DFMA® Should Costing Software Machining Tutorial

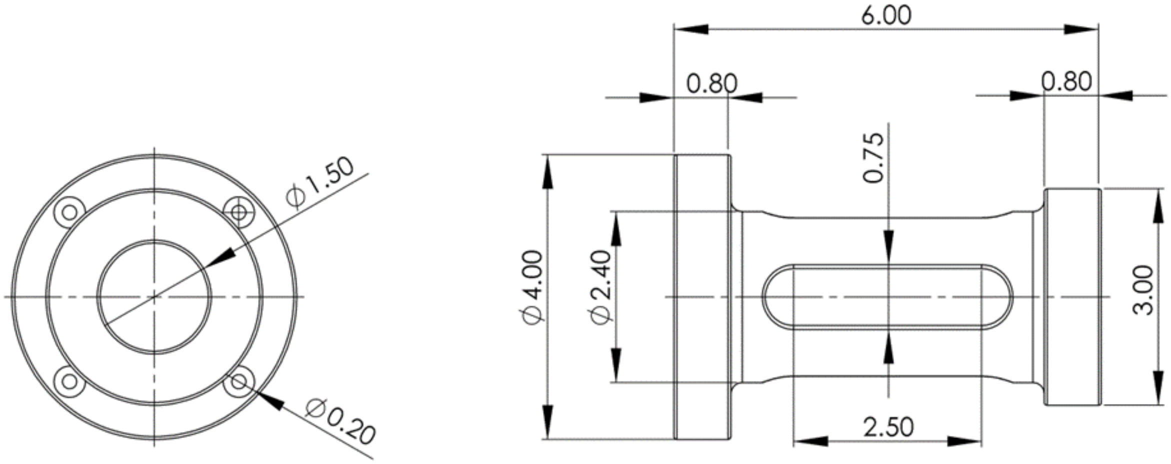
Machining is the process of removing material from a workpiece. This is a common process for creating parts, especially metal parts. Machine tool setups hold a cutting tool or abrasive wheel, hold the workpiece, and then provide for relative motion between the two in order to produce the desired surface.

The DFMA Should Costing software can be used to model the secondary machining of parts that are formed by another process as well as the machining of parts directly from a stock shape of material. The following tutorial shows the two different methods that can be used to model a part machined completely from stock.

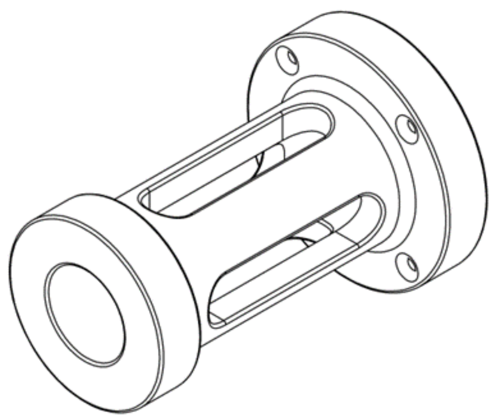
Parts machined from stock can be analyzed in the program in two distinctly different ways, by using the Dynamic Cost Agent or not. When the Dynamic Cost Agent is not used, the analysis is based on the definition of individual machine tool setups and the individual machining operations that are performed on each setup. When the Dynamic Cost Agent is used it is not necessary to define the individual machine tool setups and machining operations. Instead, the overall shape of the part is classified and various types of part features are defined. The program uses that information to automatically determine a suitable machining process as well as the resulting part cost. With the Dynamic Cost Agent, there is also an option to determine the most important cost drivers for your specific part which makes the machining analysis easier and faster to complete.

The first part of this tutorial will guide you through a machining analysis while using the Dynamic Cost Agent and the second part of this tutorial will cover a machining analysis without using the Dynamic Cost Agent.

The part analyzed in this tutorial is a hollow cylinder base that is cut from bar stock and then has various machining operations performed on it using a turning center. A dimensioned drawing of this part is shown on the next page and the completed DFMA Should Costing analyses are contained in the sample file *cylinder.dfmx* that has been included with your installation of the software (\data\samples).



