Autodesk® PowerMill®

Robot

Training Manual

AUTODESK®

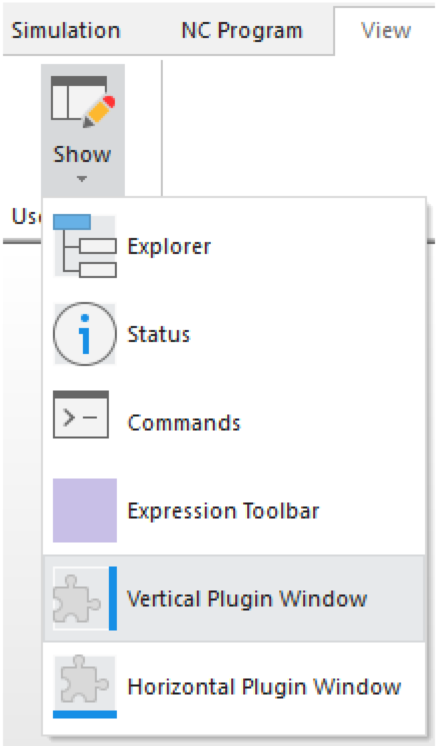
PowerMill Robot Training

This manual deals with PowerMill Robot. It implies and assumes that the user has good **PowerMill** skills. PowerMill Robot is used to convert tool paths in a machining project into robot path following programs. It allows the user to simulate and analyse the final motion of the robot. It is a Powerful integrated tool that can be used to analyse the robot simulation and avoid problems like singularities or axes limits. PowerMill Robot is also used to create the final robot program, without using third party software.

The Plugin Manager

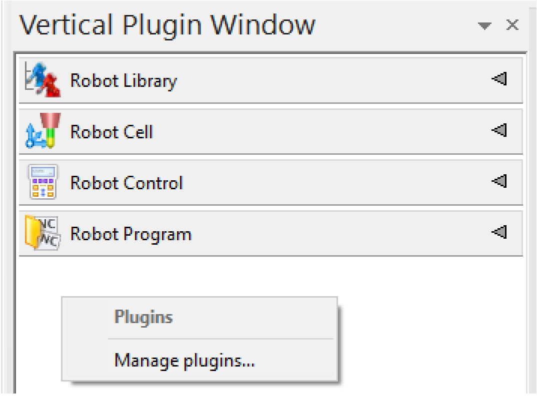
PowerMill Robot is a plugin for PowerMill and information about it is contained within the plugin manager within PowerMill.

To reveal PowerMill Robot once it is installed open the View menu on the ribbon menu and select Show → Vertical Plugin Window.

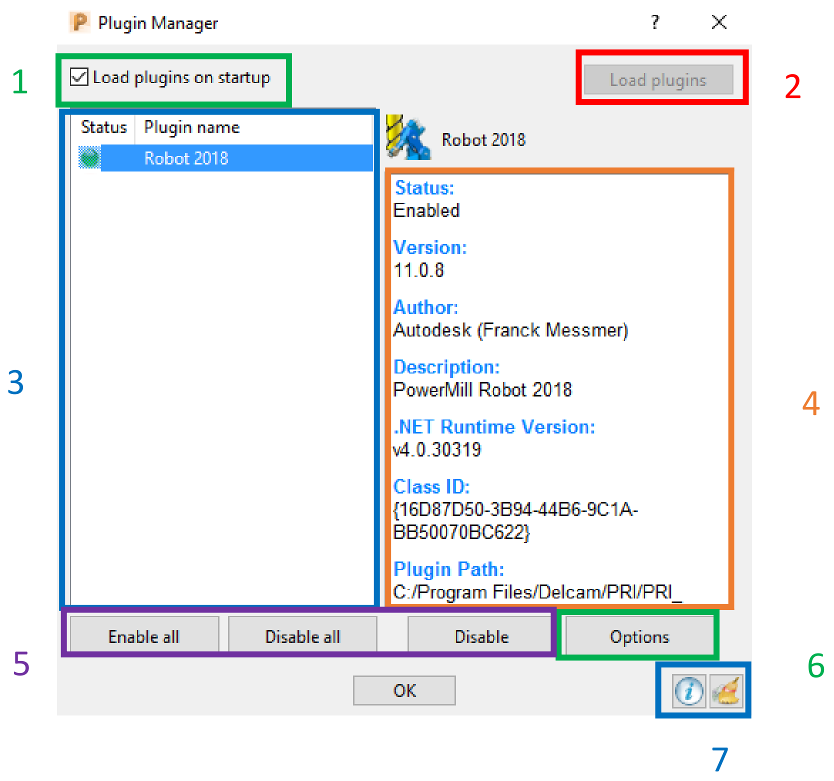


The Plugin manager allows the user a range of controls over the Plugins that have been registered within PowerMill.

To access the plugin manager simple right click on the white area after the last pane, and select Manage Plugins.



You can open the Plugin Manager at any time while PowerMill is running as demonstrated above.



This form has several sections to it:

1 Option to control if PowerMill searches for and runs plugins on startup.

2 One off control to load plugins if not loaded on start up.

3 The name and status of each of the Plugins that have been registered with PowerMill.

The status icon to the left of the name indicates whether or not the Plugin is enabled or disabled.

The green circle indicates the plugin is enabled while the red circle indicates that it is disabled.

A grey status icon indicates that the Plugin is corrupt or incompatible with the current version of PowerMill, information about why this may be the case is listed in area 2.

4 Information about the plugin such as its name, description, location, author and Global Unique Identifier (GUID).

Any errors affecting the plugin will also be listed here with potential solutions.

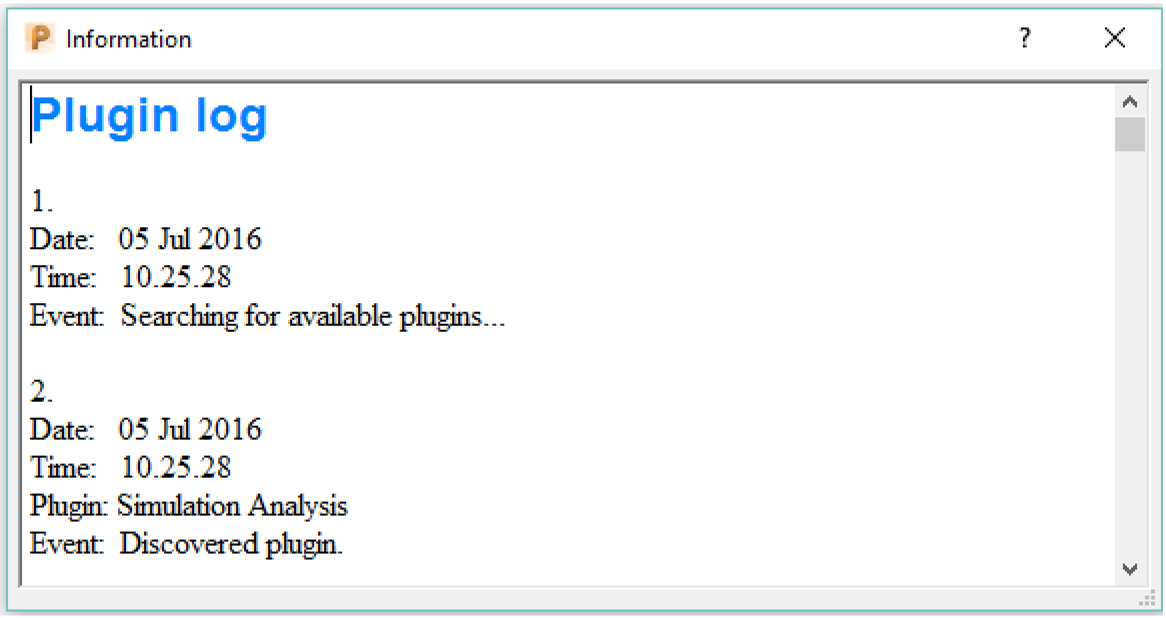
5 Options to enable or disable the Plugins.

Disabling Plugins could potentially improve PowerMill's performance or remove unnecessary items from the user interface, depending on the Plugins functionality, without removing the Plugin entirely.

6 Access to the options form for the selected plugin

Below the enable/disable/options is information about the operation of the plugins.

7 The Plugin log file, this contains information about when the Plugins were loaded and what events they are subscribed to in PowerMill, the Plugin manager also provides users with the ability to clear this file for convenience.



Layout and Workflow

PowerMill Robot is organised to allow the user to follow a structured workflow, detailed below, through the preparation of a process for the robot. This training manual assumes the user has some experience with PowerMill and so toolpath calculation will not be covered.

1 Create the toolpaths for the robot to follow.

2 Select the robot that will be used.

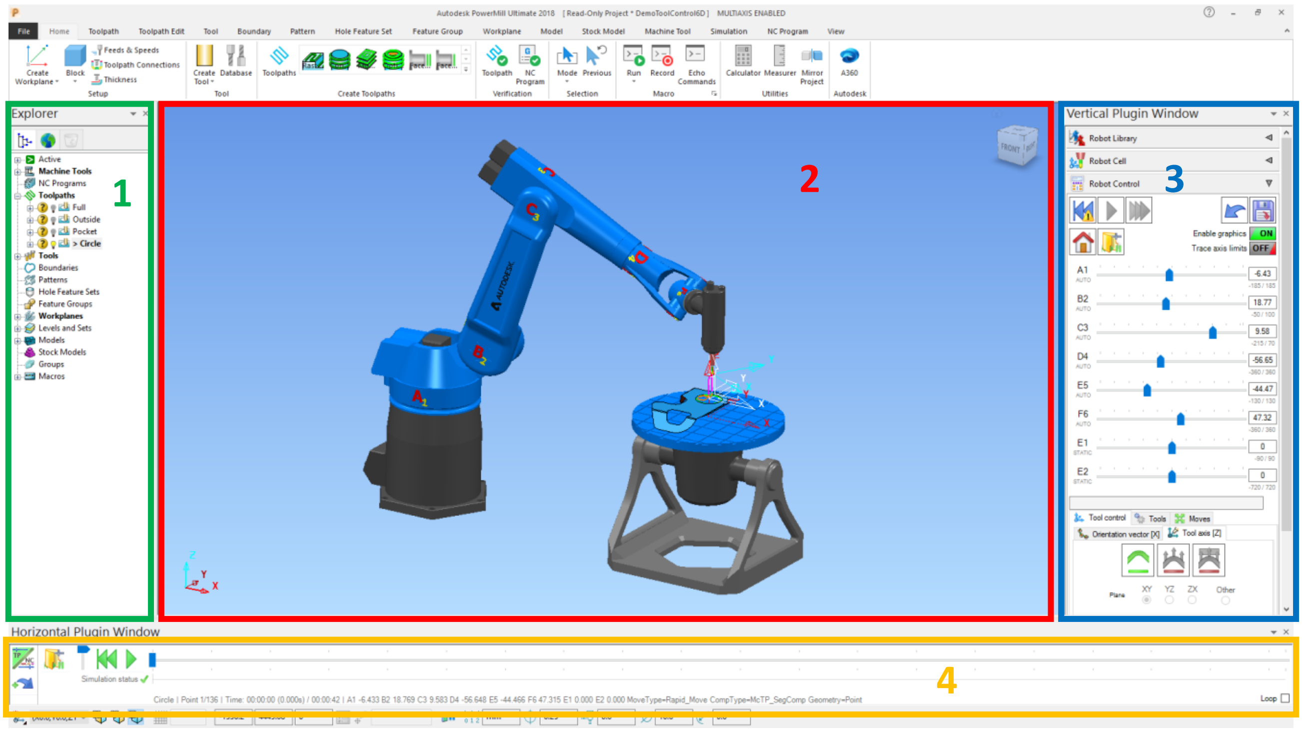
3 Align the CAD in the virtual robot cell.

4 Constrain the robot and simulate the toolpaths.

5 Write the NC Program.

The toolpaths must be simulated in PowerMill robot before they can be output to the robot's native language.

The image below highlights the division of the tools into their separate areas.



1 The solution explorer contains the tools and entities that the user requires to create, calculate and limit PowerMill toolpaths.

2 The graphical area is common to both PowerMill and PowerMill Robot and allows visualisation of the processes being created.

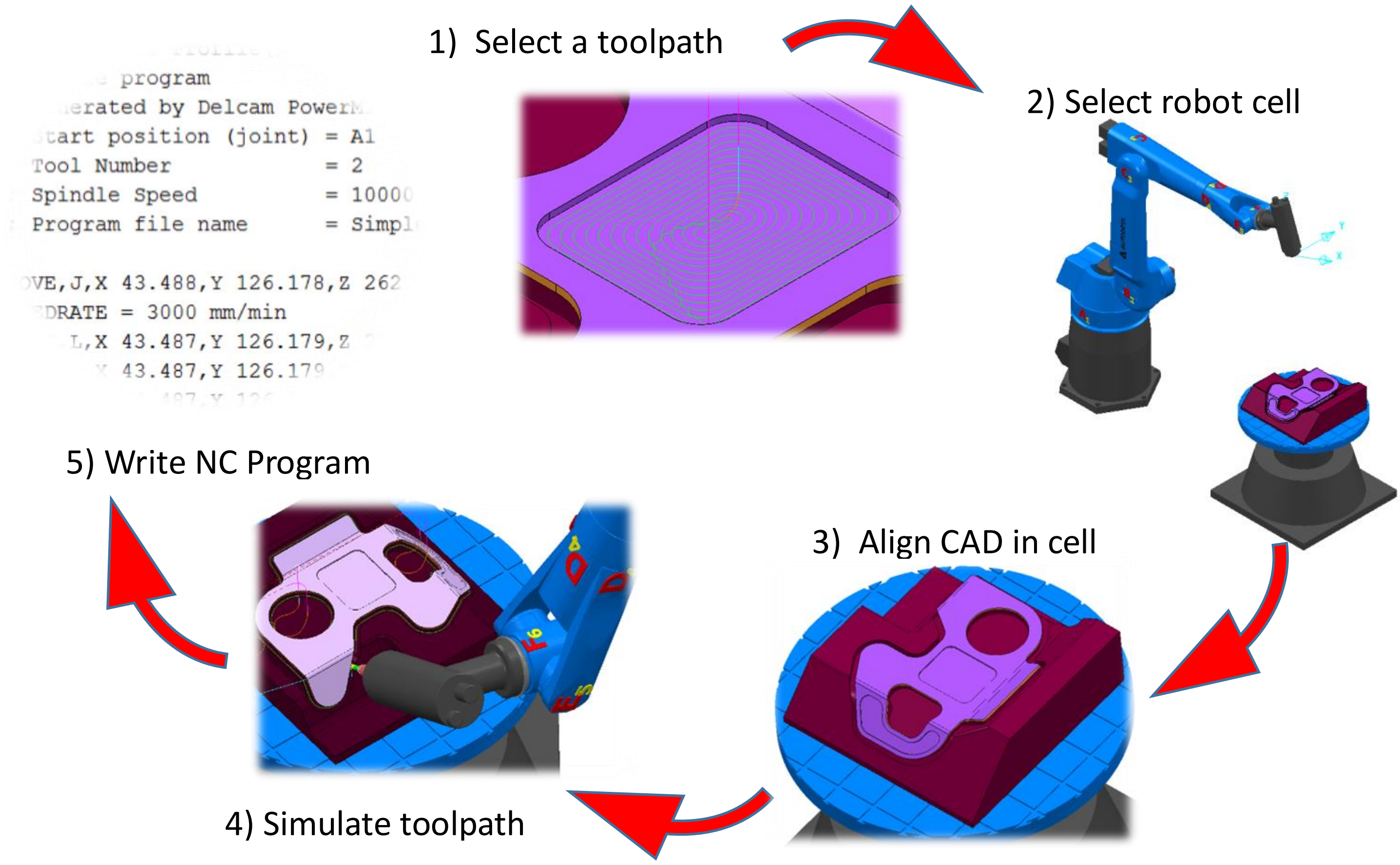
3 The PowerMill Robot tabs area, contains all the options for constraining the robot's motion. This is subdivided into 4 tabs for the robot plugin. Each containing controls required for a particular stage of the workflow.

4 The PowerMill Robot Simulation toolbar contains controls allowing the user to replay saved robot simulation files and view the analysis of the saved simulations.

Workflow

PowerMILL robot has been developed to allow users to follow a prescribed workflow.

The idea and general structure of this workflow is outlined in the diagram.



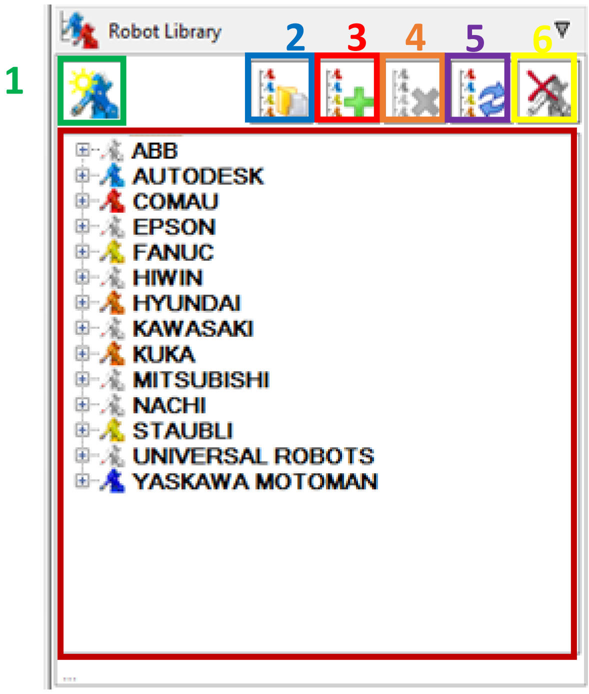
PowerMill Robot Menus

PowerMill Robot is divided into 5 sections, with controls divided according to their position in the workflow.

Robot Library Tab

Once the toolpaths have been created the next stage of the process is to select the robot that will be used to complete the process.

The robot library provides an area to store all the robots available to the user. By default, the standard robots are displayed for training purposes but these can be hidden from the options menu in order to simplify the interface.



1 Show/Hide the robot cell. Has no effect on simulation simply toggles the display status of the robot in the graphical interface to improve visibility of the part.

2 Open robot library, provides quick access to the folders containing the robot library and the currently loaded robot as well as access to the list of user defined robots in the library. The list can be edited to remove robots from the library when they are no longer needed.

3 Add a new robot to the library, opens the form to add a new robot to the library.

4 Remove robot from the library

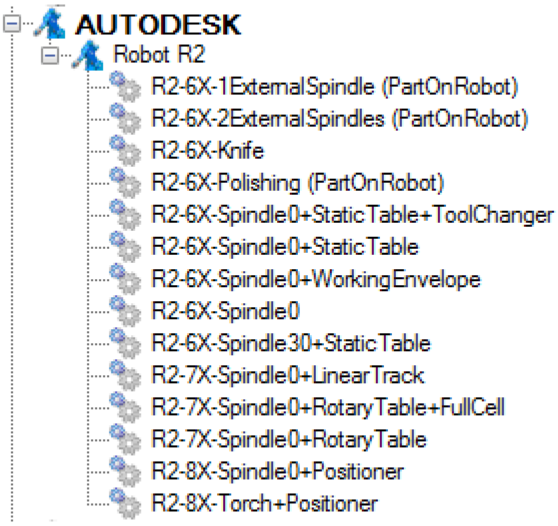
5 Refresh the library, if changes are made to any of the robot library files this button may be required before the changes will take effect in the library.

6 Unload the robot, unloads the current robot used in simulation.

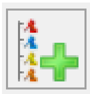
7 Available robot list, this lists all the robots currently saved in the Robot library and allows the user to switch between robots by double clicking on the name of the robot to be used.

The standard robots in the library are separated by manufacturer and sub divided by model, with the library able to support multiple configurations of each robot model.

The divisions in the library are controlled by the file structure, the standard method of dividing up the robots by model is recommended as they can share common CAD components and therefore reduce the storage space required.

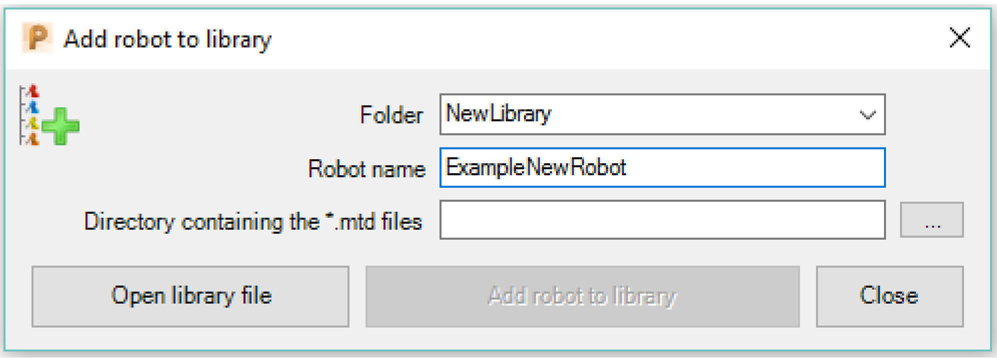


Adding a new Robot to the Library

1 On the Robot Library pane select Add a Robot to the library 

2 In the dialog that appears **NewLibrary** enter the name that will appear as the main point on the robot list

3 Displayed below as **ExampleNewRobot** enter the Robot name.



4 Select the folder that contains the mtd file to be added

5 When the folder is correctly selected the button Add robot to library is activated

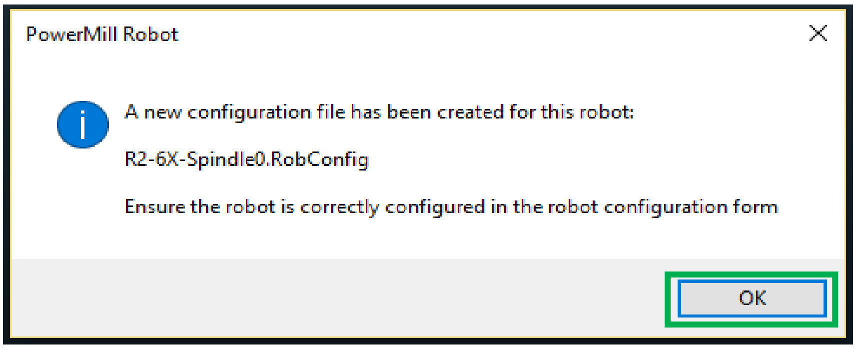
If the add robot library button is not active, this means that the wrong folder has been selected.

6 Select Add the robot to the library.

A new folder has now been created in the PowerMill robot library called **NewLibrary**, containing the subfolder **ExampleNewRobot**, currently containing a single configuration of the robot with the name drawn from the name of the .mtd file, in this instance **R2-6X-Spindle0**.

When point 6 above is complete and the robot exists on your library, you may select the robot form the list. This is done by double clicking the desired robot, you may double click anywhere within the box below. This will import into PowerMill the machine tool.

If it is the first time the mtd file is added to PowerMill the menu below will open automatically. After acknowledging the menu by clicking ok a new menu will then open. This is known as the Robot Configuration menu, it is responsible for creating the RobConfig file. This file together with the mtd file will define correctly the robot in PowerMill Robot.



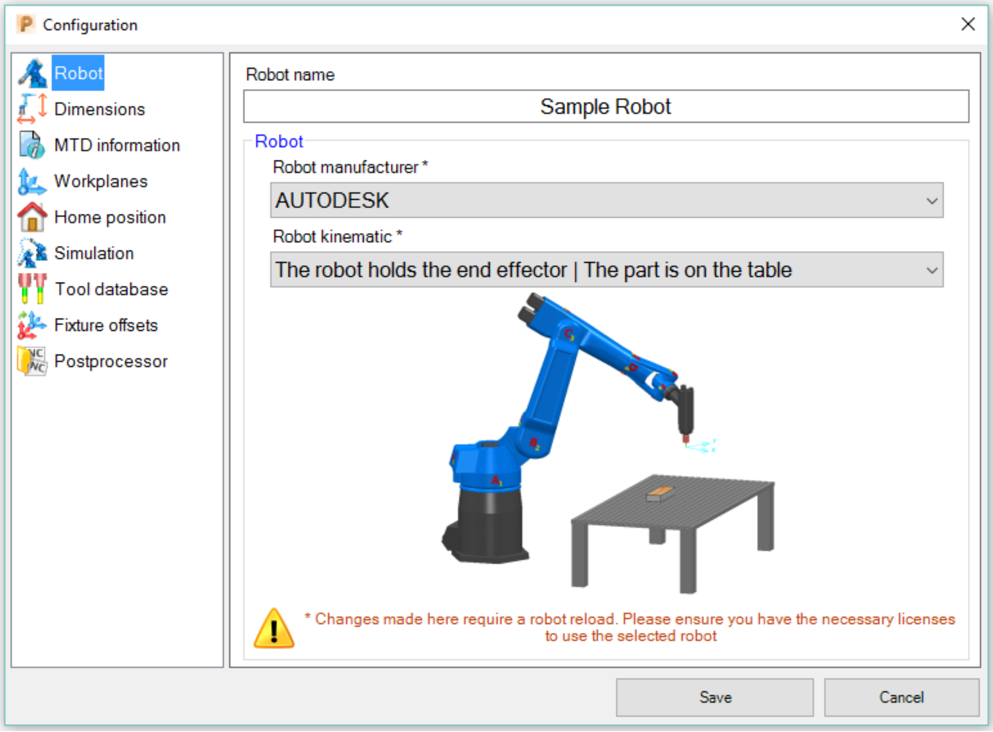
1

To Follow the steps and read the explanations go to page 24 of this document.

Any errors made on the menus may result in serious errors while running the file on the robot.

This menu is responsible for defining the Robot Manufacturer and Post Processor selection amongst other things.

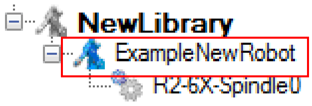
Depending on the options selected in this menu the correct functioning of PowerMill Robot can be put at risk.

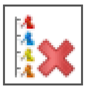


To Follow the steps and read the explanations of each tab go to the chapter Robot Configuration Form of this document.

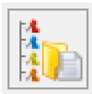
Removing robots from the library

1 To remove a robot from the library select the robot



2 Use the Remove robot from library button 

1 To remove more than one robot or to edit a list with various entries of robots

2 **Open Library Folder** .

3 From the menu that appears select **Open user defined robot library file.**

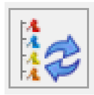
The first time you open this file you are required to select a program to open this file, select a text editor such as Notepad++ or WordPad.

This file lists all the custom robot cells available in the robot library.

4 Select the whole line defining the robot we added to the library. It should appear similar to:

<Robot Folder="NewLibrary" Name="ExampleNewRobot" MTDDirectory="*\PowerMillRobotTrainingData\Interface\RobotLibrary" />

5 Delete this line, starting at < ending at />. Save the file.

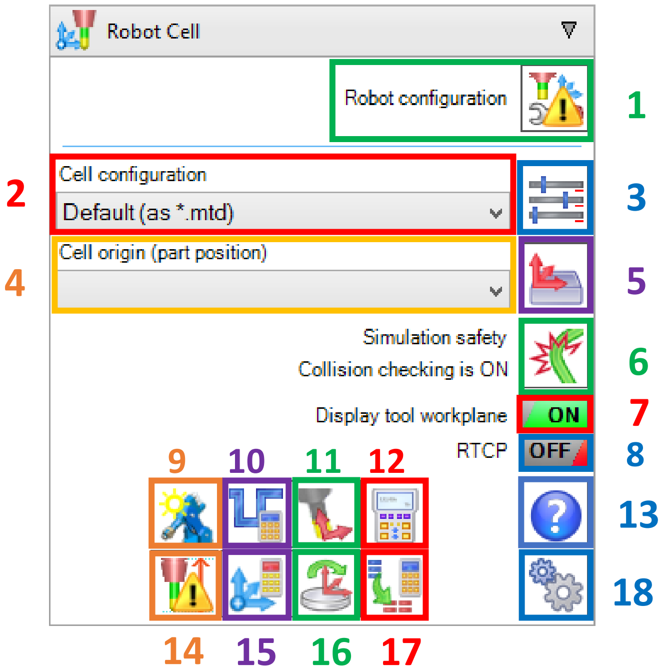
6 Click the Refresh Library button in PowerMill .

7 The robot has now been removed from the robot library.

Robot Cell Tab

The robot cell contains information about the cell configurations and allows control over the default behaviour of the robot and the simulations.

Many of the tools are only required during installation or calibration of a robot.



Key:

1 Robot Configuration options, this contains information required to ensure the output from PowerMill Robot can be interpreted by the robot controller. It is not expected that these options will be modified during normal operation of the software. This menu is respondible for the creation the RobConfig file, editing the RobConfig file should be done via this menu.

