Analysis of effect of cutting parameters on surface roughness and cutting force during turning of aluminum alloy ($AlSi_5Cu_3$)

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KEYWORDS

Turning,
Surface Roughness,
Cutting Force,
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ABSTRACT

The aim of this research work is focused on analysis of process parameters during turning of aluminium alloy ($AlSi_5Cu_3$). A study of effect of cutting parameters in turning of Aluminum Alloy ($AlSi_5Cu_3$) on the cutting force generated and machined surface roughness is carried out. In the experiment conducted, six values of feed rate, three values of depth of cut, and two values of cutting speed respectively, are used. The test pieces were turned on a centre lathe machine with different levels of cutting parameters by using full factorial design of experiment orthogonal array. The surface roughness of the machined surface was measured using surface measurement tester. Taguchi methodology was used to optimize process parameters. The results were analyzed by using Analysis of variance. From result analysis, it was found that, feed rate played a major role in producing lower surface roughness followed by cutting speed whereas depth of cut has least significance in producing lower surface roughness. To achieve better machining performance, the optimum condition parameters for surface roughness and cutting force, are as feed rate (FR = 0.045 m/min.), the cutting speed (CS = 90 m/min.), depth of cut (DOC = 0.5 mm). From analysis it is also seen that the cutting force equation and surface roughness equations are appropriate for accurate prediction. Thus, with proper selection of cutting parameters, it is possible to achieve good surface roughness, reduce tool wear while maintaining the cutting forces and temperatures at reasonable levels.

1. Introduction

Surface roughness plays an important role in metal cutting industry, as it influences the fatigue strength, coefficient of friction wear rate etc. of the machined parts (Suhail et al., 2010; Sripathy, 2009). In actual practice, there are various factors which affect the surface roughness and cutting force, such as tool geometry, work piece material and cutting conditions etc. Tool geometry include tool material, nose radius, cutting edge geometry, tool point angle, rake angle, etc (Patole & Kulkarni, 2018; Amini et al., 2015). Work piece variables include material, hardness and other mechanical properties. In turning operation, parameters such as cutting speed, depth of cut, feed rate and tool nose radius have great impact on the surface finish. Some of the researchers have developed the predictive model of surface roughness and cutting forces for the conventional turning, but these models may not be useful for hard as well as soft material turning, but such models differs from that of the conventional turning operation (Aouici et al., 2013; Singh et al., 2016). This paper deals with the turning of aluminum alloy ($AlSi_5Cu_3$) with tungsten carbide coated inserts. Taguchi parameter design and orthogonal array can optimize the response characteristics through settings of design parameters. Analysis of variance used to identify the most significant variables and interaction effects (Chen, 2008; Vinay et al., 2018). This study evaluate how to select the control parameter levels under turning of aluminum alloy ($AlSi_5Cu_3$) with parameters such as spindle speed, feed rate, depth of cut and tool nose radius that can minimize the effect of nuisance factor on response variable surface roughness. An experimental work is carried out to analyze the effect of cutting parameters on cutting force and surface roughness then select the optimal cutting parameters condition which will enhance the cutting performance and reduce cost during turning process.

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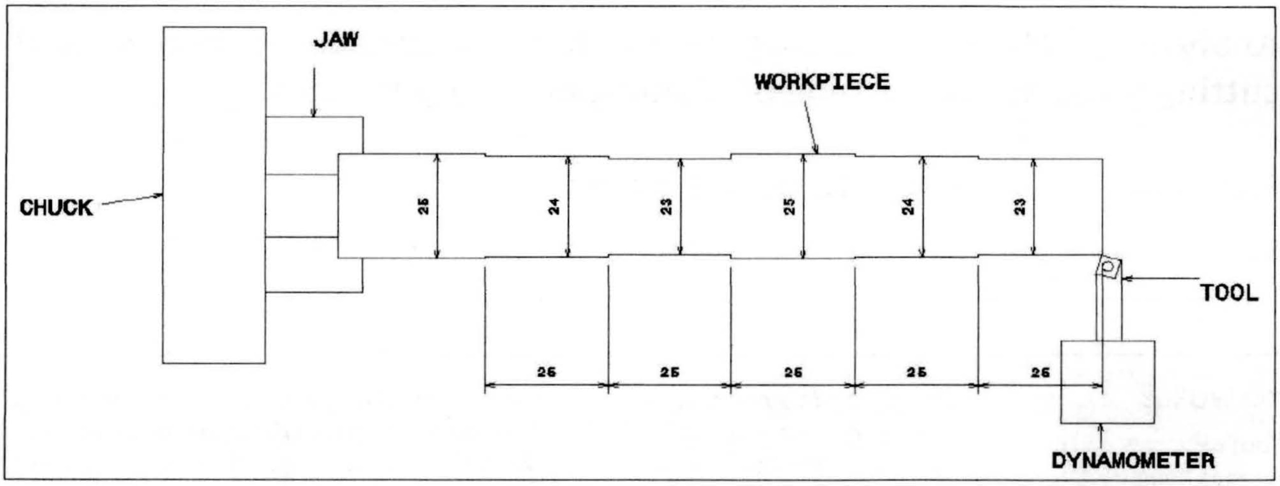

