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Kind of Modeling Method of Finite Element Simulation of Milling Process Based MSC. Marc

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Abstract: The finite element simulation of milling machining is a complex process. It is essential to develop a system to construct a model of simulation so as to obtain simulation data conveniently and rapidly. In this investigation, a parametric modeling was presented, using the commercial implicit finite element code MSC.MARC. Some key technologies were discussed, which include interface design, creating the parametrical modeling file and parametric setting of a workpiece and a milling tool's property. Then, an example was given. As a result, the parametric modeling is an available way for fast modeling of finite element simulation of metal machining process.

Key words: Milling machining, parametric modeling, FEA

INTRODUCTION

The laws of metal cutting process can improve the efficiency of machining greatly. The ways of researching the metal process frequently include analytical methods, experimental/analytical methods and numerical methods. The analytical methods and experimental/analytical methods are very difficult to study and analyze the milling process precisely. Nowadays, with the rapid development of computer technology the hardware and software of computers and the theories of metal milling becoming mature, the finite element method has becoming the most popular in the fields of metal cutting process (Maranhao and Paulo-Davim, 2010; Pedro and Tugrul, 2010; Jin and Altintas, 2012; Tang *et al*., 2011; Ozel *et al*., 2011). So far, the researchers have carried out a lot of studies and made progress in the simulation of turning and milling. However, modeling procedure is a professional and tedious. It is necessary to the cutting process model of finite element will be built fast.

In this study, the parametric modeling of the program driven method was considered. Some techniques will be discussed.

THE CONTENT ABOUT PARAMETRIC MODELING OF MILLING PROCESS

Figure 1 is the finite element model of milling process, in which the milling cutter is rotating and moving along X direction while the workpiece is still relatively. Figure1a represents and b are models of down milling and up-milling milling, respectively.

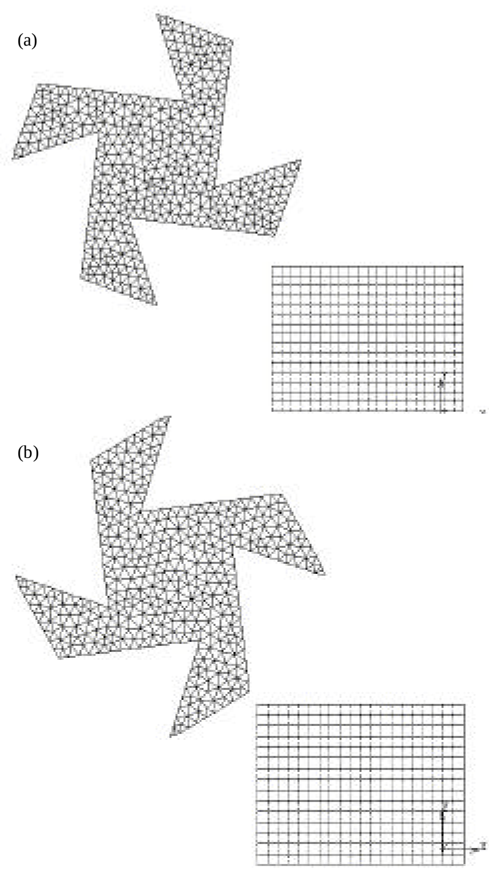

Fig. 1(a-b): The mode of orthogonal milling of finite element analysis , (a) Down milling model and (b) Up-milling model

The modeling contents include the modeling of milling system, the mesh of the model, the material's properties, the setting of the contact bodies, the initial conditions, the boundary conditions, the laws of re-meshing and the analysis conditions and so on.

THE PARAMETRIC MODELING OF MILLING PROCESS

The concept data mode of machining condition is shown Fig. 2. The information mentioned above is accessed into every table respectively, from which a model of milling process is built by knowledge acquisition machine, explanation machine. The component table includes its geometric and process information based on STEP (standard for the exchange of product model data) AP244 (application protocol). The component material table has physical and chemical properties and mechanical behaviors. The cutting-tool table describes its dimensions, angles and material). The machine tool table provide with its property parameters and machining parameters. And other tables indicate other modeling data separately.

