Scientific Forming Technologies Corporation

3D MACHINING (TURNING) LAB

1) System summary

This document details the current modeling capabilities available in DEFORM3D^{TM} system to simulate 3D metal cutting environment in turning process. The system can be used to model the industrial turning process, without any assumptions that are associated with orthogonal cutting conditions. These modeling procedures enable the engineer to study the process response for any change in process conditions. Cutting forces, cutting temperatures, chip shape, tool wear and tool life computations can be performed using this system. The engineer can study the effect of process parameters like, cutting speed, feed rate and depth of cut on the process response. DEFORM3D^{TM} supports a special purpose template that simplifies the model definition and uses the same engineering language of process engineer. For turning applications the rotating work piece, insert and their relation to the analysis domain are shown in Figure 1.1. Typical analysis model generated using the current system is shown in Figure 1.2. The main data requirements to model the machining process are material flow stress data for the work piece material and geometric data for the insert. The material flow stress data should cover the strain rate, strain and temperature range for metal cutting process. For most materials the typical range for strain rate is 0 - ~10^6/sec, the range for strain is 0 – 5 and the range for temperature is 20 – 1200^{o}C. Special material characterizing techniques are required to address this range of loading conditions. The insert geometry can be made available in STL form, generated from any CAD system.

This lab explains the step by step procedure of building the model. This includes specifying the process data, loading the materials, inserts and tool holders from the library. By specifying the model specific data, user can generate complete data required for the analysis. This stage of analysis constitutes the initial transient analysis. After executing the simulation and sufficient chip has formed, user can compute the steady state response of the process which includes the prediction of steady state thermal response and chip geometry. From the viewpoint of insert thermal response this stage will significantly reduce the computing time that is normally associated with transient analysis. The results obtained from this stage form important input to the tool wear and tool life computations. The machining template comes with a set of library files for the insert geometry. User can also use any other insert geometry and save it along with the system library for any subsequent use. The list of appendix information is provided to indicate the currently available insert and tool holder data.

