

Investigation on Effect of material surface roughness in 41cr4 alloy steel

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ABSTRACT: The effect of turning parameters on induced vibration and work surface roughness of 41Cr4 alloy steel was experimentally examined. Response Surface Methodology in conjunction with third order composite factorial Design is used to evaluate the effect of turning parameters on induced vibration amplitude and surface roughness. The results, from the turning operations performed in the experiment, gave rise to a predictive second order response surface equation. Besides, it was observed that turning parameters (dept of cut, cutting speed and work piece overhang) had significant effect on the surface roughness of work piece, and to a relative degree, influenced induced vibration. It also shows that the induced vibration and surface roughness of work- piece is directly proportional to the depth of cut, cutting speed and work piece overhang.

KEYWORDS: Turning Parameter, Alloy Steel, induced vibration, surface roughness

I. INTRODUCTION

Machining operations have been the core of the manufacturing industry since the industrial revolution [1]. Industries employing metal removing operations are now receiving great attention on cutting fluids in metal working to minimize the volume of lubricants due to occupational, economical and ecological reasons [2-6].

Milling is one of the most common metal cutting or removing processes. It is a process of generating machined surfaces by progressively removing a predetermined amount of material or stock from the work-piece at a relatively slow rate of movement or feed by a milling cutter rotating at a comparatively high speed. End milling is one of the most common metal removal operations encountered in industrial processes. It is widely used in the manufacturing industries which include the automotive and aerospace sectors, where quality is an important factor in the production of slots, pockets, precision molds, and dies. In end milling, the cutter generally rotates on an axis vertical to the work-piece. It can be tilted to machine tapered surfaces. Cutting teeth are located on both the end face of the cutter and the periphery of the cutter body [7, 8].

One of the problems which may arise in using the end milling process is that the finished part does not satisfy the product design specifications. During the machining process, friction exists between the tool and the work material, giving rise to heat and more energy is required for the machining operation [9]. The friction, heat and high energy have effect on the tool life, surface quality and tool wear etc.

The quality of the surface plays a very important role in the performance of milling as a good-quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. Surface finish also affects several functional attributes of parts, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating, or resisting fatigue [8, 10, 11]. Therefore the need to optimize cutting parameters to produce good surface finish is important.

Lou *et al* [11] developed a model for surface roughness technique for prediction of CNC end milling. The experiment was carried out on a vertical milling centre with the predictor variables being cutting speed, feed rate, and depth of cut. The material used was 6061 aluminium and multiple regression analysis was used to build the model. They were able to predict the surface roughness with about 90% accuracy and also noted that feed rate was the most significant machining parameter used to predict the surface roughness in the multiple regression models. It was recommended that further research should be considered using different cutting tools and materials of the work-piece. In addition, artificial intelligent systems such as the fuzzy logic system or neural networks technique might be included to enhance the ability of the prediction system.

Arokiadass *et al* [12] also studied the influence of four machining parameters including spindle speed (N), feed rate (f), depth of cut (d), and various percentage weight of silicon carbide (S) on surface roughness (Ra). The response surface methodology was employed to establish the mathematical relationship between the response and the various process parameters. The result obtained showed that the quadratic model is statistically significant for analysis of surface roughness. The value of regression coefficient (R) was

99.85 %, which indicated that the developed regression model is adequately significant at a 95% confidence level? The model also indicated that the feed rate was the most dominant parameter on surface roughness followed by spindle speed and %weight of SiC. Depth of cut has less influence on surface roughness. It was also concluded that the regression model is well fitted with the observed values and high correlation exists between fitted values and observed values.

The use of lubricant or cutting fluids in metal machining operations is to serve as a coolant i.e. to cool, as well as a lubricant i.e. to reduce friction and wash away chips. It is generally agreed that the application of cutting fluids can improve the tool life and results in good surface finish by reducing thermal distortion and flushing away of machined chips [13]. Better surface finish and dimensional accuracy are also obtained from cutting fluids [14]. The flooding method is the conventional method used in which a high volume of lubricant flow is applied and floods the entire machining area, effectively removing the heat generated from the machining process [15]. Flooding method required a large quantity of the cutting fluid and the cutting fluid is not able to reach the cutting zone due to obstruction from chips. This method has health implications on the operator(s) of the machining centre, environmental hazards and excessive waste of the cutting fluids and definitely high cost of production results. Ojolo *et al.* [16] made investigation into the effects of solid lubricant on the surface characteristics of some metals during orthogonal machining where it was shown that significant improvement in the surface finish of the machined steel surface and reduction in the surface roughness were obtained when compared to wet machining. The solid lubricant was also recoverable and more environmental friendly to the operator and surroundings when compared to wet machining.

The necessity to machine using less harmful cutting fluids has prompted many researchers to investigate the use of minimum quantity lubrication (MQL) [17]. MQL, also known as “Near-Dry Machining” [18] and as “Micro-lubrication” [19], is the latest technique of delivering metal cutting fluid to the tool/work interface. Dry machining, also known as green manufacturing is progressively becoming more popular as it protects the environment and reduces manufacturing cost [20-22]. MQL machining provides an economically and ecologically reasonable alternative to the traditional wet machining process [23].