2 The cell configuration combo box allows the user to choose between configurations the user has previously created.

3 The Robot cell configuration editor allows the user to create new cell configurations or edit existing ones. The user can control cell default behaviour such as tool or part attach points, axis priorities, limits and home positions as well as simulation defaults such as the default tool axis constraints.

4 The cell origin combo box allows the user to select which PowerMill workplane positions the part correctly.

5 The Part Positioner allows the user to accurately position a part based on measurements taken directly using the robot and the teach pendant.

6 The simulation safety settings allow the user to control whether the simulations are checked for collisions between any machine parts or the part itself and control the response and reporting of any singularities that may occur.

7 The display tool workplane option determines whether the workplane at the tip of the tool is visible in the graphics window, this is useful when determining suitable orientations of the tool for sections of toolpath.

8 The Rotation Tool Centre Point (RTCP) option when enabled will lock the position and orientation of the tool relative to the part, any jogging of the robot from the robot control tab will change the axis positions without altering the position or orientation of the tool.

9 Show/Hide the robot toggle button

10 The Speed unit converter provides a useful tool to allow the user to easily convert speeds from one unit system into other commonly used systems.

11 This option allows the user to create a workplane aligned to the tool workplane in its current location.

12 The Virtual Teach Pendant provides the user with a tool similar to the pendant attached to a robot cell to control the virtual cell. This allows the user to teach the robot paths in an offline environment without the need for creating a toolpath. There are also options to view tool position/coordinates and reorient the tool to improve the process the robot is completing.

13 The help icon provides a second path to access the PowerMill Robot help files, license options and options form.

14 The Tool and Spindle Calibration form is used to accurately measure the Spindle centreline and position. This allows the user to accurately calculate the tool centre point of new tools using just the protruding length of the tool from the reference surface.

This method of measuring tools is more accurate than standard TCP measurements as it can use the average of several measurements to determine tool attach point and tool axis vector and simplifies the introduction of new tools as the user only requires a length scale.

15 The workplane calculator provides an interface to view the transformations required to convert the position of one workplane to another. Links to this interface can also be accessed from the Fixture Offset Database and the Tool Database to allow tools and fixtures to be added to the respective databases.

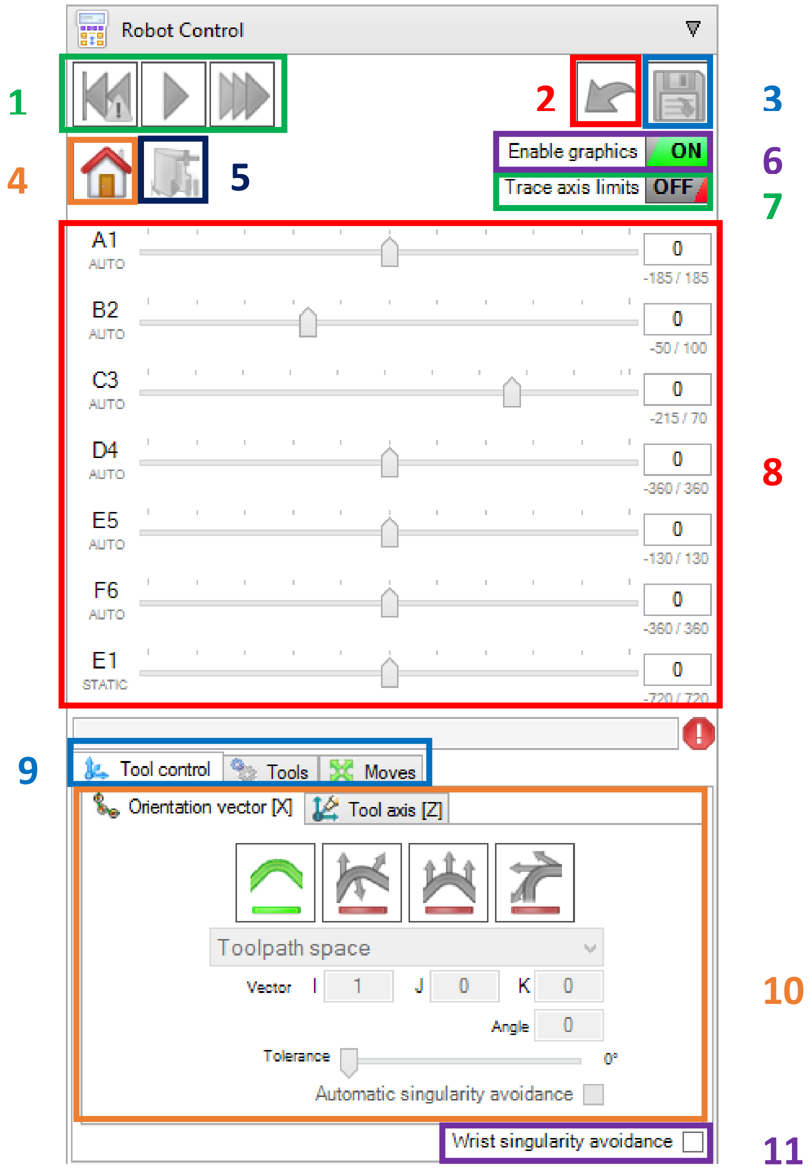
16 The rotary table calibration form provides an interface to enter measurements of 3 points around the axis of the rotary table in order to calculate the centre of rotation and the axis of rotation. This information can be used to update of the .mtd file to accurately represent the cell.

17 The transformation converter converts between standard rotation transformation formats to allow interpretation of orientations reported by the robot.

18 Access to the options menu.

Robot Control Tab

The robot control tab provides methods to control the movement of the robot as it simulates the toolpaths. It also contains direct controls for adjusting the robot axes positions.



Key:

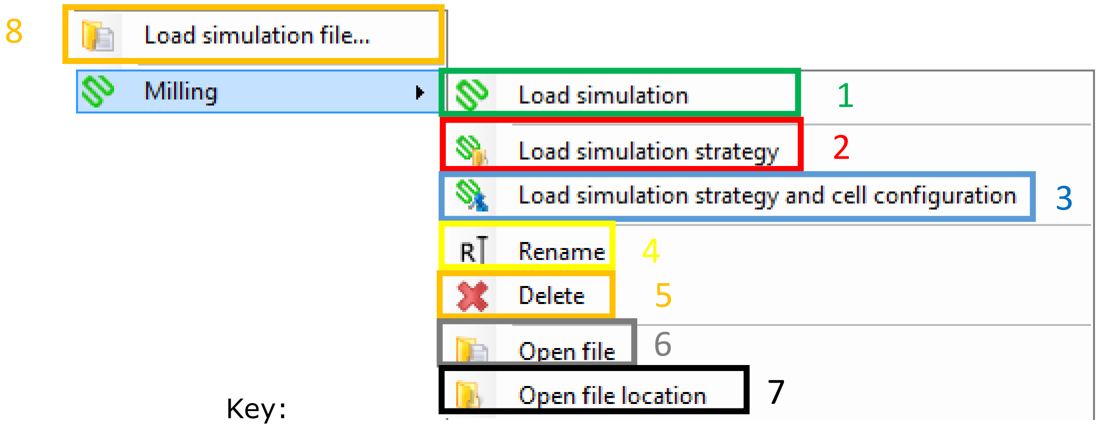
1 The simulation controls allow the user to attach to the start point of the toolpath, play through the simulation or perform a fast play through.

2 The return to simulation start option allows the user to return to the start of the previous simulation restoring the robot axes to the exact positions they were in at the start of the simulation.

3 The "Save Simulation" button allows the user to save the simulation as a Robot simulation file, required to write the robot program.

4 The return to home button restores the robot to the home position for the current robot configuration.

5 Allows the user to access a few options related to simulation files created previously.



Key:

1 Load simulation file

2 Load simulation contraints (priorities, tool contraint etc)

3 Loads same as 2 plus cell configuration

4 Rename the simulation file

5 Delete the simulation file

6 Open simulation file

7 Open folder where simulation file is located

8 Provides back track compatability for older versions of PM Robot

6 The enable graphics option allows the user to toggle whether the simulation is visible in the graphics window.

Running with graphics disabled will speed up the simulations but will not give the user the ability to watch for possible problems with the process. The full reporting of errors will still be available in the simulation toolbar once the simulation is saved.

7 The trace axis limits tool will add visual ranges to the axis position bars to show the travel that each undergoes during a process. This aids with optimisation of a process.

8 The axis position controls report the current robot position along with an indication of its proximity to its axis limit positions. Information about the axis address and priority are also listed on the left hand side of this area.

The axis priorities and axis limits can be modified from this area by right clicking on these values in this area.

9 The options tabs provide access to:

i. Tool Control – allows control of tool orientation

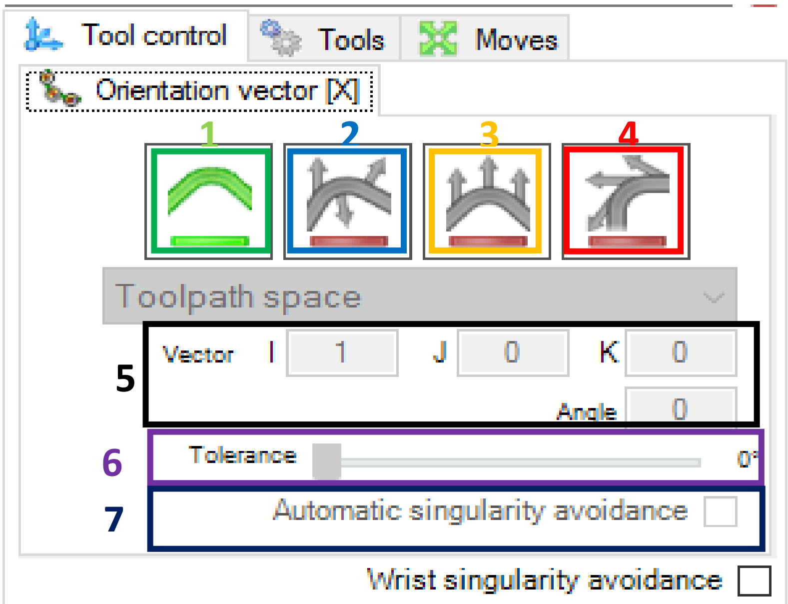
ii. Tools – provide various advanced tools

iii. Moves - manipulating the robot arm's position

10 The Tool control menu

Provides a number of options for controling the orientation of the robot head using either the orientation vectors or the tool axis.

There are 4 constrain types in the orientation vector [X], free, Orientation vector, vector and follow. These control the X component of the tool workplane.



Key:

1 Free: The robot is able to use any orientation to reach each point on the toolpath.

2 Align to Orientation Vector: At each point the x-axis of the tool workplane should align to a given orientation vector. The toolpath must have orientation vectors before the user can use this option, these will be covered in more detail in a later chapter.

3 Align to a vector: At each point in the toolpath the x-axis of the tool workplane will be forced to point in a fixed direction defined on this menu of the PowerMill robot.

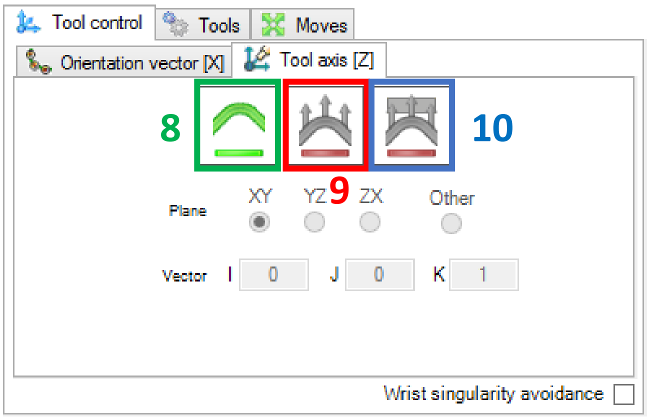
4 Align to Direction of travel: The x-axis of the tool vector is forced to follow a direction defined relative to the direction of travel.

5 This will show the vector IJK values if the Vector option isused. The values can also be set manually by numerical input.

6 Toleance will allow the simulation to diverge by from the setting used

by the degree that is displayed when the slider is dragged along.

7 Automatic Singularity avoidance will provide a toolpath free of singularities.



Constraints to control the tool axis [Z], relative to the robot world workplane.

These tools are only available when using a robot with one or more external axes.

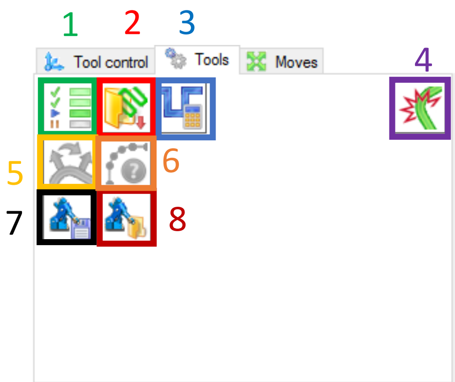
8 Free constraint, the tool axis vector is not controlled.

Vector constraint, the tool axis is limited to a specific vector, relative to the robot world workplane. Vector values for IJK can be entered.

9 Plane constraint, the tool axis is constrained to a user defined plane.

11 The automatic wrist singularity avoidance option allows PowerMill to reorient the robot to prevent alignment of axis 4 and 6, improving the consistency of the robots speed. Singularities will be covered in more detail in a later chapter.

The Tools tab provides various advanced tools



1 Simulate multiple toolpaths allows the user to simulate various toolpaths. Details on this menu are below.

2 The NC File import option allows the user to read in a pre-created NC program for use in PowerMill Robot.

3 The Speed unit converter provides a useful tool to allow the user to easily convert speeds from one unit system into other commonly used systems.

4 The simulation safety settings allow the user to control whether the simulations are checked for collisions between any machine parts or the part itself and control the response and reporting of any collisions that do occur.

5 The edit orientation vectors options provides tools to modify the orientation of the tool at different points along the toolpath. Orientation vectors will be covered in more detail in a later chapter.

6 The display number of points option gives information about the number of points contained in the active toolpath. This can be useful when working with controllers that have a limit on the number of points a file can contain.

7 The Save robot position options allows the user to create a collection of saved positions for the robot that can be loaded for use with later toolpaths.

8 The load robot position option allows the user to load robot positions previously saved by the user.

The Toolpath simulation allows the simulation of multiple toolpaths in one go.

1 Select all

2 Deselect all

3 Reverse selection

4 Start Simulation

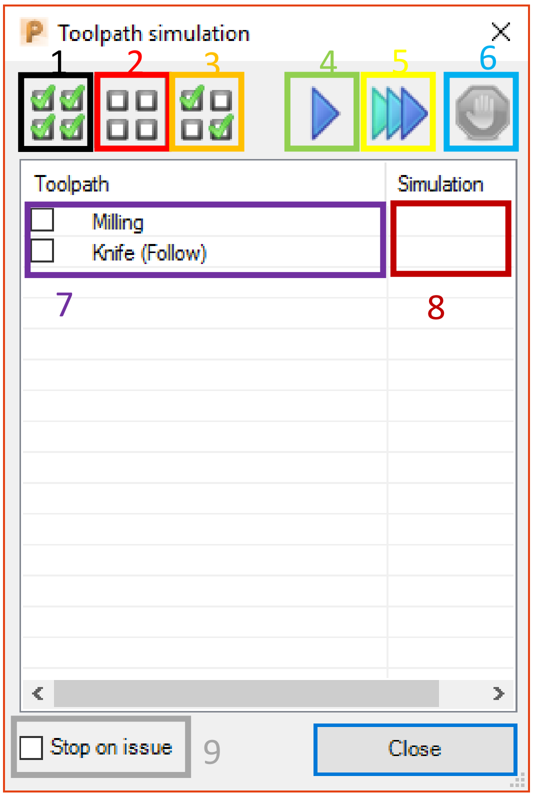
5 Start Simulation in fast speed mode

6 Stop simulation

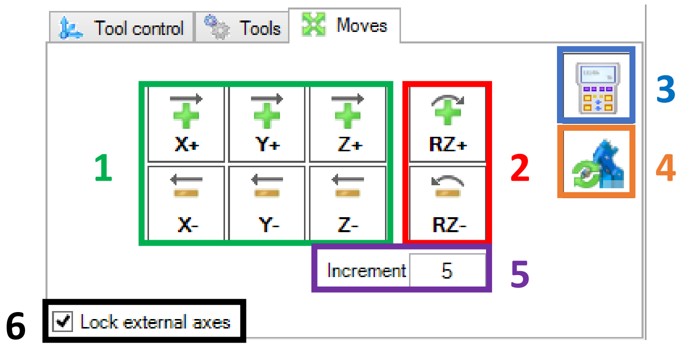
7 Toolpath list

8 Simulation file details

9 Stop on issue



The Moves tab provides manipulating tools to change the robot arm's position



1 The linear jog controls move the tool linearly relative to the tool workplane.

2 The rotary jog controls rotate the tool about the z-axis of the tool workplane.

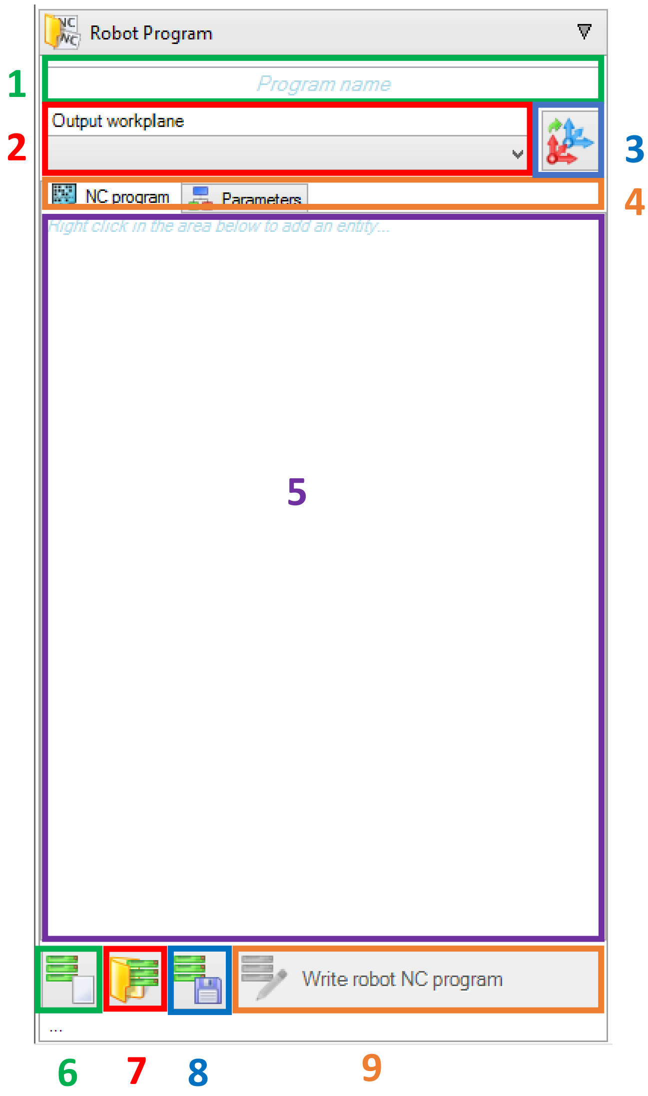
3 The Virtual Teach Pendant provides the user with a tool similar to the pendant attached to a robot cell to control the virtual cell. This allows the user to teach the robot paths in an offline environment without the need for creating a toolpath. There are also options to reorient the tool to improve the process the robot is completing.

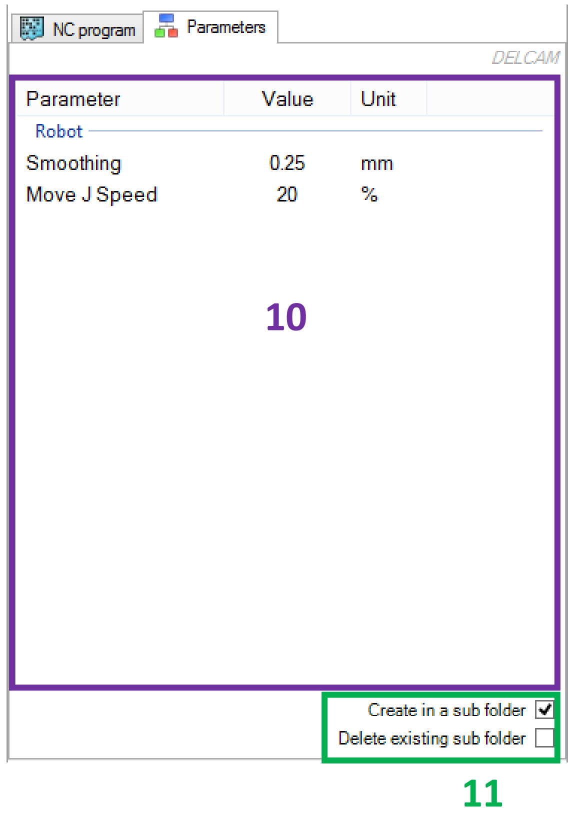
4 The reverse the wrist option allows the user to switch between the 2 wrist orientations that are capable of achieving a given tool position and orientation.

5 The Increment Option allows the user to control the linear distance or rotation angle the robot will undergo when one of the jog controls is used.

6 The lock external axes option allows the user to control how the external axes behave when jogging the robot from this tab.

Robot Program Tab





Key:

1 The robot name text is used as a name for the created program if no name is entered, preferably an identifiable name should be used.

> *Program names must start with a letter to be run correctly by a number of robot manufacturers.*

2 The output workplane selection determines where the coordinates of each point are measured from. Workplane will be output as number1.

3 The fixture offset database allows the user to choose the way PowerMill robot outputs locations for the robot program. The fixture offset database will be covered in a later chapter.

4 The NC program tab shows the program to be created and the parameters tab provides access to user parameters that can be output in the robot program.

5. The NC program space contains the simulation files and transitions that will be written into the robot program, the order in which they will be performed, and the tool the robot will use.

6. The create new NC Program will create a new Robot NC Program for the PowerMill project.

7. The load NC Program option will allow the user to load an NC program created previously, allowing the user to save multiple NC Programs for the project.

8. The save NC program allows the user to save the NC Program they are currently working on.

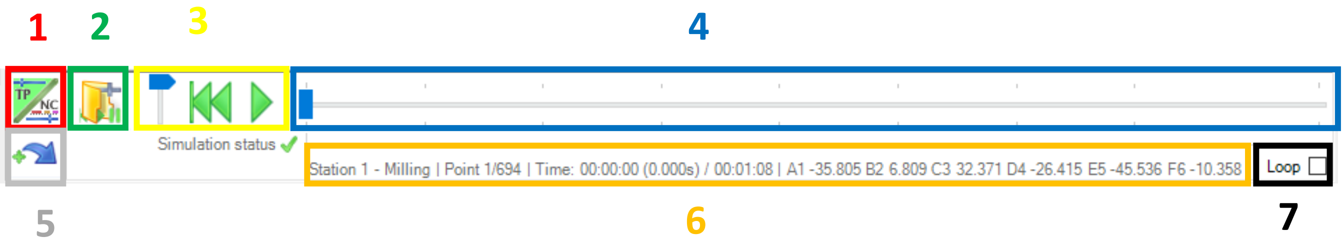
   Saving the NC Program will not write the NC program.

9. The write robot NC program creates all the files necessary the user has to load onto the robot controller to run the NC program.

10. The Parameter area allows the user to modify the user parameters that will be written into the robot program.

11. The sub directory options controls whether the NC program is created within a sub directory of the output location and whether any existing sub directories or files are deleted when the NC program is written.

Simulation Replay Toolbar



Key:

1 Toolpath/NC program toggle switches between the simulation of the individual toolpath and the NC program.

2 Allows the user to access a few options related to simulation files created previously.

3 On the previous Robot Control Tab description, point 5, this option is discussed in detail.

4 Simulation controls control the replay of the toolpath.

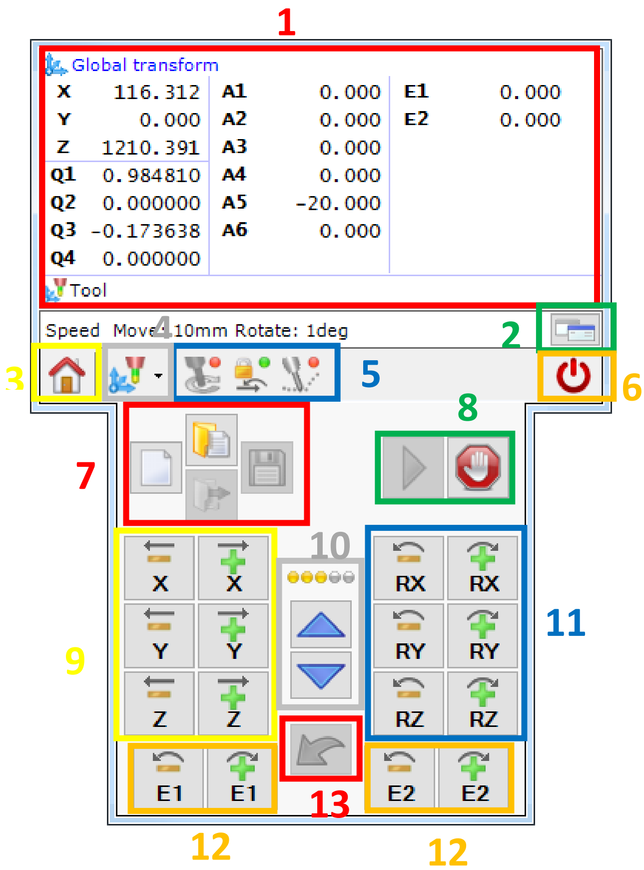
5 Simulation replay bar shows the position of the current point with in the overall simulation and allows the user to dynamically control the replay of the simulation.

6 Expand simulation status control expands upon the simulation status and displays any erros that may be present.

7 Simulation information contains detailed information about the toolpath.

8 Loop option allows the simulation to be replayed automatically when the end is reached.

Virtual Teach Pendant



Key:

1 Position display listing tooltip position, orientations and robot axis angles. These values are editable to allow the tool to be accurately repositioned.

2 Toggle between pages allows the user to access the tools for applying point parameters to the toolpath points.

3 Home the robot sends the robot to it's home position.

4 Workplane selection allows the user to select which work plane the controls will move the tooltip relative to.

5 Options to control whether the tooltip is allowed to move as the axes are rotated, control whether the external axes move when the robot is jogged and whether the path of the tool is traced.

6 Close the Virtual teach pendant.

7 Transition controls, clockwise from top: Load an existing transition file, save the current transition as a Robot Simulation file, Close the current transition and Create a new transition.

8 Play and stop the current robot motion.

9 Jogging controls, jog the robot parallel to the principal axes of the currently selected workplane.

10 Speed controls, control the speed of the movements between points in the transition.

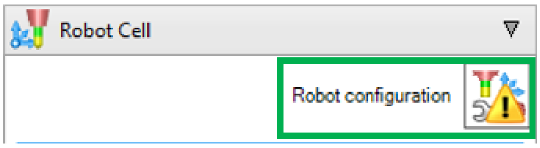
11 Rotate controls, rotate about the axes of the tool workplane.

12 External axes controls, jog the external axis.

13 Undo the last movement controlled through the virtual teach pendant.

Robot Configuration Form

The Robot Configuration form can be found in the robot cell tab and stores information about the robot and the default behaviour for the specific robot cell including how the toolpaths are written to the robot's native language.

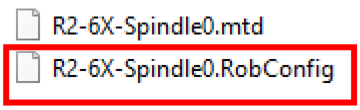


The configuration manager stores the settings of the robot divided by the type of setting.

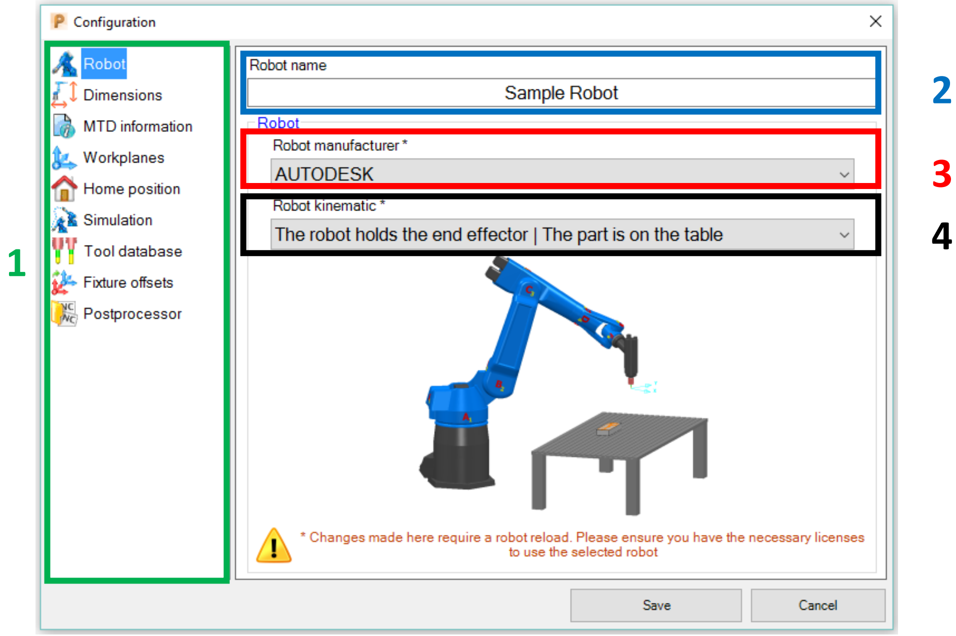
At any time the settings on the Robot Configuration Form might be changed/edited.