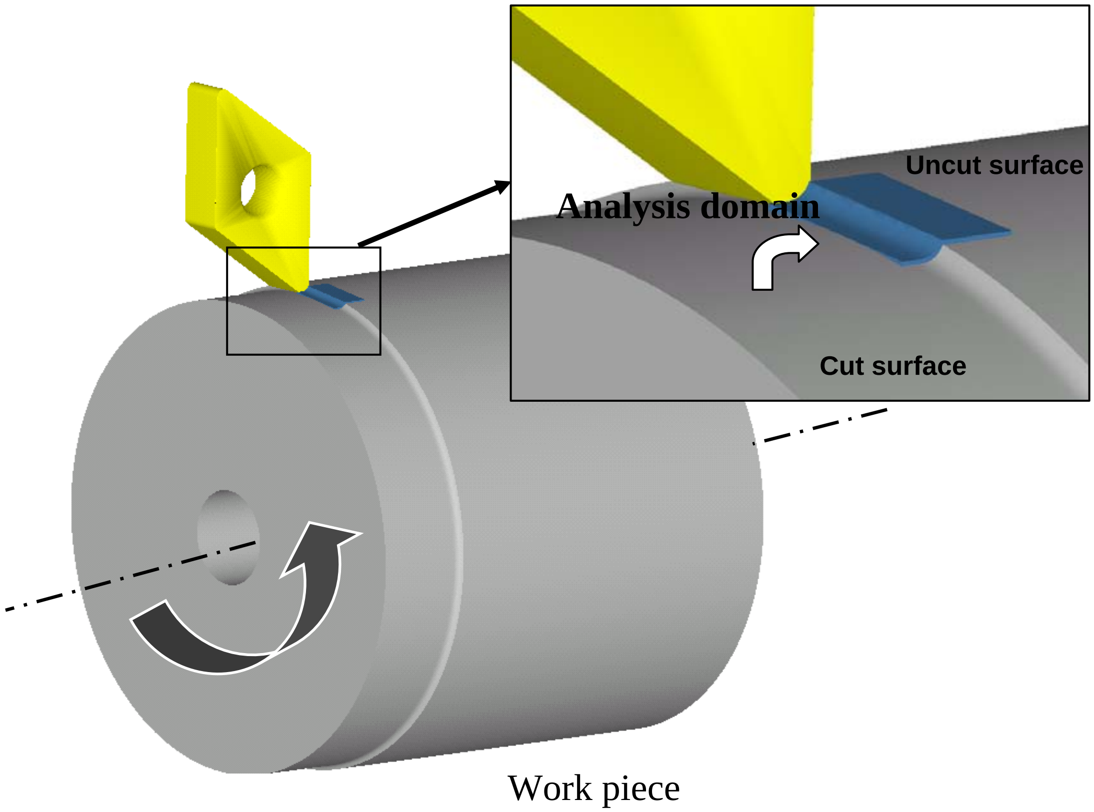


Figure 1.1: Basic components of Turning and it’s relation to analysis domain

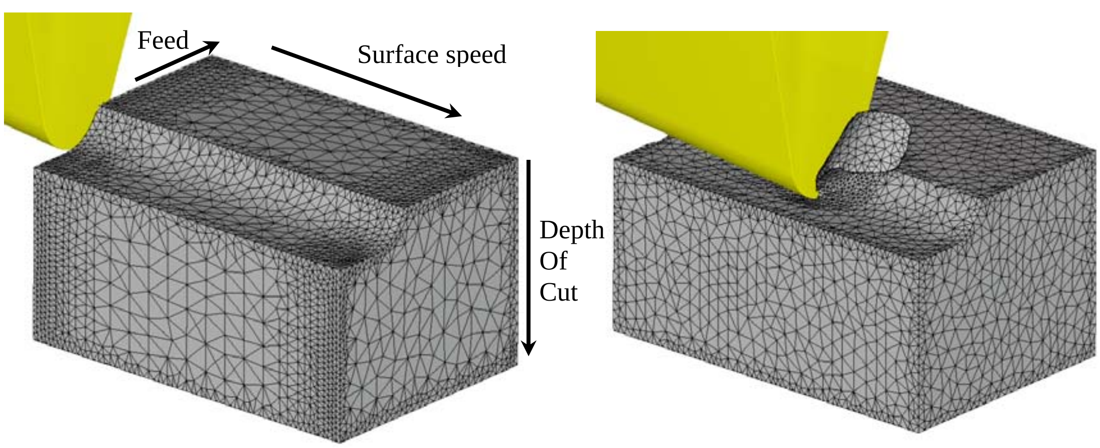


Figure 1.2: Simulation model and basic cutting parameters definition

2) Starting the 3D machining wizard

Machining wizard can be opened as a stand alone module (or the complete system) or as a special preprocessor to setup the machining problem. When opened as a stand alone module user can not only setup the problem, but also add additional operations to carryout steady state, and tool stress computations apart from access to special post processor. When opened from the regular GUI main menu either as a new problem or opening the existing problem user can access the preprocessor part of the system. On PC user can open the complete system by clicking on "All Programs" and click on this module from the list of installed programs. **(Figure. 2.1)**

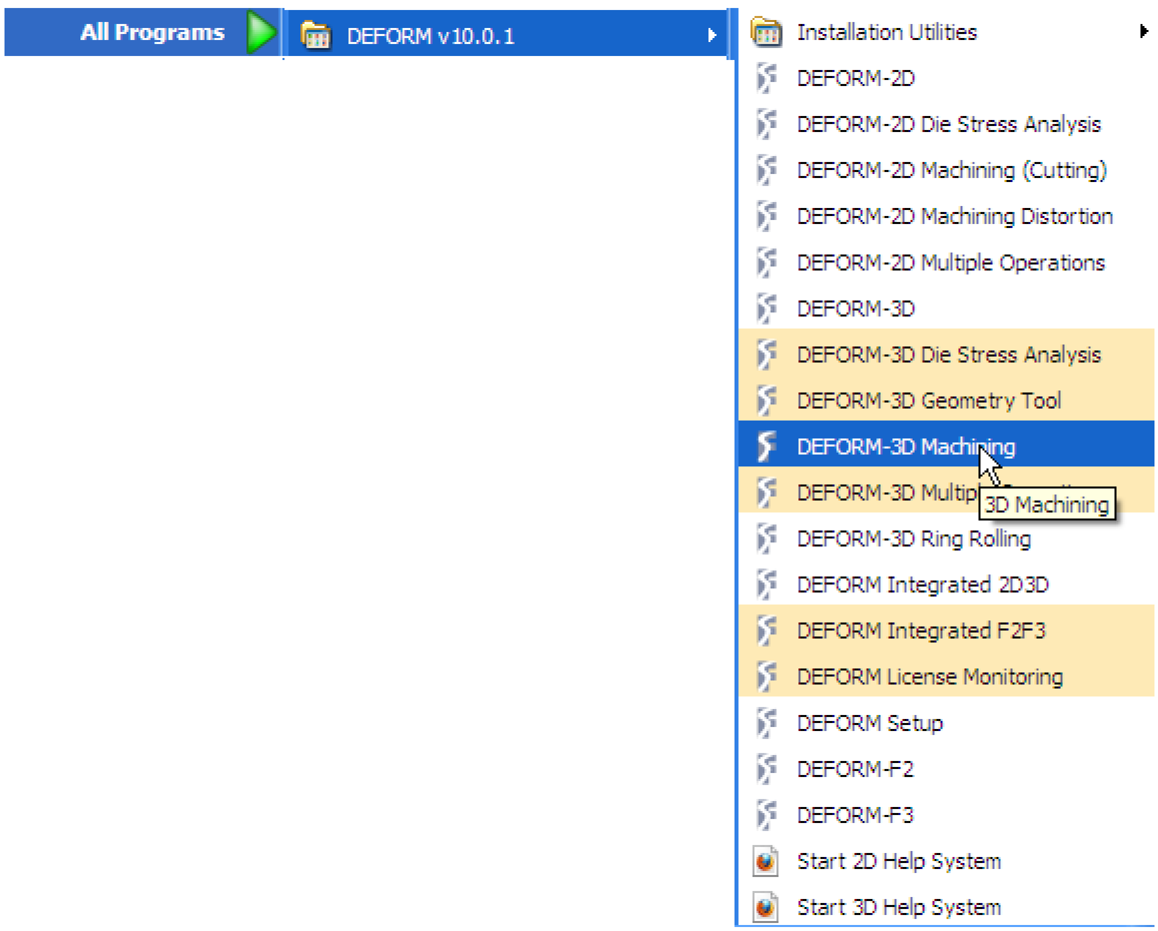


Figure 2.1: Starting the machining wizard

On Unix/Linux systems this stand alone machining module can be started thru an alias ('3d_cutting' is the alias name) at the command prompt. (for example '/home/user/joe/3d_cutting') Installation procedures ensure that the correct alias definition is setup.

Opening the preprocessor part of the machining wizard from the GUI main menu is indicated in **Figure 2.2**. Here user has options to start a new session, or open an existing session. This part of the system has same access procedures on both PC and Unix/Linux.

