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A Numerical Study Of Stress And Temperature On Turning Process By Using DEFORM-3D

U.Vishnuja[#1],K.Tamilarasan[#2] ,I.R.Sugumaran[*3] N.Arunagiri[#4],

[#]*Teaching Fellow,Department of Production Technology,MIT Campus ,Anna University.*

**Research scholar ,Department of Production Technology,MIT Campus, Anna university.*

Abstract-

The present work explains parametric study on AISI 1045 STEEL using tungsten tool insert by FEM and Taguchi technique.The simulation is carried out using DEFORM-3D, Machining software. The parameters obtained from taguchi design of experiments (DOE) 3 level 3 factorial designs considered. The output quality characteristics such as temperature, stress ,cutting forces etc are analyzed by S/N ratio. Analysis of variance is conducted to determine the most contributing factor. From this optimum condition is evolved, Validation can be done based on this in future.

Keywords: FEM analysis,Taguchi method,DEFORM-3D

I.INTRODUCTION

Residual stresses occur in a body after all external loads are removed; it is important parameter because it has direct effect on machined component fatigue life. A finite element method could be a good tool for selecting the prefect working cutting parameters, which induce a limitation of the residual stress state [1]. Used 2D FEM as a tool to understand basics of turning process, cutting conditions, effect of tool geometry, turning variables are predicted with accuracy [2]. Used 3D finite element method to study the effects of cutting edge micro geometry on tool forces, a brief study and experimental study on wears of tool inserts [3]. Calculated experimentally cutting speed on resultant forces and surface roughness in hard turning AISI H13 [4]. Clearance angle should be provided adequately otherwise it reduces to surface finish of tool, and tool life, if clearance angle is too large it may reduce tool strength. Proper edge radiusing will improve the strength [5]. Cutting edge of tool effects the cutting process because, for a given cutting depth and feed, it defines the width of cut, uncut chip thickness, and tool life, so cutting tool geometry is important[6]. Studied the effect of cutting parameters on surface roughness of AISI 4340 (coated with high strength low alloy steel ,with coated carbide insert during hard turning[7].Depth of cut and feed of work piece depends on the work piece hardness and tool material, depth of cut is consistent with amount of stock to be removed[8]. Cutting insert shape is the most significant parameter than cutting, speed and depth of cut. Optimum machining parameters ,geometrical parameters are analyzed [9].DEFORM -3D is the engineering simulation software used for analyzing various machining ,forming, and heat treatment process by trial and error method .L9 Orthogonal array is used to obtain the geometrical parameters from Taguchi technique.FEM analysis is used to study the effect of machining parameters at different cutting speed, feed , depth of cut. ANOVA technique is used to find which parameter is affecting the most.

The main contribution of this work is to study the maximum stress, temperature and average loads at cutting forces with respect to different parameters obtained from taguchi technique, and analyze which parameter is contributing most by using DOE. Following the introduction, material used for FEM analysis is explained. Details of the FEM Validation and results were finally concluded numerically.

II. Material used for work piece and cutting tool insert

AISI 1045 Steel is medium carbon steel. It has tensile strength of 570-700mpa and Brinell hardness ranging between 170 and210. AISI 1045 is a low cost alloy with good strength and toughness. It is widely used in engineering applications like machining, drawing, extrusion etc...Chemical composition of AISI 1045 steel is given in the following table1.

Table 1. Chemical composition of AISI 1045 steel.

ELEMENT	CONTENT
Carbon,c	0.420-0.50%
Iron,fe	98.51-98.98%
Manganese,Mn	0.60-0.90%
Phosphorous,P	≤ 0.040%
Sulfur,S	≤0.050%

The material used for cutting insert in the analysis is tungsten carbide. Tungsten carbide is chosen for analysis because of its high hardness and strength for general machining operations. The Brinell hardness of tungsten carbide insert is 1433 BHN. Chemical composition of the insert is given in the table2.

