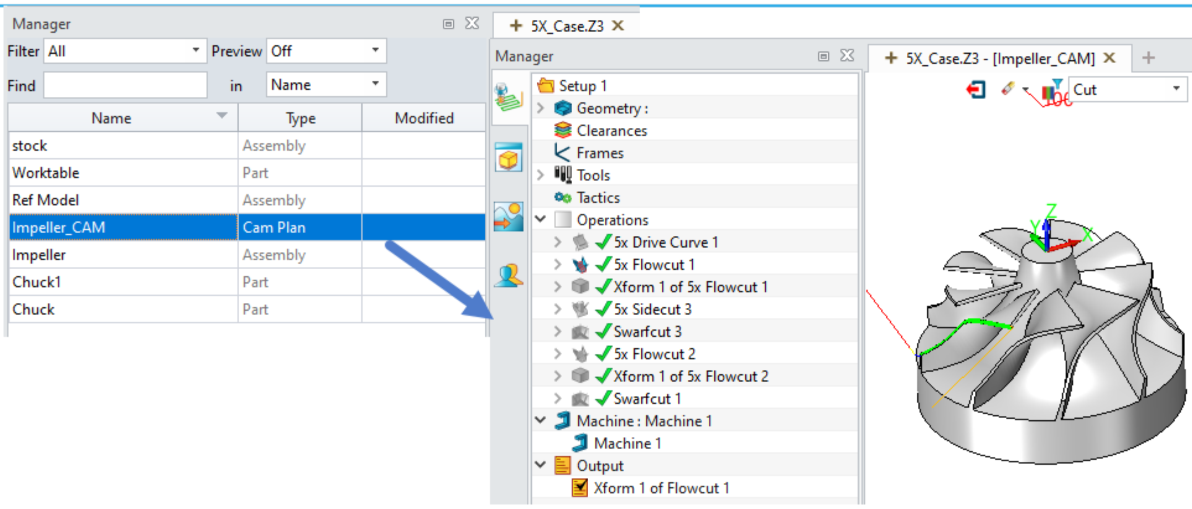


Figure 54 Opening Impeller_CAM

STEP 02 Right-click on the **5x Flowcut 1** operation and click **Full Machine Simulation** to enter the FMS environment.

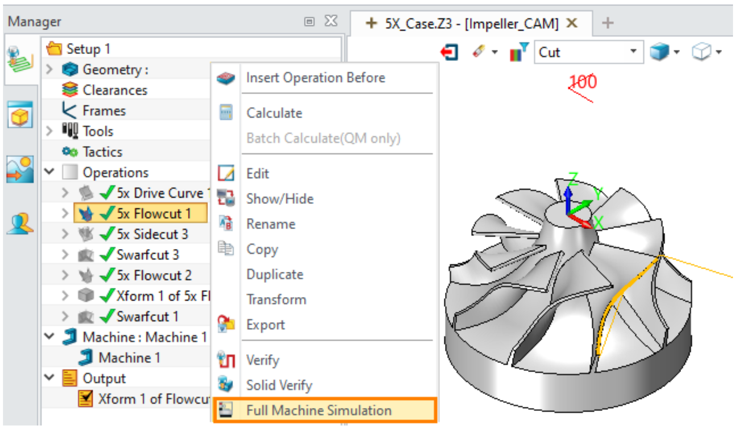


Figure 55 Entering the FMS Environment

STEP 03 Adjust the position and work coordinates of the workpiece.