Geometrical modeling of milling condition: Geometric modeling is very important for the simulation of milling. It affects the simulation system's execution and results directly. The model of cutting condition is presented in Fig. 2. For confirming the milling cutter's rotating center conveniently, the origin of the coordinate is placed on the milling cutter's rotating center. In Fig. 3, Δx represents the transverse distance between the outer circle of the milling cutter and the lateral surface of the workpiece and Δy is the height between the outer circle of the tool and the machining surface of the workpiece.

Geometric modeling of milling cutter: When upmilling is used, the polygon line of the milling cutter is as shown in Fig. 4. After getting the shape of single tooth, the 2-D model of milling cutter can be derived from duplicating the shape of single tooth along origin O. The coordinates of tooth are seen in Table 1.

In which, θ_1 is the angle between face and back of tooth, θ_2 is the angle of chip flute, γ is the rake angle, a_{01} is the first relief angle, a_{02} is the second relief angle, ε is the angle between teeth, b_{a1} is the width, h is height of teeth and d_0 is the diameter of cutter.

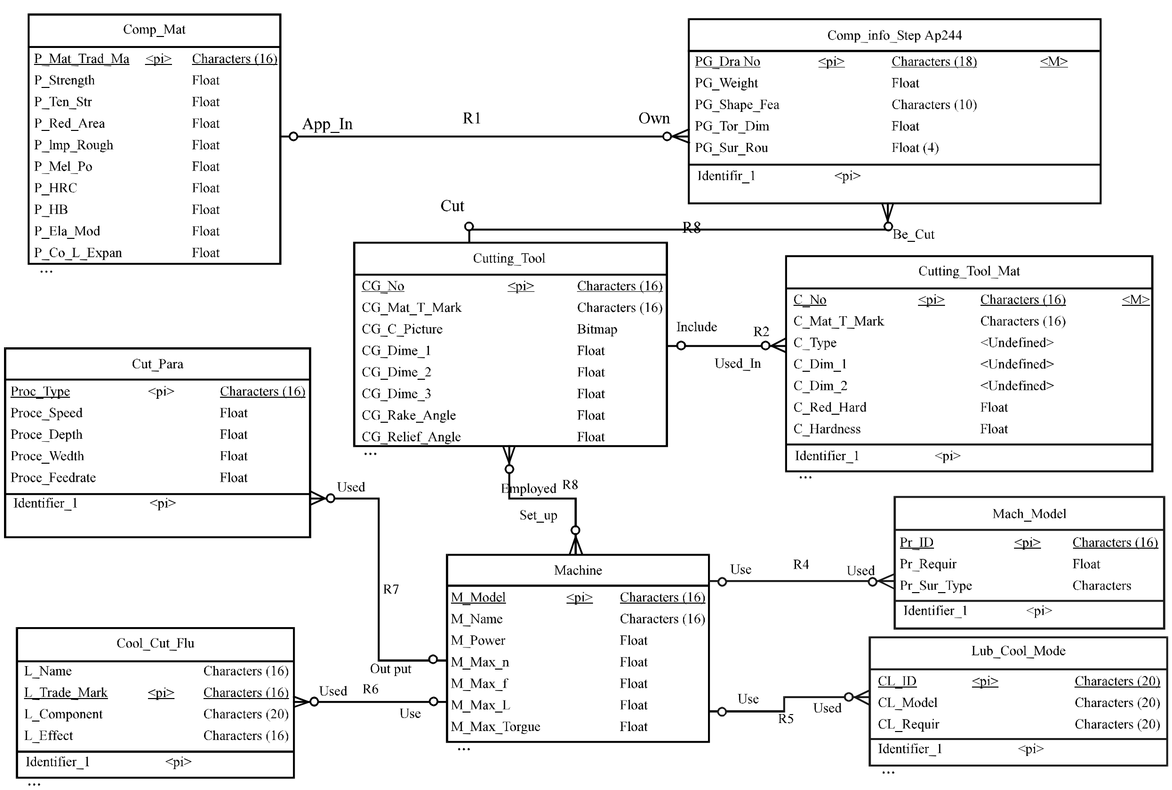

Fig. 2: The concept data mode of machining condition

Table 1: Calculating equations of milling-tool coordinates

Point	x-coordinate	y-coordinate
P_1	$x_1 = d_0/2+h$	$y_1 = h\times tg\gamma_0$