Table 2.chemical compositions of tungsten carbide insert

Compound	Percent %
Tungsten carbide	96.4
Titanium carbide	0.5
Tantalum carbide	0.8
Cobalt	2.19

*1.2 **Finite element method:***

Now a day's FEM is the major contributing tool used for simulation of machining ,forging drawing to find stresses in the automobile parts.FEM has become prominent because ,parameters of machining such as cutting speed ,feed , depth of cut ,temperatures ,stresses ,strains can be calculated before actually machining the work piece .Trial and error method is expensive and time consuming ,so simulation model reduces cost and time and more over the results obtained from FEM analysis stays close to results obtained from experimental work from literature survey..It is proven to be an effective way for analyzing stresses, temperature, cutting forces etc….

*1.3 **DEFORM-3D:***

DEFORM-3D software is used to simulate the turning process, which is based on the lagrangian equation .The software is used to simulate the effects on temperatures , effective stresses cutting forces etc in machining of AISI 1045 steel . Deform-3D system has

1. Archard's model
2. Usui's model

Usui's model is used for machining applications (i.e.) compute insert wear. Archard's model can used for either isothermal or non-isothermal runs. Usui's model can be run only be used with non-isothermal run as it required interface temperature calculations.

*1.4 **APPLICATIONS:***

Applications of FEM models for machining can be divided into six groups: Tool wear, Tool edge design, Chip flow, Tool coating, Burr formation, Residual stress and Surface integrity. The direct approach of experimental study in machining processes is expensive and consumes long time. So, finite element method is used frequently. FEM has many advantages than conventional method of statistical approach; FEM provides useful data such as stresses, strain, cutting force, tool wear, temperature etc.

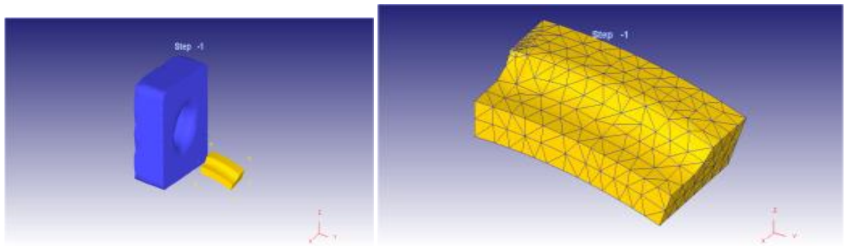


Fig (1) Tool and work piece interface

(2) Work piece meshing

Tool mesh generation was taken as 25000 relative mesh, tool taken from the library of deform was –CNMA432, work piece type was taken as plastic. The tool was subjected to move in (+Y) direction at constant speed and constrained against movements in other directions.

1.5 Taguchi technique:

Taguchi is tool used in quality optimization; through optimization of process parameters we can obtain better results. Taguchi method makes use of orthogonal array (L9, L18, L27…)to examine the parameters through a minimum number of experiments.The experimental results based on orthogonal array are then transformed into S/N ratio to evaluate the performance characteristics. Taguchi design of experiments is used to design the orthogonal array for 3 parameters such as cutting speed, feed, and depth of cut and for each parameter 3 different values are chosen in Table3. The minimum number of experiments to be conducted for parametric optimization is calculated as,

Table 3.Input parameters and its levels

Parameters	Level1	Level2	Level3
Cutting speed(m/min)	130	165	200
Feed(mm/rev)	0.100	0.145	0.200
Depth of cut(mm)	0.2	0.3	0.4

The various combinations of Input parameters obtained from Taguchi technique design of experiments is used for conducting simulation analysis using DEFORM-3D.

Table 4.shows the designed L9 orthogonal array, finite element simulation are carried and response parameters like stress, temperature, cutting forces are calculated .the statistical measure of quality characteristic like signal to noise ratio is applied to analyze the effect of input parameters. For analysis, there are 3 categories of performance characteristics, (i.e.) Smaller-the-better,Larger-the-better and Nominal-the-better.

