

Study of Process Parameters on Machining Process Using Single Point Cutting Tool

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Abstract- This research work studies the influence of cutting process parameters used in single point cutting tool based machining operations. In this study design of experiment methodology is used for some qualitative outcome. Taguchi method is used for experimental design. It is solved using ANSYS Explicit Dynamics software. ANOVA analysis is also performed in this study using Minitab software. Results show that most critical factor which affects stress generated during cutting operations are rake angle of the tool and feed rate. In this study model equations are also generated for further analysis using linear regression modeling technique using Minitab software.

Keywords: Single point cutting tool, ANOVA, FEM, Taguchi

I. INTRODUCTION

Machining is the process of the gradual removal of metal from a workpiece in the form of chips to obtain specified geometrical dimension and the surface finished by using single and multipoint cutting tool. The metal cutting process is the very complex process and its complexity is mostly because of the problematic chip formation. Now day advancement in the new manufacturing process, the conventional machining processes is the most common manufacturing process. It involves with high stress and strain which must be known to improve all of the process. In recent years Finite Element Method (FEM) based on Eulerian and updated Lagrangian formulation has been developed to analyze the Machining process. Finite Element Method (FEM) is a powerful tool to predict cutting process variables which are difficult to obtain with experimental methods. The Eulerian formulation is applied in many of FEM models used for orthogonal metal cutting. Finite Element techniques such as element separation criterion, the modelling of cutting tool wear, re-meshing zone and friction modelling are applied to improve accuracy and efficiency of Finite Element Method in the metal cutting process. The cutting condition and quality of machining operation can be determined by understanding the characteristics of the metal removal process. A single point cutting tool has one sharp cutting edge and used for turning boring and planning. The cutting tool is made by material harder than the work piece. The cutting edge separates the chip from the parent work material to impart the required size and

shape of the work piece. The cutting tools are used as a rigid body and it moves horizontally with the variable speed into the work piece. It also sets a suitable cutting condition like cutting velocity, feed and depth of cut. The cutting velocity, feed rate and depth of cut are from the three dimensions of the machining process.

II. NUMERICAL SIMULATION AND PROBLEM IDENTIFICATION

According to ANSYS Explicit Dynamics 14.5, it is a complete suite of the perfect tools for simulating, analyzing, optimizing and validating machining products used by various industries. This software addresses the broadest range of manufacturing issues and design geometry types associated with machining processes.

There are three stages of the simulation in Explicit Dynamics. The first stage of a Finite Element (FE) method based simulation is called “pre-process”. This can be performed by using either the simulation software itself or one such as Autodesk Inventor, and Auto-cad. The geometric model is then meshed using triangular mesh elements (automatic mesh generation). Afterwards, the desired material (Al6061) is selected and tool location is set for simulation which is treated as rigid material. To finish this first stage, it is required to set the process conditions into the simulation software. In the second stage of a simulation process, various governing equations are performed and applied to a model analysis. The last stage of a FEM simulation is called “post-process”, where the experience of the analyst is required to extract the reliable and most important information from multiple colors contour results offered by the simulation software. Pre-process is very important for the efficiency of the simulation model. Hence, it must be thoroughly analyzed on the part geometry and its conditions as described in the following section. In Table 1 material properties of Al 6061 are presented.

TABLE 1 PROPERTIES OF AL6061

Property	Value	Unit
Density	2703	Kg/m ³
Sp. Heat	885	J/kgC

Steinberg Guinean Strength		
Initial Yield Stress	2.9E+08	Pa
Max Yield Stress	6.8E+08	Pa
Hardening Constant	125	NA
Hardening Exponents	0.1	NA
Derivative dG/dP	1.8	NA
Derivative dG/dT	-1.7E+07	Pa/C
Derivative dY/dP	0.018908	NA
Melting Temperature	946.85	C
Shear Modulus	2.76E+10	Pa
Shock EOS Linear		
Gruneisen Coefficient	1.97	NA
Parameter C1	5240	m/s
Parameter S1	1.4	NA
Parameter Quadratic S2	0	s/m