Fig. 1. Turning set up arrangement.

Table 1
Input parameters.

Sr. No.	Parameters	Value
1	Work piece material	Aluminum alloy (Grade -LM4)
2	Tool material	Tungsten Carbide Coated inserts grade – K10 Specifications a) CCGT Insert 090304
3	Environment	Without coolant
4	Length of cut (mm)	25 mm
5	Tool over hang	20 mm

Table 2
Chemical compositions.

Sr. No.	Constituent Material	Percentage
1	Copper	1.38
2	Lead	0.025
3	Silicon	6.4
4	Iron	0.55
5	Manganese	0.32
6	Nickel	0.18
7	Chromium	0.048
8	Aluminum	93.72

2. Experimental Procedure

Aluminum specimen piece (LM4) material is selected for experimentation. Before the turning operation, the specimen (LM4 round bar dia. 26 mm) has to be cut into desired dimension of 300 mm in length for each piece. There is need for a systematic methodological approach by using experimental methods and statically mathematical models. The design of experiment is an efficient procedure for the purpose of planning experiments. Data obtained from experiments is analyzed to test validity and arrive at conclusions. The experiment was carried out by using design of experiment (D.O.E.) method. Using design matrix (61 * 31 * 21) i.e. three values of depth of cut, six values of feed rate, two values of cutting speed, and constant value of tool nose radius are used. No. of Sets of Experiment = $6^1 * 3^1 * 2^1$ = 36 set.

3. Methodology

The general approach to planning and conducting the experiment is called strategy of experimentation and following are the steps of experimentation (Montgomary, 2001; CMTI, 1982). The experimentation was carried out by using input parameters as shown in Table 1.

3.1 Testing of material properties

The Brinell, chemical and strength tests were carried out of LM4 material. Brinell hardness number of aluminum alloy (LM4) test piece is 64.4. The chemical composition of the work material was tested using arc spectrometer and verified to be of grade LM4 also find out the percentage of material mentioned in the Table 2. Physical properties of the material are shown in Table 3. The values of tensile strength and Brinell hardness number required for determining force and power analytically.

Table 3
Physical properties.

Sr. No.	Strength Test	Value
1	Yield strength (Kg/mm^2)	116.5
2	Tensile strength (N/mm^2)	130.71
3	Elongation (percentage)	2
4	Reduction in area (percentage)	2.65
5	Izod Impact	0.7
6	Brinell Hardness Number	64.6

Table 4
Cutting force and surface roughness values.