P_2	$x_2 = -d_0/2$	$y_2 = 0$
P_3	$x_3 = -d_0/2+b_{a1}\times tg\alpha_{01}$	$y_3 = b_{a1}$
P_4	$x_4 = \frac{y_5 - y_3 + ctg\alpha_{02}\times x_3 - tg(\theta_2 - \varepsilon + \gamma_0)\times x_5}{ctg\alpha_{02} - tg(\theta_2 - \varepsilon + \gamma_0)}$	$y_4 = \frac{y_5 ctg\alpha_{02} - y_3 tg(\theta_2 - \varepsilon + \gamma_0) + tg(\theta_2 - \varepsilon + \gamma_0)(x_3 - x_5)ctg\alpha_{02}}{ctg\alpha_{02} - tg(\theta_2 - \varepsilon + \gamma_0)}$
P_5	$x_5 = -\sqrt{(-d_0/2+h)^2 + (h\times tg\gamma_0)^2}\times\cos(\varepsilon + arctg\frac{h\times tg\gamma_0}{d_0/2-h})$	$y_5 = \sqrt{(-d_0/2+h)^2 + (h\times tg\gamma_0)^2}\times\sin(\varepsilon + arctg\frac{h\times tg\gamma_0}{d_0/2-h})$
P_6	$x_6 = -d_0/2\times\cos\varepsilon$	$y_6 = d_0/2\times\sin\varepsilon$

Table 2: Calculating formula of a rigid wall

Point	x-coordinate	y-coordinate
R_1	$a+d_0/2+\Delta x$	$d_0/2-\Delta y+1$
R_2	$a+d_0/2+\Delta x$	$d_0/2-\Delta y+b-1$
R_3	$d_0/2+\Delta x-1$	$d_0/2-\Delta y-b$
R_4	$a+d_0/2+\Delta x+1$	$d_0/2-\Delta y-b$

Table 3: JC Material law parameters

Parameter	A/MPa	B/ MPa	n	C	m
Value	626	3614	0.82	0.0268	1

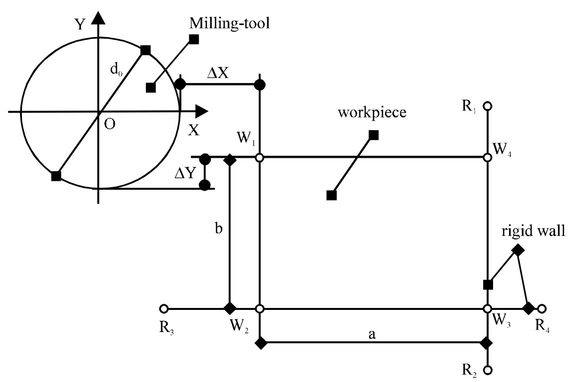

Fig. 3: The mode of two-dimension milling

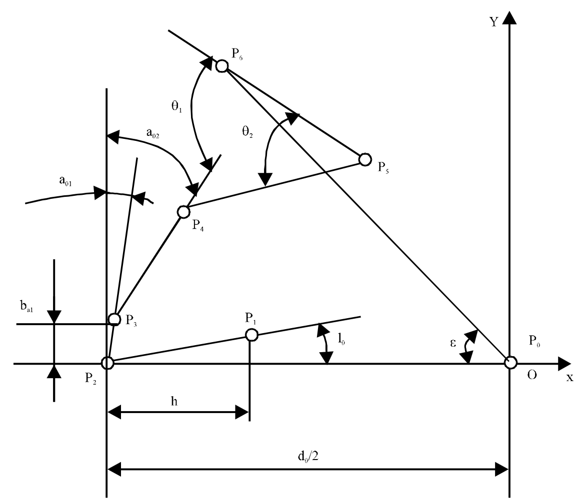

Fig. 4: The polygon line of milling cutter

The calculating equations of the coordinates of down milling can be obtained by negative the abscissa in the formula shown in Table 1, while keeping the value of ordinate the same.