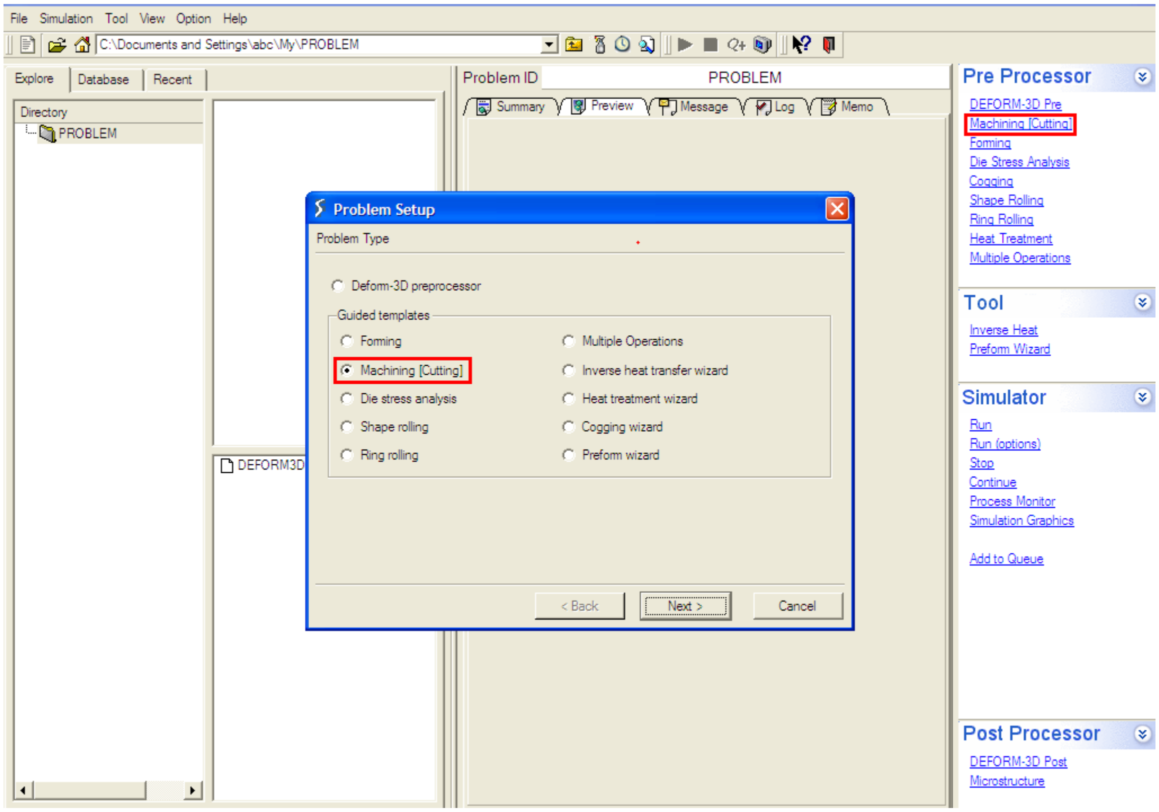


Figure 2.2 Initiating the Preprocessor part of machining wizard

In this lab we go through a typical setup with process conditions as follows

- Material used: AISI 1045 Steel, Initial temperature = 20 ^{o}C.
- Insert used: TNMA332 (uncoated, WC as base material), Tool holder: DTGNL
- Process: Cutting speed = 250 mm/sec, Feed = 0.35 mm/rev, Depth of cut = 0.3 mm

3) Process setup and conditions

After opening the wizard, specify the unit system as ‘SI’, indicate the problem/project name and the process type as ‘Turning’. For each of these steps and for the reminder of this document clicking on ‘**Next**’ will navigate through the subsequent steps unless otherwise stated. Boring and Drilling are the other process types for which this wizard can be used to setup the process model. Process conditions for tuning can now be defined as 250 mm/sec for cutting surface speed, 0.3 mm for depth of cut and 0.35 mm/rev for feed rate. In the subsequent ‘Process conditions’ menu, define 20^0C as environment temperature, 0.5 as shear friction factor and 45.0 N/Sec/mm/C as interface heat transfer coefficient. **(See Figure. 3)**