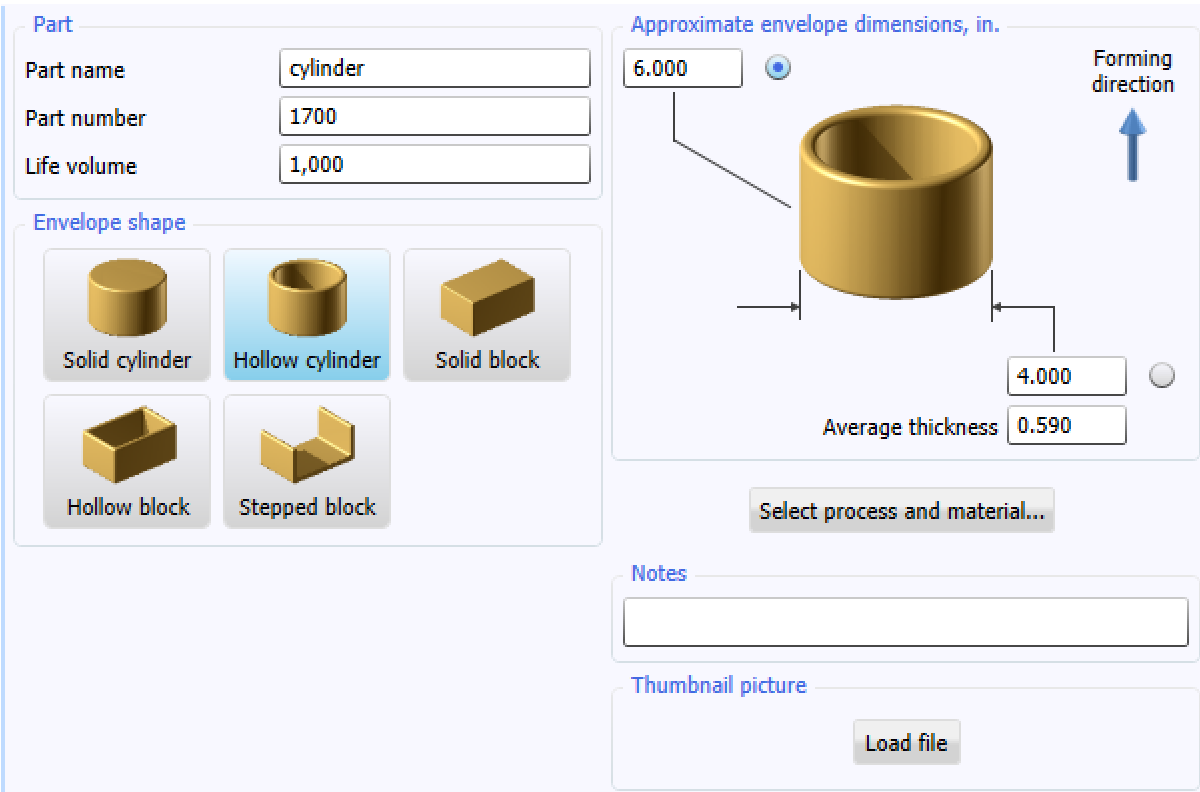
⌀1.50
⌀0.20
6.00
0.80
0.80
0.75
⌀4.00
⌀2.40
3.00
2.50



Part 1 - Analysis of a machined part with the Dynamic Cost Agent

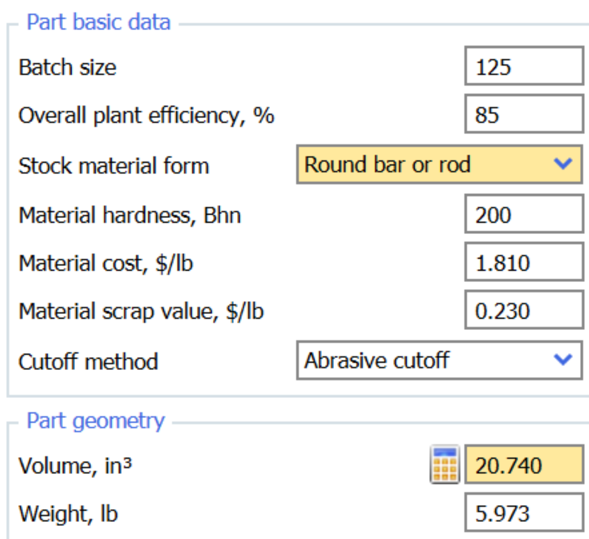
Begin the analysis

1. In a new analysis, complete the part description as shown here:



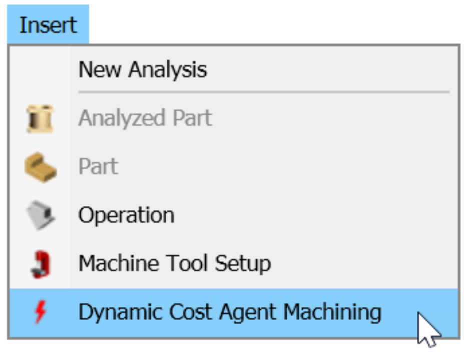
2. Accept the default forming direction shown above because this is the direction in which the bar stock would have been produced.
3. Double-click the *Original* name on the tab above the Process Chart. Type **Dynamic Cost Agent** and press the **Enter** key.
4. Click the **Select process and material** button.
5. On the left side of the *Process and Material selection* window choose *Machining or cut from stock* for the process. On the right side of the window, expand the *Stainless steel* material category and choose *Generic stainless steel*. In the middle, be sure the *25B BDI United States* manufacturing profile is selected.
6. Click **OK** to return to the main window with the responses for the *Stock process* entry displayed on the right panel.

7. Note that the stock material form is defaulted to *round tube* because the hollow cylinder part envelope shape was chosen at the beginning of the analysis. This part will actually be machined from solid bar, so select *Round bar or rod* for the stock material form. Click **Calculate** in the *Cost results* box.
8. Leave the cutoff method set to *Abrasive cutoff*. The default values for material cost and scrap value come from the material library and any edits made here to these defaults apply only within this analysis of the part.
9. When a machined part is analyzed with the Dynamic Cost Agent, the *Volume* and *Weight* displayed in the *Part geometry* section are used to estimate the amount of material removed during machining and they affect the software's estimate of the rough machining time required. For this analysis, we know the volume of the finished cylinder so change the *Volume* to 20.74 and click **Calculate** to update the *Weight* field and cost results.