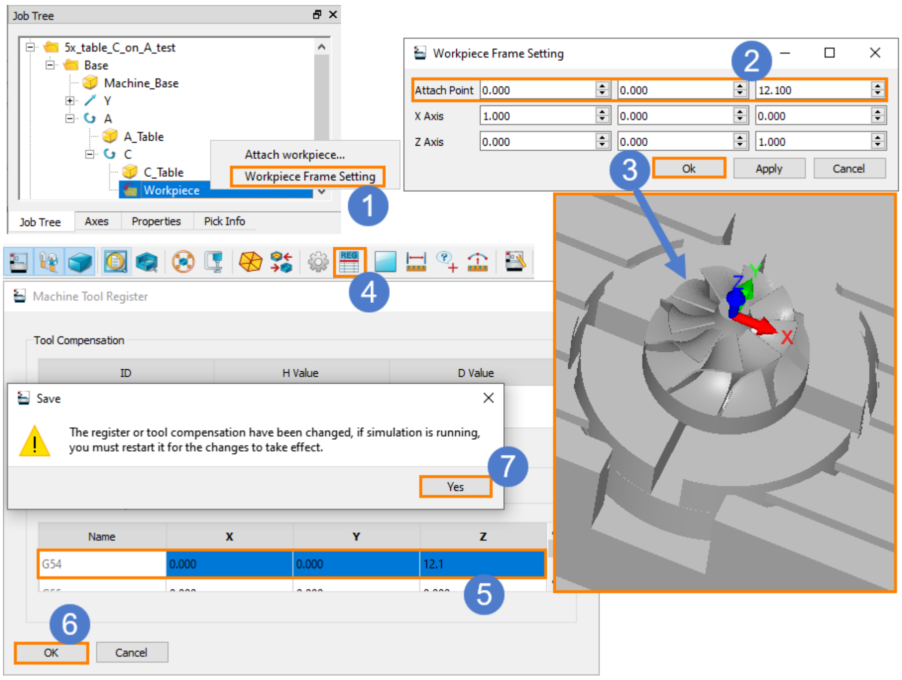


Figure 56 Adjusting the Position and Work Coordinates of the Workpiece

STEP 04 Run the simulation with RTCP. You can adjust the perspective to better observe the movement of the tool.

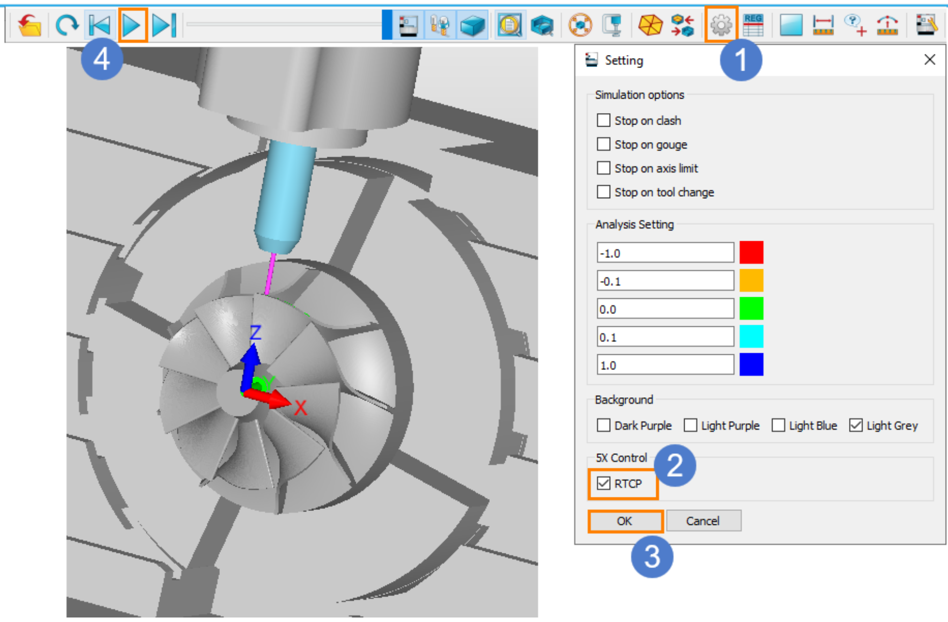


Figure 57 Simulation with RTCP

3.4.2 Simulation without RTCP

To run the simulation without RTCP, you need to repeat STEP 01~03 in **Chapter 3.4.1**, and then uncheck the **RTCP** option in the Setting dialog box.

In this case, the simulation result will be incorrect without RTCP.