III. PROBLEM DESCRIPTION

The problem focused in this study is to apply CAE methods in single point cutting process to improve productivity of machining based products. In this study three controlling factors named cutting speed, feed rate and rake angle were used with four levels and taguchi tables were used for design of experiment which is shown in table 2 and 3. Fig. 1 show CAD file of problem used in this study

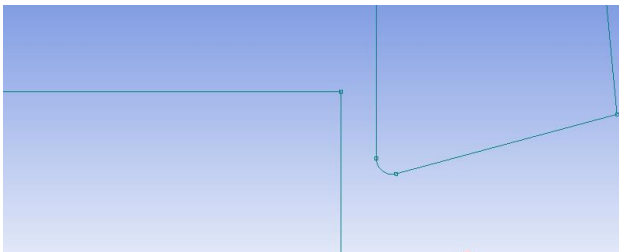


Fig. 1 (a) SPC tool at zero degree angle.

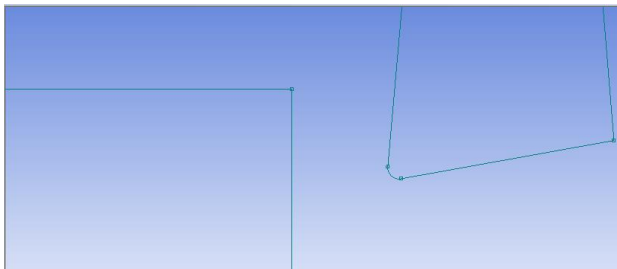


Fig. 1 (b) SPC tool at five degree angle.

IV. DESIGN OF EXPERIMENT AND RESEARCH METHODOLOGY

The effects of process parameters were studied by various researchers from last decades. It is very difficult to design, experiments for any type of research and here a scientific approach is helpful for researchers which is known as "DESIGN OF EXPERIMENT". This technique is adopted by researcher for this study. By use of D.O.E. techniques any researcher can determine important factors which are

responsible for output result variation of experiments. DOE can found optimum solution for particular experiments. In this study taguchi methods are used for ANOVA analysis. Factor and their levels are shown in table 2 after selection of factors and levels for current study it is important to select accurate orthogonal array and for this task MINITAB software was used for making of orthogonal array of factors and their levels which are shown in table 2.

V. FACTOR AND LEVELS

TABLE 2 SUMMARY OF ALL LEVELS AND THEIR FACTORS

Factor/ Level	Cutting Speed (m/min)	Feed Rate (mm)	Rake Angle
Low	250	0.6	0.0
Medium	625	0.9	3.75
High	1000	1.2	7.5

This design process is done in Minitab software and summary of results are shown below. In table 3 all experiments are shown.

TABLE 3 L9 Orthogonal array

S.No.	Cutting Speed	Feed Rate	Rake Angle
1	250	0.6	0
2	250	0.9	3.75
3	250	1.2	7.5
4	625	0.6	3.75
5	625	0.9	7.5
6	625	1.2	0
7	1000	0.6	7.5
8	1000	0.9	0
9	1000	1.2	3.75

After design of DOE table it is important to find out significance of input parameters with output results and here ANOVA analysis is applicable. Some steps were followed during ANOVA analysis using Minitab software.

Single point cutting process is simulated in this study for one design cases which is shown in Fig. 1.

VI. RESULT AND DISCUSSION

ANSYS Explicit Dynamics FEM package is used for simulation purpose. All experiments were designed according to DOE technique (Taguchi orthogonal array table), which were presented in table 3 and table 4. Main outcomes focused in this study are following:

ANOVA Analysis

Signal to noise ratios analysis

Model equations generation

In this study response is von-misses stresses (MPa) developed during cutting process is selected, and all results according to experiments design by Orthogonal array is presented in table 4.

TABLE 4 Response result from FEM code simulation

Sr. No.	cutting speed	Feed Rate	Rake Angle	Stress
1	250	0.6	0	394.56
2	250	0.9	3.75	400.36
3	250	1.2	7.5	406.16
4	625	0.6	3.75	399.52
5	625	0.9	7.5	405.32
6	625	1.2	0	401.29
7	1000	0.6	7.5	404.49
8	1000	0.9	0	400.45
9	1000	1.2	3.75	406.25

Minitab software is used for ANOVA analysis in this study. Summary table of three factors and their levels is presented in table 2.