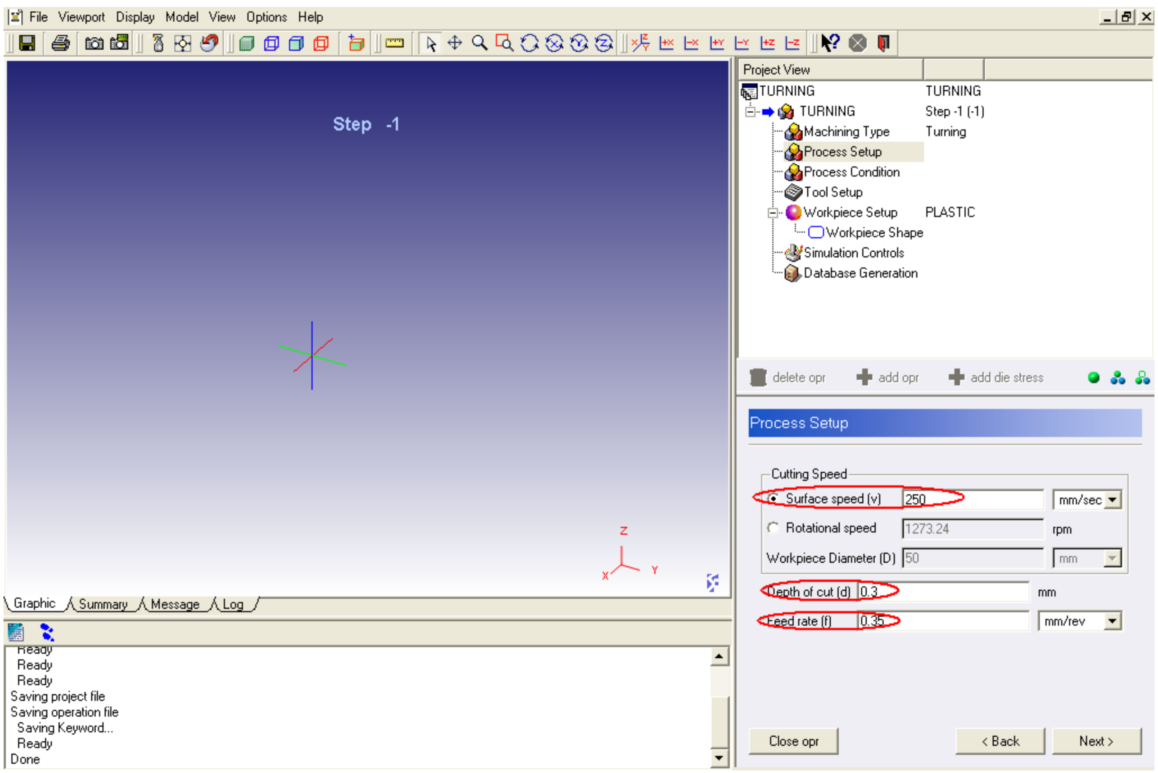


Figure 3. Defining the process setup

4) Insert definition

In the 'Tool Setup' menu, select the first option 'Load an existing tool from library' **(Figure 4)** to load the required insert (TNMA332) from the library. Once the insert is identified user can check the basic parameters of this insert, base material details and coatings if any, prior to loading the same.

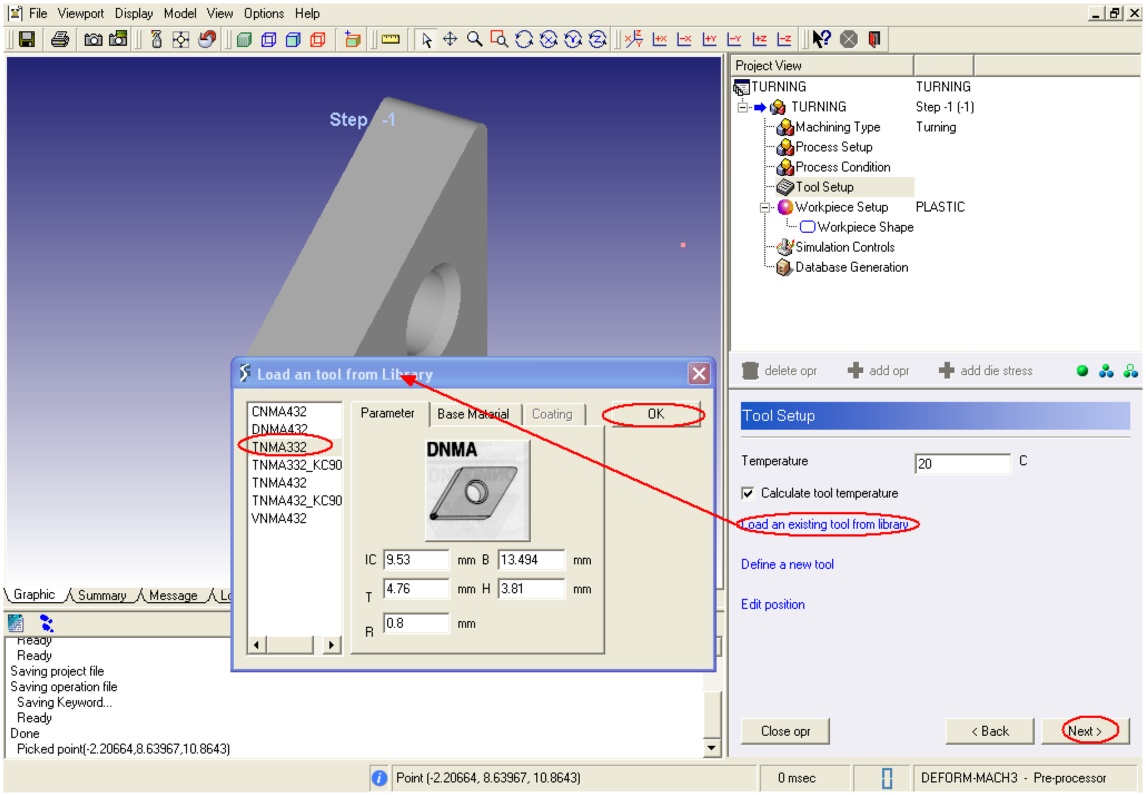


Figure 4: Insert loading options

5) Tool Holder definition

For the selected insert, the corresponding tool holders can be loaded from the tool holder library, or a new tool holder can be defined by providing basic cutting angles. Any new tool holder user creates can be saved in the library and accessed for subsequent modeling sessions. For the insert TMNA332, the wizard will indicate the available holders from the library. Load the holder DTGNL from the library **(Figure 5).** Basic cutting angles that are inherited from the tool holder data are SCEA (side cutting edge angle or the lead angle), BR (back rake angle) and SR (side rake angle). These basics angles and the process data (feed rate and depth of cut) control the correct position of the insert with respect to the work piece. User can also define different cutting angles for a new holder and save them in the library for later use.