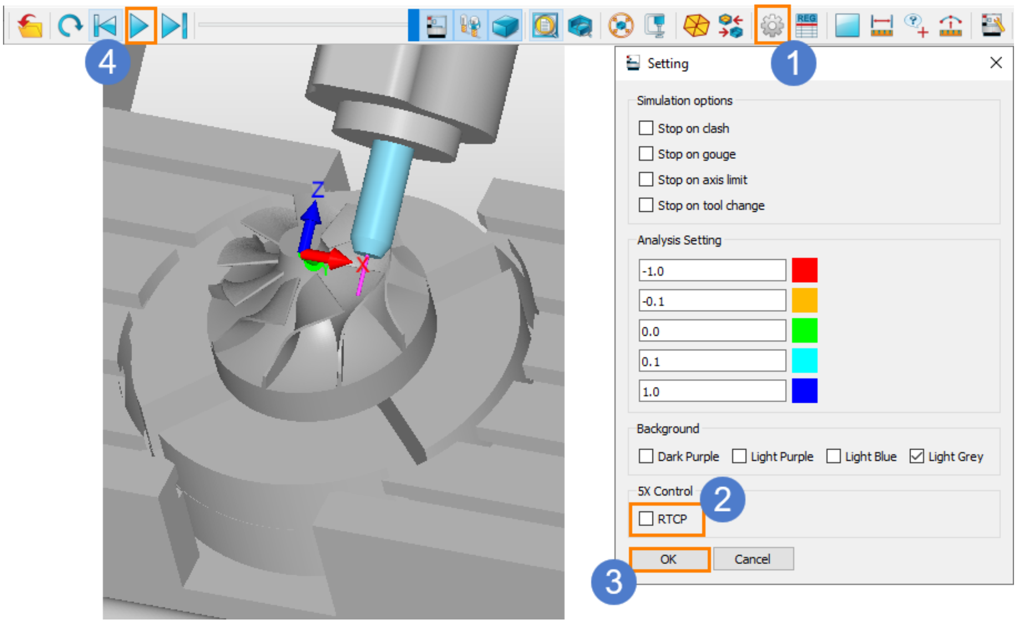


Figure 58 Simulation without RTCP

***Note:** When the simulated machine does not have RTCP, the NC codes are directly related to the structure type of the 5X machine and the position of the workpiece on the table, which indicates the relationship between the workpiece origin and the machine rotation center. Therefore, you need to confirm the position of the workpiece, measure the relationship between its origin and the rotation center, and then set the specific relationship in the post processor to generate the correct NC codes. In this way, you can still get the correct machine simulation result even without RTCP.*

The following steps will show you how to modify the post processor manually and get the expected result from the machine without RTCP.

STEP 01 Repeat STEP 01~03 in **Chapter 3.4.1** to get the coordinates of the workpiece origin relative to the machine origin.

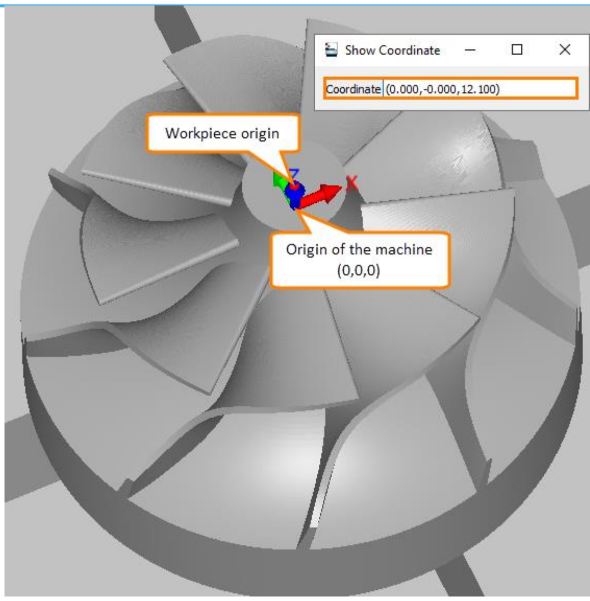


Figure 59 Getting the Coordinates

STEP 02 Turn off RTCP and modify the relevant values according to the measurement in STEP 01 in the **ZW_FMS_5X.znc** file following the installation path (...ZW3D 2022\ZWPostConfigs).