Geometrical modeling of rigid walls: In the study, two direct lines to represent two rigid walls R_1 R_2 and R_3 R_4 were employed. The two rigid walls were used to restrict the movement of workpiece on x-direction and y-direction. The coordinates of the two rigid walls are shown in Table 2.

Mesh: After the models of milling cutter and workpiece were got as described above, the milling cutter was meshed with constant length elements. The workpiece was meshed after the elements' basic lengths of X and Y directions were set.

Properties of material: It is a necessary process to set properties of material. Because the material of workpiece generates elastic-plastic deform under high temperature, large deformation and large deformation rate, the influence of many factors to stress fluid of the material during simulation should be took into consideration. Johnson-Cook's empirical model was adopted (Liu and Ronaldo, 2010). The JC Material law parameters were derived from SHPB equipment. The parameters employed in this investigation were seen in Table 3.

Setting of contact: The milling cutter was set rigid while workpiece is set deformable. Then the contact relationships between milling cutter, workpiece and rigid walls were also set.

Because there were gliding area and agglutinate area on milling cutter's fore face during cutting process, stick-slip coulomb frictional law to simulate the conditions of friction are used.

Updated Lagrangian laws were adopted and the value of equivalent plastic deformation was got, so as to judge whether the chips has separated from workpiece. The minimum separate force was also defined as the standard of whether chip or machined surface was separated from fore face and back face of tool.

Initial conditions: Because rigid walls were adopted, the initial displacement didn't need to be set again in the cutting condition. Further the conditions of thermal conductivity like initial temperature of system required to be set.

Boundary conditions: The heat flow generated in the process of metal cutting mainly come from the plastic deformation of chip, the friction between milling cutter's fore face and chip and the friction between back face and workpiece. Here, the ways of thermal conductance and thermal convection were taken into consideration (John *et al*., 2013).

Remeshing: Commonly, the Update Lagrange analysis law is used to solve the problems like metal cutting and many other metal molding problems. The technique of re-meshing is also needed to prevent elements' serious deformation caused by large deformation of chip, because element's serious deformation will affect the accuracy of calculation or even make the analysis fail. The method that combine contact penetrating with direct meshing was conducted while re-meshing.

Analysis conditions: Coupled thermal-mechanical analysis, large deformation, large movement and Updated Lagrangian law were chosen to simulate the cutting process. In the analysis process, residual stress and displacement were adopted as convergence standard (Crichigno Filho, 2012).

KEY TECHNIQUES OF PARAMETRIC MODELING OF SIMULATION OF MILLING PROCESS

Interface design: To realizing parametric modeling, the system would have the function that includes both geometric modeling and materials properties of cutting system, friction and contact condition. With the help of procedure file generated by secondary development tool, consumer can fulfill all modeling tasks automatically in MSC.Marc software. The procedure file generated can be operated according to a specified format. So the modeling process becomes easy. Figure 5 shows the block diagram of the modeling process.

Interface of database: C++ Builder software was adopted as exploit tool and data type *.dbf which is supported by Visio Foxpro as database software was chosen. Considering the factors of operation and maintenance, Borland Database Engine was used as interface to handle the database of parameters mentioned above.