The mtd and RobConfig file together are responsible for the correct definition of the robot in PowerMill Robot.

The Robot Configuration Form is responsible for the creation of the RobConfig file.



Robot Page



Key:

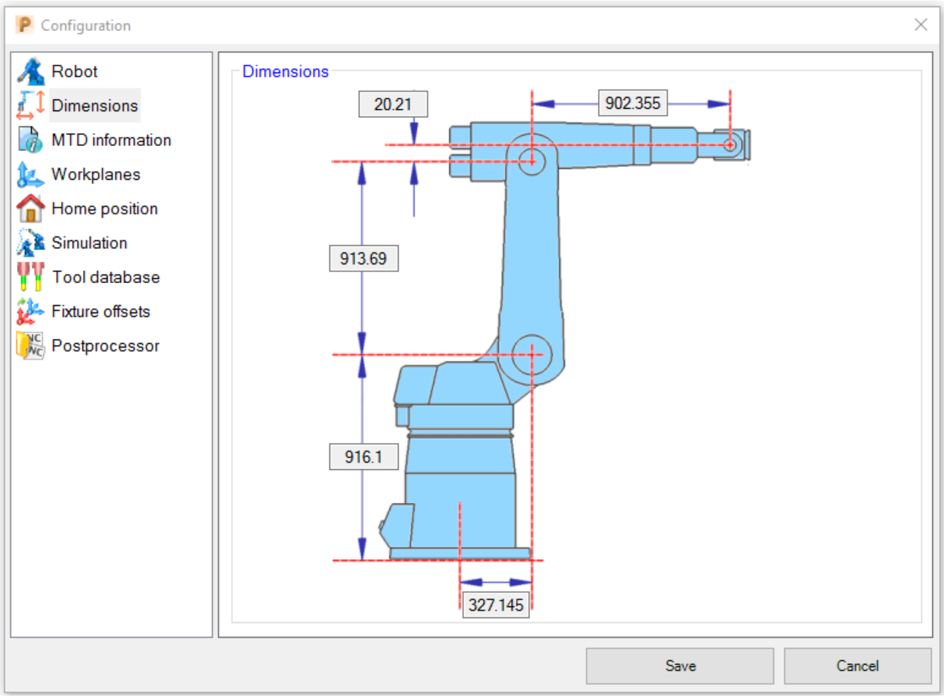
1 Configuration form navigation pane, used to move between the separate pages of the Configuration form.

2 Enter a descriptive name for the robot.

3 Select the manufacturer of the robot, this is important as it will determine which postprocessor files are available and which configurations are used for workplane orientations and transformation conventions.

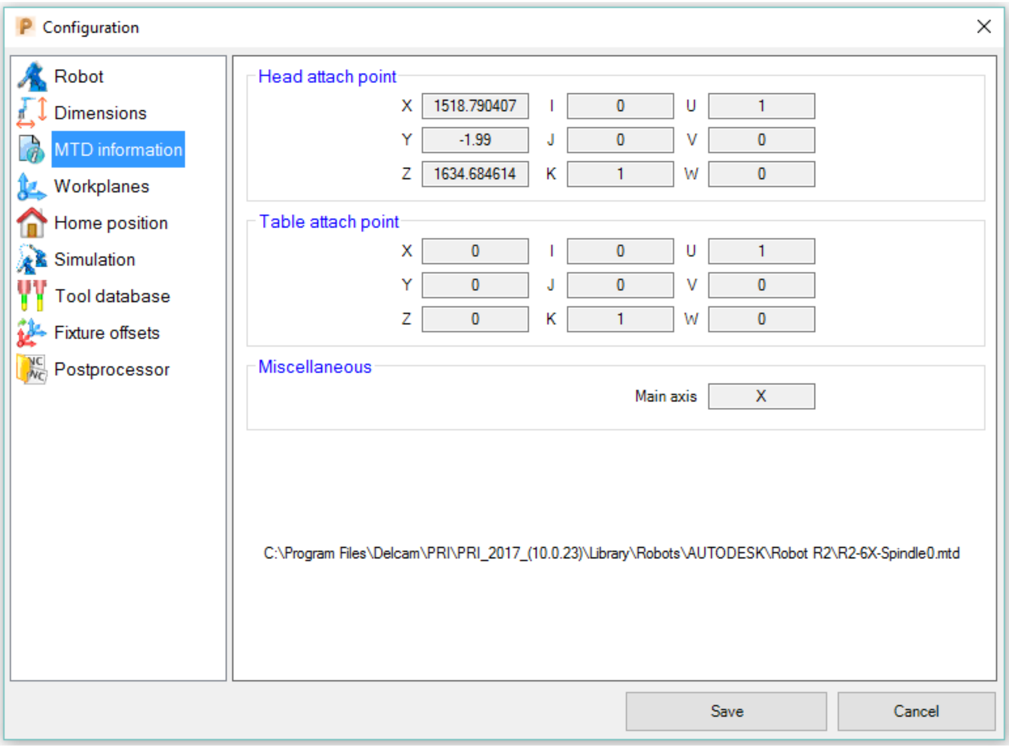
4 The robot kinematic determines whether the robot is holding the tool or the part.

Dimensions Page



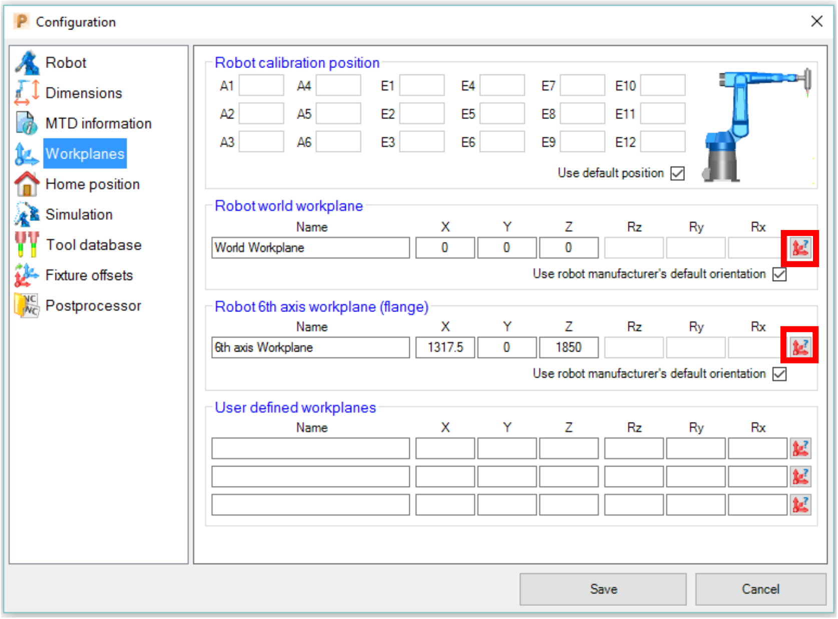
The dimension's page contains measurements, extracted from the mtd file, that allow the user to confirm the robot is the correct model by verifying the vital dimensions.

MTD Information Page



The MTD information page lists information about the key locations of the tool attach point on the robot and the location of the global transform, relative to the Robot World Workplane

Workplanes

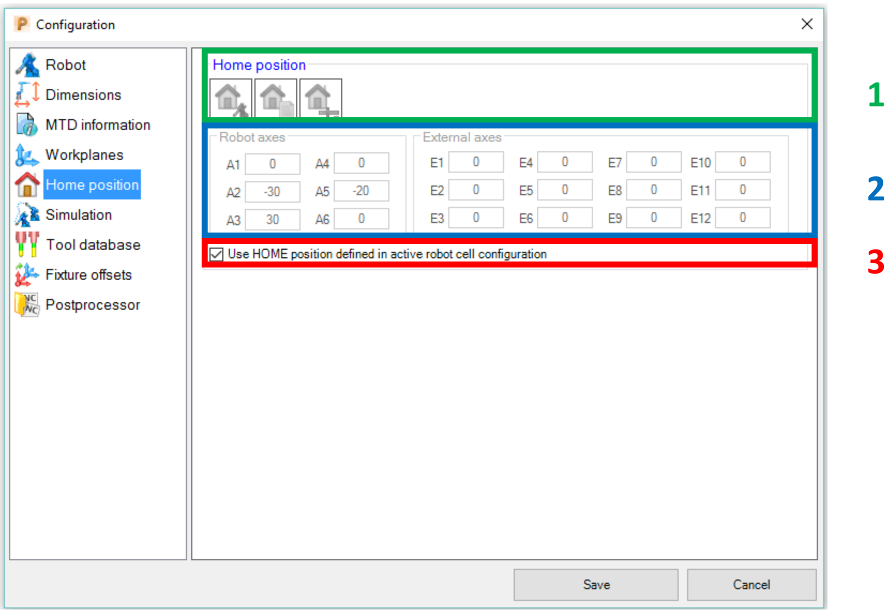


The workplanes window allows you to define workplanes relative to the robot base (the coordinates are measured relative to the origin of the exported CAD model). This allows the user to check the positions of workplanes defined in real world cells and use them as outputs in the robot code or for positioning parts.

The information about the robots 6th axis workplane is also stored here and is used when writing any tool information into the robot code.

On the right hand side is the check (**Red** Square in image above) position button allowing the user to visualise the workplanes they have created.

Home Position



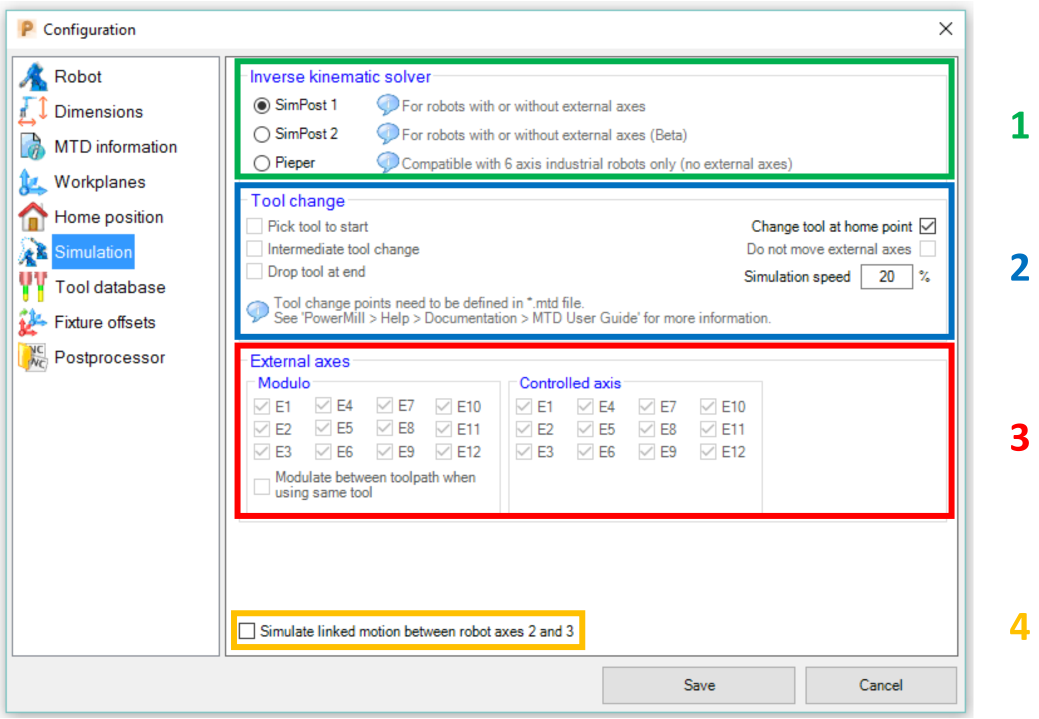
Key:

1 These options allow the user to load into **2** a predefined home position, using either the current robot position, the position defined in the machine tool definition or use a position defined in the active cell configuration.

2 These options display the Home Positoin, and allow the user to manually enter or modify the home position of the robot.

3 This option sets the home position to always be the same as the one defined in the current cell configuration. This will grey out the other controls on this page.

Simulation



Key:

1 These options determine which Solver will be used by the software. SimPost solvers are compatible with up to 12 external axes, whereas the Pieper solver is only compatible with 6 axis robots with no external axes.

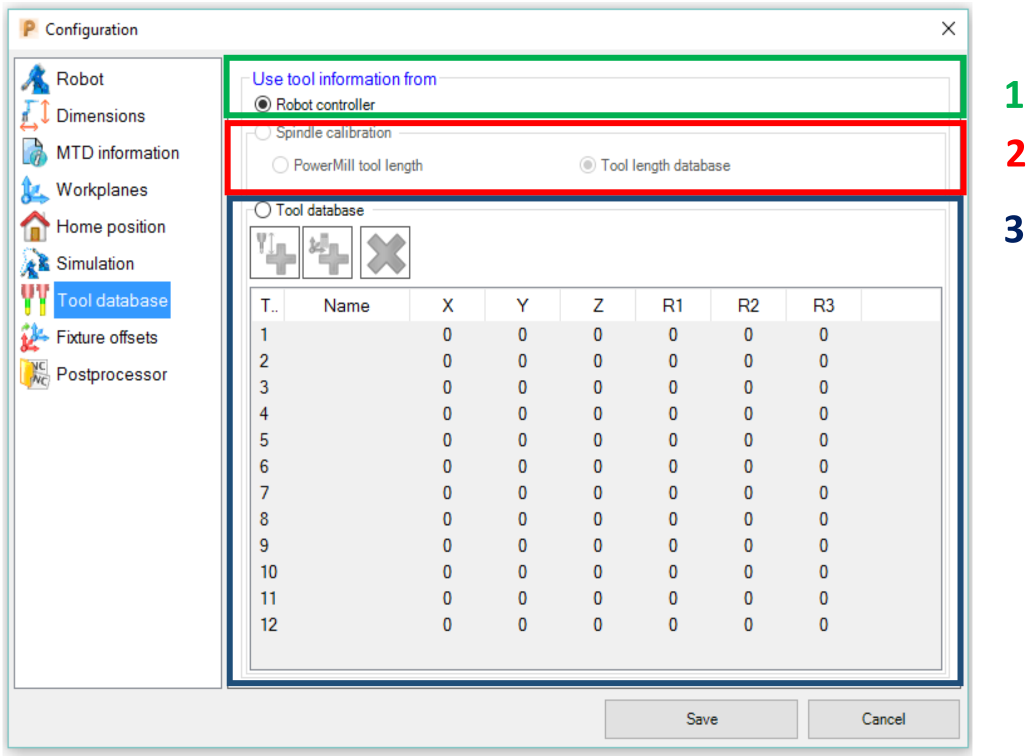
2 These options deal with how tool changes are simulated in the software. The tool change processes must be defined in the mtd file and there are examples of these in the PowerMill Robot library.

3 The Modulo controls determine whether sending the robot to it's 0 position will instead send it to the nearest full rotation 0 position.

The controlled axes determine which axes the robot has control over in PM Robot.

4 This option determines the kinematic of the robot. Parallel robot arms that keep the top section of the arm at the same angle relative to the ground during movement of axis 2 must have this option selected in order to simulate correctly.

Tool Database



The tool database page allows the user to choose where the tool information used by the robot comes from. This choice will also affect what type of output will be in the postprocessed file. There are 3 options:

1. This option relies on the Tool data saved on the robot controller, PowerMill **will only output a tool number** to the code. This will be used by the controller to specify what tool data is used, the relevant tool data is read from the robot's tool database.

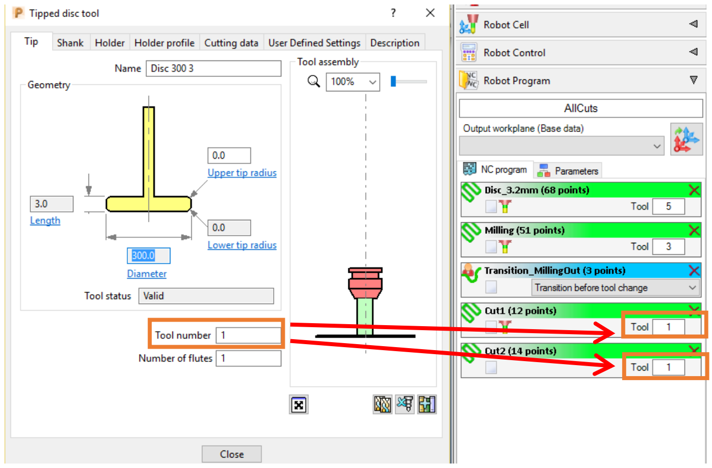
2. This option implies the "tool and spindle calibration" procedure has been completed. This option is only avalible if the procedure has been completed and the data stored.

   Tool data will be written on the file that will be loaded and run on the robot.

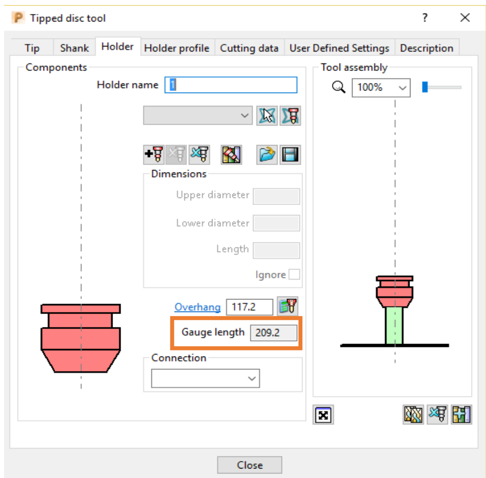
   The tool and spindle calibration allows the user to **output the Tool data**, only having to measure the Gauge length.

   PowerMill Tool database or PowerMill Robot database can be used for getting the tool length.

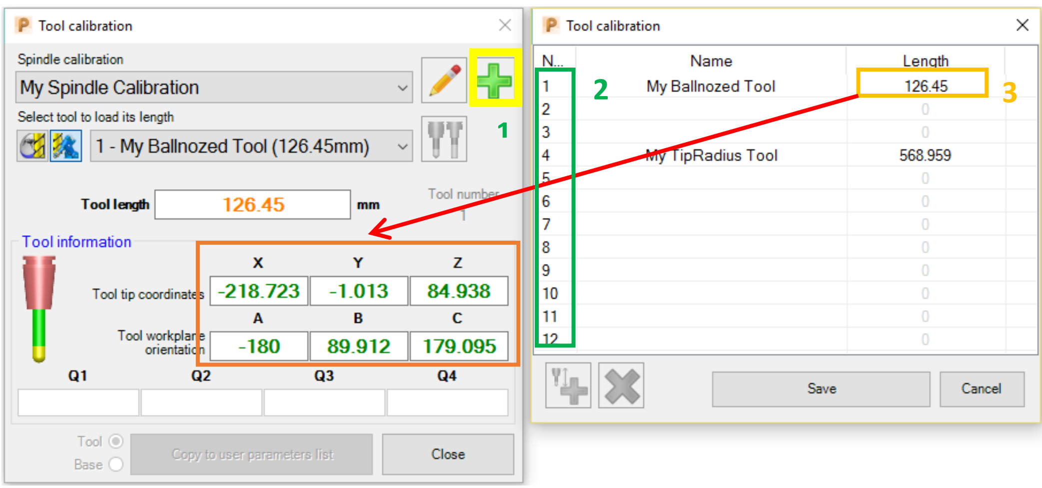
If using PowerMill Tool database make sure the tool number is correct, as this will be used to define the tool number in the NC program tab.



The Gauge length is used to calculate the Tool Data, so make sure the tool is correctly defined.



Defining a Tool in PowerMill Robot database



1 From tool calibration menu open the Tool Length database

2 Select from list numerb of tool, define name

3 Enter gauge length as measured. This will define automatically the tool data as X Y Z RX Ry Rz.

This will be written in the post processed file.

More information can be found in the help documentation: PowerMill Robot - Tool and Spindle Calibration.pptx

3 This option will write the tool data on the post processed file.

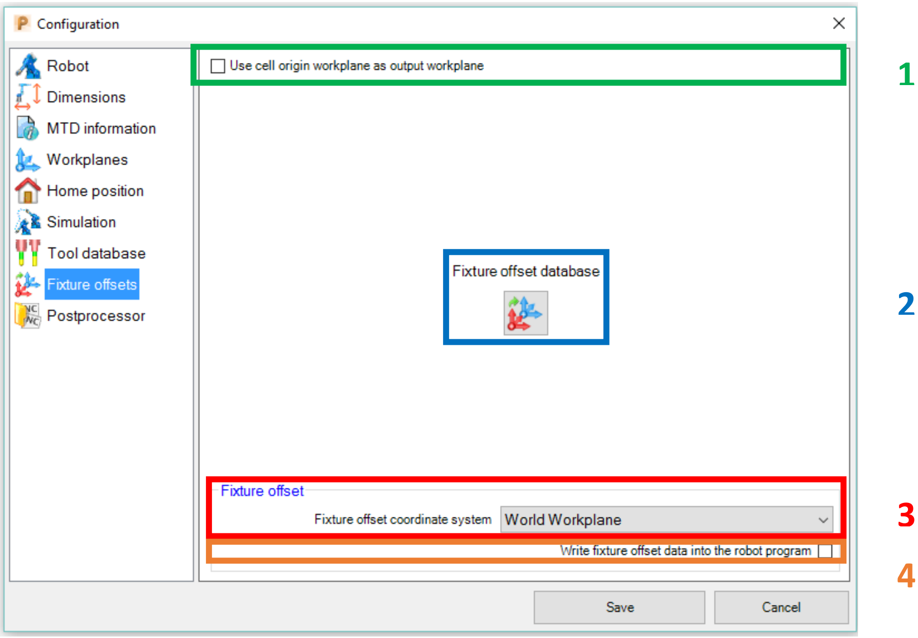
The Tool data can be calculated from:

A – Tool & Spindle Calibration

B – Workplane calculator.

You may calculate the tool data and store it in the spreadsheet type list.

Fixture Offsets



Key:

1 Output workplane is fixed to the workplane that positions the robot.

This option should be used if the workplane used to position part is the same as output workplane. Rotary table cell is a good example as the output workplane is generally located on the top surface of tha rotary plate. On this option, the Workplane number that is written in the output is fixed to 1.

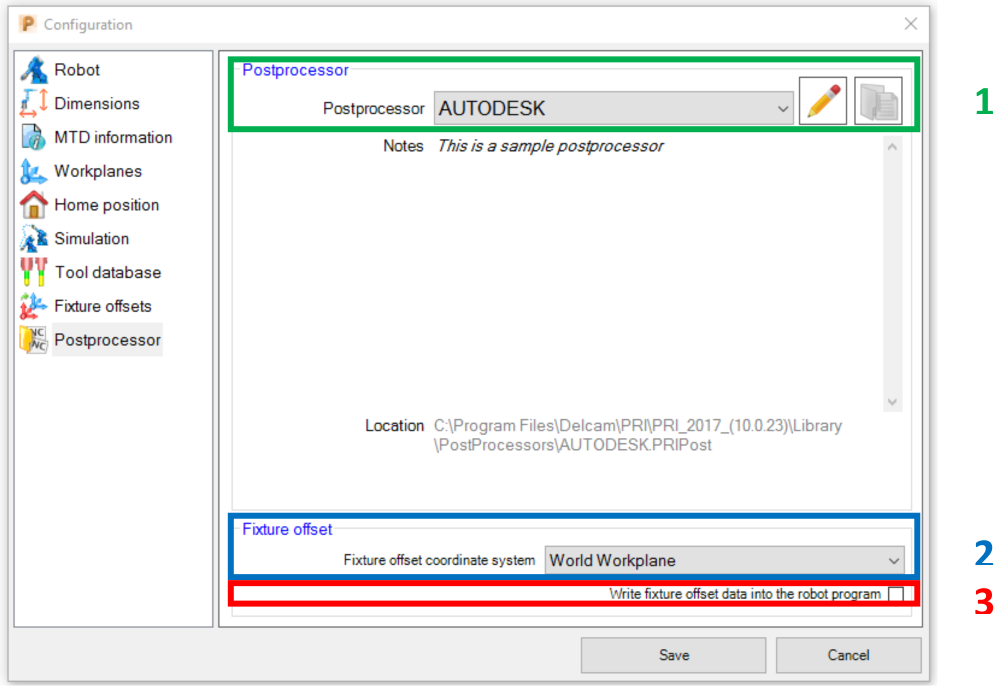
2 Provides access to the Fixture Offset database where the user can add exact locations of workplanes from virtual workplanes or from measured positions.

The number of the workplane written in the output can be chosen here, any number can be chosen.

3 Choose which workplane on the cell to offset other workplanes from in the output.

4 With this option “On”, the Workplane Defenition (xyZ RxRzRz) will be written on the post processed file. So this option defines whether the fixture data is written out, or only the number is written, and so the fixture data saved on the controller is used.

Postprocessor



Key:

1 Options to select the postprocessor, or edit the selected postprocessor using the button to the right.

The postprocessor files are xml documents and can be edited with a text editor such as Notepad++.

More information about editing postprocessor files can be found in the help documentation: PowerMill Robot – PostProcessors.pdf

2 Choose which workplane on the cell to offset other workplanes from in the output.

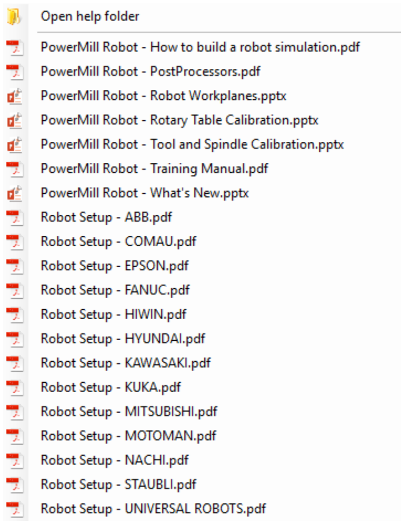
3 Choose whether to write fixture data to the robot code or use fixtures saved on the controller. This option defines whether the fixture data is written out, or only the number is written, and so the fixture data saved on the controller is used.

Loading the Robot Cell and Positioning the Part

This manual assumes the user is familiar with toolpath creation using the PowerMill tools and will therefore focus on the translation of these pre-created toolpaths into the robot NC program.

To open PowerMill Robot Help folder that contains all the trainig material follow the steps below:

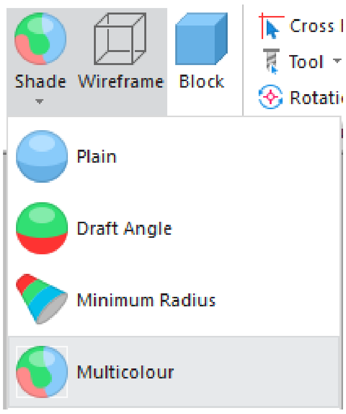
1. On the Robot Library tab double click on the entry named R2-6X-Spindle0+StaticTable. This will load the Robot cell.

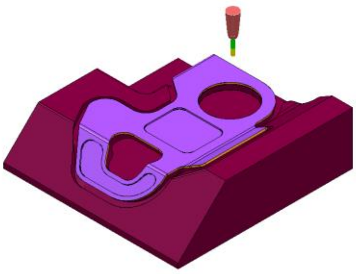


2. Open the Robot Cell tab and click on the icon 
3. From the menu that pops up select “Open help folder”
4. This will open the folder containing all the documentation
5. In windows explorer go up one level, and then open the Library folder.
6. Once in the Library folder, open the folder named Projects. This is where all the training projects are located.

With the project folder open, you are ready to start the training. You may keep this folder open as projects from this folder will be required later.

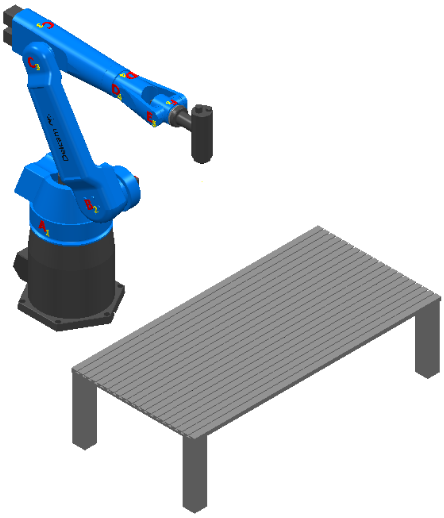
1. Load in the PowerMill project DemoToolControl6DWithFixture from …\Library\Projects
2. Change the shading of the model to view the surface





3. From the View menu, Select the Iso 2 view

4. From the Robot Library tab expand the Autodesk list and expand the Robot R2 list within the Autodesk folder.
5. Double click on the entry named R2-6X-Spindle0+StaticTable.