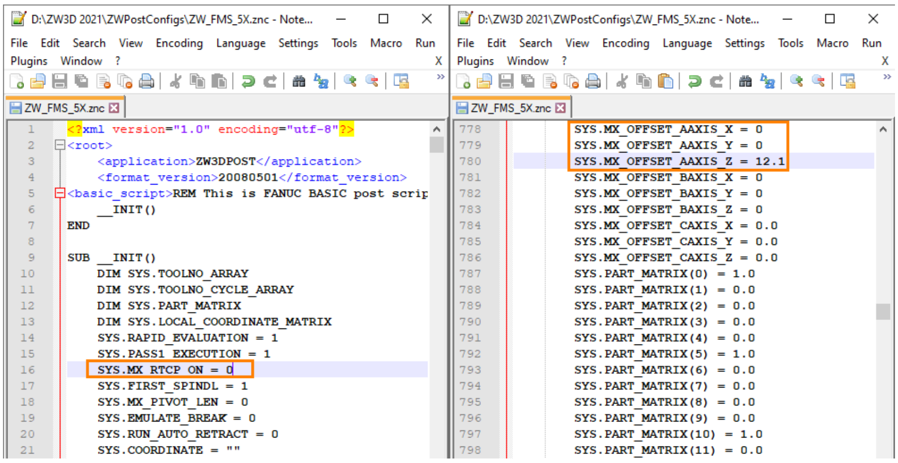


Figure 60 Turning off RTCP and Modifying the Relevant Values

STEP 03 Re-enter the FMS environment and repeat STEP 01~03 in **Chapter 3.4.1**, then uncheck the RTCP option and run the simulation to get the correct simulation result withour RTCP.

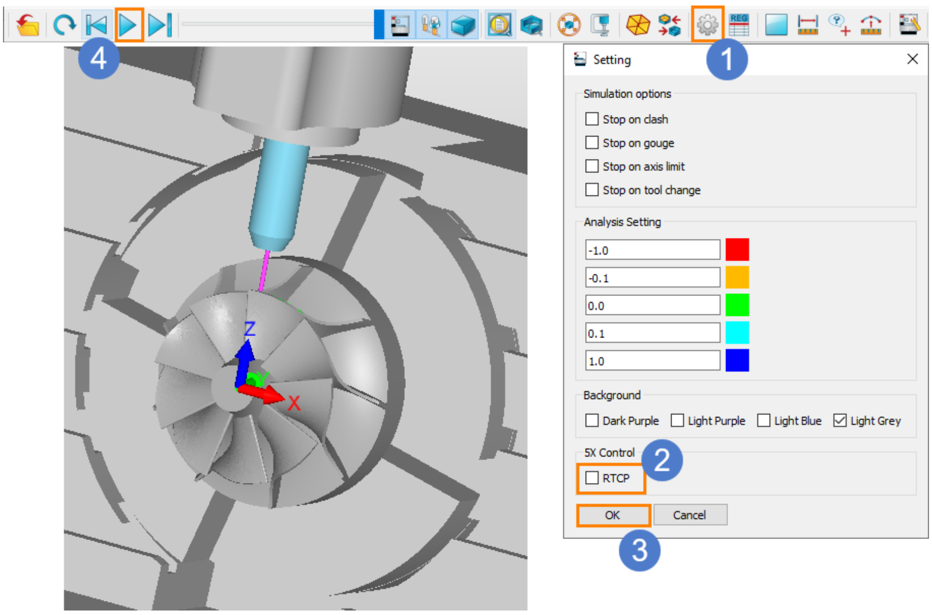


Figure 61 Simulation without RTCP

Epilogue

Thank you for your valuable time.

In this tutorial, we've shown you the workflow and specific operation of machine builder and machine simulation through the cases. We hope this tutorial can help you understand the way to apply Full Machine Simulation in ZW3D.

Notice: This tutorial is based on version ZW3D 2022, some functions or icons may not match the current version. If you have any suggestions or questions about this tutorial, please contact us.

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ZW3D Support Team: sales@zwsoft.com