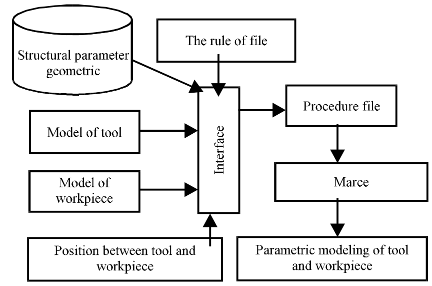

Fig. 5: The block diagram of parametric modeling

Interface of entering finite element environment for modeling: By programming, MSC. Marc environment was entered to finish modeling of milling through the function which call the interface of modeling file conveniently. Part of the interface file is represented as below:

```
{••••••; s_Procname=tblZjiao->FieldByName("bh")->AsString+".proc";
ProcPath=tblPath->FieldByName("path1")-AsString;
c_Procname=ProcPath+s_Procname;
ShellExecute(Handle, "open", c_Procname.c_str(), NULL,NULL,
SW_SHOWMAXIMIZED); }
```

Creating the interface of parametric modeling file: Based on the simulation model constructed above, modeling information was written into process file according to the information of milling tool, workpiece, rigid wall models and the rules of finite element process file. Part of the interface file is as follows:

```
{••••••;s_file=tblPath->FieldByName("path1")->AsString.Trim()+s_file+".proc";
FILE*outf; outf=fopen(s_file.c_str(),"w+");
fprintf(outf,"%s\n","Version : MSC.Marc Mentat 2005 (32bit)"); •••••• }
```

Creating the parametrical modeling file: Parametric modeling file can construct the model and further simulate the process of milling in finite element software MSC.Marc. So through process file's translation machine, the geometric information of cutting system's points and lines can be fulfilled. The process file is shown below:

```
{ ••••••;*material_value is otropic:youngs_modulus
109000.0 0.3 0.000000008
*material_option is otropic:plasticity:elastic_plastic
*material_type plasticity
*material_option plasticity:method:johnson_cook
*material_value plasticity:johnson_cook_a
593.0 580.0 0.133 0.023 ••••••;}
```

Parametric setting of workpiece and milling cutter's property: Before simulation of cutting process, geometric