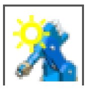


Double clicking on any name will load in that robot. Robots can be replaced by double clicking on a different robot name, without the need to unload the current robot first.

By default, the attach points for robots with no external axes is the robot world workplane.

The location of the robot world workplane varies by manufacturer, but is either at the base of the robot or just above it.

This workplane can be drawn at anytime from the Workplane Calculator or the Robot Configuration manager in the Robot Cell tab.

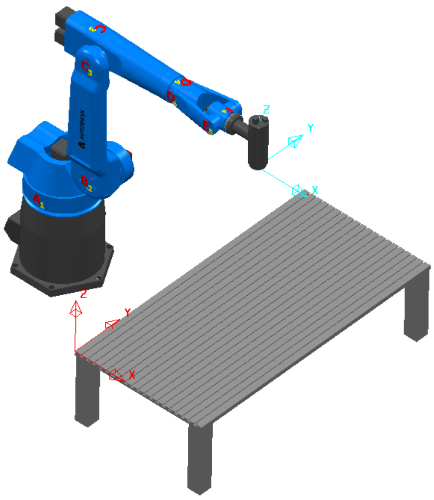
6 From the robot cell tab click on the diplay robot, to hide it .

7 You can see that the part is positioned at the base of the robot

This is because the coordinate system of the CAD of the part is aligned to the Robot world workplane.

8 In powerMill Create a new workplane located at 1000 -1000 530 and rename it table

This should be located at the right back corner of the table and have the orientation as the workplane below.



Now the part needs to be positioned in a sensible position for machining. This can be done in a number of ways.

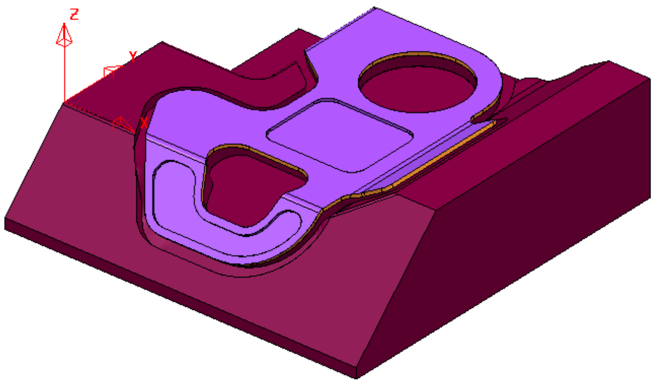
We will position the part using a workplane located on the fixture, using coordinates relative to the table workplane we just created.

If the part is already positioned in the robot cell, this positioning can be replicated in PowerMill Robot by entering the part workplane location and orientation. Use the robot measure a workplane using a position on the part that can be replicated on the 3D model.

9 Record the position and rotation of this workplane from the robot controller.

On this example we will use XYZ position as 250, 800 and 125 and RxRyRz Rotations as 0 0 0. We assume the controller supplied these values to us.

10 Create a workplane located and orientated as shown on the image below. Rename it fixture.

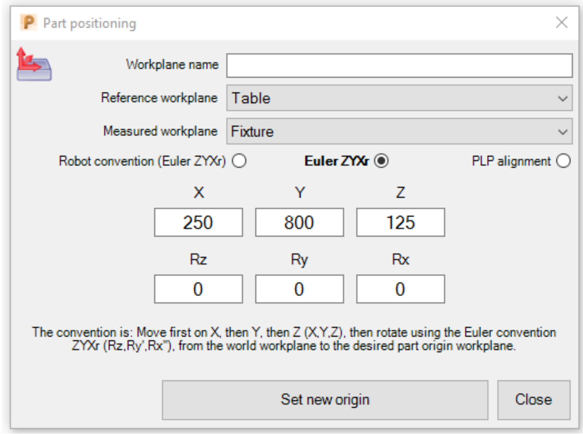


11 Open the robot cell tab in PowerMill Robot and select the Part Positioning form. Select table Workplane from the drop down menu for Reference workplane, the measured workplane is the workplane on the fixture.

In most instances the robot world workplane will be the Reference workplane. For a cell with only a robot, PowerMill global Transform will be coincident to the robot world workplane.

12 Enter values for X, Y and Z of 250, 800 and 125 respectively.

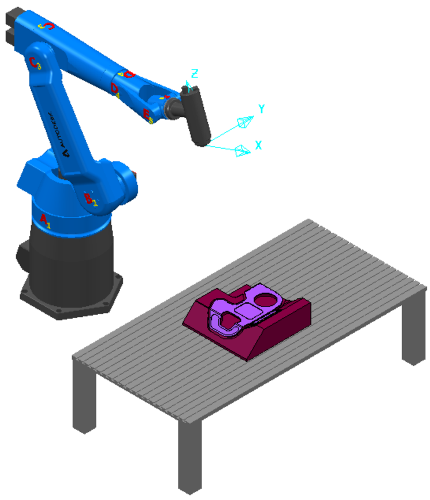
Leave the values for Rz, Ry and Rx at 0.



These values will be given by the robot teach pendant, certain robot manufacturers will give you the rotation values using a different method and PowerMill robot can handle these in this form as well.

13 Apply this new position using the Set new origin button, close the menu.

14 Inspect the new position, the part and fixture should be just above the top of the table and towards the back of the table surface. The part is now positioned and ready to use.

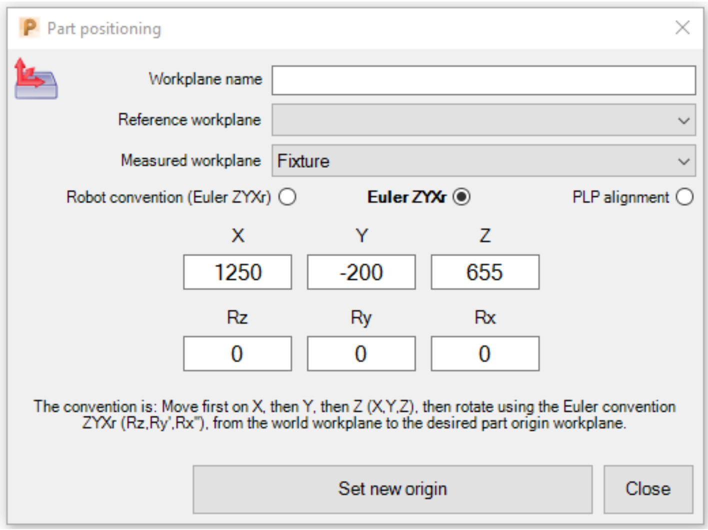


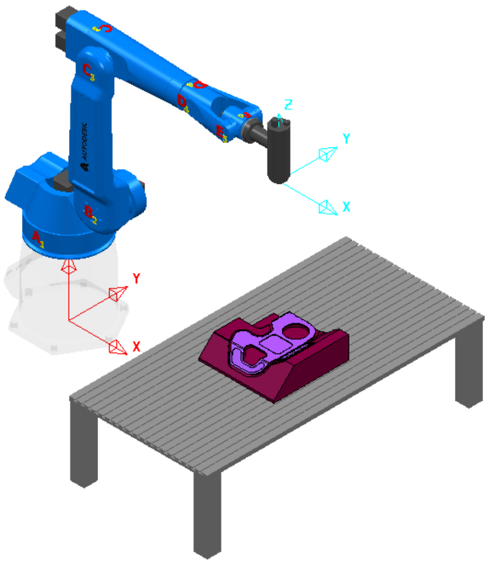
Open the Part positioning form again. This time remove any selection from Reference workplane, the menu should be empty as below.

Select fixture as the measured workplane. Enter XYZ as 1250 -200 655, leave rotations as 0 0 0 and click set new origin. Close the menu when finished.

The resulting position is exactly the same as this time we have used coordinates relative to robot world workplane.

The most common practice is to measure workplanes on parts relative to the robot world workplane. The Global transform for cells containing just a robot have the robot world workplane coincident with PowerMill global transform.





With an ABB IRB6640 PowerMill robot provides options to enter the rotations as the Euler angles, or the robot convention, in this case Quarternions

Creating a Robot Program

Robot Workplanes

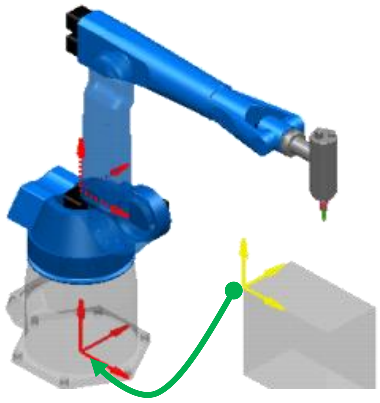
Before any files are written it is important that the user understands robot workplanes, measurements and transformations.

There are 2 key workplanes defined on the robot arm that the user needs to be aware of.

Robot World Workplane

The robot world workplane is normally defined at the base of the robot arm for cells containing a single robot arm. Some manufacturers create the world workplane at the intersection of the centre of rotation of axis 1 and axis 2. For more information, see the help documentation for the specific robot manufacturer in use.

For cells where the robot arm holds the tool the part is positioned relative to the robot world workplane.

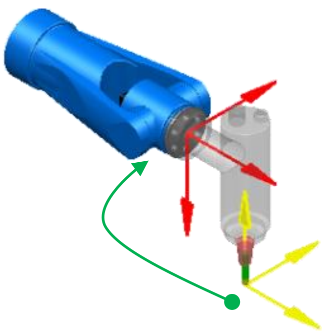


These measurements are very important as it tells the robot where in the cell the part is positioned.

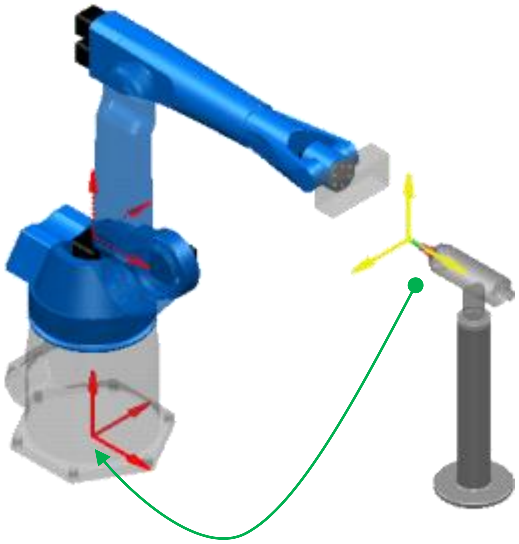
6th Axis Workplane

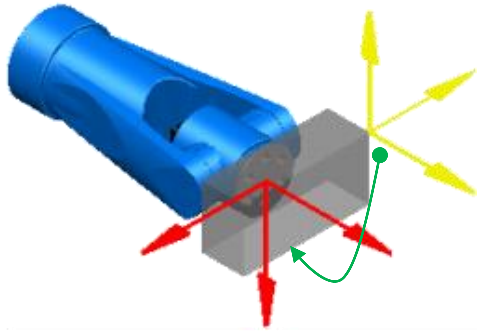
The second workplane the user has to be aware of is the 6th Axis Workplane. This is defined at the centre of the flange face of the robot and moves with the 6th Axis of the robot. The orientation of the 6th Axis Workplane varies according to the manufacturer, for more information see the help documentation for the specific robot manufacturer in use.

For cells where the robot is holding the tool the tool centre point is defined relative to the 6th Axis Workplane.



For cells where the robot is holding the part; the part position is measured from the 6th Axis workplane, while the tool centre point is measured relative to the robot world workplane.





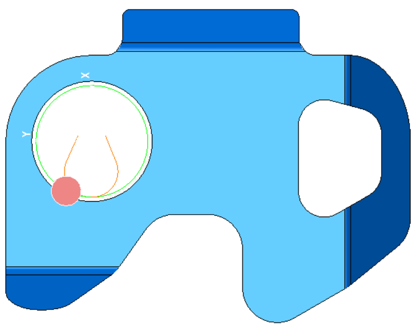
Writing the Robot Program

Once the part is positioned correctly within the cell the process that the robot will follow can now be created.

All robot programs are created from PowerMill toolpaths and these must be created before they are used in the robot program.

1 Activate the toolpath called Circle.

   This is a simple profiling toolpath that will run round inside round pocket.



2 Expand the Robot Control tab.

3 Press the Home button  followed by Attach to Start 

Using the home button is not essential, however it will improve the repeatability of the simulation as PowerMill robot will always attempt to minimise axis movement when it attaches to the start of a toolpath.

Cell configurations can be used to modify the robots home position if different joint orientations are desireable. This will be covered in a later chapter.

4 Record a simulation using the Start Simulation button

This will play through the robot’s motions required to follow the toolpath.

At the moment the robot is not constrained in any way meaning it will look for the simplest set of movements to reach the next point of the toolpath.

5 Save the simulation using the Save Simulation button

6 Give the simulation a unique, identifiable name, in this case Circle-FreeConstraints, and press Save

A robot simulation file has now been created, these are the building blocks of robot programs but are different to the files that can be uploaded to the robot.

The post processed file that will run on the robot originates from the robot simulation file.

The robot simulation files can be loaded into the simulation replay bar at the bottom of the PowerMill window. When a new robot simulation file is created it is automatically loaded in to the simulation replay toolbar.

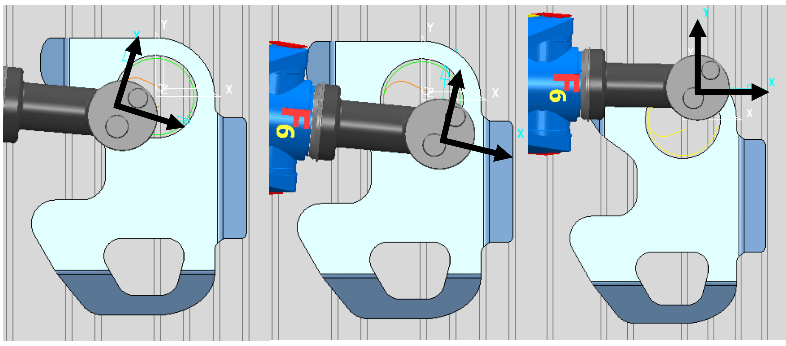
7 View the project from the top

8 Zoom in so the whole toolpath is clearly visible.

9 Ensure that the Tool workplane is drawn by turning on the Display Tool Workplane option in the Robot Cell tab Display tool workplane ON

10 Either play through the simulation using the Play button or by dragging the handle along the slider bar to view the simulation.

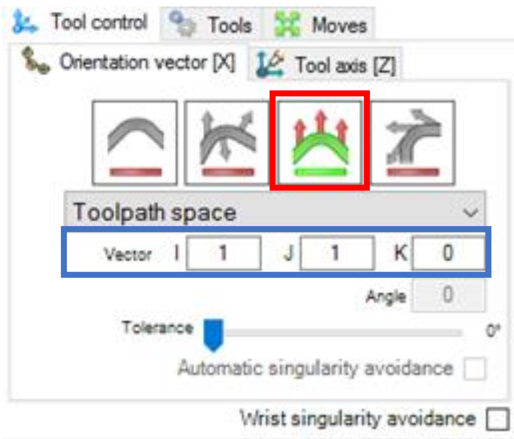
Notice how the x axis of the tool axis work plane is free to rotate at present. This can be controlled to allow more precise control over the robot’s motion.



11 Reopen the Robot control tab. Send the robot to the home position and then attach to the start of the simulation.

An alternate way to ensure the same start position is used is to select Move to Simulation Start Position . This will move the robot to the start position of the currently loaded robot simulation file.

12 From the Tool control menu select Orentation vector[X], set it to vector and enter IJK values of 1, 1, 0 respectively.

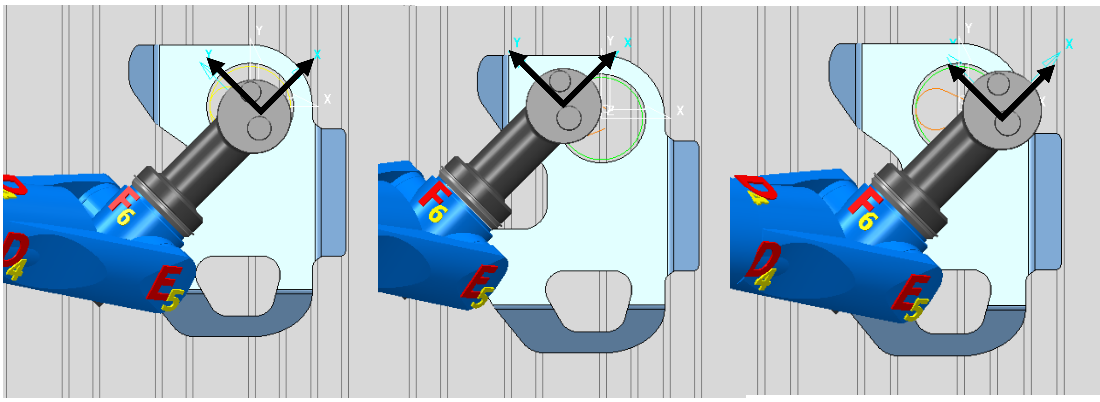


This will lock the x axis of the tool to be parallel to the x axis of the project.

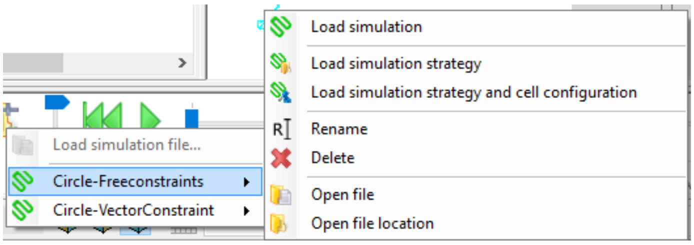
Any modification made to the constraints of the toolpath will also require the user to reattach the simulation to the start of the toolpath. If this is not done, the new settings will not be applied.

13 Attach to the start of the toolpath, record the simulation and save it with the distinct name, Full-VectorConstraints.

14 Play through the simulation again, noting the change in the robots control.



To view the previous simulation select Load a simulation file...  *this will list all the simulation files for the current active toolpath. Hover the cursor over the previously generated simulation file in the list. Select Load simulation from the new flyout menu.*



Once the simulation has been run and the user is happy with the result the simulation files can be combined to create the robot program.

15 Open the Robot Program tab.

16 Enter a descriptive name in the Program Name field. In this case TrimmingOperation-World.

Do not start program names with numbers as this will cause errors on some controllers.

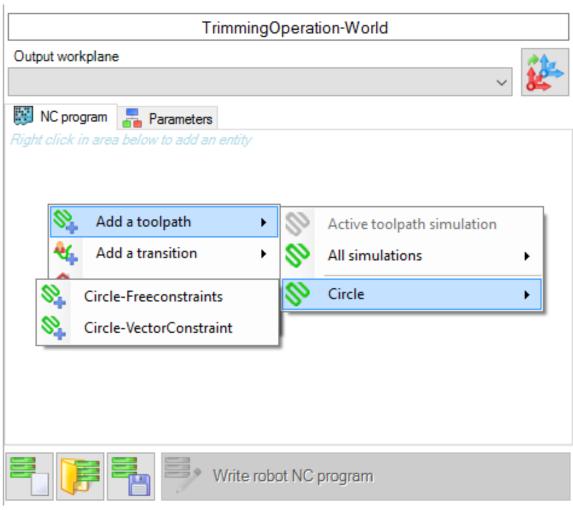
17 Leave the Output Workplane blank, this will select the measured workplane by default.

18 Right click anywhere in the NC Program area, select add a toolpath.

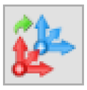
This menu lists all the toolpaths that have robot simulation files associated with them and allows the user to add them to the robot program.

Additionally this menu provides access to any other robot simulation file available through the All Simulations option.

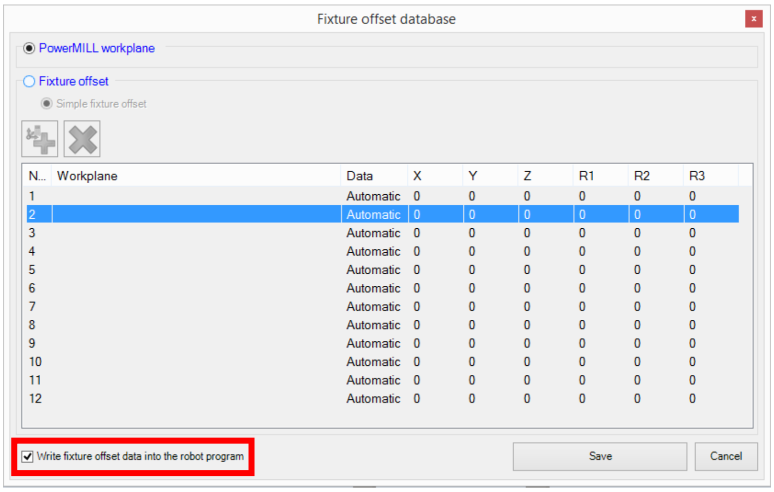
19 Select the Circle toolpath option and select Circle-VectorConstraints from the new flyout menu.

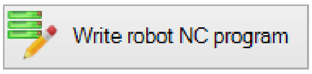


This will add the selected simulation file to the robot program.

20 Click on  to Open Fixture offset database

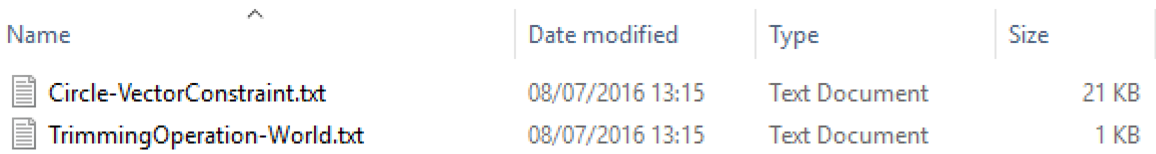
21 Make sure *Write fixture offset data into robot program* is ticked



22 Select *Write robot NC program* 

A Windows Explorer Window will open up to the output directory for the NC Program files.

This will contain 2 .txt files.

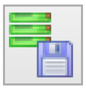


A robot program differs from a CNC machine NC program as it is divided into separate files. This is to allow for the limited memory of a robot controller, each file is limited to a certain number of points and these are only loaded when the main file requires it. The main file in this instance is the one called TrimmingOperation (the robot program name).

The exact structure of the robot NC program will depend on the robot manufacturer.

The robot we are using in this example is an example robot only. While the code is representative of a structure of a Robot program the output from it will not work with any robot controllers.

23 Open the files with a text editor to inspect the NC program.

24 Save the NC Program .

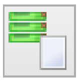
The project has now been successfully post processed.

Changing the Output Workplane

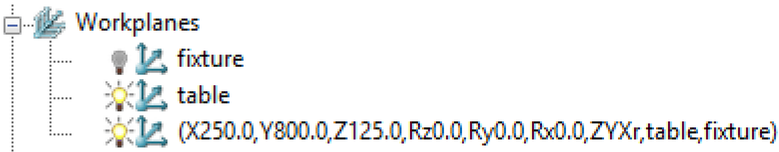
If using the part position as the output workplane is not an option, for example if multiple users are using the robot and may be modifying the location of measured userframes, then an alternative can be selected.

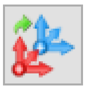
The robot world work plane is a common reference point between the controller and PowerMill robot so we will use that as an example of how to output the program using a different workplane.

Any workplane used as the output must first be created within PowerMill.

1 Create a new NC Program . Name it TrimmingOperation-Fixture.

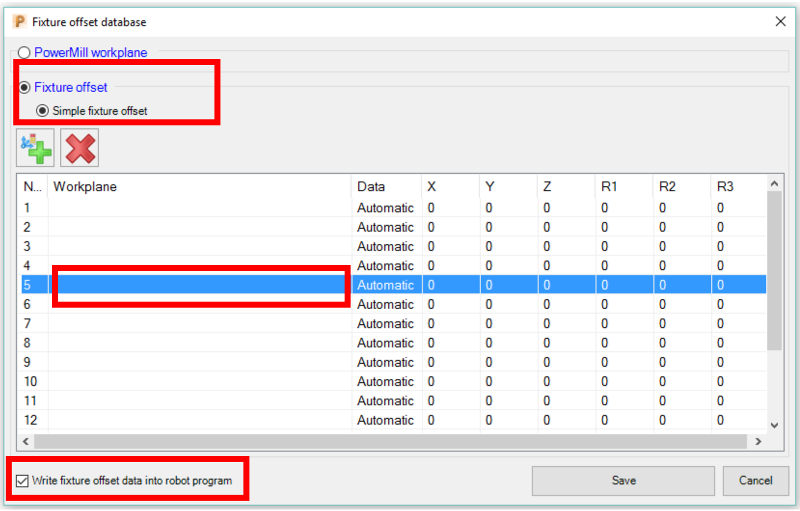
1 In the solution explorer on the left hand side of the screen expand the Workplanes menu. There are 3 workplanes we will use now fixture as the output workplane.



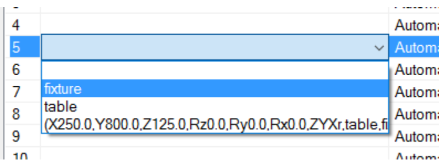
2  Open Fixture offset database.

3 In the menu apply the settings below.

Make sure *Simple Fixture Offset* and *Write fixture offset data into robot program* are selected.



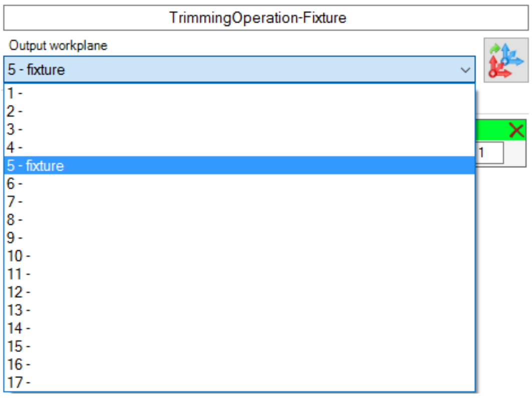
4 On the position 5 line, double click the cell, a drop down menu will appear. Select Fixture.



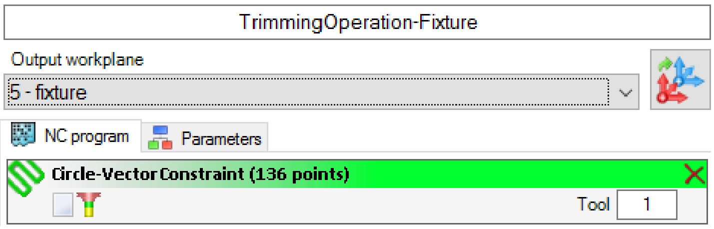
5 With Fixture selected as the workplane on line 5, Save the menu.

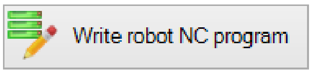
6 On the Output Workplane you will have now the same list of output workplanes as on the fixture offset database.

Select 5 - Fixture



7 The menu should now look like this.



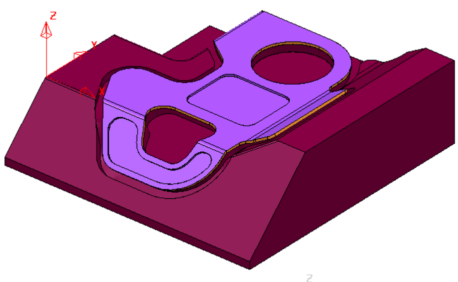
8 Select Write robot NC program 

9 Open the recent created NC programs in a text editor and compare it to the previous NC Program.

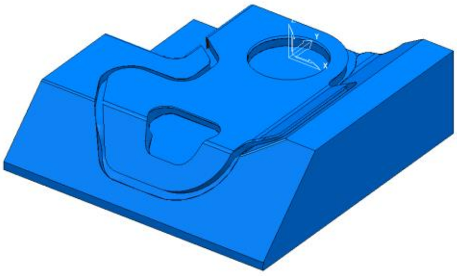
The difference between these 2 NC Programs will be that all the coordinates have been transformed to reflect each individual point’s position relative to the output workplane.

Using the robot world coordinate system makes it difficult to assess whether the machining will occur in the correct location.

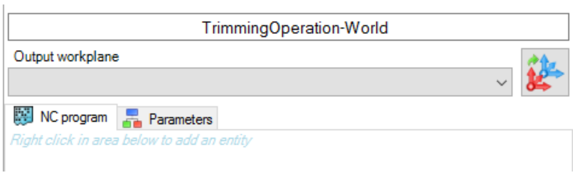
TrimmingOperation-Fixture has coordinates relative to the output workplane - fixture (shown on the right/red).