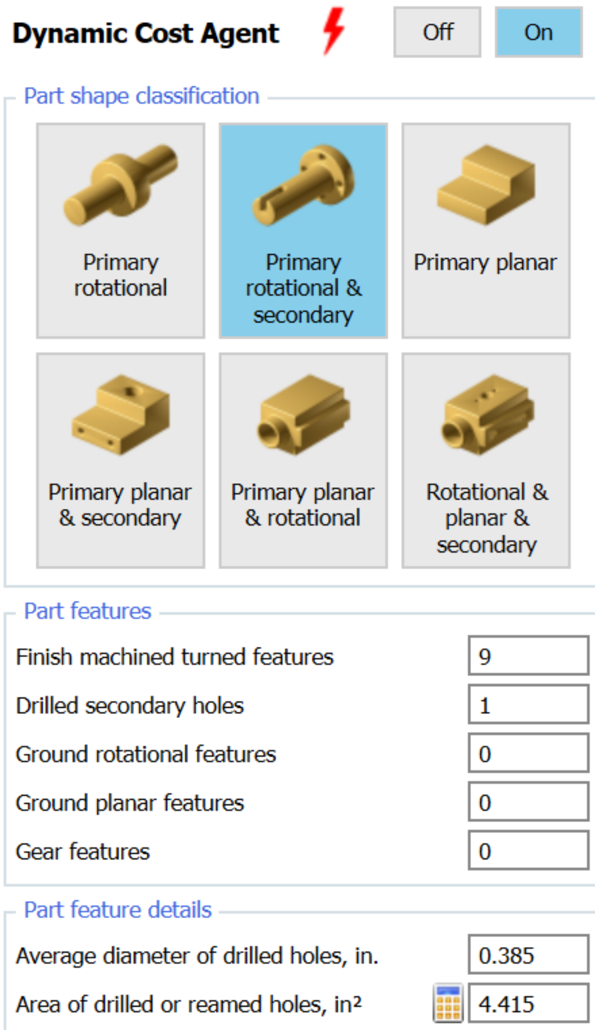
10. Click the *Workpiece* entry on the Process Chart and then review the responses on the right panel. Here, the fields that affect workpiece cost and volume prior to machining are recorded.
11. Click the *Abrasive cutoff* entry on the Process Chart and then review the responses on the right panel. For this analysis, we accept these default values which include the hourly rates and setup time for the cutoff operation.

12. Click the *Insert* menu at the top of the window and then click *Dynamic Cost Agent Machining*.

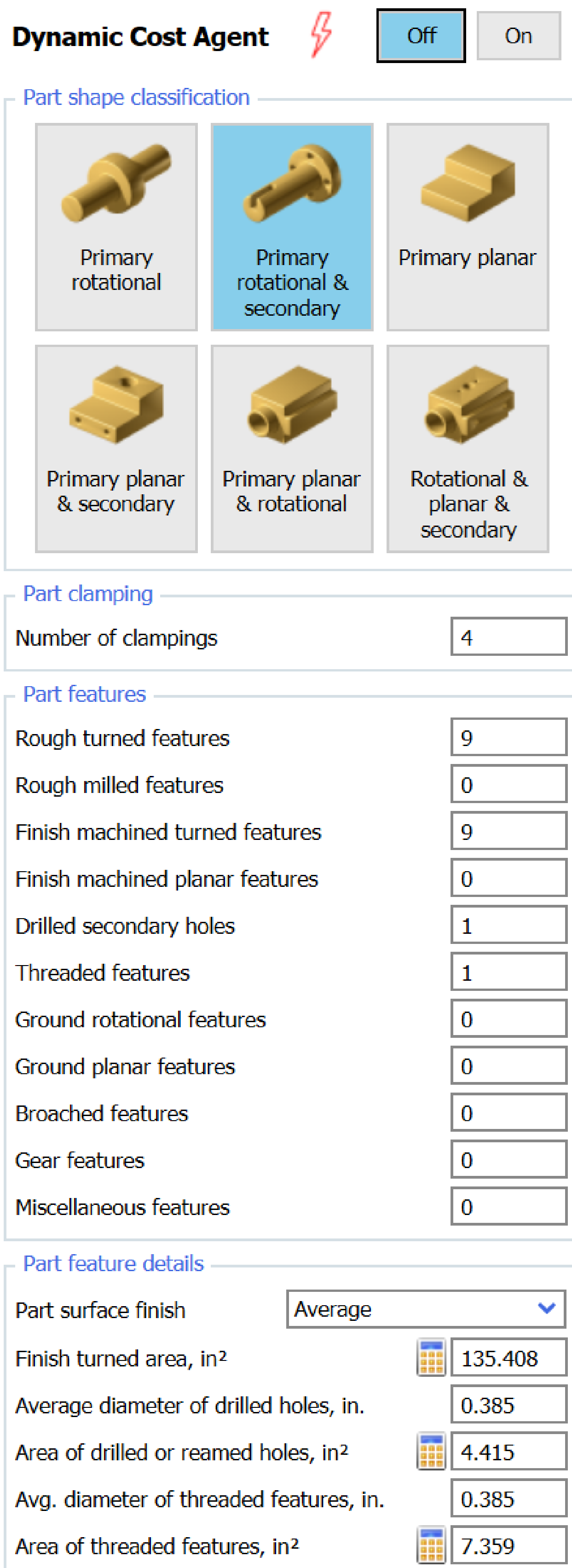


The *Machining operations* entry is added to the Process Chart and a default cost estimate for machining the part has been generated by the program. This default machining cost estimate will now be refined to make it more accurate.