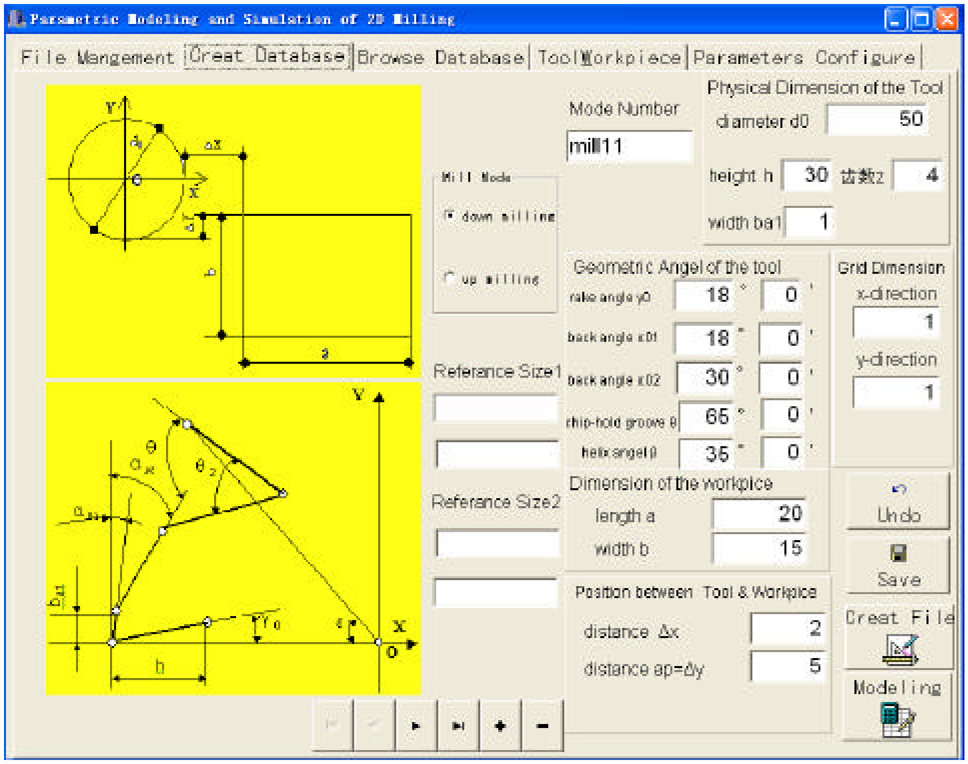

Fig. 6: The interface of simulation modeling

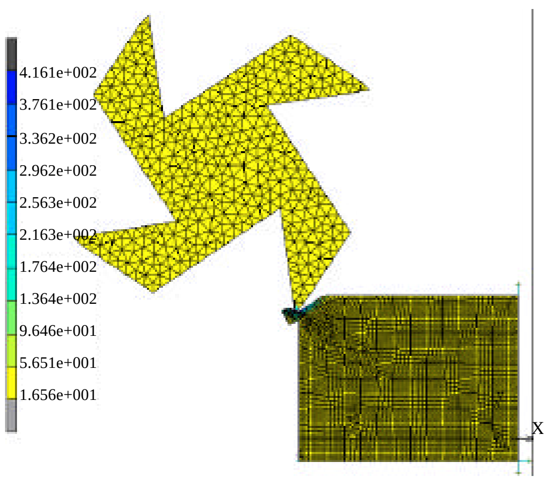

Fig. 7: The simulation plot of down milling

properties and material property of elements, contact relationship of bodies, mechanics and thermal conductivity between milling cutter and workpiece need to be defined and evaluated. However, the number of elements is influenced by the size of work, structural sizes and geometrical angles of tool, so meshing workpiece and tool dynamic are a key technique.

Element sets is used to store the workpiece and tool elements separately. The technique does not apply methods of calculating the number of elements used before but make use of unit sets to make units invisible or visible.

EXECUTION OF EXAMPLE

The interface of modeling system was presented in Fig. 5. The interface has five columns that include file management, adding modeling database, browsing modeling data, parameters of cutter and work and contact parameters between tool and work. The running example is in Fig. 6.

In the example, the diameter of tool is 30.2 mm, the height of teeth is 4 mm and other parameters are given. The model of down milling is shown in Fig. 1a and the model of up-milling is shown in Fig. 1b.When the amount of feed is 46 mm min^{-1}, the rotating rate of milling is 275 rpm and the width of cutting 3mm, the situations of down milling and up milling are shown in Fig. 7 and 8. The cutting force trends simulated are shown in Fig. 9 and 10.