Trial	Cutting Speed (m/min)	Feed Rate (mm/rev.)	Depth of Cut (mm)	Avg. Calculated Vertical Force (Kg)	Avg. Surface Roughness (µm)	Trial	Cutting Speed (m/min)	Feed Rate (mm/rev.)	Depth of Cut (mm)	Avg. Calculated Vertical Force (Kg)	Avg. Surface Rough. (µm)
1	60	0.045	1.5	2.95	2.34	19	90	0.045	1.5	2.94	2.52
2	60	0.045	1	1.97	2.24	20	90	0.045	1	1.97	2.33
3	60	0.045	0.5	0.98	2.18	21	90	0.045	0.5	0.98	2.19
4	60	0.05	1.5	3.28	3.34	22	90	0.05	1.5	3.28	2.69
5	60	0.05	1	2.19	2.88	23	90	0.05	1	2.19	2.42
6	60	0.05	0.5	1.09	2.86	24	90	0.05	0.5	1.09	2.24
7	60	0.071	1.5	3.81	3.97	25	90	0.071	1.5	3.81	2.79
8	60	0.071	1	2.54	3.50	26	90	0.071	1	2.54	2.49
9	60	0.071	0.5	1.27	3.12	27	90	0.071	0.5	1.27	2.30
10	60	0.1	1.5	5.37	5.61	28	90	0.1	1.5	5.37	4.05
11	60	0.1	1	3.58	4.76	29	90	0.1	1	3.58	3.51
12	60	0.1	0.5	1.78	4.36	30	90	0.1	0.5	1.79	3.21
13	60	0.2	1.5	8.35	7.2	31	90	0.2	1.5	8.35	5.65
14	60	0.2	1	5.57	6.57	32	90	0.2	1	5.57	4.68
15	60	0.2	0.5	2.78	6.42	33	90	0.2	0.5	2.78	4.12
16	60	0.25	1.5	8.95	8.12	34	90	0.25	1.5	8.95	5.98
17	60	0.25	1	5.96	7.30	35	90	0.25	1	5.96	5.36
18	60	0.25	0.5	2.98	7.14	36	90	0.25	0.5	2.98	4.92

Table 5
Response table for S/N ratio for Ra.

Level	CS	FEED	DOC
1	-12.4890	-7.2152	-10.7216
2	-10.3812	-8.6192	-11.3171
3		-9.3840	-12.2666
4		-12.2471	
5		-15.0206	
6		-16.1245	
Delta	2.1079	8.9092	1.5450
Rank	2	1	3

Table 6
Response table for S/N ratio for cutting force.

Level	CS	FEED	DOC
1	-9.489	-4.923	-4.301
2	-9.554	-5.947	-10.38
3		-7.269	-13.88
4		-10.306	
5		-14.059	
6		-14.628	
Delta	0.064	9.7045	9.583
Rank	3	1	2

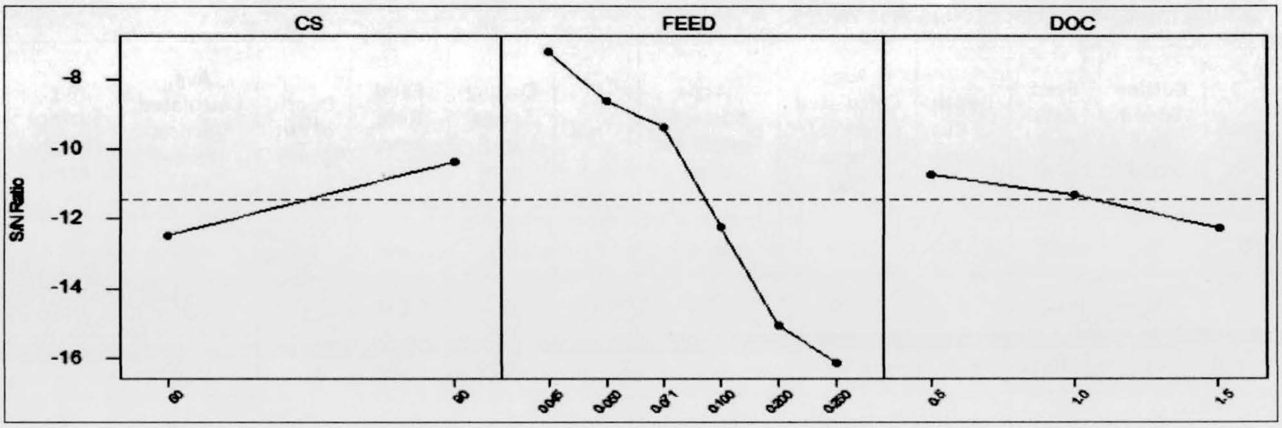

Fig.2. Main effects plot for S/N ratio (Ra).