Table 4. L9 orthogonal array

Trail no	Cutting speed(m/min)	Feed(mm/rev)	Depth of cut(mm)
1	130	0.100	0.2
2	130	0.145	0.3
3	130	0.200	0.4
4	165	0.100	0.3
5	165	0.145	0.4
6	165	0.200	0.2
7	200	0.100	0.4
8	200	0.145	0.2
9	200	0.200	0.3

For our objective, to obtain optimal machining performance, the smaller-the-better performance characteristic of output parameters should be chosen.

2. Simulation results and discussion:

From the finite element simulation results, the effect of cutting speed, feed, Depth of cut on the work piece is analyzed. After performing the simulation analysis, the output characteristics like stresses, temperature, cutting forces isdetermined and tabulated in Table 5.

Table .5 output quality characteristics of simulation analysis

Trail no	Max.stress(Mpa)	Max.temp(˚c)	Feed force(x)N	Cutting force(Y)N	Thrust force(Z)N
1	1680	416	6	126	38
2	1740	361	8	178	55
3	1650	415	17	249	80
4	1970	870	7	165	47
5	2950	834	47	267	80
6	1330	556	80	142	45
7	1870	852	16	243	74
8	1920	788	10	186	60
9	1710	802	9	169	54

2.1 Regarding stress simulation results:

We can observe from table 5 with increase in speed effective stress was initially increased and later decreased with further increase in speed. While observing we can say that while feed rate was increasing effective stress was decreasing. At the same time with increasing in Depth of Cut effective stress increased initially and decreased with further increase in DOC effective stress was decreasing.

2.2 Regarding temperature simulation results:

We can observe from table 5 with increase in speed temperature was initially increased and then there was no change observed further. While observing we can say that while feed rate was increasing temperature was decreasing. At the same time with increasing in Depth of Cut temperature was increased initially and there was slight reduction in Temperature.

Using Minitab-17 statistical software, analysis is carried out .Using smaller –the –better technique of signal to noise ratio the combined S/N ratio is determined which is tabulated in Table 6. Based on the determined combined S/N ratio the response table for cutting speed, feed rate, depth of cut are determined by averaging the combined S/N ratio for each level of input parameters, as shown in Tab. 7.

Analysis of Variance (ANOVA) is an important technique for analyzing the effect of categorical factors on a response. It is performed to determine the factors that contribute to the quality characteristics. Minitab-16, statistical software is used to perform the analysis. Table 8 shows the ANOVA table for the combined S/N ratio. From the ANOVA table, it is observed that the is the Depth of cut is the most significant factor contributing by 83.69%, followed by feed 11.24% , cutting speed by 2.78%.

Table 6.Combained S/N ratio of the output quality characteristics

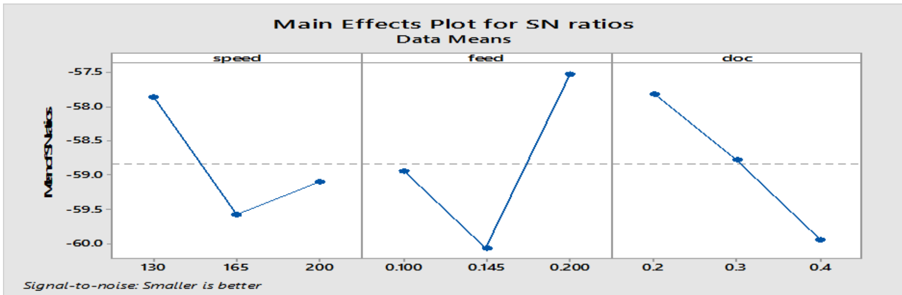
Trail no	Maximum stress(Mpa)	Maximum temperature(˚c)	Feed force(X)N	Cutting force(Y)N	Thrust force(Z)N	Combined S/N ratio
1	1680	416	6	126	38	-57.8000
2	1740	361	8	177	55	-58.0519
3	1650	415	17	249	80	-57.7282
4	1970	870	7	165	47	-59.7010
5	2950	834	47	267	80	-62.7774
6	1330	556	80	142	45	-56.2465
7	1870	852	16	243	74	-59.3334
8	1920	788	10	186	60	-59.3908
9	1710	802	9	169	54	-58.5720