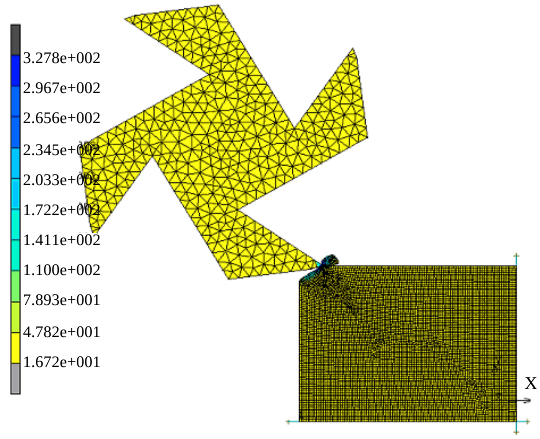

Fig. 8: The simulation plot of up-milling

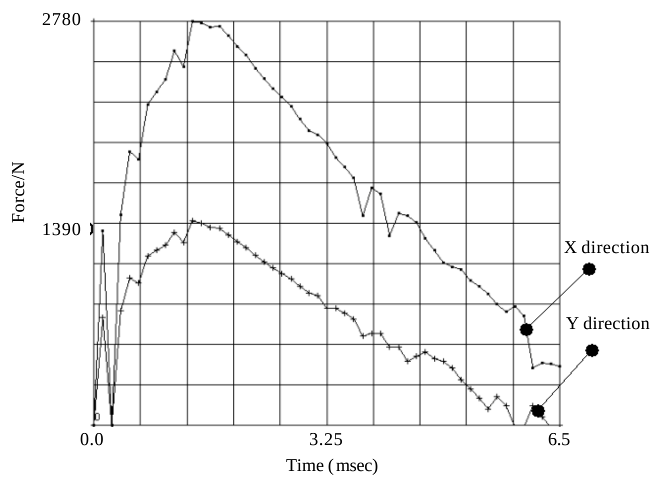

Fig. 9: The trends of milling force of down milling

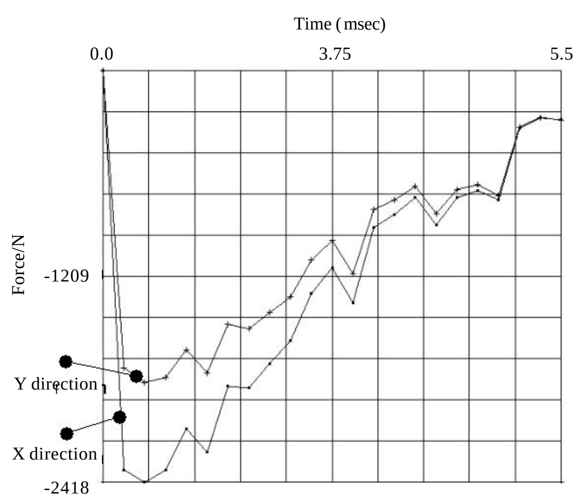

Fig. 10: The trends of milling force of up-milling

CONCLUSIONS

The techniques of parametric modeling, database and C++ Builder programming were also used to design interface. A model of the orthogonal milling process can be constructed and employed to simulate so as to predict the change of cutting force and temperature, etc. The given example test and verify the parametric modeling in finite element analysis. The intelligent parametric modeling will be further investigated to perform a lot of simulation condition.

It is believed that parametric modeling method will applied to simulate other aspects such as the quality of machined surface and tool wear in cutting process by the aid of finite element software.

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REFERENCES

Crichigno Filho, J.M., 2012. Prediction of cutting forces in mill turning through process simulation using a five-axis machining center. Int. J. Adv. Manuf. Technol., 58: 71-80.

Jin, X.L. and Y. Altintas, 2012. Prediction of micro-milling forces with finite element method. J. Mater. Process. Technol., 212: 542-552.

John, M.R.S., K. Shrivastava, N. Banerjee, D.P. Madhukar and B.K. Vinayagam, 2013. Finite element method-based machining simulation for analyzing surface roughness during turning operation with HSS and carbide insert tool. Arabian J. Sci. Eng., 38: 1615-1623.

Liu, F.S. and I.B. Ronaldo, 2010. Stabilized low-order finite elements for frictional contact with the extended finite element method. Comput. Methods Applied Mech. Eng., 199: 2456-2471.

Maranhao, C. and J. Paulo-Davim, 2010. Finite ele-ment modelling of machining of AISI 316 steel: Numerical simulation and experiment-tal validation. Simul. Mod. Pract. Theory, 18: 139-156.

Ozel, T., T. Thepsonthi, D. Ulutan and B. Kaftanoglu, 2011. Experiments and finite element simulations on micro-milling of Ti-6Al-4V alloy with uncoated and cBN coated micro-tools. CIRP Ann. Manuf. Technol., 60: 85-88.

Pedro, J.A. and O. Tugrul, 2010. Investigations on the effects of friction modeling in finite element simulation of machining. Int. J. Mech. Sci., 52: 31-42.

Tang, L.H., J.L. Huang and L.M. Xie, 2011. Finite element modeling and simulation in dry hard orthogonal cutting AISI D2 tool steel with CBN cutting tool. Int. J. Adv. Manuf. Technol., 53: 1167-1181.