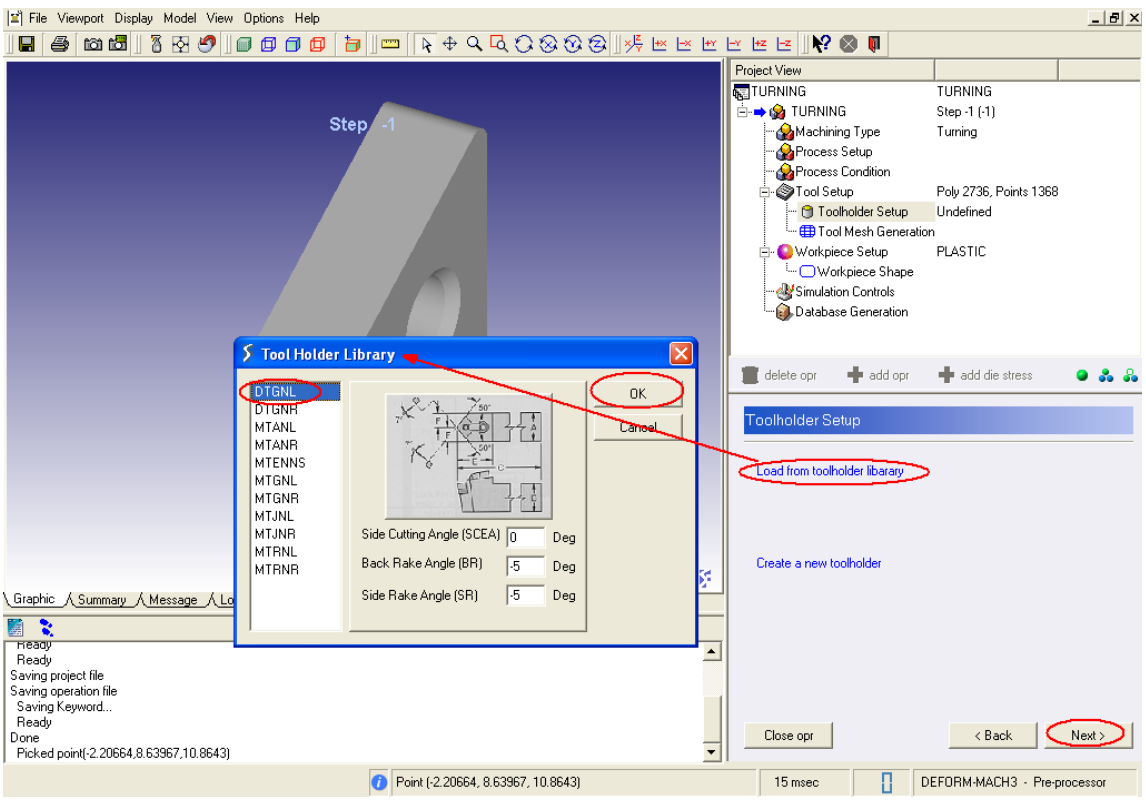


Figure 5. Insert loading options

6) Insert mesh and boundary conditions

In the 'Tool Mesh Generation' menu select the size ratio as 4, and using 45000 tetrahedral elements generate mesh for the insert. Cutting edge information being part of the insert data, the wizard automatically applies finer mesh near the cutting zone. After this stage (click 'Next') check on the thermal boundary conditions the system applies on the insert mesh. The surface far from the rake surface are applied with specified temperature and rest of the faces are applied with heat exchange with environment boundary conditions. **(Figure 6).** In the next menu for work piece setup select 'Plastic' for work piece object type. Click 'Next' to continue.

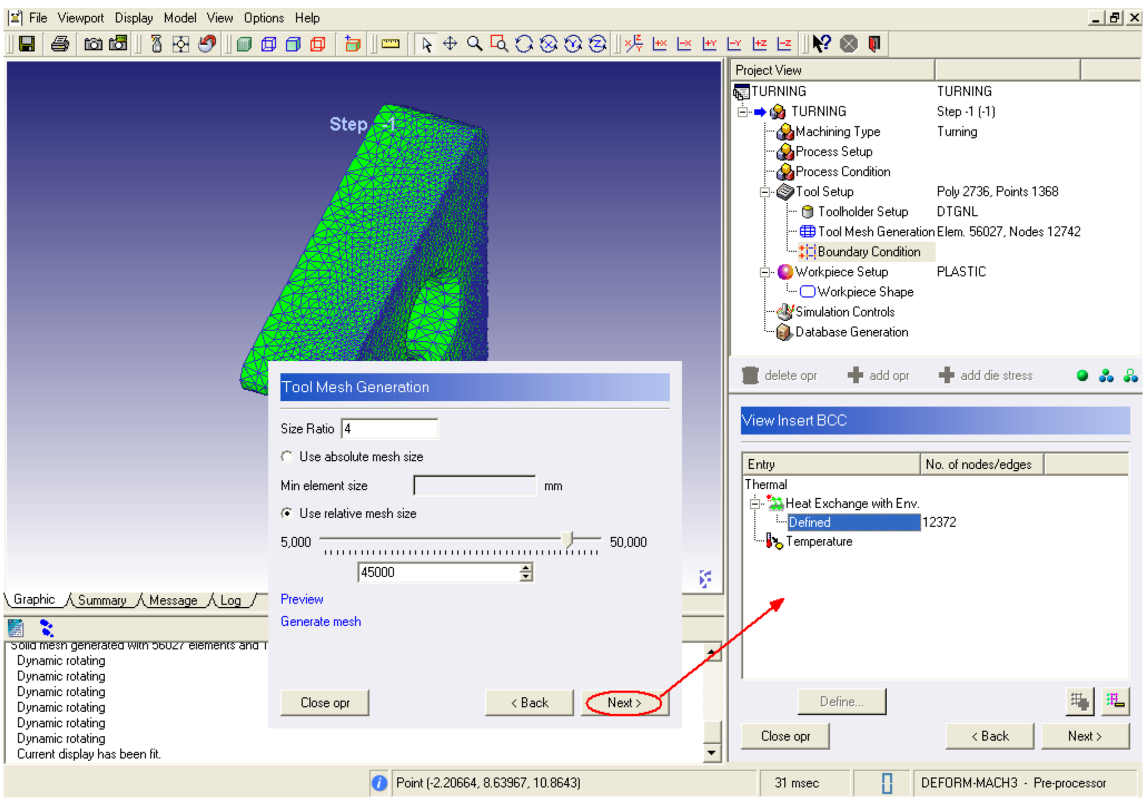


Figure 6. Insert mesh generation and BCC's

7) Work piece geometry and mesh generation

In the ‘Workpiece Shape’ menu, specify the work piece details. Depending upon the work piece diameter user can specify either a flat model or a curved model. The template will prompt for the related data, and will generate the work piece setup in the display area. For the current lab we use a ‘simplified model’ with 7 mm length and first click on ‘Create geometry’ and then ‘Next’ to continue.