Signal to Noise Ratio

Signal to noise ratio is simple technique to predict the effect of changing of factors according to their levels to find effect on product quality. In this study “smaller is better” option is adopted as quality indicator for S/N ratio and means ratio. The response tables for S/N ratio and mean are presented in table 5 and table 6.

TABLE 5 RESPONSE TABLE FOR SIGNAL TO NOISE RATIO

Level	cutting speed	Feed Rate	Rake Angle
High	-52.05	-52.03	-52.01
Medium	-52.09	-52.09	-52.09
Low	-52.12	-52.14	-52.16
Delta	0.07	0.11	0.14
Rank	3	2	1

Both tables show factors importance ranking and it is clear that rake angle is most important factor, which can reduce von-misses stress magnitude during cutting process

TABLE 6 RESPONSE TABLE FOR MEAN RATIO

Level	cutting speed	Feed Rate	Rake Angle
High	400.4	399.5	398.8
Medium	402.0	402.0	402.0
Low	403.7	404.6	405.3
Delta	3.4	5.0	6.6
Rank	3	2	1

Best and worst cases from experiment factors and their levels are also presented in this study and were calculated from Fig. 2 and Fig. 3.

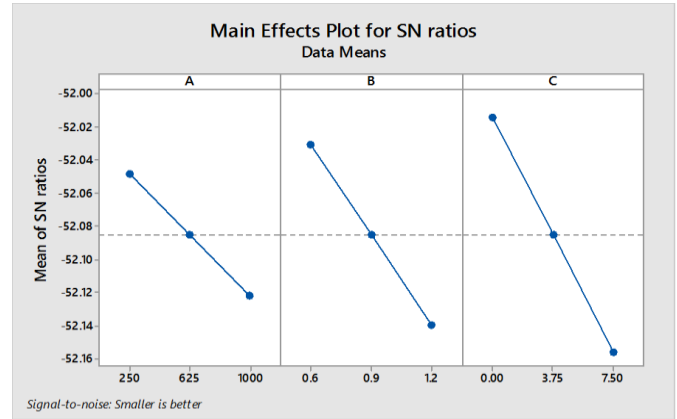


Fig. 2 Data means for smaller is better for S/N ratios.

Best case: A1 B1 C1 Worse Case: A3 B3 C3

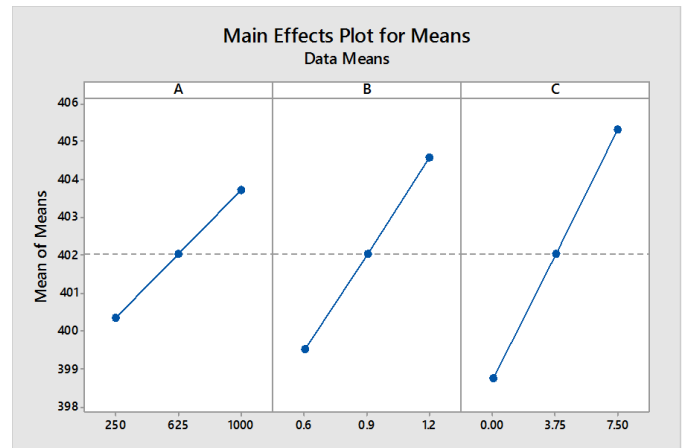


Fig. 3 Data means for mean ratios.

Best case: A1 B1 C1 Worse Case: A3 B3 C3

Here A B and C represent factor cutting speed, feed rate and rake angle respectively.

ANOVA ANALYSIS

The analysis of variance is calculated for this study and results are shown in table 6 respectively. In ANOVA analysis F-Test is conduct to compare a model variance with a residual variance. F value was calculated from a model mean square divided by residual mean square value. If f value was approaching to one means both variances were same, according F value highest was best to find critical input parameter.