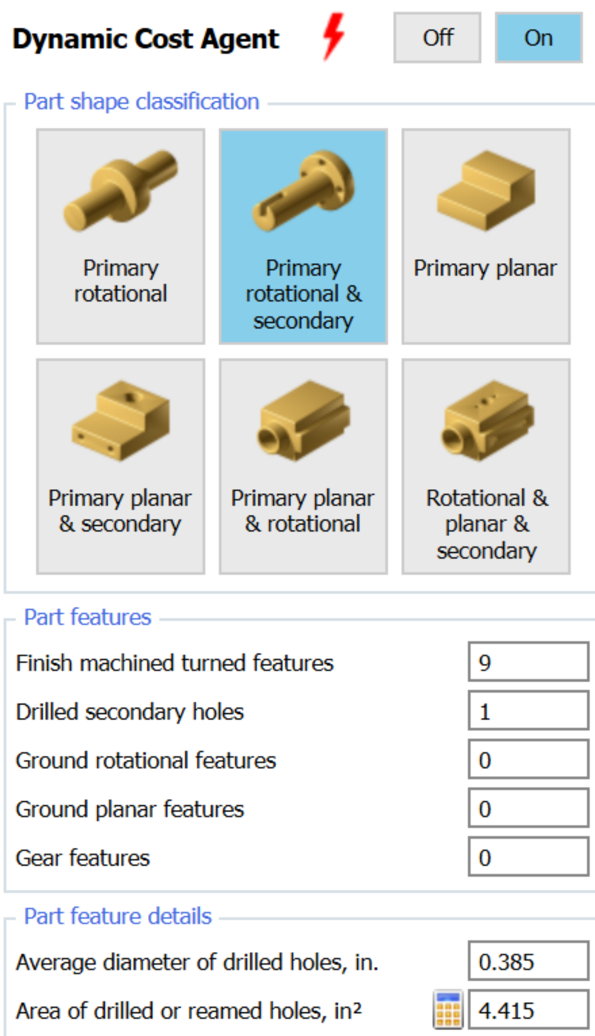
13. The cylinder is a turned part with drilled and tapped holes in its flange as well as milled grooves in its body. These part features require live tooling on the lathe during machining which means the part should be classified as a rotational part with secondary features. For that reason, click the *Primary rotational & secondary* button. The response panel updates, as shown on the following page.



14. At the top of the response panel, click *OFF* to turn off the Dynamic Cost Agent. Note that the Dynamic Cost Agent lightning bolt becomes hollow and the response panel updates to display all the inputs needed to completely describe a rotational part with secondary features, as shown on the following page.