TrimmingOperation-World has all coordinates relative to the Global Transform of PowerMill (shown below in white)



This is because the Output workplane was left as empty, and this is the same as selecting the Global Transform (white workplane), so all coordinates are relative to this workplane.



If you open the file TrimmingOperation-World.txt on line 10 you will find the base coordinates.

BASE[1] = [X 1547.343, Y 92.872, Z 660.000, A 0.0000, B 0.0000, C 0.0000]

This will overwrite any userframe saved in the identified position in the robot controller user frame database. This will normally be position 1 (indicated by the integer in the square brackets BASE[1]) when using PowerMill workplanes.

If you open the file TrimmingOperation-Fixture.txt on line 10 you will find the base coordinates.

BASE[5] = [X 1250.000, Y -200.000, Z 655.000, A 0.0000, B 0.0000, C 0.0000]

Notice the default value when the output workplane is selected is 1, and in the fixture offset menu will be the value you have selected, we selected 5.

If overwriting user frame 1 in the robot controller is not an option, then the Fixture offsets can be used to write the output workplane location to a separate entry in the Robot controller.

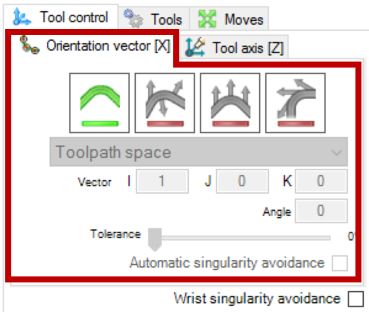
It is also possible to define as the output workplane a workplane defined somewhere on the stock. And this one would be selected instead of the global tranform.

Advanced Tool Controls

The Orientation vector [X] constraint was explored in the previous example but PowerMill Robot has a range of other tools for controlling the movement of the robot during the simulation and the operation.

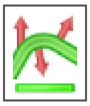
There are three main methods to control the robot simulation:

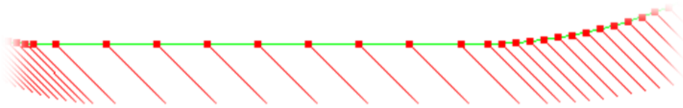
- **Tool workplane X axis control** (done during the basic training)



- By editing the **Robot Axes Limits** and/or **Priorities**

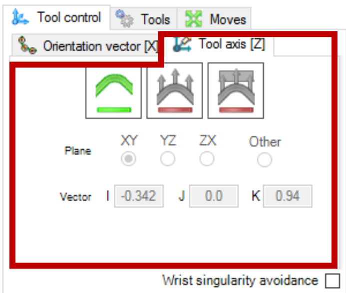
- By using **Orientation Vectors** (which can also be set from simulation)





- **Tool workplane Z axis control** - Tool axis [Z] Constraint

  In the previous example we used Orientation vector [X] that controls the X component of the tool workplane. This menu, Tool axis [Z] , controls the Z axis of the Tool.



Dynamic Axis Priorities and Limits

It is possible to change the axes movements that PRI will generate by changing which axes PowerMill will prioritise, ie, which axes PowerMill will move significant amounts and which it will try not to move. It is also possible to lock axes in static positions.

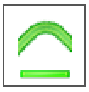
1 Load in the PowerMill project DemoToolControl2 from …\Library\Projects

2 Load the Robot cell from the library named R2-6X-Spindle0

3 Activate "Milling" Toolpath

4 Move robot to HOME

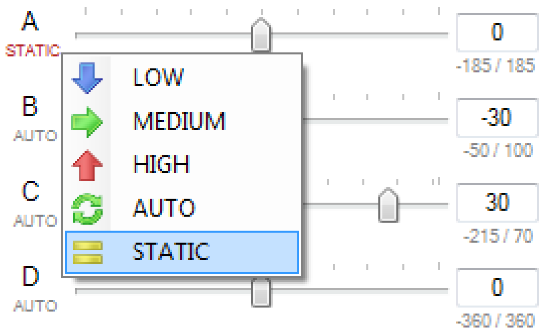
5 Set the tool axis constraint to free

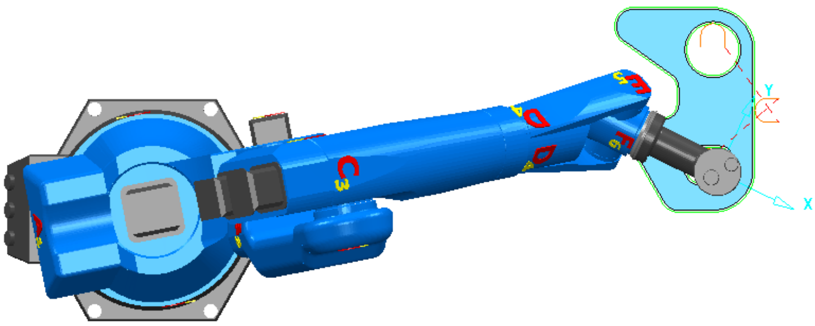


6 Select static from the drop down menu

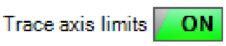
7 Jog manually the axis A to -11°

(This angle, the robot can reach the whole toolpath without moving axis A)





8 Turn Traxis Axis Limits on

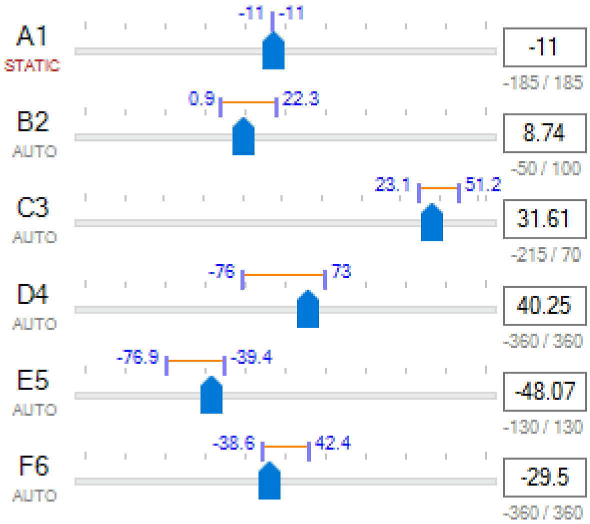


This allows the user to visualise the maximum and minimum values the individual axes reach during the simulation.

9 Attach to the start of the toolpath.

10 Play the simulation and watch the results to see the difference in process achieved.

Axis 1 will remain completely stationary, as shown by the axis limits sliders.



If any other constraint type is used in this example the solution will be over-constrained and will not be able to reach all the positions.

External Axes

This can be used with external axes as well to control how they are used and whether they act as positioners or an active part in the process.

This example will look at the use of **Tool workplane X axis control** constraints on a rotating workpiece to further control the robot position.

1 Open project DemoBody2 (Rotary Z).

This project contains the surfaces for the torso of a figure to be machined from polystyrene and some basic surface finishing toolpaths to achieve this.

2 From the robot library select and load robot: Autodesk, Robot R2, R2-7X-Spindle0+RotaryTable.

3 Open the Robot Control tab and check the axis priorities.

The axis priorities for all the robot joints are set to Auto while the external axis E1 is set to static.

4 From the solution explorer activate toolpath ***Full Spiral 30°***

5 Attach to the start of the toolpath and record the simulation.

With the current constraints the head of the robot is forced to move around the part and reach over it to reach positions on the opposite side.

This will result in numerous collisions and the robot being unable to reach certain positions of the toolpath.

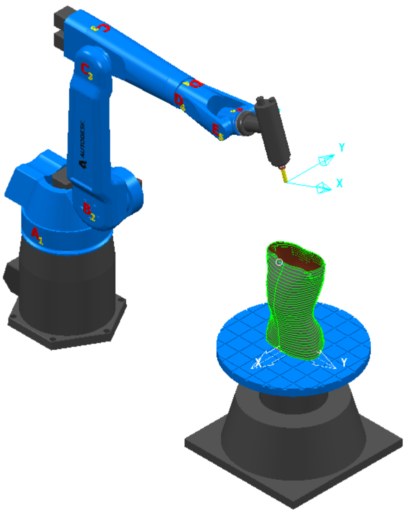
Click anywhere in the graphics window to stop the simulation.

6 In the Robot Control tab send the robot to the home position.

Note the home position of axis E1 is at 0°. We will update this to improve the repeatability of the simulation later.

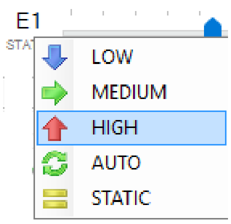
7 Alter the position of axis E1 to -90°.

This can be done my typing the value in the position box followed by return.



8 Attach to the start of the toolpath.

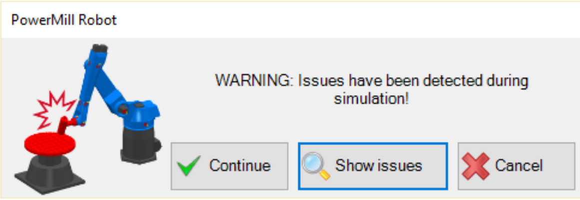
9 Right click on the word auto below the E1 label in the Robot control tab. Change the axis priority to High.



When any changes are made to axis priorities, constraint type or axis limits you will need to reattach the robot to the start point of the toolpath.

10 Attach to the start of the toolpath

11 Play and record the simulation.

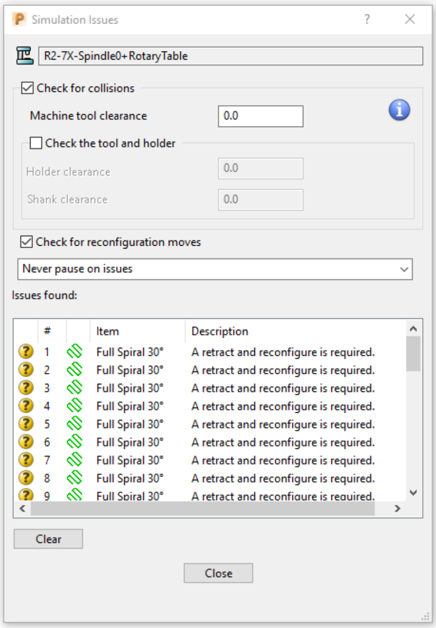


This PowerMill Robot Warning will pop up. Click on the Show issues to view what is wrong.

12 PowerMill will open the Simulation issue menu.

On this menu we can see that there are a few Retract and reconfigure moves required.

This is due to the fact that the toolpath is a full spiral and the limit of axis E1 is -720/720, so clearly the axis limit has been reached.



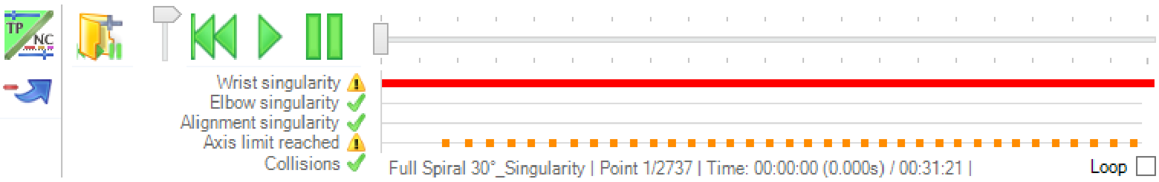
To overcome this issue:

1 – use an external axis with a higher limit, or no limit. powerMill wil always need an upper limit enev if the hardware on the robot has no limit.

2 – change the toolpath to Bidirectional, as this will not exceed the limits.

13 Save the simulation and expand the analysis in the Simulation Replay bar

The simulation replay toolbar now reveals that the robot is constantly in a singularity position throughout the toolpath, besides axis limit.



As the arm moves down the part the arm starts to come over the top of the tool. While this may not cause a collision we want to constrain this further to avoid any potential problems.

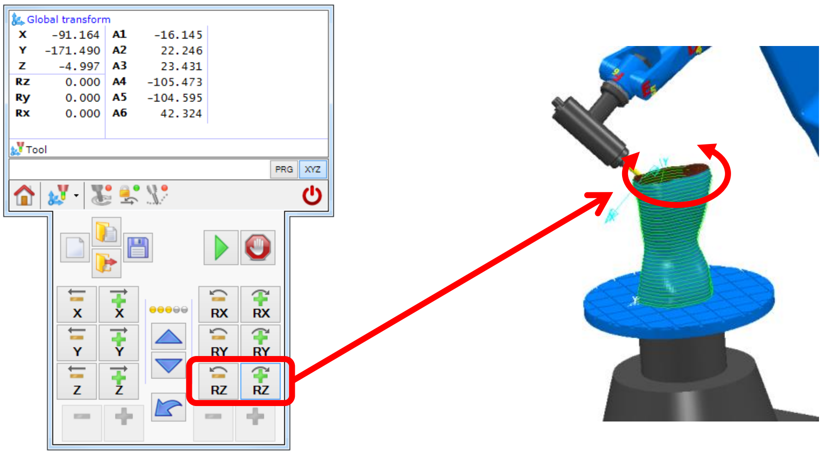
14 Activate the toolpath named ***Full Bidirectional 45°***

15 Click on the Move to simulation Start Point icon 

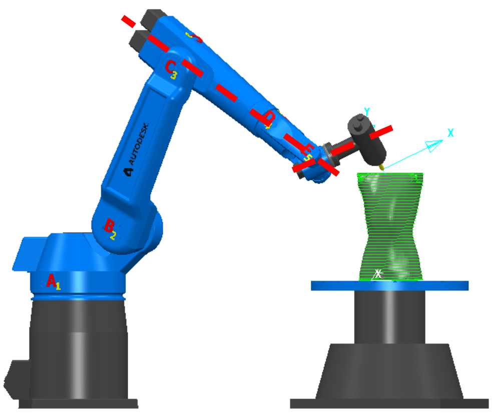
This will attach the Robot to the first point of the current toolpath with the previous simulation settings.

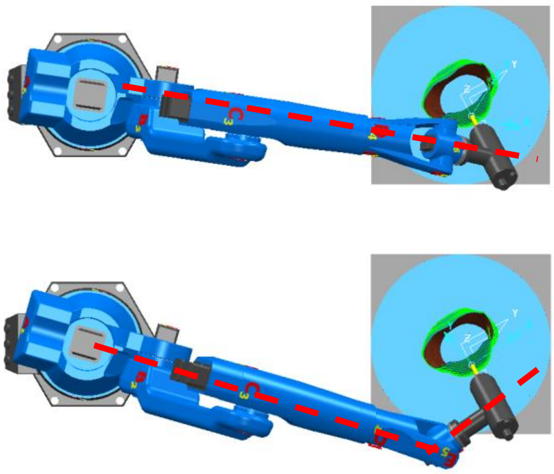
16 Use the Teach Pendant to rotate the Robot around the Tool

This will rotate around the Z axis of the tool.



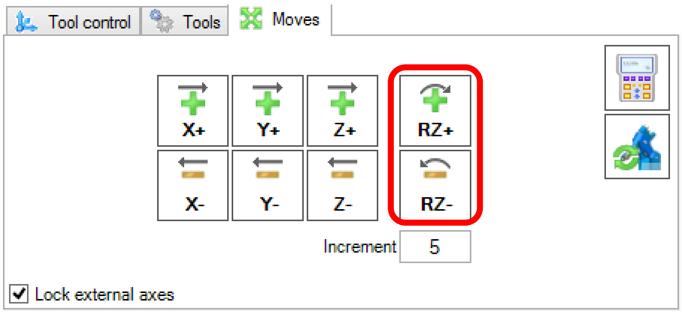
This will move the robot joint 5 away from the part, and also introduce an angle between joint 6 and 4. The angle between joint 6 and 4 will remove any wrist singularity.



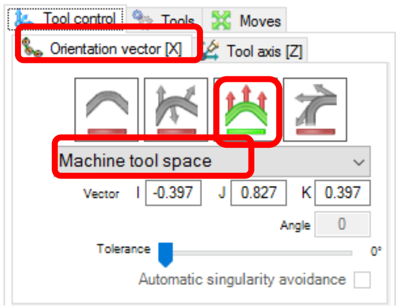


An alternative to the Teach pendant is shown below.

Switch the Tool control area to the Moves Tab. Rotate the tool about the Z axis



17 Make sure the Orientation vector [X] is set to vector, and that Machine Tool Space is selected from the Tool Control Tab.



18 Attach to the start of the toolpath

PowerMill Robot will read the vector to be used from the tool tips current position and will update the IJK values automatically if the tool is manually rotated.

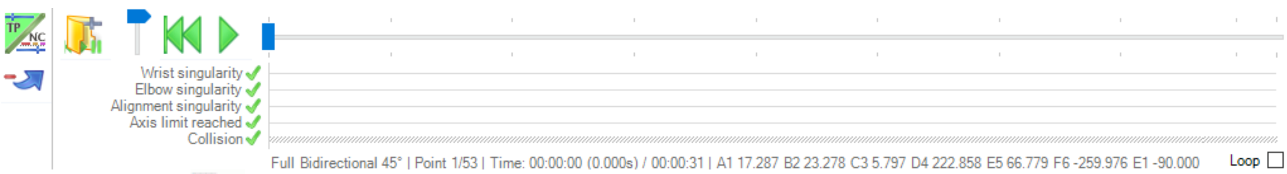
Alternatively IJK values can be entered into the corresponding box to precisely control the orientation of the tool

If you do not attach to the start after rotating around the tool and applying the Orientation vector [X] tool constraint, there will be no difference in the simulation.

Pay special attention to the exlamation mark on the Attach to start Icon. This informs us that the simulation settings have changed and we need to apply them by attaching to start.

19 Play and record the simulation.

This time the end result is quite different, the robot posture is maintained throughout the toolpath and singularities are avoided by maintaining the angle between axis 4 and 6.

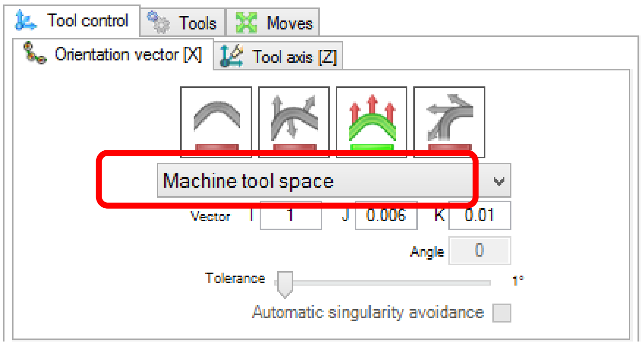


Select Machine tool space from the drop down menu when using the Orientation vector [X] on a rotary table.

This determines whether or not the coordinate system used to define the vector rotates with the toolpath.

In Toolpath space the tool orientation will remain constant relative to the dynamic surface of the table as it rotates.

In Machine tool space the orientation of the tool will remain constant relative to the static robot world workplane. Regardless of the rotation of the part/toolpath.

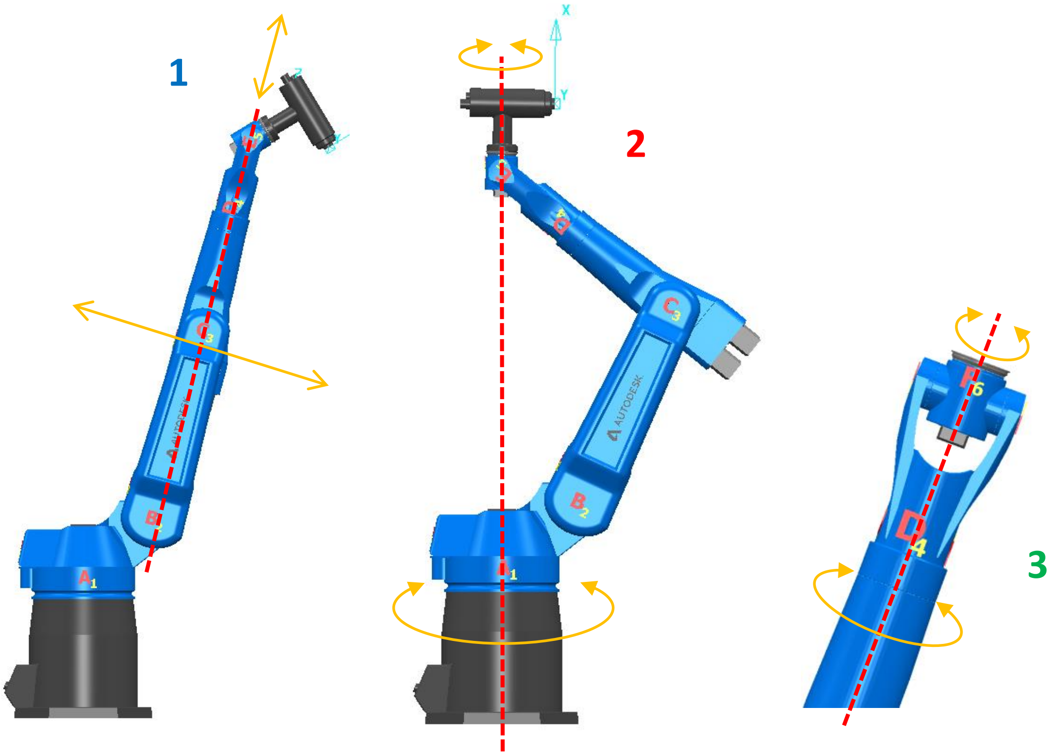


Singularities

Singularities are a mathematical problem, for robots they are caused when 2 or more axes are aligned resulting in an infinite number of combinations that will acieve the same tool position. In other words if axis 4 and 6 are aligned (a wrist singularity) if axis 4 is rotated to 45° and axis 6 is rotated to -45° it is the same as axis 4 being at 0° and axis 6 being at 0°. Basically any position where the rotation angles are equal and opposite.

This results in a large amount of axis rotation in areas around singularities. And will slow down the operation of the robot arm.

There are 3 kinds of singularities:



Key:

1 Elbow singularity when axes 2, 3 and 5 are aligned

2 Alignment singularity, when axis 1 and 6 are aligned

3 Wrist singularity, when axis 4 and 6 are aligned

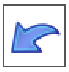
Singularities are especially detrimental to processes where the movement speed is important to the process.

1 From the solution explorer activate toolpath ***Full Spiral 30°***

2 Send the robot to the home position.

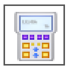
Note that the robot restores all axes including the external axis to the 0 position. This will undo the earlier rotational positioning of the axis.

The home position can be updated to improve repeatability of the simulation.

3 Select Move to Simulation start point 

This restores all axes to their previous starting position, or to the last position that attached to the tool to the first toolpath point.

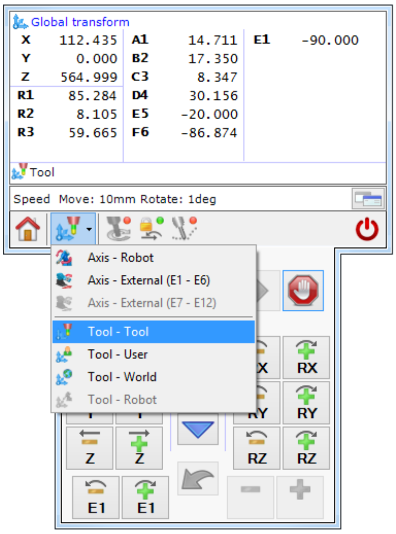
This position can now be used to create the new home position.

4 From the robot cell tab open the virtual teach pendant 

The virtual teach pendant is a software version of the teach pendant connected to a robot to allow direct control of the robot position and to allow simple movements to be taught directly from within the software.

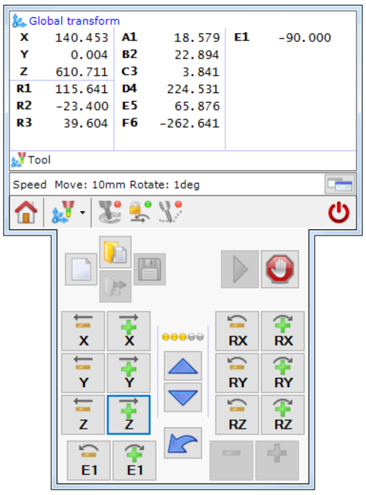
5 Change the coordinate system in use to Tool-Tool.

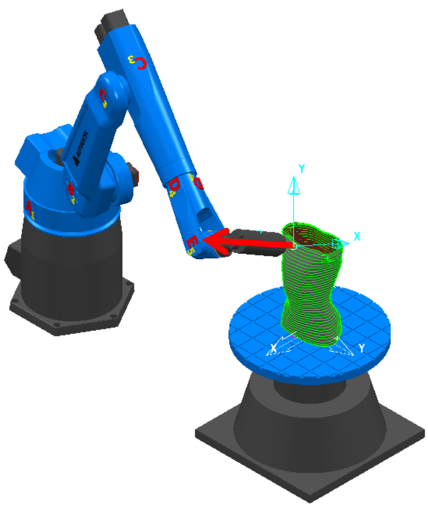
This will alter the direction the tool tip will move in to be parallel to the axes of the workplane at the tip of the tool.



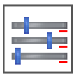
6 Move the tool in the positive Z direction by 5 increments (press  5 times).

This will lift the tool away from the part along its own axis by 50 mm (or 5 times the increment distance shown in the Move Speed field on the teach pendant).





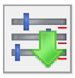
7 Close the virtual teach pendant 

8 Open the Cell Configuration Manager 

The cell configuration manger controls the default properties for the robot cell and allows the use of different positions, axis priorities and limits for different parts of the robot operation.

9 Select New and enter an identifiable name for the cell configuration to be created. In this instance HighTable

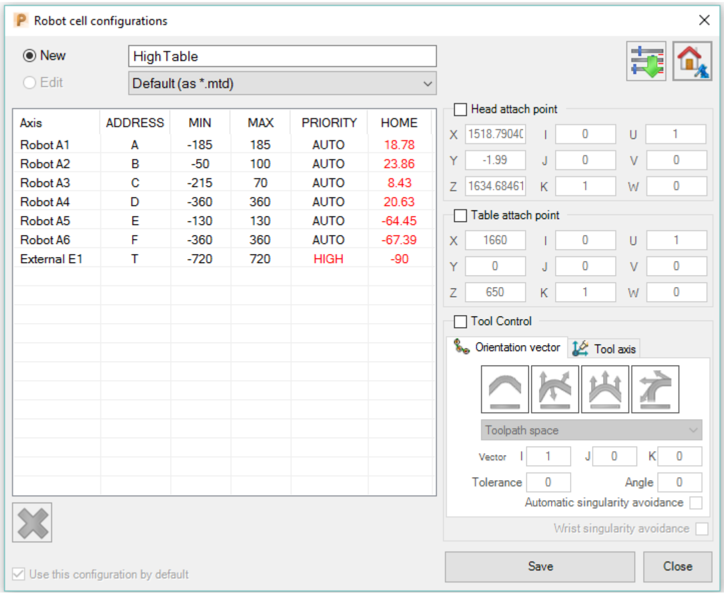
The values and settings in the database can be edited by double clicking on any of them, alternatively the current settings can be quickly imported using the 2 buttons in the top right hand corner of the menu.

Load Current Configuration  *will load in the current axis priorities and limits as the defaults for the new configuration.*

Load Current Position as HOME  *will update the home values of each axis to match the current robot position.*

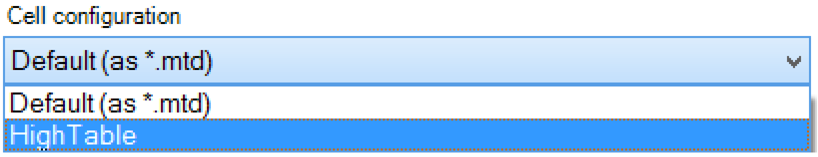
10 Select Load Current Configuration  and Load current Position as HOME 

The changes made to the cell configuration will be highlighted in red in the table.



11 Save the new configuration and close the Cell Configuration Manager.

12 From the Cell Configuration drop down menu select HighTable.



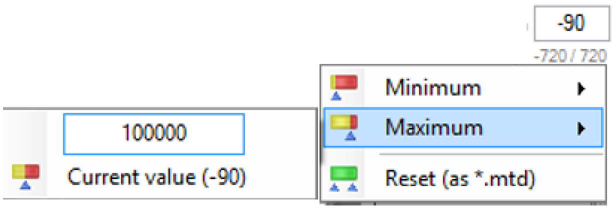
The robot position will now update to the Home position set and change the axis priority of axis E1 to High.

The only remaining issue is the Axis limits, in this instance PRI is reporting the simulation is reaching the limit of axis E1, the rotary table.

In this case the limits on the axis are software limits and the axis itself is continuous. The limits can be altered to reflect this in PowerMill.

13 Right click on the axis limits information underneath the position information in the Robot Control tab.

14 Enter a high value for the maximum value that the axis is unlikely to reach, in this case 10,000 and press enter.



An error message will pop up to warn you this is outside the limits of the axis as defined by the mtd. Accept the message menu.