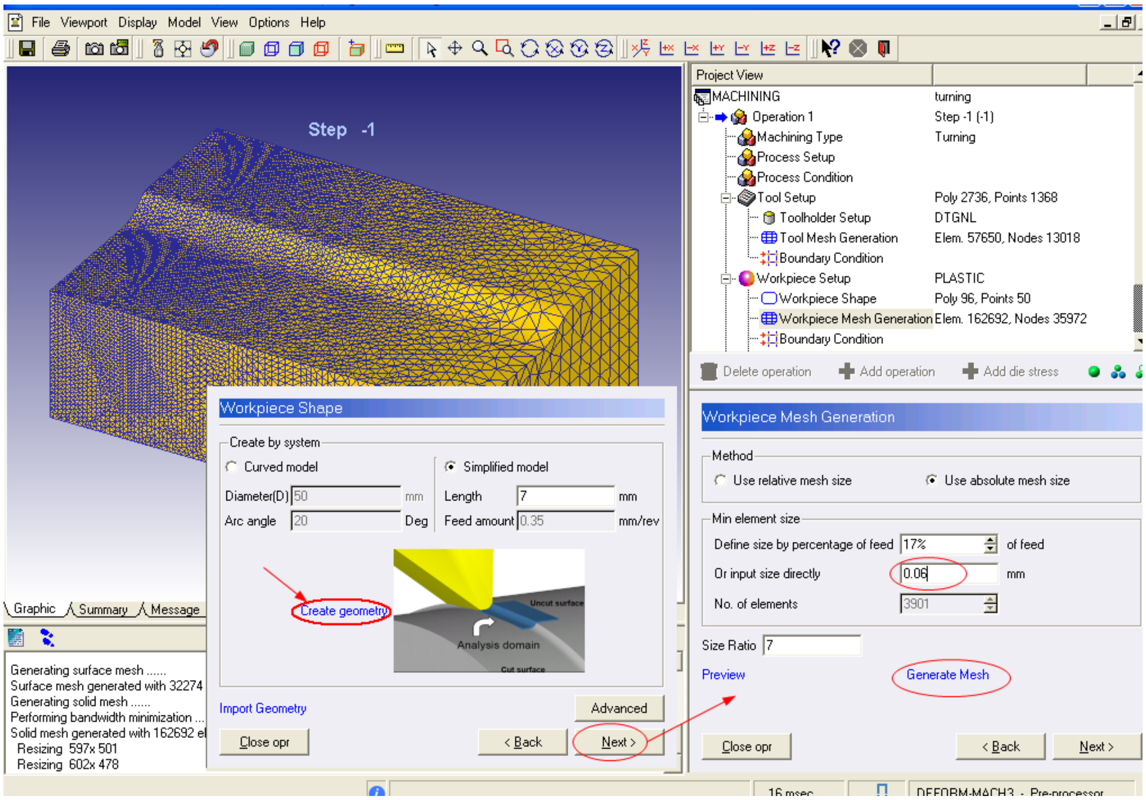


Figure 7.1 Work piece and mesh generation

After the work piece geometry is generated, generate mesh with element size ratio of 7, and minimum element size of 0.06mm.**(Figure 7.1)** Click on ‘Generate Mesh’ to generate mesh and ‘Next’ to continue. In the next step load the work piece material from the library. For this example we load ‘AISI 1045(machining)’ from steel category**. (Figure 7.2).** Click ‘Next’ to continue.