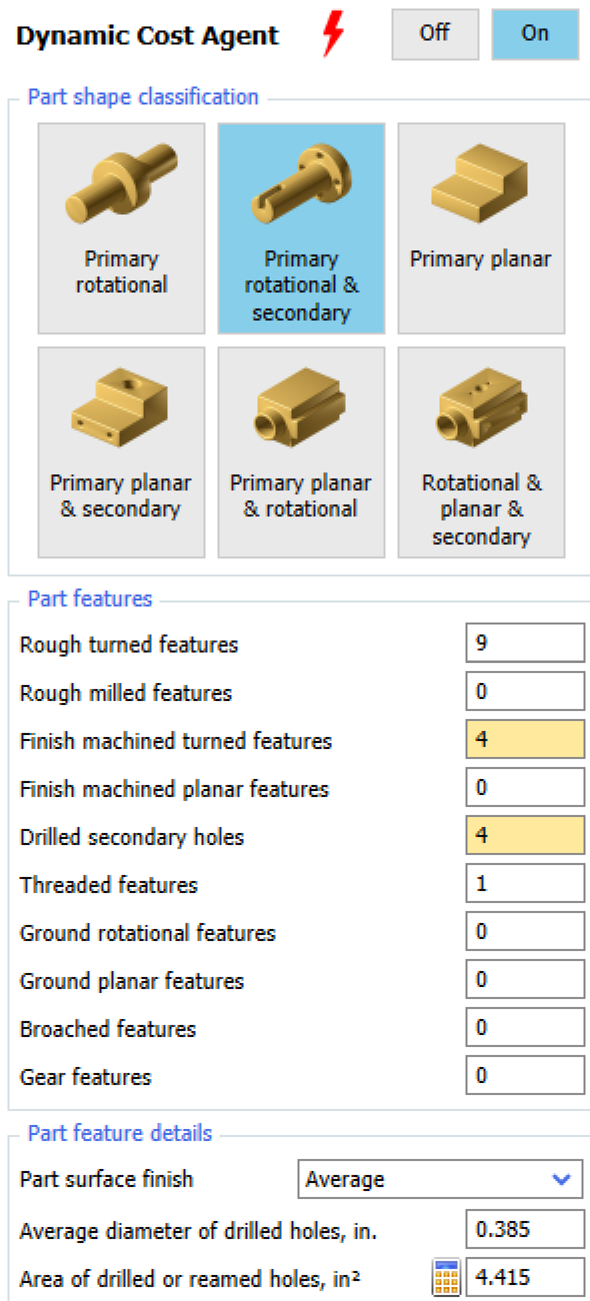

Dynamic Cost Agent
Off
On
Part shape classification
Primary rotational
Primary rotational & secondary
Primary planar
Primary planar & secondary
Primary planar & rotational
Rotational & planar & secondary
Part clamping
Number of clampings
4
Part features
Rough turned features
9
Rough milled features
0
Finish machined turned features
9
Finish machined planar features
0
Drilled secondary holes
1
Threaded features
1
Ground rotational features
0
Ground planar features
0
Broached features
0
Gear features
0
Miscellaneous features
0
Part feature details
Part surface finish
Average
Finish turned area, in²
135.408
Average diameter of drilled holes, in.
0.385
Area of drilled or reamed holes, in²
4.415
Avg. diameter of threaded features, in.
0.385
Area of threaded features, in²
7.359

15. Click *ON* to turn the Dynamic Cost Agent back on and note that a much smaller list of inputs is displayed, as shown below. This list reflects the most important cost drivers for the analyzed part, and it will vary depending on the conditions defined in the analysis. Focusing your analysis on these inputs minimizes the time and effort required to analyze a part while also minimizing errors in the accuracy of the cost results.

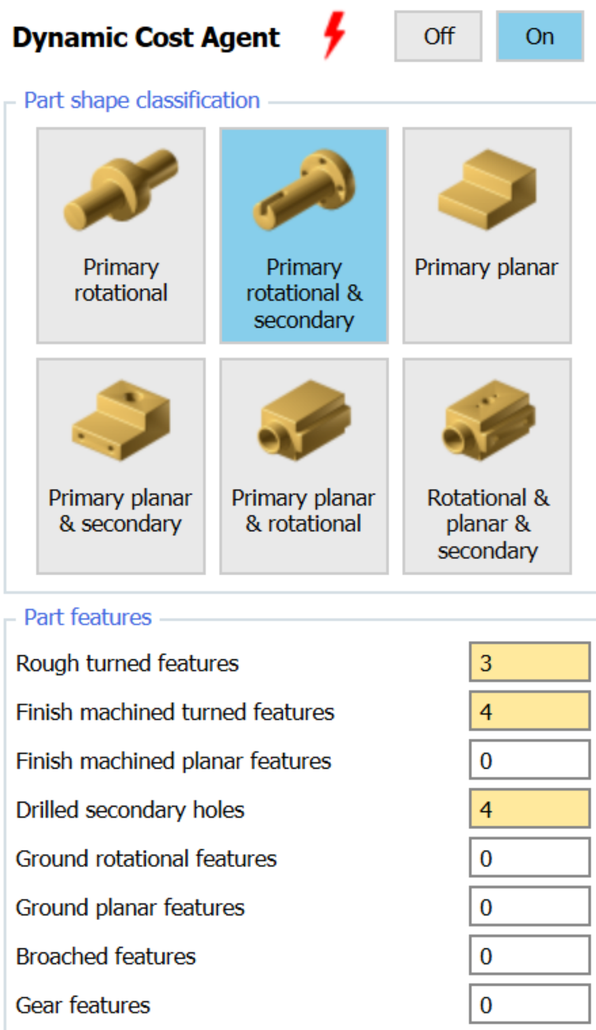


16. Finish turning of the cylinder is carried out on the outside and inside faces of the large flange, the outside face of the small flange, and the central bore. For these features, enter **4** into the *Finish machined turned features* input. Click **Calculate** to update the response panel and note that the important inputs displayed remain unchanged.

17. Enter **4** for the *Drilled secondary holes* input to account for the four secondary holes that are drilled into the large flange. Click **Calculate** to update the response panel and note the additional important inputs displayed, as shown below.



18. Return to the top of the input list and specify the *Rough turned features* input. Rough turning is done down to the outer diameter of the small flange all the way to the inside face of the large flange. Rough turning is also done down to the middle diameter of the part between the inside faces of the large and small flanges. The primary hole rough drilled through the center of the part, prior to finish boring, is also classified as a rough turned feature because it is made using the lathe main spindle. For these features, enter 3 into the *Rough turned features* input. Click **Calculate** to update the response panel and note the number of important inputs displayed has been reduced substantially, as shown below.



19. The cylinder has no finish machined planar features so it is unnecessary to modify the zero default value for that input. There are also no ground rotational or planar features on the part and no broached or gear features which means the zero default values for those inputs apply. The machining analysis of the cylinder using the Dynamic Cost Agent to identify the most important cost drivers is now complete.