15 Repeat for Minimum, -10 000

This change will prevent the robot cell reorientating the table during the operation, creating a smoother process, however it will still be flagged as an error in the Simulation replay bar and the solution to this is to edit the values in the mtd file. The process for this is covered in the help documentation however it is beyond the scope of this training manual.

The changes to the toolpath (new start position and new axis limits) have not been added to the cell configuration.

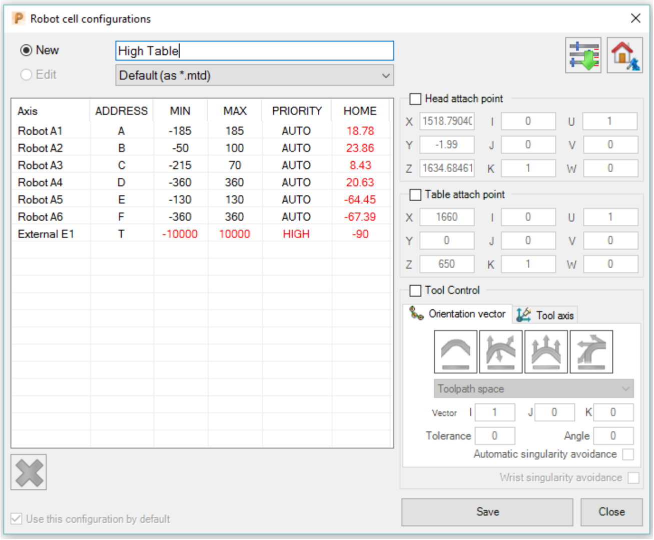
To edit a cell configuration

16 Open the Cell Configuration Manager from the Robot Cell tab.

17 Select edit and choose HighTable from the drop down menu of available cell configurations.

18 Select Load Current Configuration  and Load current Position as HOME 

The changes made to the cell configuration will be highlighted in red in the table.



19 Save the edited configuration.

While the latest simulation is collision free and singularity free there may be times when more control is desireable.

Direction of Travel

For certain operations the orientation of the tool needs to follow the direction of travel.

1 Close the project.

2 Reopen the project DemoToolControl2.

3 Load in the robot Autodesk Robot R2: R2-6X-Knife from the Robot Library.

4 From the robot cell tab select the workplane created earlier as the Cell Origin. The name should have the form: (X1800,Y0,Z700,Rz0,Ry0,Rx0,ZYXr,,OnPart)

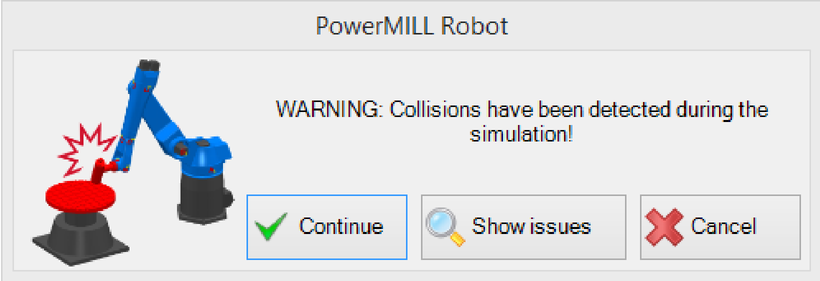
If the project was not saved after the last section the workplane will need to be recreated. Open the Part Positionner form from the Robot Cell Tab, select OnPart as the measured workplane and enter XYZ values of 1800 0 700 respectively.

5 From the Explorer window activate the Toolpath Knife.

6 In the Robot Control tab, select attach to start and record the simulation using the default (free) constraint type.

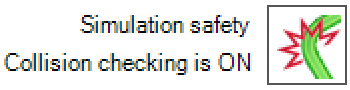
7 Save the Simulation file.

PowerMill will display a warning to indicate that a collision has been detected.

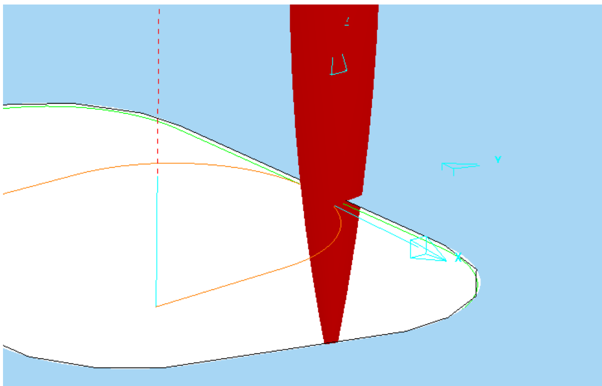


Select continue.

If no warning pops up ensure that collision checking is switched on from the Robot Cell tab.

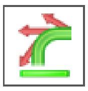


8 Play through the simulation in the simulation replay bar until the first collision



As this is a knife cutting process the tool orientation must be relative to the direction of travel of the tool.

9 From the robot control tab, send the robot to the home position, attach to the start of the process.

10 Select Set Tool Control: Follow 

This tool constraint type will align the x axis of the tool to the direction of travel.

11 Attach to the start of the process again and record the simulation.

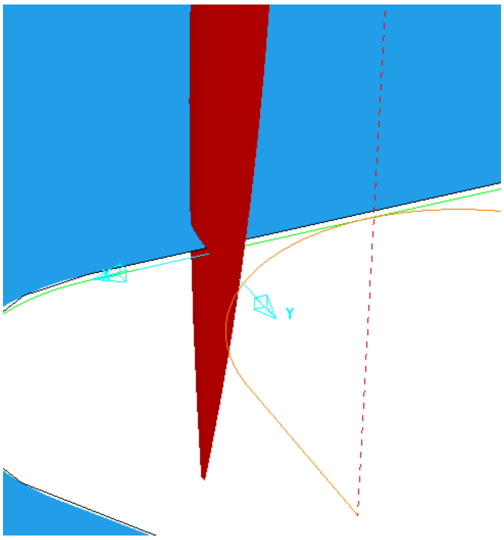
12 Save the simulation as Knife-Follow.

The same message will be displayed warning of a collision.

13 Click continue.

14 Play through the simulation in the Simulation replay bar.

Inspecting the simulation replay it should become apparent that the x axis of the tool workplane should actually be perpendicular to it, rather than parallel which is the default for the follow constraint.



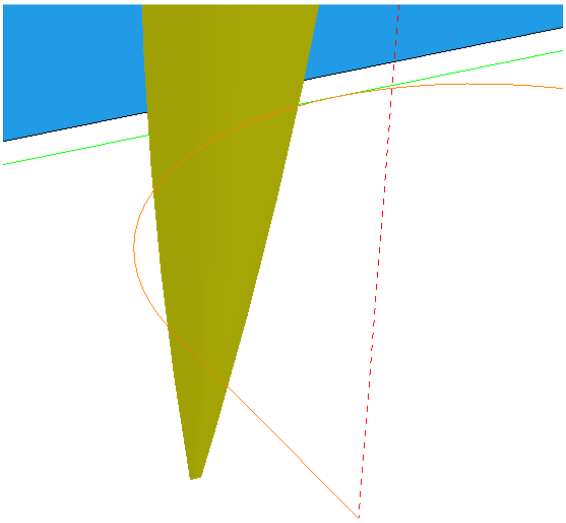
15 In the Tool control area of the robot control tab change the Angle value to 90°.

16 Send the robot home, attach to the start of the toolpath, and record the simulation.

17 Save the simulation as Knife-Follow90.

18 Play through the simulation.

The tool will now orient with the x axis of the tool workplane aligned perpendicular to the direction of travel.



Orientation Vectors

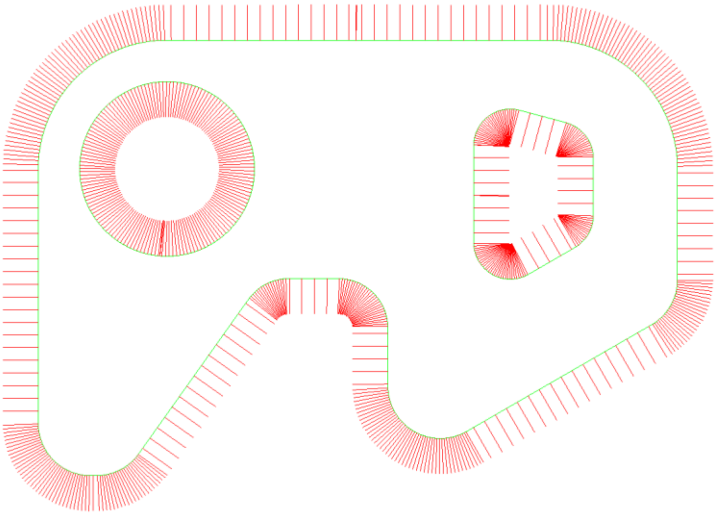
Orientation vectors are vectors created at each point along the toolpath which control the direction the x-axis of the tool workplane will be oriented in.

Orientation vectors were created in each of the previous control types however no user interaction was required to control the orientation of the tool so there was no need to display them.

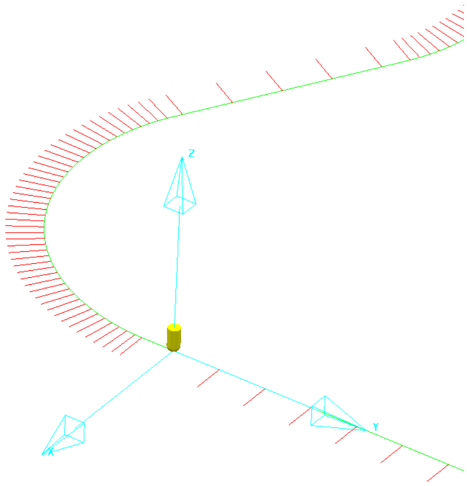
1 Unshade the model so the toolpath is clearly visible 

2 Hide the robot so the tool and toolpath are the only entities visible 

3 From the Toolpath toolbar turn on the visibility of the orientation vectors 



This shows a graphical representation of the orientation the tool will be in at each point along the toolpath.



Manipulating Orientation Vectors

In the previous examples a constant control was enough to create a good repeatable solution. In certain instances different positions along the toolpath may require different orientations of the tool.

Orientation vectors can be used to control these and PRI has a range of tools to create and edit them.

There are 2 ways to create the orientation vectors on the toolpath:

- Created with the toolpath from the Machine Axis Control tab.

- Saved with a successful simulation.

These 2 methods will have similar outputs and will be down to user preference.

Orientation Vectors from the Toolpath

1 Open the Toolpath Strategy Selector 

2 From the Finishing options select Profile Finishing.

3 Change the name to OrientationVectorsTest.

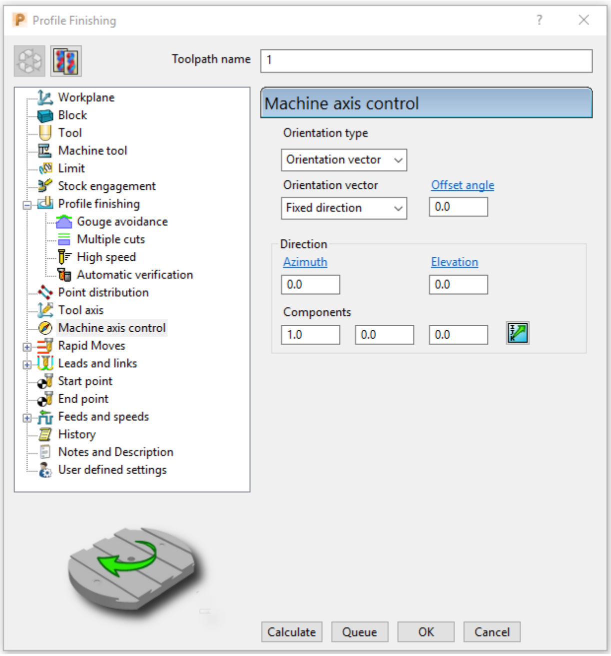
4 From the graphics window select the surface.

5 Toggle to the Machine axis control tab.

6 From the dropdown menu for Orientation Type select Orientation vector.

7 There are now similar options to those contained within the PowerMill Robot for orientation options, ie Free, Direction of travel and fixed direction.

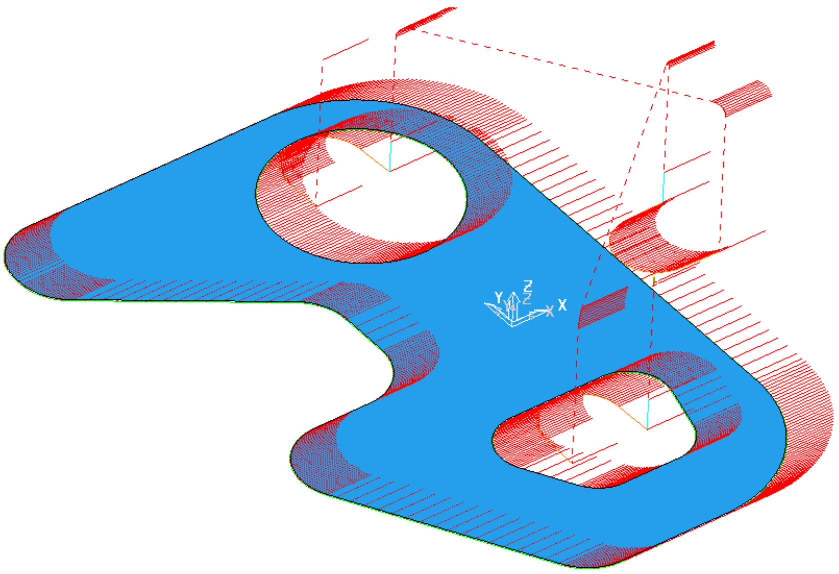
8 Select fixed direction and enter values of 1 0 0 in the components area.

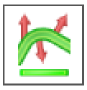


9 Calculate the Toolpath.

10 From the Toolpath toolbar turn on the visibility of the orientation vectors 

11 Every toolpath point now has an orientation vector running parallel to the x axis of PRI (IJK 1,0,0 the component values entered earlier).



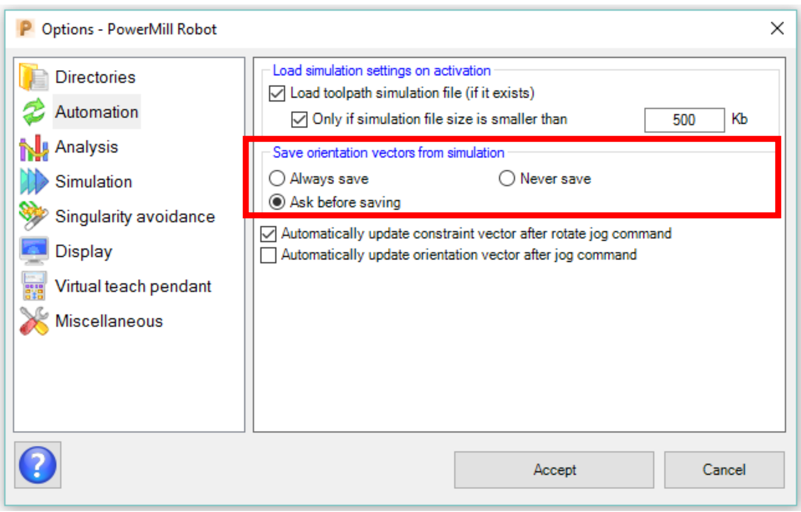
12 To use the newly created orientation vectors select Set Tool Control: Orientation Vector 

13 Simulate the new toolpath.

The x axis of the tool will be locked to the x-axis direction.

Orientation Vectors from the Simulation

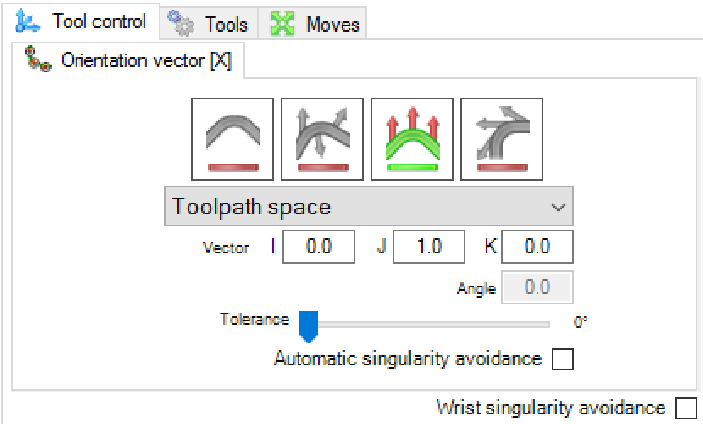
1 Open the PRI Options form. On the Automation page change the Save orientation vectors from simulation to Ask before saving.



This option will give you the option to save the orientation vectors used in each simulation when the simulation is saved. Always save will overwrite any existing orientation vectors, each time a simulation is saved. Never save will not save the orientation vectors used by the simulation.

2 With the OrientationVectorsTest toolpath still active. Select Set Tool Control: Vector.

3 Change the vector to IJK 0,1,0.



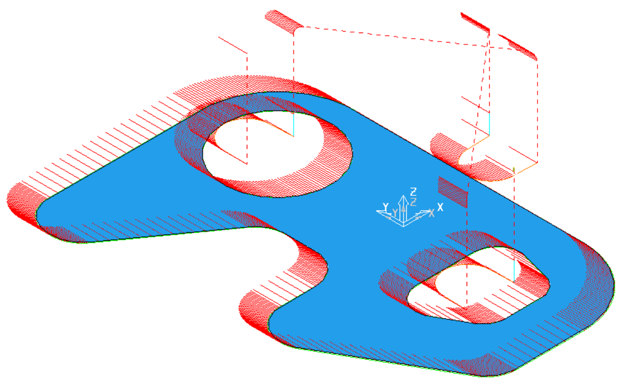
4 Attach to the start of the simulation, record the simulation and save the simulation as OrientationVectorsTest.

If PRI warns of any collisions it is safe to continue as this is only an example of functionality.

PRI will now give you the option to save the new Orientation Vectors.

Look at the current direction of the orientation vectors. If they are not visible select No, tun on Orientation Vectors  and repeat step 4.

5 Select Yes and observe the effect on the direction of the orientation vectors.



All the orientation vectors have now been rotated by 90° to be parallel to the Y-axis of PRI.

Editing Orientation Vectors

Editting orientation vectors in individual regions of a toolpath can result in very flexible and controllable simulations and solutions. We will now have a look at our options to edit orientation vectors.

Selected Segment, Local Point and Region.

As the name implies, selected segment will act on a whole toolpath segment.

Local point will edit locally on a specific point where the tool/robot are located on the toolpath. We will be able to define a blending distance for smoother transition.

Region works in a similar way to Local Point, but we use a boundary instead of the position of the robot.

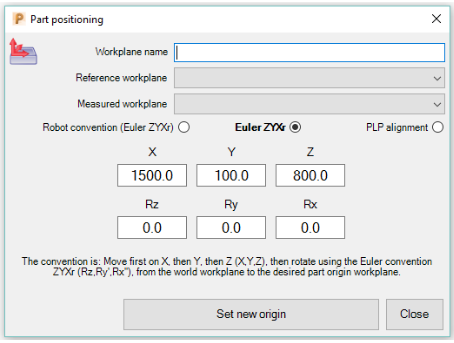
We will start by looking at selected segment.

1 Open the PowerMill project DemoToolControl6D

2 Load robot Autodesk: Robot R2: R2-6X-Spindle0.

3 From the Robot Cell tab open the part positioner and enter X1000 Y100 Z800

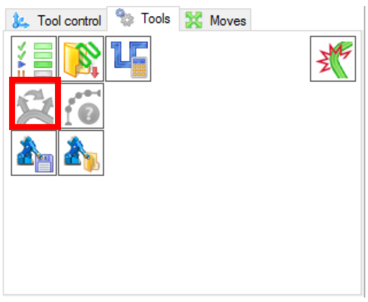
Click on Set new origin.



4 Activate the toolpath Pocket.

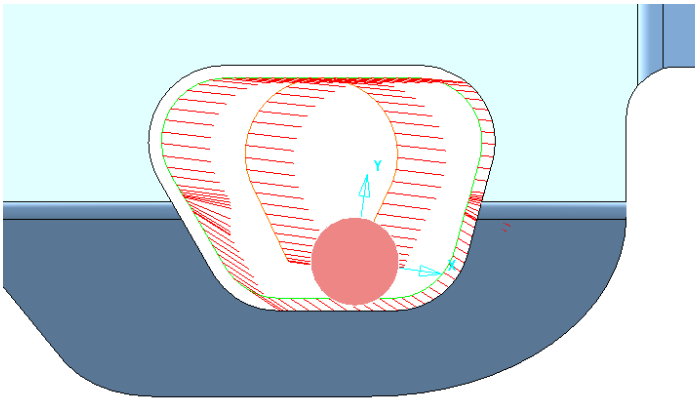
5 Simulate the toolpath, save the simulation as Pocket-Free.

6 Switch to the Tools section of the Robot Control tab



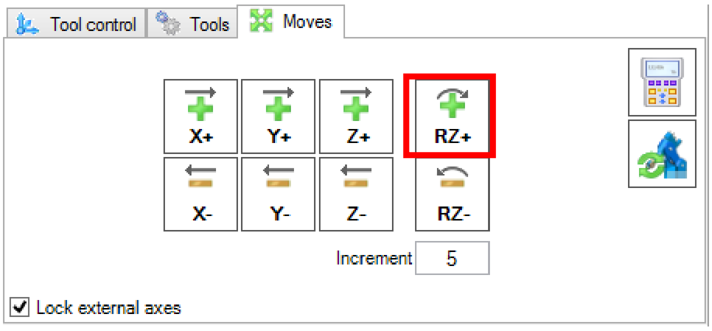
7 Open the Edit toolpath orientation vectors form 

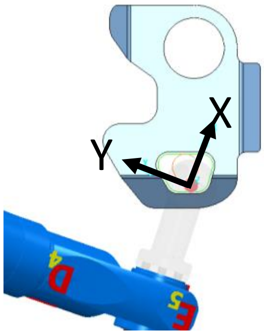
8 Draw the Orientation Vectors 



These orientation vectors have been created automatically once the simulation si saved. The orientation vectors can now be seen.

9 Switch to the moves section of the Robot Control tab. And rotate around the Z+ to align the spindle like the image below.

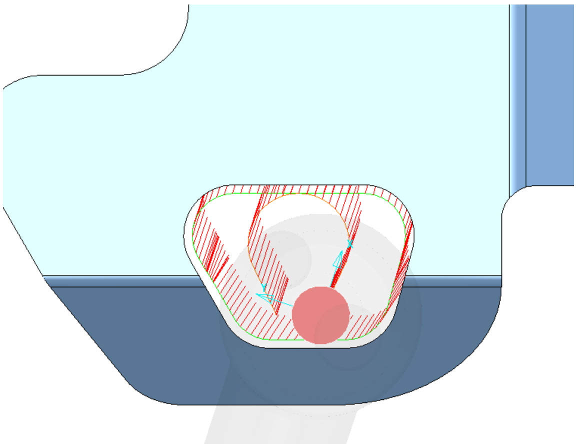


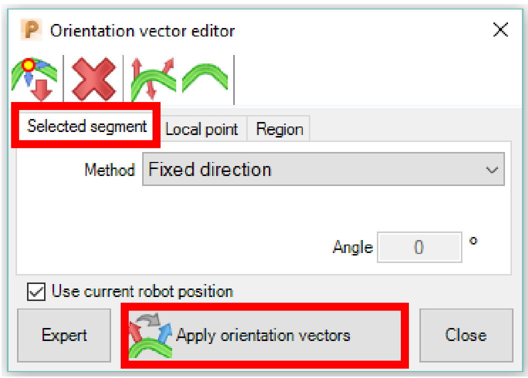


10 Select the toolpath segment (must be highlighted yellow).

11 On the Orientation vector editor menu:

Make sure you are on Selected segment tab and click apply orientation vectors. The end result are brand new orientation vectors that can be used for simulation.

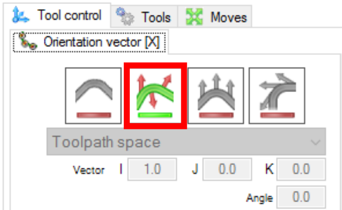




12 Attach to the start and simulate.

13 Save the simulation as Pocket-SelectedSegment.

When a toolpath orientation vector is edited, by default the Orientation vector[X] constraint applied will be Orientation vector.



We must resimulate after orientation vectors have been edited in order to save the new tool orientation.

We will now look at Local point edit.

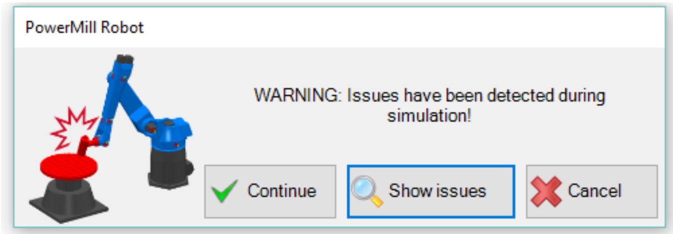
1 Activate the toolpath Outside.

2 Make sure the the Orientation vector[X] constraint is set to vector.

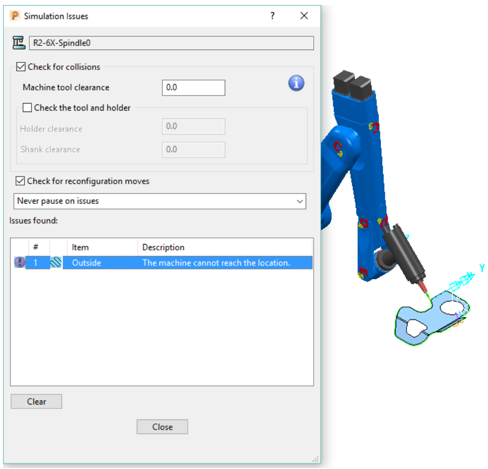
Set vector 1 0 0.

3 Attach to the start and simulate.

4 When saving the simulation a PowerMill message pops up.



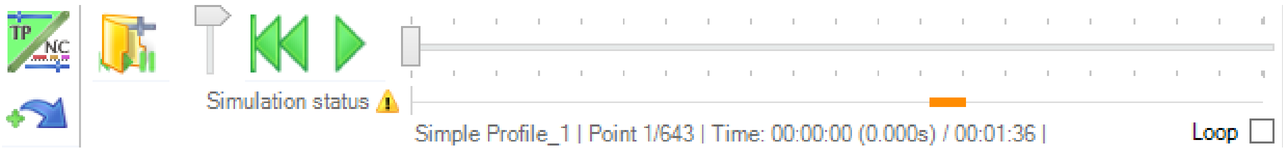
5 If you click on Show issues, you can see that the robot cannot reach a specific location.



By clicking on the message the tool will be position on the place along the toolpath that has the issue.

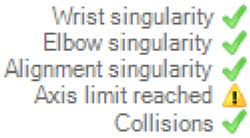
6 Save the simulation.

7 In the simulation replay bar the toolpath status bar is highlighting a potential problem with the operation of the toolpath.



8 Expand the analysis section 

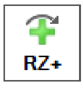
The analysis area shows the source of the highlighted error is the robot is approaching an axis limit.



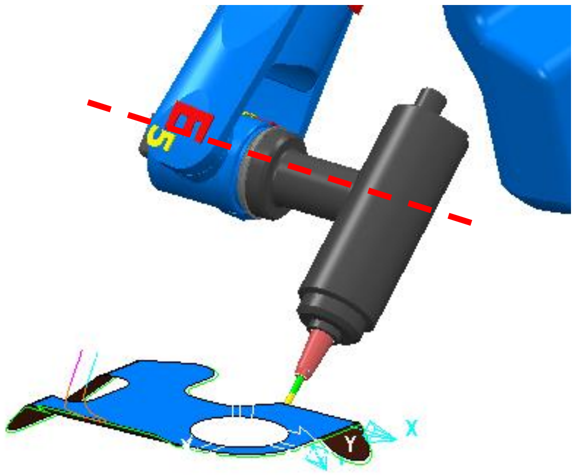
As the simulation approaches the highlighted region it is clear that the robot may not complete the the simulation correctly.

9 Using the simulation replay bar play through the simulation until the tip of the tool is positioned at the closest point of the problem area.

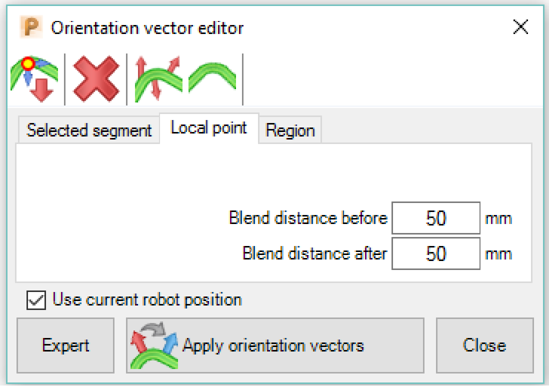
10 Switch to the moves section of the Robot Control tab.