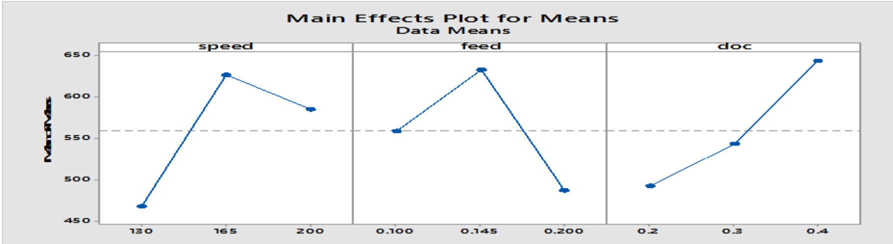
Table 7.Response Table for Combined S/N ratio

parameter	Cutting speed(m/min)	Feed(mm/rev)	Depth of cut(mm)
1	-57.86	-58.94	-57.81
2	-59.57	-60.07	-58.77
3	-59.10	-57.52	-59.95

Table 8.Analysis of variance

Source	DF	Seq ss	Adj SS	Adj MS	F-Value	P-Value	%Contribution
Speed	2	53.66	53.56	26.78	1.21	0.452	2.78%
Feed	2	216.89	216.89	108.44	4.90	0.162	11.24%
Doc	2	1614.89	1614.89	807.44	36.52	0.027	83.69%
Error	2	44.22	44.22	22.11			2.29%
Total	8	1929.56					100.00%





From the response table, the main effects plot of S/N ratio is plotted for cutting speed, feed ,depth of cut are shown in the Fig.3

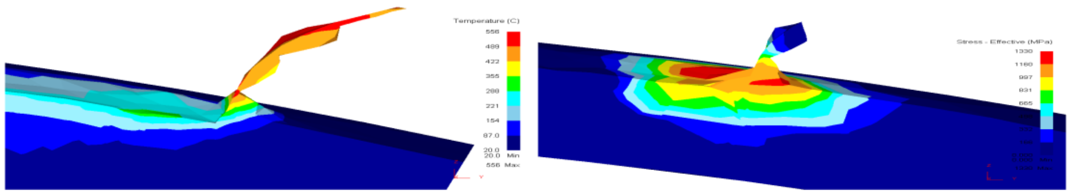


Fig.3 Simulation result of temperature and stress zones in the work piece.

The maximum and minimum stresses and temperatures formed at 9 parameters were analyzed using DEFORM -3D.Cutting forces induced in the work piece is also analyzed.

3. Conclusions*:*Maximum and minimum stresses, temperatures obtained while machining AISI 1045 steel by finite element simulation analysis using DEFORM-3D and optimized using Taguchi technique

1.Maximum stress that we can observe while machining AISI 1045 was 2950Mpa at cutting speed(165m/min),feed (0.145mm/rev),depth of cut(0.4mm).Minimum stress that we can observe while machining AISI 1045 was 1330Mpa at cutting speed(165m/min),feed(0.200mm/rev),doc (0.2mm).

2. Maximum temperature that we can observe while machining AISI 1045 was870˚c at cutting speed (165m/min),feed (0.1mm/rev),depth of cut(0.3mm). Minimum temperature that we can observe while machining AISI 1045 was 361˚c at cutting speed(130m/min),feed(0.145mm/rev),depth of cut(0.3mm).

3. Maximum feed force (X) 81 N was observed at cutting speed (165m/min), feed (0.2mm/rev), depth of cut (0.2mm). Maximum cutting force (Y) 268 N was observed at cutting speed (165m/min), feed (0.2mm/rev), depth of cut (0.2mm). Maximum Thrust force (Z) 80 N was observed at cutting speed (165m/min), feed (0.145mm/rev), depth of cut (0.4mm).

4. From Analysis of variance, it is observed that the depth of cut is the most significant parameter contributing 83.69%, feed by 11.24%, cutting speed by 2.78%.Only Numerical study has been studied by using software to find out most contributing parameter

5. In future, Experimentation can be done for theseparameters, Influence of tool geometry can be determined in Future.

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