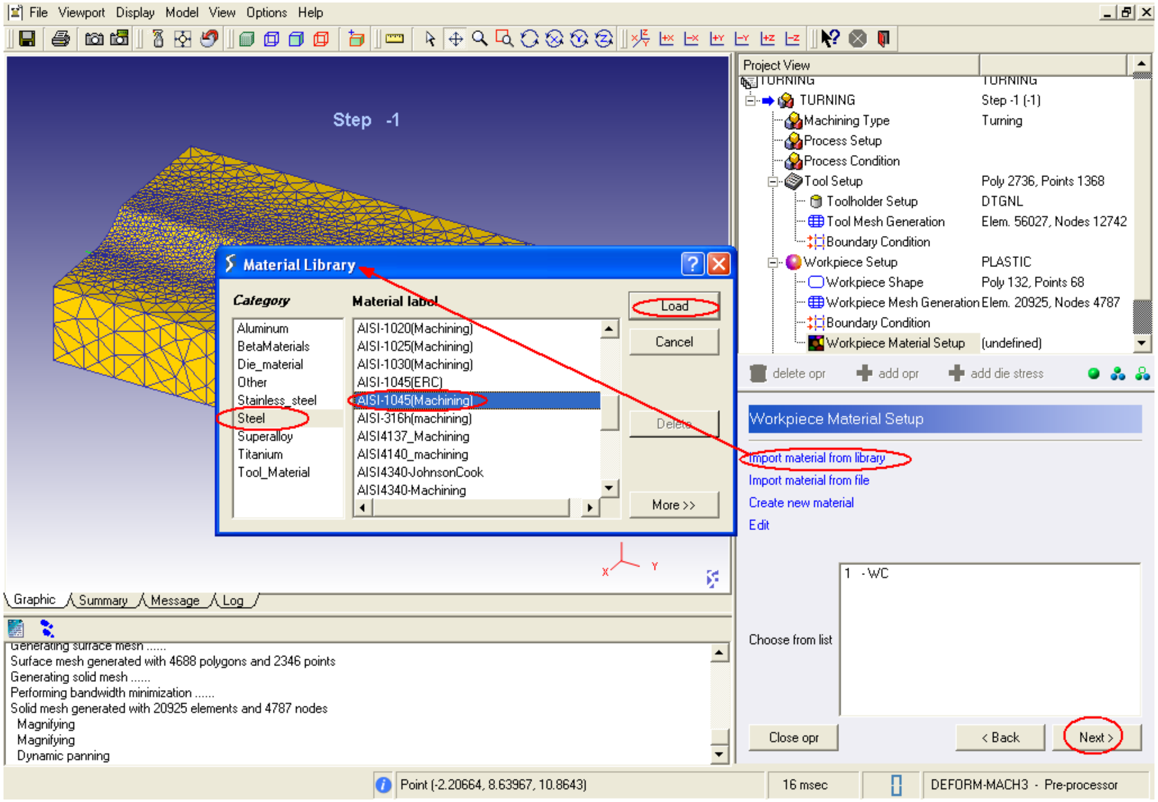


Figure 7.2 Loading work piece material from the material library

8) Simulation controls and tool wear definitions

Specify the simulation controls, including the number of steps (10000), steps to save (25) and length of cut (3.5mm) for the initial Lagrangian run. Even though we have specified large number of steps, simulation will have a stopping criteria based on length of cut. Then check on the tool wear model parameters. Currently the system supports only 'Usui's' model. The coefficients used in this model should be determined based on experimental calibration as they depend on the process conditions and the materials used for accurate results. As an example for this case we use a = 0.0000002 and b = 650.5 **(Figure 8).**

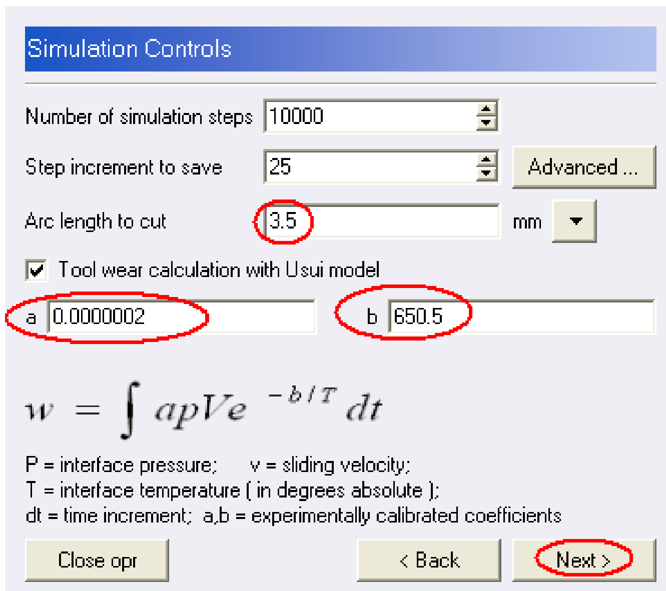


Figure 8. Simulations controls and wear model data definition

After this user can 'Generate the database' and 'Close' this operation to run the simulation

9) Running the simulation

After closing the operation, click on the ‘Simulator’ and on ‘Run simulation’ **(Figure 9)** to start the simulation.

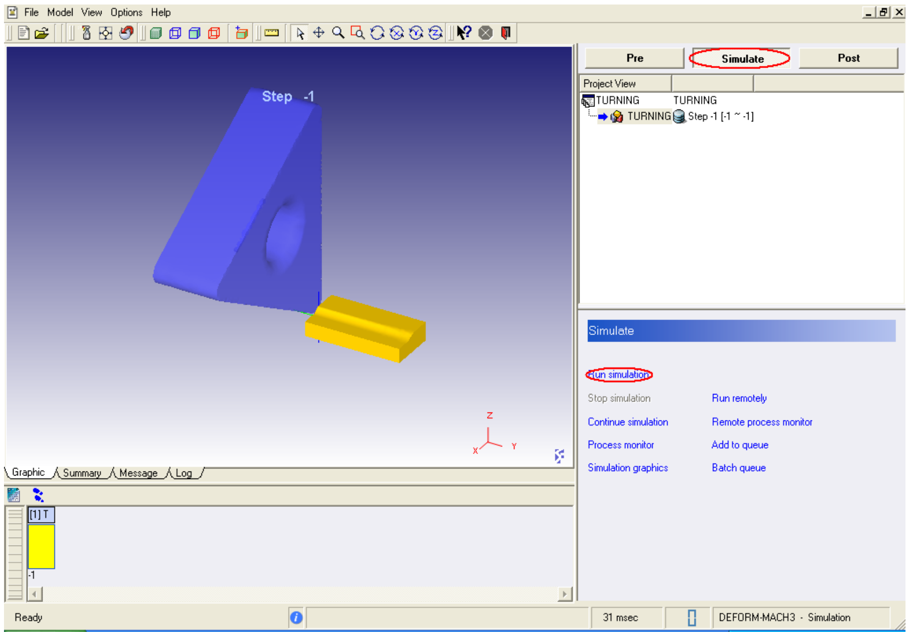


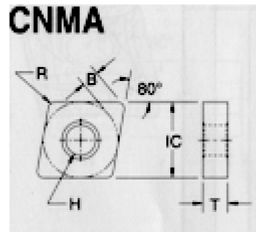
Figure 9: Simulator page – Running the model

After completing the simulation, user can either review the results by selecting ‘Post’ or proceed to setup the data required for steady state run or tool stress simulation.