11 Rotate the robot about the z axis 

until the wrist (joint 5) is horizontal.



12 Switch to the Local Point tab on the orientation vector editor menu.



13 Enter a blend distance before of 100 and after of 350. Apply orientation vector.

These settings determine how far before/after the defined point the robot will start reorienting itself to return to it's previous orientation.

A higher value will reduce dwell time, but may cause issues in other areas.

14 Draw the Orientation Vectors  make sure the edit is successful.

15 Replay the simulation and save it as Profile-Local.

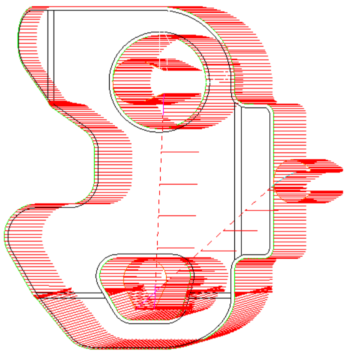
The tool now enters the multiaxis region in a more suitable orientation and has no axis limits and the simulation is successful.

The next example we will use a boundary to show the region option of the orientation vector editor menu. On this menu, the vectors are edited inside a boundary, this will update all the points contained within, plus an additional blend distance.

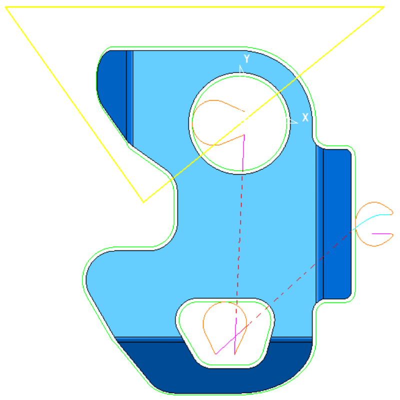
1 Activate the toolpath Full.

2 Ctrl+5 to view from the top and home the robot to get a clear view.

3 Open the orientation vector editor menu, use selected segment to apply orientation vectors like image below.

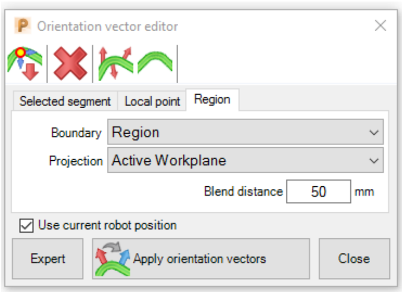


4 Create a boundary like the image below, name it Region.



5 On the orientation vector editor menu, go to Region tab.

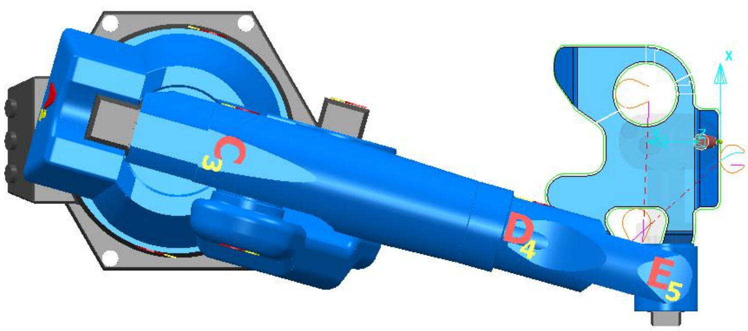
6 Here select the boundary Region, and leave the blend distance as 50.



The boundary will be projected down the z axis of a workplane and all points that fall within that region can be altered simultaneously.

7 From the Moves area of the Robot Control tab rotate the robot about 

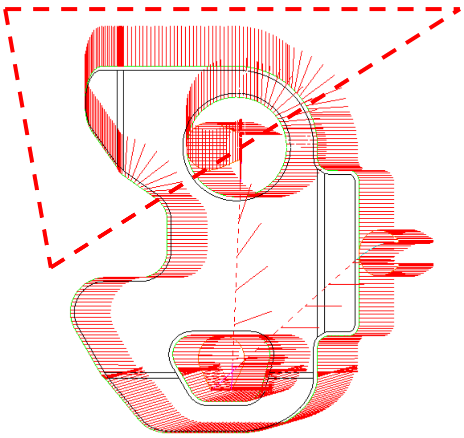
the Z axis until the robot has a positon like image below



8 Click apply orientation vectors.

The orientation vectors within the boundary will all be updated according to the robot position.

9 Simulate the toolpath.



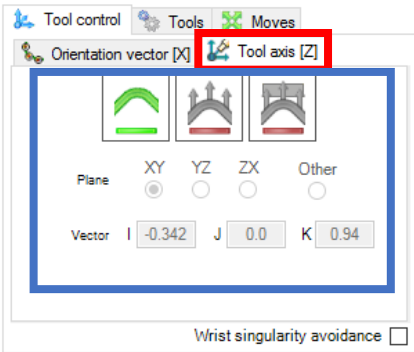
Tool Axis Control [Z]

This is a new functionality added since PowerMill Robot 2017, and is controlling the Z Axis of the tool throughout the toolpath.

It is only available when the Robot Cell has an external axis is Present.

We have seen previously that we can control the X component of the Tool via Orientation Vector [X] in the Tool control tab. This menu will enable the control of the Z component of the tool. These can be used separately, or together to control the movement of the tool during simulation.

There are 3 options: Free, Vector and Plane. By default, it is set to Free.



1 Load the project DemoCylinderTrim.

2 Load in the robot Autodesk: R2-8X-Spindle0+Positioner

3 Activate the toolpath MultiAxis

4 Select View from Right (X), or hold (CTLR + 6)

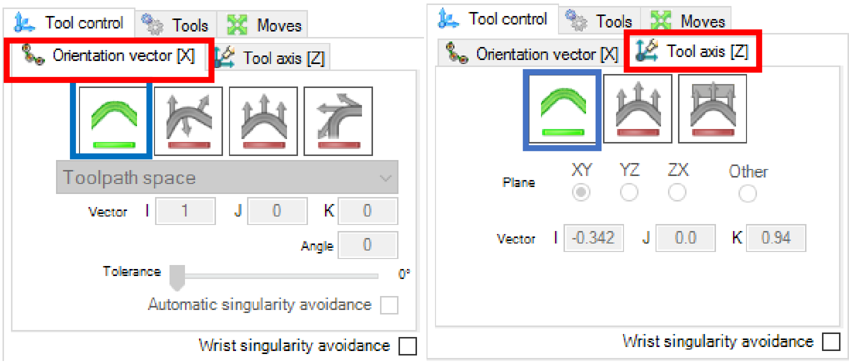
5 Type 45 in E1 followed by return, that will position E1 at 45 degrees.

Type 90 in E2 followed by return, that will position E2 at 90 degrees.

6 Set E1 Priority to Auto

Set E2 to High.

Confirm that Tool Control is set to, Orientation Vector [X] – Free and Tool axis [Z] – free



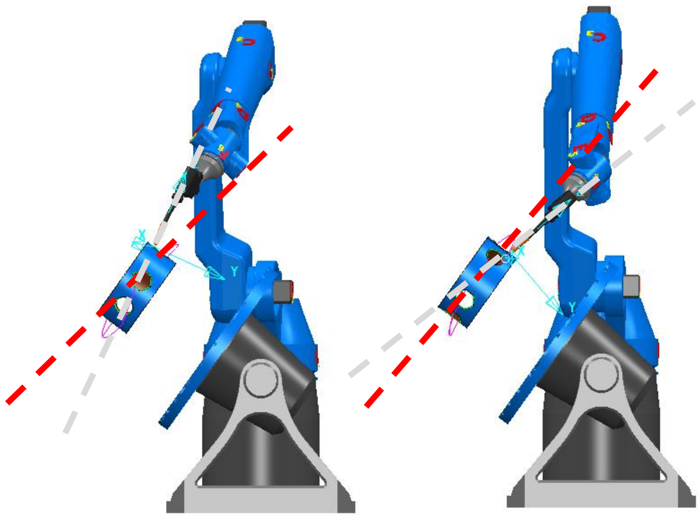
7 Attach to the start

8 Rotate around the Z of the tool in order to orientate the robot as below.

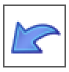
9 Play simulation & Save simulation file.

You will notice that during the simulation of the toolpath is conluded with no issues.

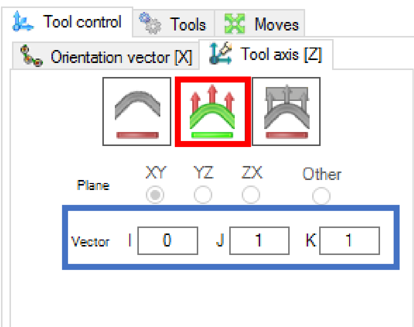
If you look closer at the tool orientation relative to the part, you will notice that the spindle orientation changes a lot due to the toolpath Tool axis variation. E1 is static.



In order to reduce this, we will use the Tool Axis constraint. Follow the steps below to re-simulate this time maintaining the tool axis constant throughout the toolpath.

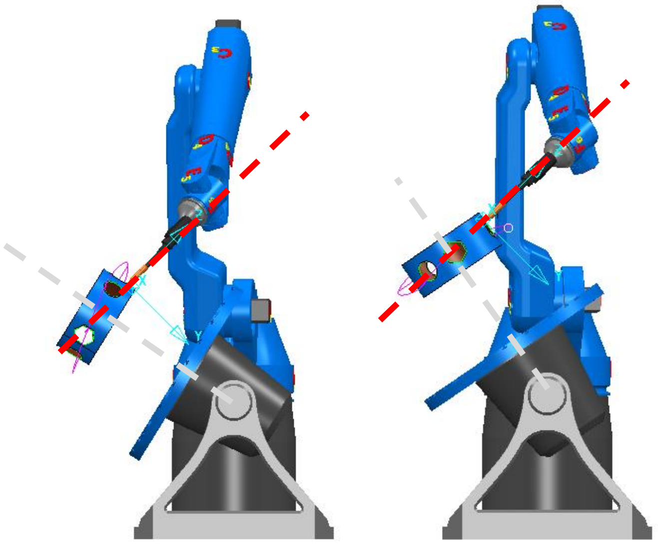
1 Click on Move to Simulation start point 

Set Tool Axis [Z] to Vector, Type in 0 1 1



2. Attach to the start
3. Play simulation
4. Save Simulation

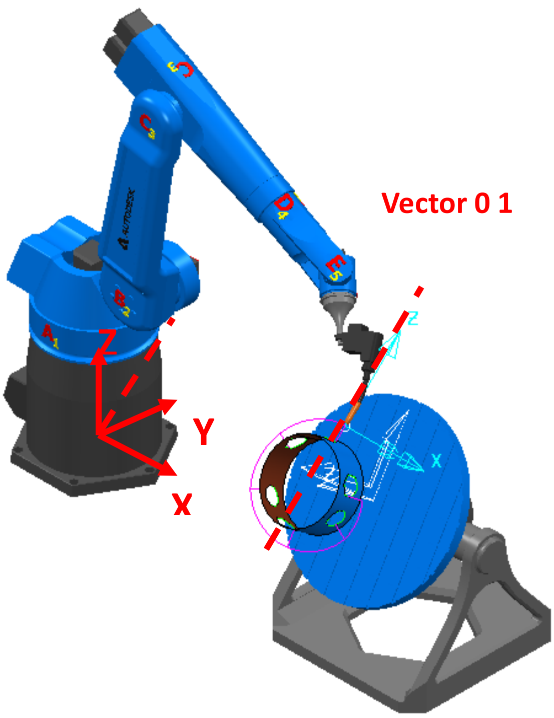
The end result is different as the toolpath axis is maintained, E1 is moving more than before. The Robot head is mostly static and the external axis compensate for the toolpath axis and positions the part correctly, while maintining the tool/spindle orientation.



The Tool axis [Z] is only available on robot cells with external axis.

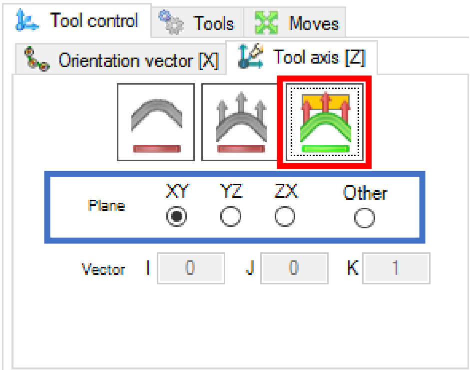
The Vector introduced is relative to the Robot World Workplane.

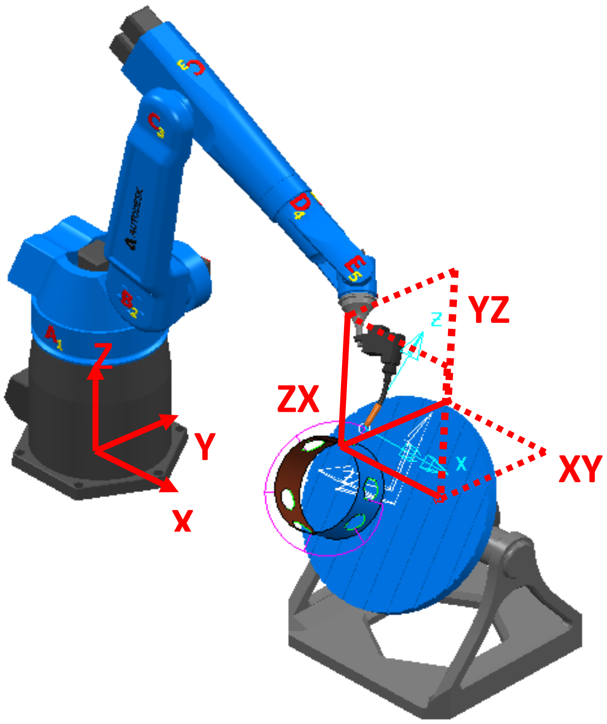
This is the same as the export workplane used to create the DMT components.



Plane works in a similar way. The tool is allowed to move within a predefined 2D plane or another inputed workplane.

This is relative to Robot World Workplane.

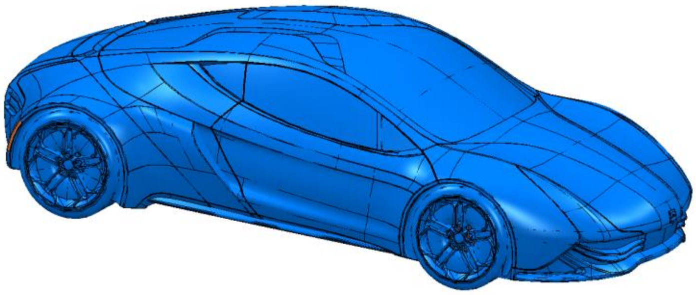




Transitions

The moves between toolpaths can be as important as the toolpaths themselves. These are automatically calculated by PowerMill by default but can be controlled and programmed by the user if required.

1 Load the project AutodeskEvoCar.



2 Load in robot Autodesk: Robot R2: R2-7X-Spindle0+LinearTrack

The car will be loaded at the base position of the robot.

3 From the Robot Cell tab set the Cell origin to be Center Right (Rail)

4 Activate toolpath SideWindow

5 From the Tool control tab, Set Orientation vector [X] to vector, type IJK

0,-0.452,-0.89.

In this instance as the toolpath is not attached to a rotating base the Toolpath/Machine tool space option will not affect the output.

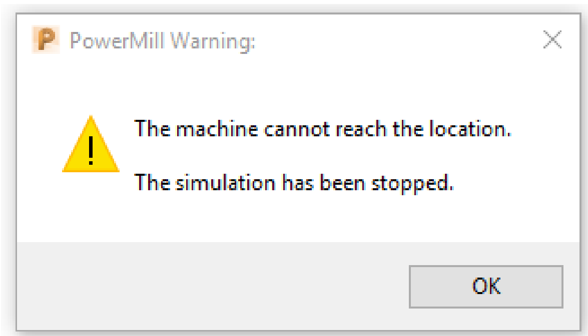
6 Attach to the start of the toolpath, simulate and save the simulation as SideWindow 3+2.

7 Activate toolpath RearNumberPlate

8 Send Robot to Home Position

9 Makse sure Tool Control is set to Free – Both Orientation Vector [X] and Tool Axis [Z]

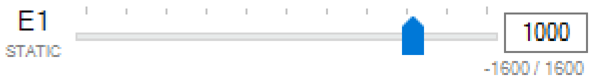
10 Attach to the start and play the simulation.



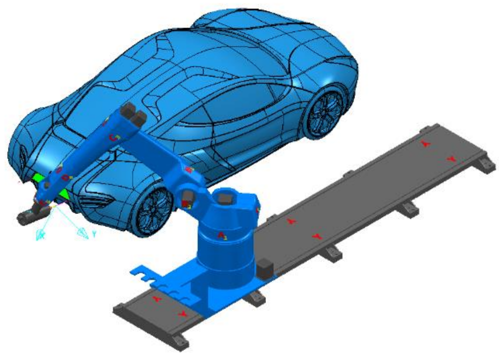
The robot is unable to reach areas of the toolpath due to the distance from the robot base.

11 Send the robot to it's home position.

12 Use the position slider for Robot axis E1 to move the robot along the linear track to a position at about 1000 mm



13 Attach to the start of the toolpath, repositioning the head and using Orientation Vector [X] set to vector if necessary, simulate the toolpath and save the simulation as RearNumberPlate.



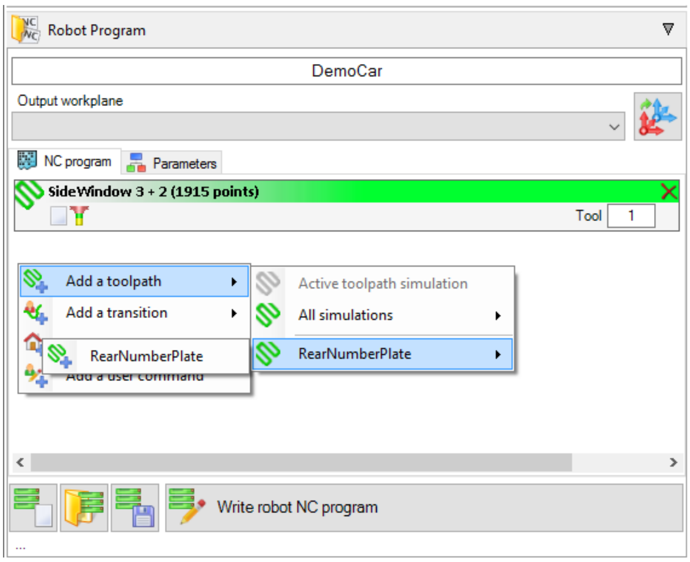
Two simulation files have now been created and can be combined into a single Robot NC program.

14 Open the Robot Program tab.

15 Name the Program DemoCar.

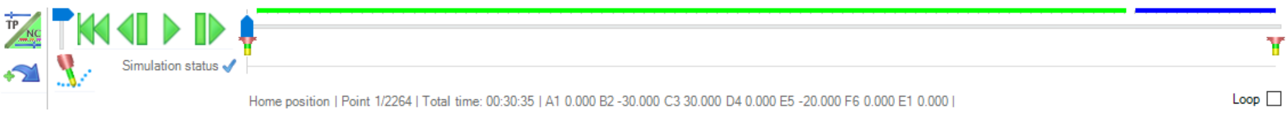
Right click in the NC program area, select Add a Toolpath, SideWindow, SideWindow 3+2.

16 Repeat the procedure to add the RearNumberPlate simulation file.



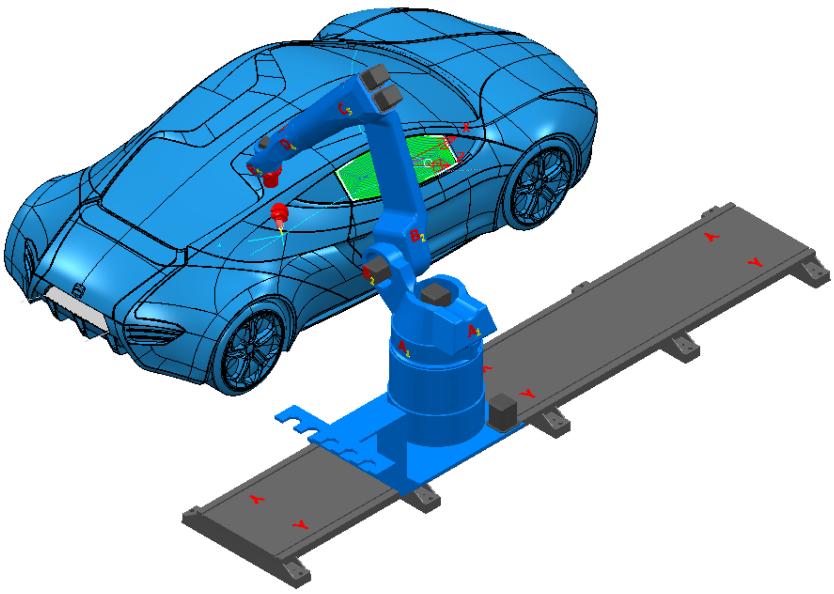
Note the Simulation replay bar has been altered to NC Program mode and the replay bar is now populated with two different coloured regions.

The different coloured regions correspond to the separate toolpaths contained in the NC Program while the white regions indicate areas where the robot is jogging axes to move between toolpaths but no control is currently applied.



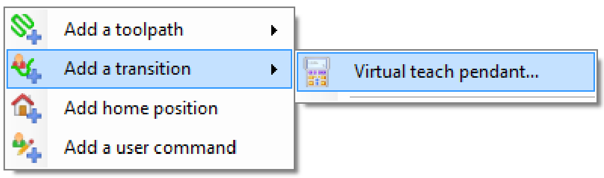
17 Play through the NC program from the simulation replay bar.

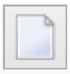
The robot travels straight through the part during the transition between the 2 toolpaths.



This can be resolved through the use of a transition.

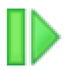
18 Right Click in the NC program area, select add a transition and select Virtual Teach Pendant



19 Select New 

This provides us with options to manually teach the robot a program, similar to using a robot controller. Keep the Virtual Teach Pendant open.

20 On the NC replay bar use Go To Next Key point to move to the end of Toolpath 1



21 From the Virtual Teach Pendant select add  .

This will save the last point of the toolpath as the first position in the transition.

22 From the Teach pendant, send the robot to home position.

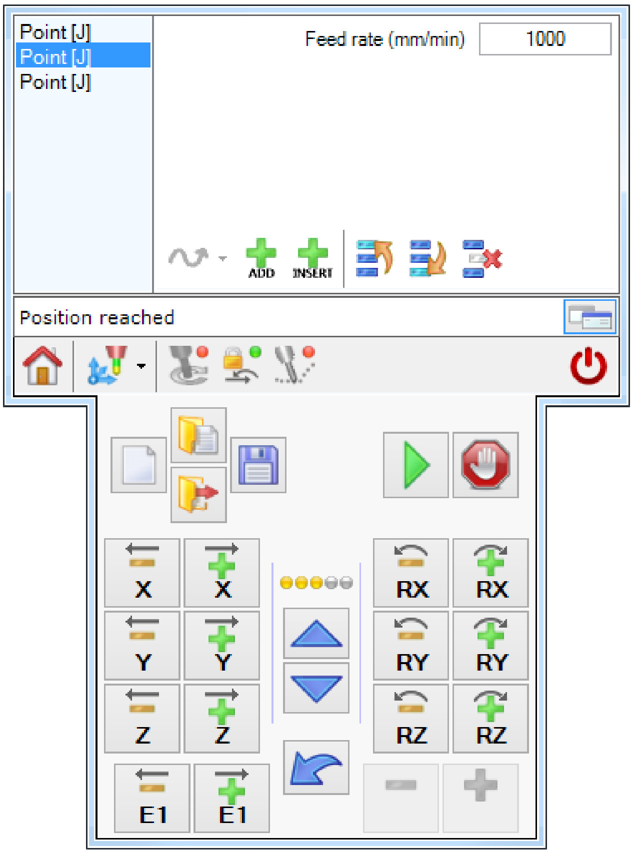
23 Add this position to the transition

24 On the NC replay bar use Go To Next Key point to move to the Start of Toolpath 2.

25 Add the first point of this toolpath to the transition.

The transition should be made up of 3 points:

- The last point of toolpath SideWindow
- The robot home position
- The first point of toolpath RearNumberPlate.



Clicking on any point in the transition will move the robot to that position.

Any position can be added to a transition, in this instance easy to identify positions have been used to simplify the process.

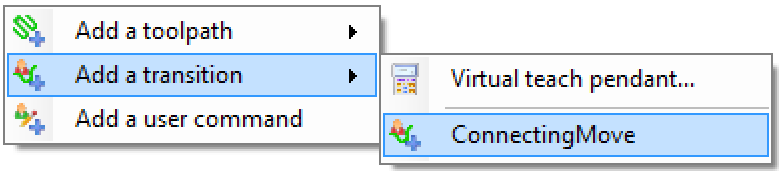
Replaying from the start will also animate the transition. Select the first point and press play in the teach penadant

26 Save the transition and name it ConnectingMove

27 Close the Virtual Teach Pendant

28 From the Robot Program tab right click in the NC Program area.

29 Select add a transition and select ConnectingMove

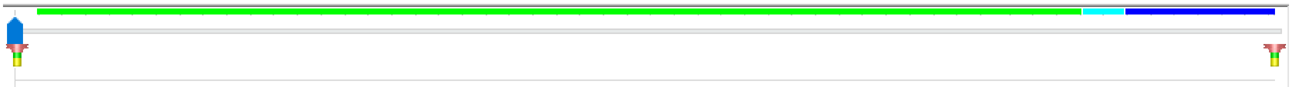


30 By default the transition is placed last in the NC program order

31 Select it and drag it on top of Rear Number Plate.

This will reorder the NC Program so that the transition happens between the 2 toolpaths.

The display in the Simulation Replay Toolbar has also been updated and the blank space has been replaced by a pale blue segment to show the transition has now been added and will be simulated.



32 Play through the simulation again to see the updated NC Program.

33 Write the robot NC program.

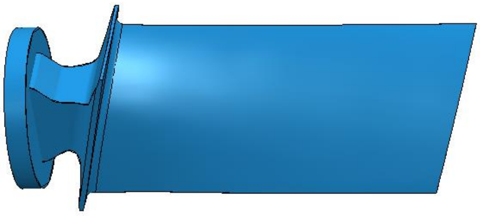
The writing process is the same regardless of the number of toolpaths or transitions in the NC Program.

34 Close the project

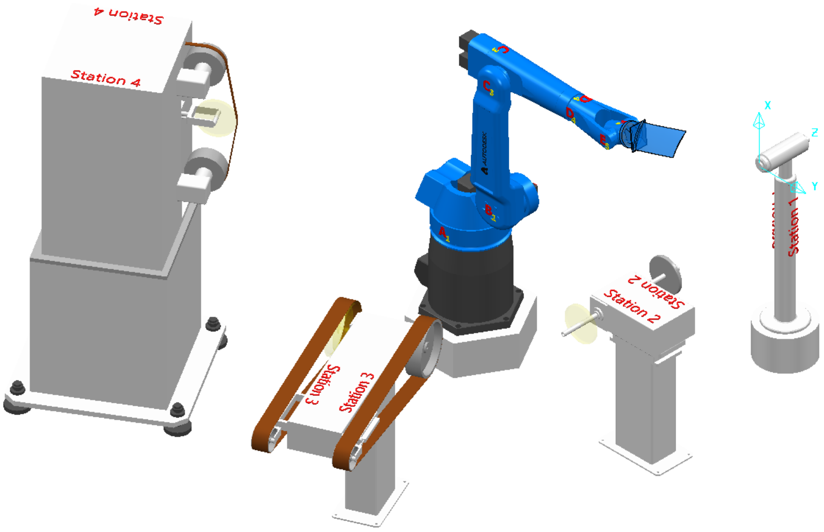
Part on Robot

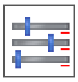
For a wide variety of applications, the part is carried by the robot to externally mounted tools. PowerMill Robot can control these movements and simulate the processes.

1 Open project PartOnRobot_Blade



2 Load the robot Autodesk → R2 Robot → R2-6x-Polishing (PartOnRobot) into PowerMill.



3 From the Robot Cell tab open the Cell Configuration Manager 

4 From the drop down menu click through the different available configurations.

In this instance the difference between the configurations is the attach point (where the tool is attached to the robot). Have a look at the different cell configurations options.

5 Select cell configuration Station 1 – Milling.

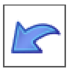
6 Activate the toolpath Station 1 - Milling. Note where the tool is attached to the machine tool.