20. Click the top-level of the process chart and note that the *total* cost result is $49.8125 per part.

Part 2 - Analysis of a machined part without the Dynamic Cost Agent

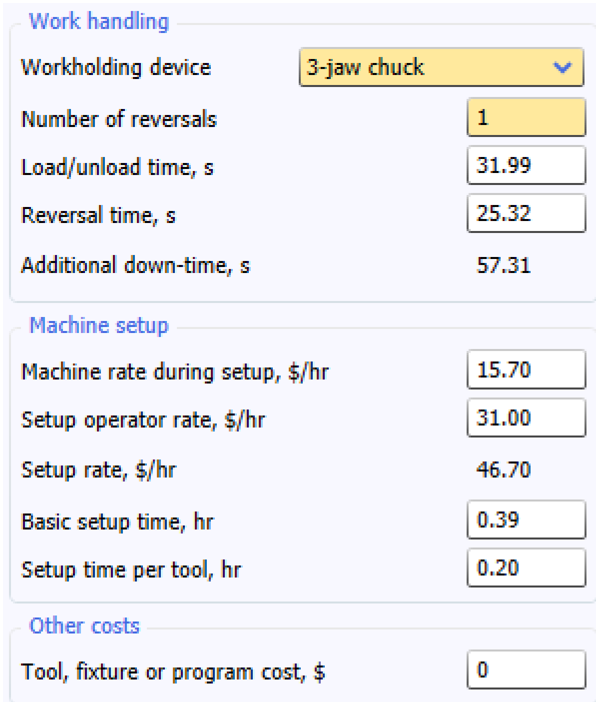
In the second part of this tutorial, a copy of this analysis will be used to analyze the same part without the Dynamic Cost Agent and then the cost results will be compared.

21. Click the *Dynamic Cost Agent* analysis tab at the top of the Process Chart. Click the *Edit* menu at the top of the window and then click *Copy*. Click the *Edit* menu at the top of the window again and then click *Paste* to create a copy of the analysis tab.
22. Double-click the rightmost *Dynamic Cost Agent* analysis tab and change its name to **No Dynamic Cost Agent**.
23. Delete the *Machining operations* entry from the Process Chart.

Adding a machine tool setup

24. Add a machine tool setup. Click the *Insert* menu at the top of the program window and then click *Machine Tool Setup* on the menu. In the dialog that opens, expand the *Lathes* category, if necessary. Click the *Shenyang HTC2050im CNC Lathe* machine.
25. Click the **Insert** button to add the machine to the Process Chart.
26. Close the *Insert machine* dialog and view the responses for the lathe.
27. Note that the batch size and the material hardness can both be changed for individual setups. For this analysis we will accept the default values.
28. Also note that the *Rejects, %* input appears in the *Basic data* group box. This is the percentage of parts rejected after all operations on the setup have been completed. The cost allocated to each acceptable part because of these rejected parts is shown in the *Cost results* panel, underneath the Process Chart.
29. Note the *Result* box on the Responses Panel where the total cycle time and the total setup time are both displayed for the setup. These will be recalculated and updated as machining operations are added to the setup.
30. Click the *Setup/load/unload* Process Chart entry that appears beneath the machine and review the responses on the right panel. Here, the hourly rate and the time required to set up the machine tool can be specified along with the cost of any required fixtures or programming.

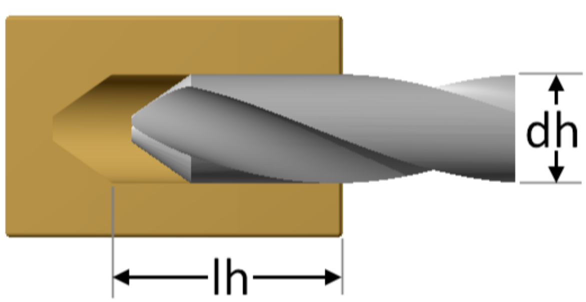
31. In the *Work handling* box, choose *3-jaw chuck* from the *Workholding device* dropdown list. Change the *Number of reversals* to **1** because the part must be reversed in the chuck and machined from both ends. Click the **Calculate** button to update the Responses Panel and the *Cost results*.



32. Add machining operations to the setup. With the *Setup/load/unload* operation selected on the Process Chart, Choose *Operation* from the *Insert* menu to open the *Insert Operation* dialog.

33. Expand the *Machining* category and then the *Drilling* subcategory. Highlight the *Drill single hole operation* and click the *Insert* button to add it to the machine. Close the *Insert Operation* dialog.

34. The Responses Panel shows a picture of the drilling operation with appropriate dimensions labeled to simplify the specification of cut dimensions. Results are not calculated until the dimensions have been entered.



35. Enter 1.5 inches for the *Diameter of drilled hole (dh)* and 6 inches for the *Length of drilled hole (lh)*. Change the tool material selection to *Carbide*. See that the box remains checked to include the tool replacement cost.

36. Click the **Calculate** button to update the *Cost per part* results. The Responses Panel for the operation appears as shown below.

Note that the *Maximum power required* and the *Maximum spindle speed required* are both below the *available* values on the selected machine. This indicates the drilling operation is not limited by the machine and will be carried out at optimal machining conditions.

The *special tooling cost* input is used to specify the cost of any special fixtures or other special tooling that is not included elsewhere.

The *Operation time* result includes the time to position and change the tool whenever necessary. Default values for the tool positioning time and the tool change time are available in the responses for the machine tool.