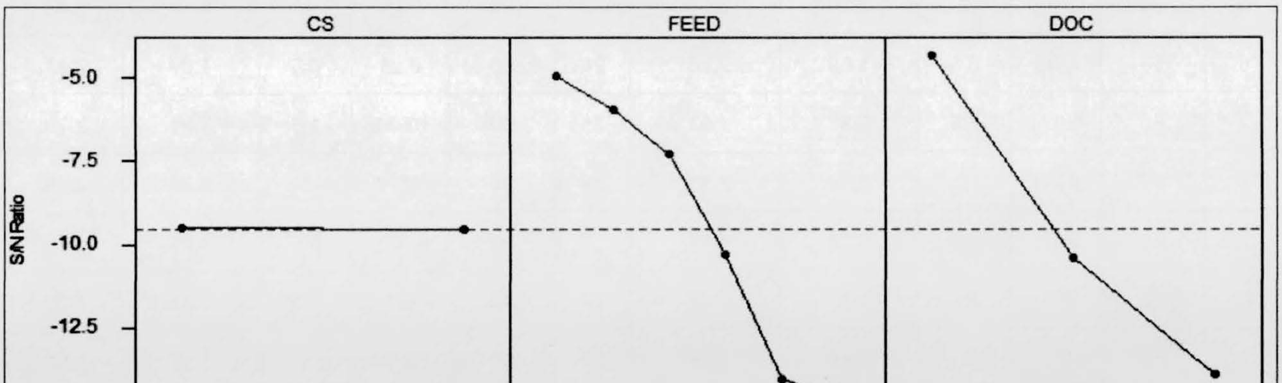

Fig. 3. Main effects plot for S/N ratio (Cutting force).

4. Results and Discussions

The various tests are conducted; analyses of experimental results and analytical calculations are described. The results of surface roughness and cutting forces are tabulated in Table 4. The results are useful to construct mathematical model for surface roughness and cutting force.

4.1 Analysis of variance

To achieve optimum condition, smaller the better performance characteristic for cutting force and surface roughness was taken. ANOVA was carried out to show the effect of process parameters that significantly affect on cutting force and surface roughness (Patole & Kulkarni, 2017a; Patole &

Kulkarni, 2017b). ANOVA table is created and signal to noise ratio was calculated by using Minitab software. The results of analysis of variance with surface roughness and cutting force are shown in Table 5 and 6 respectively. The influence of each control factor can be more clearly presented with response graphs. Response graphs for all control factors are shown in fig. 2 and 3.

4.2 Regression analysis

Regression analysis was implemented to develop prediction models using the predictors such as cutting speed, feed rate, depth of cut and tool nose radius in turning of aluminum alloy ($AlSi_5Cu_3$). The Minitab software was used for the analysis of experimental work and to develop the predictive model for cutting force and surface roughness.

$$Ra = -10.3 + 0.0703\ CS - 40.8\ FEED - 1.55\ DOC \quad ....(1)$$

$$CF = -2.41 - 0.00000\ CS + 20.2\ FEED + 3.64\ DOC \quad ....(2)$$

5. Conclusions

The following are the conclusions drawn based on the experiment conducted in turning of aluminum alloy ($AlSi_5Cu_3$). The inserts used with tool nose radius of 0.4 mm.

1. From analysis, it is verified that the feed rate (0.045 m/min.) and depth of cut (0.5 mm) are significant factors in achieving desired surface roughness and cutting force value.
2. It is observed that at constant cutting speed and depth of cut, as feed rate increases, cutting force and surface roughness value increases.
3. It is observed that, at constant feed rate and depth of cut as cutting speed increases, better surface quality is produced but cutting force remains constant.
4. To obtain optimal machining performance, the smaller the better performance characteristics for surface roughness and cutting force, the obtained optimal parameters are as feed rate (FR = 0.045 m/min.), the cutting speed (CS = 90 m/min.), depth of cut (DOC = 0.5 mm)
5. From regression equations, which can estimate the surface roughness and cutting force in turning process of aluminium alloy ($AlSi_5Cu_3$) work material. From analysis it is seen that the cutting force and surface roughness equations are appropriate for accurate prediction.

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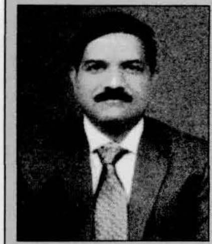

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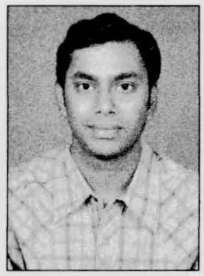

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