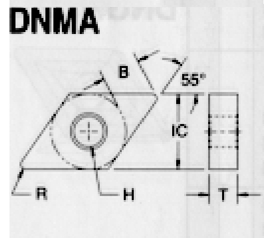
<u>Appendix A</u>

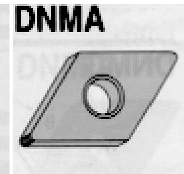
Listing of available inserts in the library

1) CNMA 432: IC = 1/2, T = 3/16, R = 1/32
B = 0.1216, H = 0.203

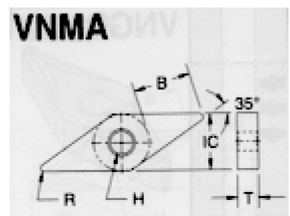


2) DNMA 432: IC = 1/2, T = 3/16, R = 1/32
B = 0.2550, H = 0.203



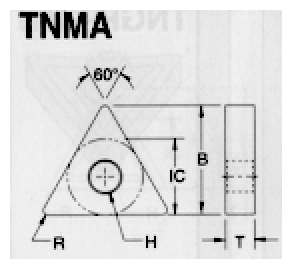


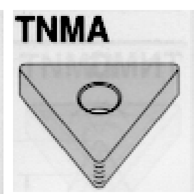
3) VNMA 432: IC = 1/2, T = 3/16, R = 1/32
B = 0.5087, H = 0.203



4) TNMA 432: IC = 1/2, T = 3/16, R = 1/32
B = 0.7188, H = 0.203

4.1. TNMA 332: IC = 3/8, T = 3/16, R = 1/32
B = 0.5313, H = 0.150





5) TNMA 432 _ KC9025: Same as TNMA 432 but with Kennametal KC9025 coating (TiN: 1μ , Al_2O_3: 9.5 μ , TiCN: 4 μ)

6) TNMA 332 _ KC9025: Same as TNMA 332 but with Kennametal KC9025 coating (TiN: 1μ , Al_2O_3: 9.5 μ , TiCN: 4 μ)

Note: *The default base material for all the above inserts in the library is* ***WC.***

Appendix B

Listing of available Tool holders in the library

#	Name	SCEA	BR	SR	For Insert
1.	MCFNR, MCFNL	10	-5	-5	**CNMA / CNMG**
2.	MCGNR, MCGNL	0	-5	-5	
3.	MCHNN	50	-7	-7	
4.	MCKNR, MCKNL	-5	-5	-5	
5.	MCLNR, MCLNL	-5	-5	-5	
6.	MCMNN	40	-5.37	-4.5	
7.	MCRNR, MCRNL	15	-5	-5	
8.	DCKNR, DCKNL	-5	-5	-5	
9.	DCLNR, DCLNL	-5	-5	-5	
10.	DCRNR, DCRNL	15	-5	-5	
11.	MDJNR, MDJNL	-3	-5	-5	**DNMA / DNMG**
12.	MDPNN	27.5	-5	-5	
13.	MDQNR, MDQNL	-17.5	-7	-7	
14.	DDJNR, DDJNL	-3	-5	-5	
15.	DDPNN	27.5	-10	-5	
16.	DDQNR, DDQNL	-17.5	-7	-7	
17.	MTANR, MTANL	0	-5	-5	**TNMA / TNMG**
18.	MTENNS	30	-5	-5	
19.	MTGNR, MTGNL	0	-5	-5	
20.	MTJNR, MTJNL	-3	-5	-5	
21.	MTRNR, MTRNL	15	-5	-5	
22.	DTGNR, DTGNL	0	-5	-5	
23.	MVJNR, MVJNL	-3	-9	-5	**VNMA / VNMG**
24.	MVUNR, MVUNL	-3	-5	-9	
25.	MVVNN	17.5	-4	-4	

Holder # in the table			**Insert:**
1,2,5,6,9:	80^{o}	Nose angle at the cutting tip.	CNMA/CNMG
3,4,7,8,10:	100^{o}	Nose angle at the cutting tip.	CNMA/CNMG
11,12,13,14,15,16:	55^{o}	Nose angle at the cutting tip.	DNMA/DNMG
17,18,19,20,21,22:	60^{o}	Nose angle at the cutting tip.	TNMA/TNMG
23,24,25:	35^{o}	Nose angle at the cutting tip.	VNMA/VNMG

SCEA: **Side Cutting Edge Angle (Lead Angle),**
BR: **Back Rake angle (Inclination angle),**
SR: **Side Rake angle (Normal Rake/Relief angle)**

Appendix C

Units and conversion factors

To convert from	*To*	*Multiply by*
Surface Cutting Speed		
mm/sec	m/min	0.06
m/min	SFM	3.33333333
mm/sec	SFM	0.2
SFM	mm/sec	5.0
SFM	m/min	0.3
m/min	mm/sec	16.66666667
in/sec	SFM	5.0
in/sec	ft/sec	0.0833333333
in/sec	in/min	60.0
SFM	in/sec	0.2
ft/sec	in/sec	12.0
in/min	in/sec	0.01666666667
Feed		
mm/rev	in/rev	0.039370079
in/rev	mm/rev	25.4
Depth of Cut		
mm	in	0.039370079
in	mm	25.4
mm	mils	39.37007874
mils	mm	0.0254
in	mils	1000.0
mils	in	0.001
Coating layer thickness		
mm	μm	1000.0
μm	mm	0.001
in	μm	25400.0
μm	in	0.00003937
Thermal conductivity		
N/sec/^{o}C	Btu/sec/in/^{o}F	1/74764.0
Heat capacity		
N/mm^{2}/^{o}C	BTU/in^{3}/^{o}F	1/115.89
Convection Coefficient / Interface heat transfer Coefficient		
N/sec/mm/^{o}C	BTU/sec/in^{2}/F	1/2943.0
Flow stress / Young's modulus / Stress		
MPa	KSI	6.8918