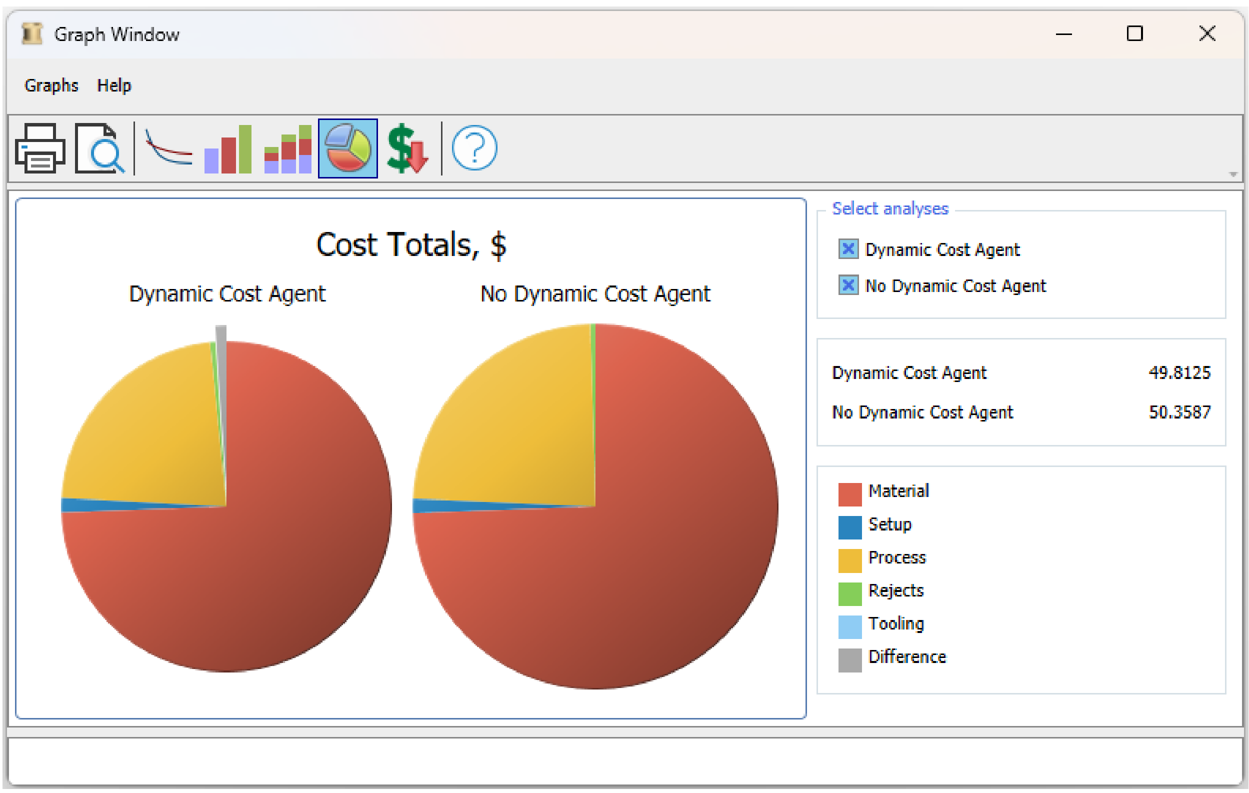
The remaining machining operations would now be added to the analysis in the very same way until all of the machining required to produce the part has been described.

View the completed sample analysis

37. Click the *File* menu at the top of the program window and then click *Open*. In the Open dialog, navigate to the \data\sample folder if necessary and open the cylinder.dfmx analysis file.

38. The leftmost analysis tab in this sample file contains the machining analysis that was completed during the first part of this tutorial using the Dynamic Cost Agent. The rightmost analysis tab contains a completed version of the analysis started in the second part of this tutorial without the Dynamic Cost Agent and with all the individual machining operations defined.

39. Click the *Results* menu at the top of the program window and then click *Cost Totals* to display the graph. Click the  toolbar button to display the Pie chart and then, on the right side of the graph window, check the boxes to compare both analyses, as shown below.