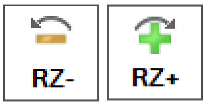
7 Make sure Orientation Vector [X] and Tool Axis [Z] are set to Free

8 Attach to the start.

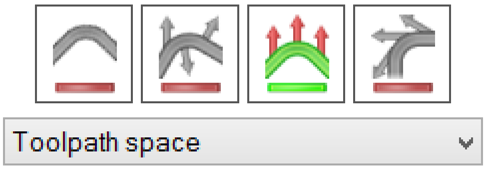
9 Simulate.

You will notice that the simulation is not smooth, and the part is constantly changing orientation. This is not a desired robot motion.

10 Click on "Move to Simulation start position" 

11 Use the Moves tab in Tool control to rotate around the Z 

12 Set the Orientation Vector[X] to vector, rotate to the desired vector, in Toolpath space, and attach to the start.



Toolpath space must now be used as the orientation of the tool is fixed relative to the machine space.

Notice that rotating around the tool with Rz+ or Rz- will rotate the Part, not the spindle.

13 Simulate the toolpath and save the simulation as Station 1 – Milling1.

This project already contains simulation files, do not writ eon top of them, just rename the file. The original files might be useful later on.

14 Activate toolpath Station 2 - Edge grinding

15 From the Robot Cell tab change the Cell configuration to Station 2 - Grinding.

Note the new location of the tool in the cell.

16 Set the Orientation Vector[X] to vector: input the values 0, -1, 0 in Toolpath space, and attach to the start.

17 Simulate the toolpath and save the simulation as Station 2 - Edge grinding1.

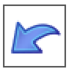
18 Set the Orientation Vector[X] to Free

19 Activate the toolpath Station 3 - Surface polishing and change the cell configuration to Station 3 - Polishing.

20 Attach to the start and simulate.

In this case a grinding belt is being used and has in this case been simulated with a tool at one of the drive wheels.

Care must be taken with toolpaths like this to ensure the part does not collide with the belt.

21 Click on Move to Simulation start point 

22 Set Orientation [X] to vector, and modify the position of the robot using the rotate commands in the Moves area until the connected point is on a part of the tool on the belt surface.

23 Simulate the toolpath and save as Station 3 - Surface polishing1.

24 Activate toolpath Station 4 - Flat belt polishing and use Cell configuration Station 4 - Polishing (Flat Belt).

This example demonstrates a different method of defining a tool for a belt which is to use a ballnose tool at the desired point of contact.

This method will produce more controllable simulations but will be difficult to reproduce using a tool centre point measurement on the robot controller. Solutions to this will be described later in this chapter.

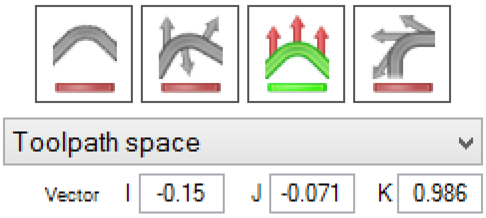
25 Set Tool Control:Orientation [X] vector to Free

26 Attach to the start

27 Use the Moves tab in Tool control to rotate around the Z

28 Place the part parallel to the part floor, or horizontal.

Set Orientation [X] vector to vector, the current vector will be loaded automatically, or set manually the values shown below.



29 Attach to the start

30 Simulate and save simulation as Station 4 - Flat belt polishing1.

31 Switch to the Robot program tab.

32 Open the NC program named Polishing

33 Ensure the output workplane is set to none (the global transform will be used).

34 Write the NC Program.

35 Open the file Polishing.txt.

Note that between module calls the tools are loaded/unloaded, but no tool definitions are written in the code. They would appear after line 6 in the current file.

36 This means that the tool definitions in use will be the tool definitions saved in the controller with the corresponding tool number.

Notice that more simulations have been loaded than were simulated. This is because the project already contained simulation files recorded previously.

To select the cell configuration used for each simulation file. Activate the toolpath, On the Simulation replay bar click on Load a Simulation file

Select Load a Simulation Strategy and cell configurations.

Load simulation strategy and cell configuration

This ensures the correct tool attach point is active for each toolpath simulation.

37 Activate Toolpath Station 1 – Milling

Use Load a Simulation Strategy and cell configurations to make sure the correct cell configuration is active.

Load simulation strategy and cell configuration

38 From the Robot Cell tab open the Robot Configuration Manager.

39 Switch to the tool database tab.

The tool database page contains the options that determine how the tool data will be output in the code.

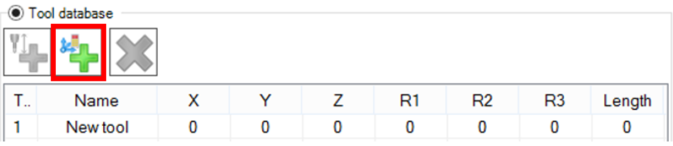
There are 3 options: Robot controller/Spindle calibration/Tool database.

The third option is only intended as a test as it would rely on the virtual model of the tool to perfectly reflect the real cell.

40 Change the option selected to be Tool database.

The tools need to be added to the database.

41 Click add a new tool to the database



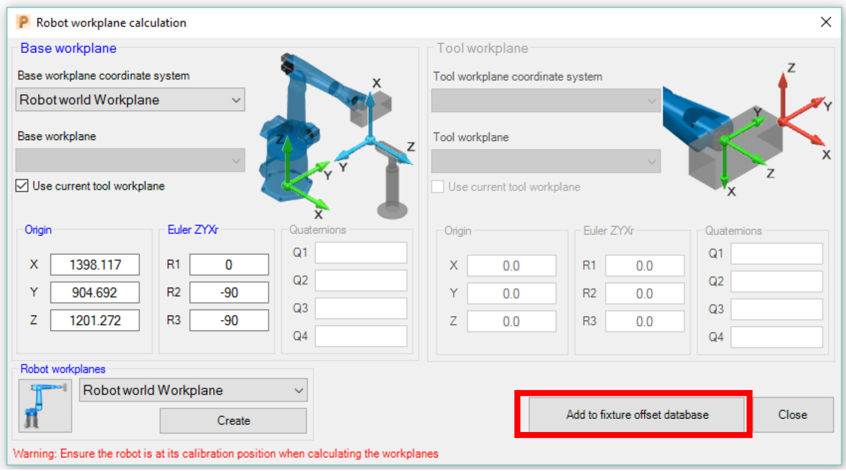
T..	Name	X	Y	Z	R1	R2	R3	Length
1	New tool	0	0	0	0	0	0	0

42 Create the Robot World Workplane, using the Robot workplane calculator

43 Select line 1 from the tool data base, as we are defining tool 1.

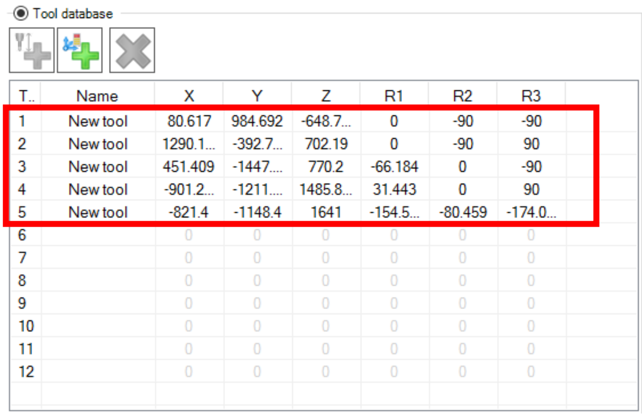
44 Select the robot World Workplane as the coordinate system.

45 Check the Use current tool workplane button and click Add to tool database.



46 Repeat the same process (step 38-46) for each of the different tool numbers used in the different configurations, ensuring the tool is correctly located for the toolpath each time.

The Tool menu wil be filled in with 5 tools, all tool data is now defined.



T..	Name	X	Y	Z	R1	R2	R3
1	New tool	80.617	984.692	-648.7...	0	-90	-90
2	New tool	1290.1...	-392.7...	702.19	0	-90	90
3	New tool	451.409	-1447....	770.2	-66.184	0	-90
4	New tool	-901.2...	-1211....	1485.8...	31.443	0	90
5	New tool	-821.4	-1148.4	1641	-154.5...	-80.459	-174.0...
6		0	0	0	0	0	0
7		0	0	0	0	0	0
8		0	0	0	0	0	0
9		0	0	0	0	0	0
10		0	0	0	0	0	0
11		0	0	0	0	0	0
12		0	0	0	0	0	0

47 Write the NC Program and open the file Polishing.txt.

The file will now have the tool information written in it. It will appear similar to the code shown below.

TOOL[1] = [X 80.617, Y 984.692, Z -648.728, R1 0.0000, R2 -90.0000, R3 -90.0000]

TOOL[2] = [X 1290.195, Y -392.704, Z 702.190, R1 0.0000, R2 -90.0000, R3 90.0000]

TOOL[3] = [X 451.409, Y -1447.742, Z 770.200, R1 -66.1840, R2 0.0000, R3 -90.0000]

TOOL[5] = [X -821.400, Y -1148.400, Z 1641.000, R1 -154.5530, R2 -80.4590, R3 -174.0860]

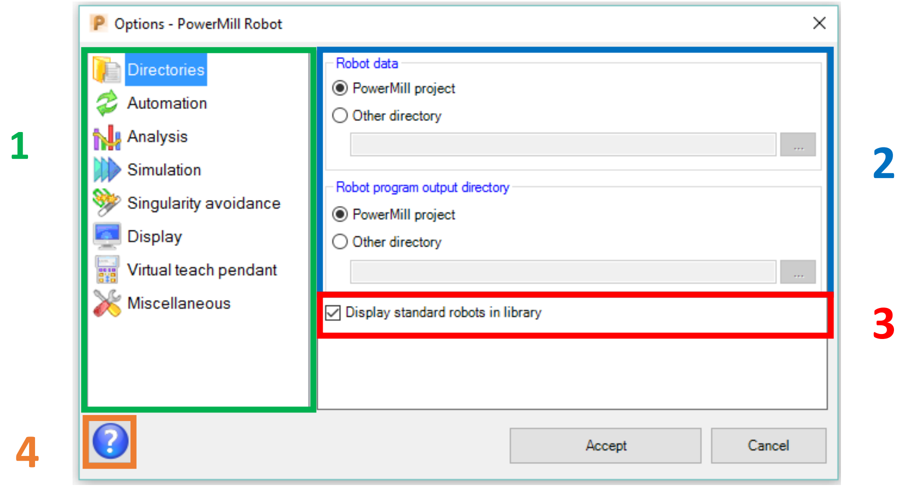
TOOL[4] = [X -901.237, Y -1211.939, Z 1485.872, R1 31.4430, R2 0.0000, R3 90.0000]

Depending on the manufacturer the tool Workplane can be the either the cutting tool or the actual part on the robot. Check this on the manufacturer manual.

The Options Form

Clicking on the Options Form in the Plugin Manager while the Robot plugin is selected will provide access to a number of options that control the operation of PowerMill robot.

Directories



Key:

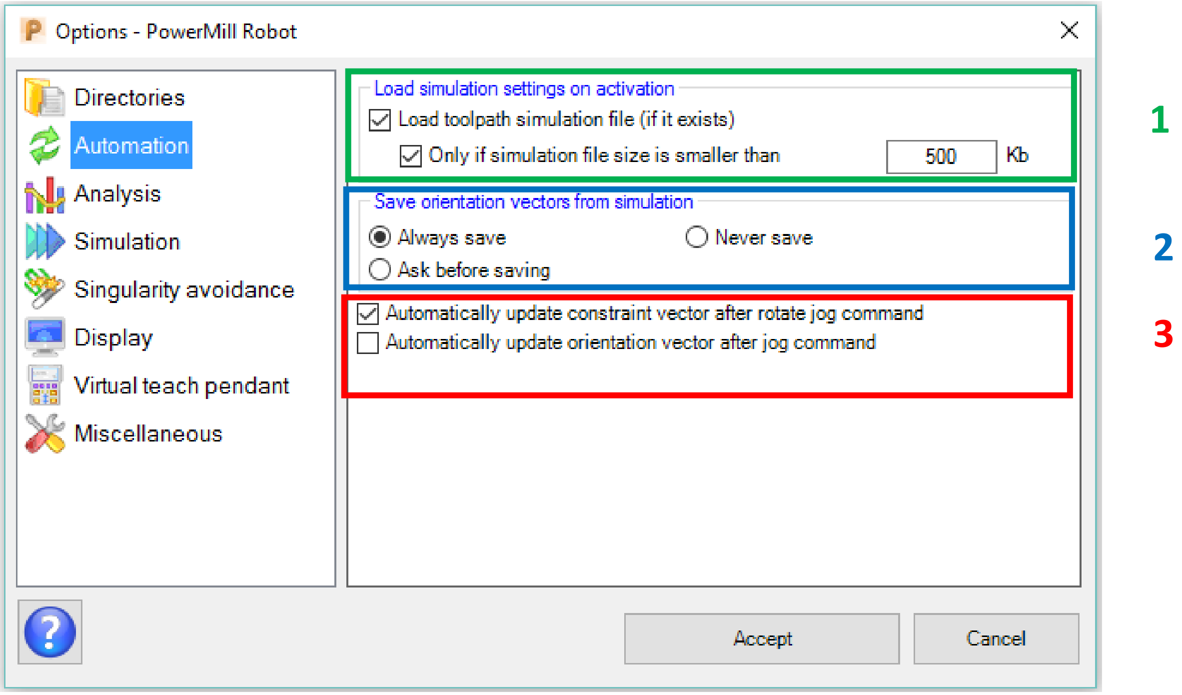
1 Options tabs list, used to navigate between different options menus within the form.

2 Robot data options, determines where the data generated by PowerMill robot is saved. The default is to save it within the PowerMill project file.

3 Control allowing the user to determine whether or not the standard robots appear in the library tab in PowerMill robot (Changes take effect the next time the robot library is refreshed).

4 Link to the folder containing the PowerMill Robot Help documentation

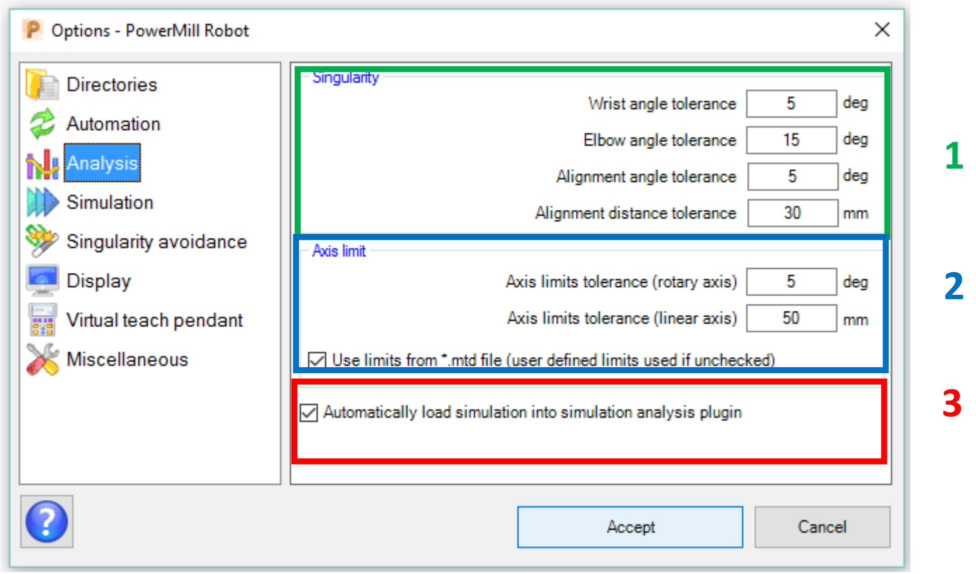
Automation



Key:

1. These options control whether the previous simulation file is loaded by PowerMill robot when the associated toolpath is activated.
2. This option controls whether orientation vectors are created when the toolpath is simulated. Once orientation vectors have been created they can be used to constrain the toolpath for future simulations.
3. These options control whether vectors and orientation vectors are automatically updated when the tool is jogged into a position by the user.

Analysis



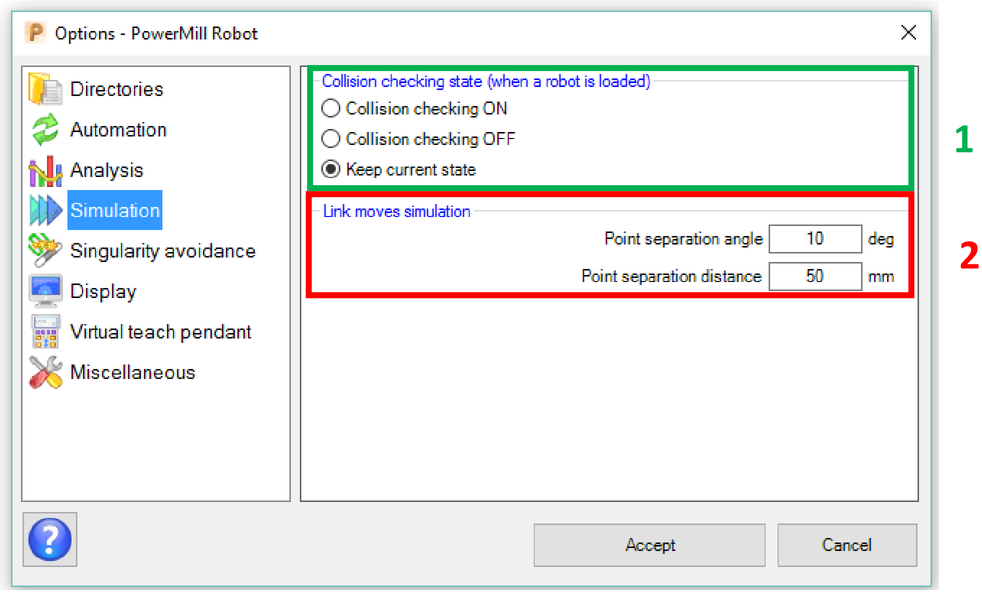
Key:

1 These settings determine how close the robot has to be to a singularity position to be highlighted as a potential issue within the simulation toolbar.

1 These settings determine how close the robot has to be to an axis limit to be highlighted as a potential issue within the simulation toolbar.

2 This option allows the completed simulation to be loaded into the advanced simulation plugin for analysis of the robot motion while it follows the toolpath.

Simulation

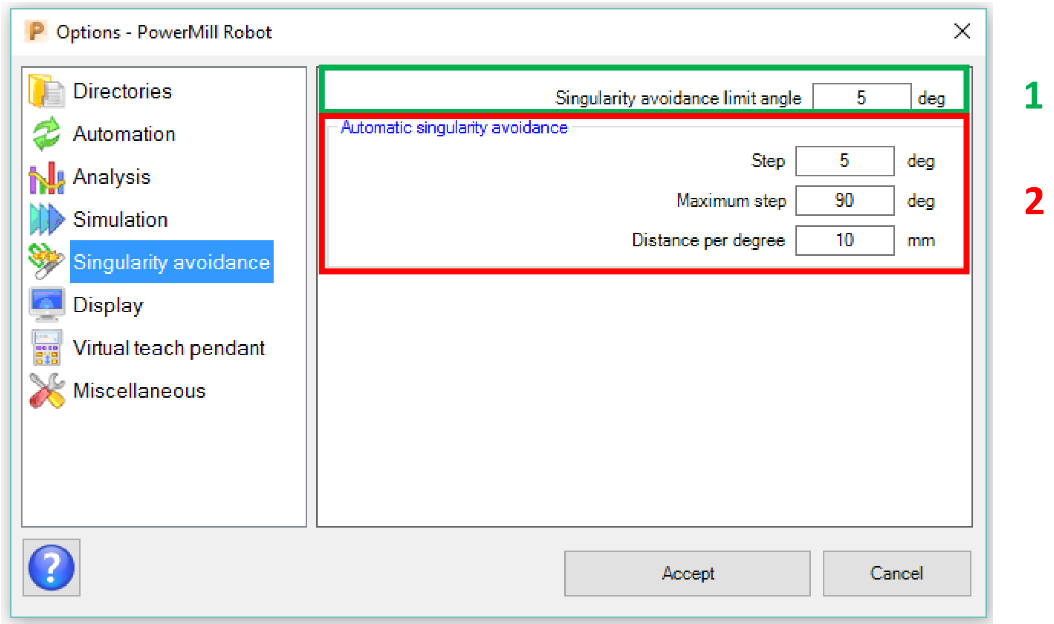


Key:

1 These are the options allowing the user to switch on or off the collision checking for PowerMill robot.

2 These options control the frequency of points within a transition path to allow for simulation and control of the robot path in the cell.

Singularity Avoidance



Key:

1 This option controls how close to a singularity position a robot will be allowed to get before PowerMill robot will attempt to automatically reorient the axes to avoid the singularity.

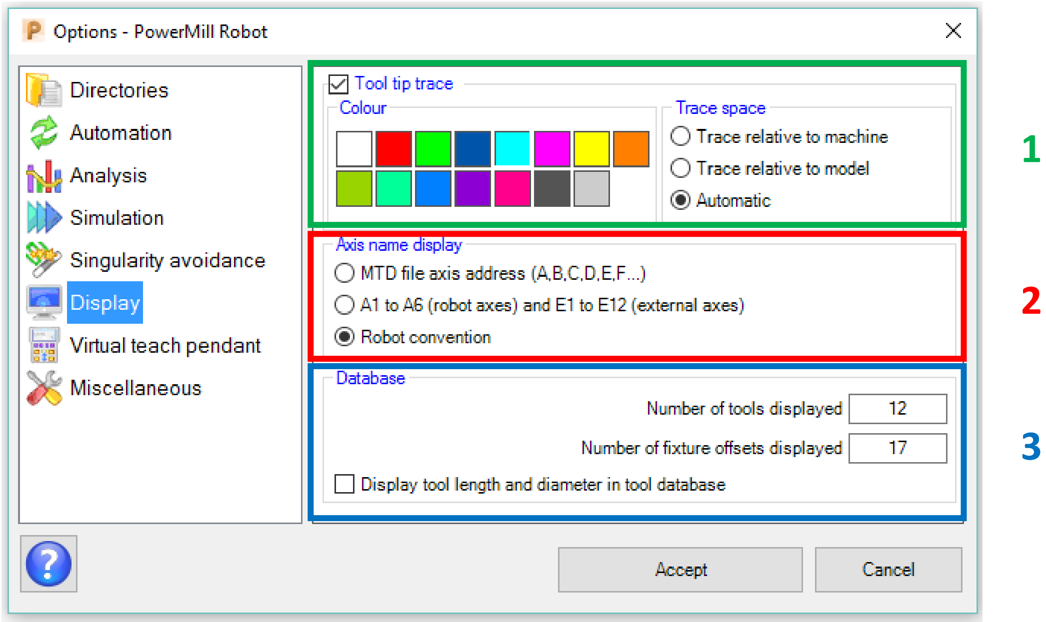
2 These settings determine the behaviour PowerMill will follow to avoid a singularity.

Step determines the increments PowerMill will alter the orientation vector angle by when searching for a singularity free solution.

Maximum step controls the maximum deviation angle from the original tool orientation that PowerMill is allowed to use.

Distance per degree controls how sharply the robot will move into the new orientation, i.e. 10mm required per degree rotated, this is used to smooth the transition.

Display



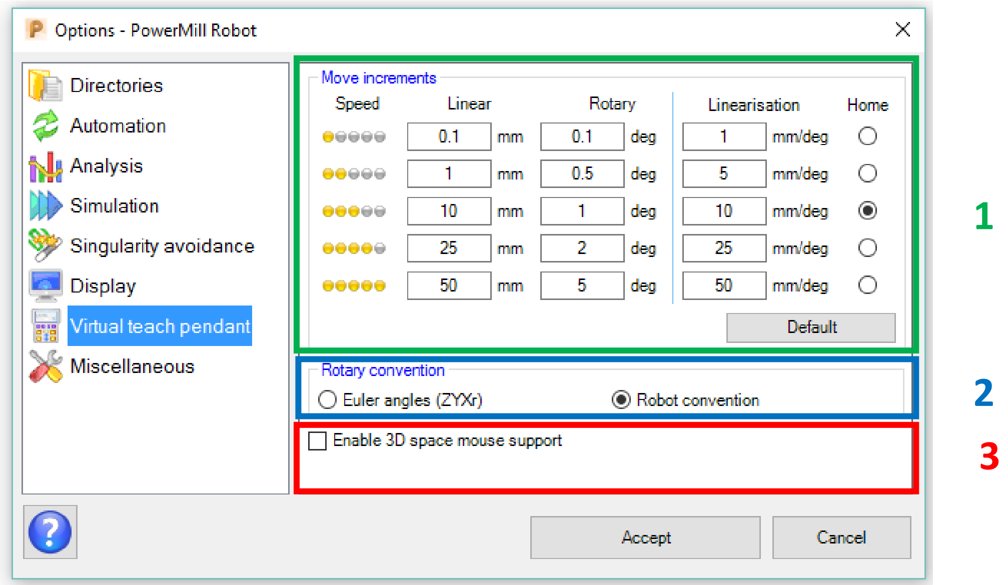
Key:

1 These options control the appearance and settings related to the tool tip trace or the path of the tool tip relative to either the machine tool space or the part.

1 These options control how the names of the axes appear in the Robot Control tab and in the virtual teach pendant.

2 These options allow the user to control how many rows appear in the tool and fixture offset forms and therefore how many can be used in a robot program.

Virtual Teach Pendant



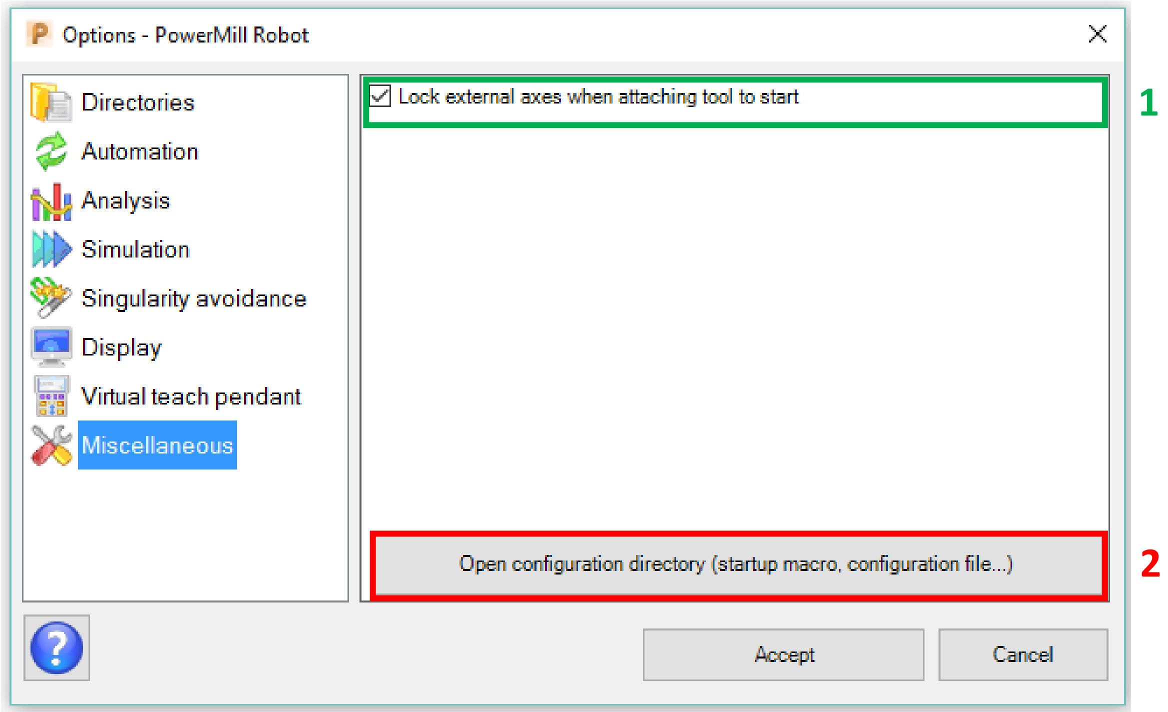
Key:

1 hese settings allow the user to control the increments that the robot will move by when using the Virtual Teach Pendant in each of the speed settings.

1 This option controls how the tool orientation is displayed in the Virtual Teach Pendant.

2 This option allows the user to use a 3D mouse to control the axes and position of the robot

Miscellaneous



Key:

1 This option allows the user to control how the external axes behave when the user attaches to the start of the toolpath.

2 This will open a folder with 2 files.

Application.cfg and Application.mac

Application.mac should not be edited or moved, as it is the start up macro for PowerMill Robot. This File allows the user to modify the processes and commands that are run when the first robot is loaded into the PowerMill

Application.cfg is PowerMill Robot configuration file, where the user preferences are saved.

This file has direct influence on some options inside powerMill Robot, some of these are for example:

Control how the names of the axes appear in the Robot Control tab and in the virtual teach pendant.

How many rows or numbers of tools that appear in the tool and fixture offset forms and therefore how many can be used in a robot program.

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