TABLE -6 ANALYSIS OF VARIANCE FOR MASS FRACTION

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	119.673	39.8910	5128842.14	0.000

Cutting speed	1	17.035	17.0353	2190259.29	0.000
Feed rate	1	38.153	38.1528	4905362.14	0.000
Rack angle	1	64.485	64.4848	8290905.00	0.000
Error	5	0.000	0.000		
Total	8	119.673			

Table 6 lists out one important result that F value for regression models are very high, than one and P value is very less (approx 0.0000) suggested that all cases were significant. From literature review various researchers found that if p value was very small (less than 0.05) then the terms in the regression model have a significant effect to the responses.

ANOVA analysis is also tell that Solidus and liquids temperature has very low p value than other factor like Pouring speed and temperature, All four factors in which only three factor have acceptable p value so it can concluded that mass fraction at moving wall are affected by mainly three factor, this ANOVA analysis is linear single factor analysis, multi product ANOVA analysis can show more accurate results, which are presented in table 7, but not show good agreement for this study. Model equations for stress are presented in table 7 and ANOVA analysis with model equations.

TABLE-7 MODEL SUMMARY FOR ANOVA ANALYSIS

S	R-sq	R-sq(adj)	R-sq(pred)
0.0027889	100.00%	100.00%	100.00%

TABLE-8 DIFFERENT COEFFICIENTS

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	388.393	0.004	93035.26	0.000	
Cutting speed	0.004493	0.0000003	1479.95	0.000	1.00
Feed rate	8.40556	0.00380	2214.81	0.000	1.00
Rack angle	0.874222	0.000304	2879.39	0.000	0.1

Regression Equation

Stress = 388.393 + 0.004493 Cutting speed + 8.40556 Feed rate + 0.874222 Rack angle

The adequacy of regression models shall be inspected to confirm that the all models have extracted all relevant information from all simulated cases. If regression equations results were adequate, than the distribution of residuals should be normal distribution.

For normality test, the Hypotheses are listed below - Null Hypothesis: the residual data should follow normal distribution

Alternative Hypothesis: the residual data does not follow a normal distribution Normal probability for all responses were shown in Fig. 4.

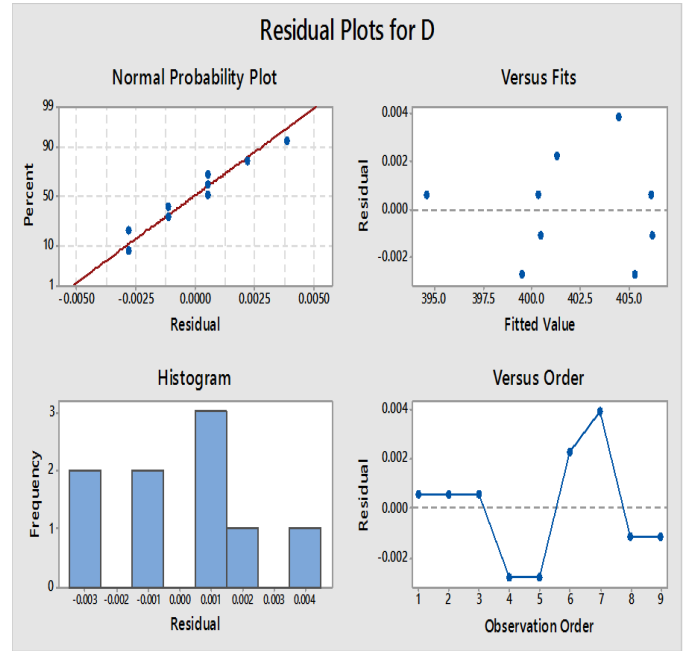


Fig.4 Normal probability for Von-Misses Stress.

VII. CONCLUSION

The aim of this study is to try to balance among response results and FEM simulation results for single point cutting machining process. This study utilizes L9 orthogonal array for FEM based data analysis. In this study Analysis of variance (ANOVA), and linear regression analysis is main key techniques to show response and factor relations strongly with each other. Main results are summarized as follows:

Best parameter combination for FEM results are following respectively

Case_1 best Set (S/N Ratio): A1 B1 C1

Case_1 best Set (Mean ratio): A1 B1 C1

ANOVA analysis is performed in this study and with the help of regression modeling general modeling equation is generated for future application i

Model equation generated in this study is following

Stress = 388.393 + 0.004493 Cutting speed + 8.40556 Feed rate + 0.874222 Rack angle

VIII. REFERENCES

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