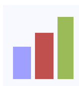
Discussion of results

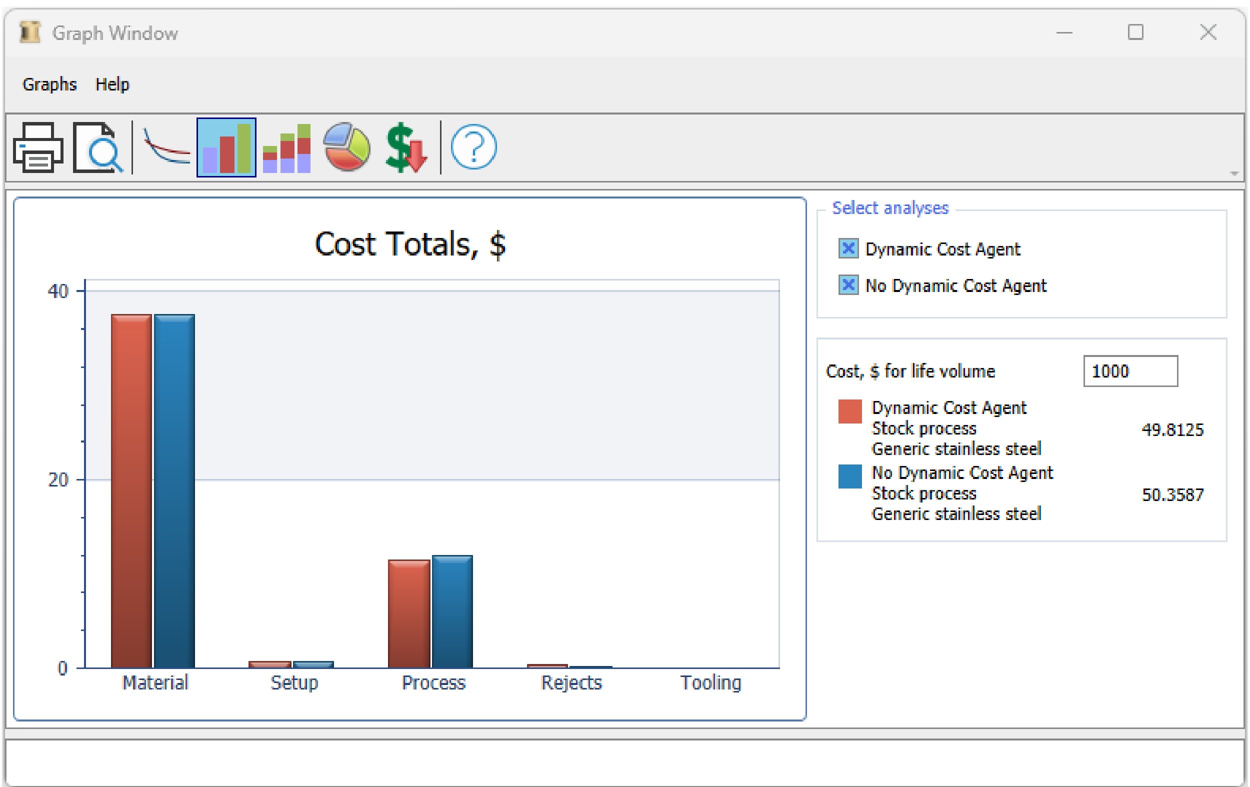
The most detailed and accurate cost estimate is achieved from the analysis completed with no Dynamic Cost Agent where each individual machining operation has been defined and each movement of the cutting tool has been accounted for. The analysis done with no Dynamic Cost

Agent also provides a very detailed breakdown of machining costs so the cost of each individual part feature can be estimated and examined. The total cost per part result shown on the graph for this analysis is $50.3587.

In the analysis that used the Dynamic Cost Agent, the program automatically made a tradeoff between the time and effort required to analyze the part and the accuracy of the cost results. For this part, the analysis done with the Dynamic Cost Agent has resulted in a cost estimate of $49.8125.

40. Mouse over the gray *Difference* pie piece and note that a pop-up message displays to indicate the error in the analysis that used the Dynamic Cost Agent is -0.5462, or roughly 1.08%. The magnitude of this error, on a percentage basis, is typical for an analysis completed while using the Dynamic Cost Agent.

41. Click the  toolbar button to display the comparison bar chart, as shown below. This graph enables an easier comparison of the individual cost results for the two analyses.



As you can see from the graph, the two analyses have the same material cost result. This is because the part material cost is estimated in the same way regardless of the type of analysis done. In this case, more than 74% of the part cost is due to the cost of the part material. This means nearly 3/4 of the estimated cost does not depend on the type of analysis done and the approximations made while using the Dynamic Cost Agent have only affected 1/4 of the cost estimate. This is typical, and for most machined parts the cost of material makes up more than half the part cost. This is one reason why using the Dynamic Cost Agent has a negligibly small impact on the overall cost results for machined parts. And this means the benefit of the substantially reduced effort needed to complete the analysis of a machined part can be realized by using the Dynamic Cost Agent without substantively affecting the overall cost results.

The setup and rejects costs are both very small, which means the impact of the Dynamic Cost Agent approximations on these results are also very small. With the Dynamic Cost Agent, the setup cost was overestimated by $0.0747, and the rejects cost was also overestimated by $0.015. This shows that the Dynamic Cost Agent approximations in these costs have contributed to a difference of less than nine cents, or 0.18%, in the overall estimate of part cost and most of that difference was due to approximations in the estimate of setup cost. This is typical for machined parts that are produced in medium to high production volumes and in these cases the Dynamic Cost Agent approximations will result in very small errors in the setup cost per part.

With the Dynamic Cost Agent the process cost has been underestimated by $0.6359, which accounts for most of the cost difference between the two analyses. This difference is primarily due to the way the machining non-productive time has been estimated by the program. When the Dynamic Cost Agent is not used, each movement of the cutting tool has been defined directly and has been accounted for in the time and cost results generated by the program. However, when the Dynamic Cost Agent is used to analyze a machined part, the program automatically estimates the number of cutting tool movements required, and in this case, the program has underestimated the value. The impact of this non-productive time on the machining cost results tends to become larger for machined parts that are smaller in size. This means the approximations used by the Dynamic Cost Agent will yield reasonable results for all but the tiniest of machined parts and the estimates produced while using the Dynamic Cost Agent tend to improve as machined parts increase in size.