Abhang *et al.* [24] investigated the use of minimum quantity lubricants in alloy steel turning where 10% boric acid is mixed with base oil SAE 40 proved to be a feasible alternative to the conventional cutting fluid. The result obtained indicated that there is a considerable improvement in machining performance with MQL machining compared to dry machining. It was concluded that MQL can reduce the chip tool interface temperature by 20 to 30% depending upon the level of process parameters and work material. The reduction in cutting temperature using MQL was high at lower level of machining parameters and low at high level of machining parameters. Also that the cutting forces is reduced by about 5% to 12% favorable change in the chip-tool interaction and retention of cutting edge sharpness due to reduction of cutting zone temperature seemed to be the main reason behind reduction of cutting forces by the minimum quantity of lubrication. Surface finish also significantly improved mainly due to significant reduction of wear and damage at the tool tip by the application of minimum quantity lubrication

II. EXPERIMENTATION AND METHOD OF ANALYSIS

A. Materials and Equipment

The following Materials and equipment are used to perform the experiment; Work-piece type 41Cr4 alloy steel round bar of 25Ø x 150 mm with the following specifications; (UTS = 902.83 N/mm², BHN = 278.55 and chemical composition of 0.4% C, 0.25 S, 0.65 Mn, 1.0 Cr) (Fig 1); conventional lathe Machine (Fig 2) with carbide (F30 Type) cutting tool (Fig 3) of dimension (25x25x12.5mm) type (HSS-718) with the following angles; back and side rake angle is 10°, 12° respectively, side relief angle is 5° and side cutting edge angle is 15° using the standard angle given in Jaton N.W[11].



Figure 1: Work-Piece Material



Figure 2: Lathe machine



Figure 3: Cutting Tool

B. Induced Machining Vibration

Self-excited vibration or self-induced vibration, which is also known as chatter, is the basis under consideration. It is caused by the interaction of the chip removal process and the structure of the machine tool that results in disturbances in the cutting zone.

Chatter always gives rise to defects on the machined surface; vibration especially self-excited vibration is associated with the machined surface roughness. A Vibration Meter 908Be series type measurement device (Fig 4), was used for measuring the amplitude and velocity of a point on the cutting tool. The tool vibration level was measured using a vertical data of a transducer mounted near to the tip and connected to the devices. The data include displacement and velocity of the indicated point on the tool for each sample. The acceleration was calculated by using general equation relating amplitude to acceleration.



Figure 4: Vibration Meter



Figure 5: Set-Up for the Measurement of Induced Vibration

C. Work Surface Roughness

An inside surface Roughness tester, ISR-16 type instrument (Fig 6) was used for the measurement of surface roughness. Three different positions for each sample at 120° with each other and the average of the three reading are

considered as surface texture of the turned surface.



Figure 6: Surface Roughness Tester

D. Response Surface Method

A third order composite factorial design and Response Surface Methodology RSM were chosen, so that different interactions between independent variables could be effectively investigated. The levels of the independent variables are as shown in Table I. The independent variables considered in the study are dept of cut F_1 , cutting speed F_2 , and work-piece overhang F_6 as shown in Table II. The constant variables are given in Table III.

Table 1: Levels of Independent Variables

S/N	Factor Design	Design of Exp. Notation	Symbol	Unit	Levels		
					Low	Medium	High
1	Depth of cut	F_1	T	mm	1.0	2.0	3.0
2	Cutting speed	F_2	N	rpm	260	320	400
3	Feed rate	F_3	F	mm/rev	0.15	0.20	0.30
4	Tool nose radius	F_4	R	mm	0	1	2
5	Tool overhang	F_5	h_t	mm	50	55	60
6	Work-piece overhang	F_6	h_w	mm	80	100	120

Table 2: Independent Parameters Under Consideration

S/N	Parameters	Unit	Levels		
			Low	Medium	High
1	Depth of cut	mm	1.0	2.0	3.0
2	Cutting speed	rpm	260	320	400
6	Work-piece overhang	mm	80	100	120

Table 3: Constant Variables

S/N	Parameters	Unit	Levels		
			low	medium	high
1.	Tool Overhang	mm	50	55	60
2.	Tool Nose Radius	mm	0	1	2
3.	Feed Rate	mm/rev	0.15	0.20	0.30

III. RESULT AND DISCUSSION

The study was undertaken to investigate the effect of turning parameters (dept of cut, cutting speed and work piece overhang) on induced vibration and surface roughness by turning 41Cr4 alloy steel. Machining data for dept of cut, cutting speed and work piece overhang on induced vibration and surface roughness, were tabulated accordingly in table IV. The result from the turning operating performed in the experiment gave rise to a predictive RSM equation for induced vibration (A) and surface roughness (Ra) respectively, given as: The dependent variables are the resulting surface finish and the acceleration in both radial and feed directions. In order to minimize the effect of tool wear, which could affect the surface roughness, the tool was changed after 4 cuts. The newly installed tool was run for a few machining times to eliminate rapid tool wear.

Table4: Third Order Composite Factorial Design

Experimental Run	Factor			Induced Vibration		Surface Roughness	
	F ₁	F ₂	F ₆	Acceleration	Predicted	Ra Value (mm)	Predicted
1	1.0	260	80	0.15	0.17	7.712	8.14
2	1.0	260	100	0.15	0.19	10.781	9.43
3	1.0	260	120	0.18	0.17	7.612	7.47
4	1.0	320	80	0.14	0.12	5.579	5.25
5	1.0	320	100	0.18	0.17	5.209	6.83
6	1.0	320	120	0.24	0.18	5.867	5.16
7	1.0	400	80	0.14	0.11	6.044	5.57
8	1.0	400	100	0.21	0.19	5.869	7.44
9	1.0	400	120	0.14	0.23	6.673	6.05
10	2.0	260	80	0.13	0.15	8.441	9.13
11	2.0	260	100	0.06	0.14	12.857	10.37
12	2.0	260	120	0.13	0.09	6.02	8.36
13	2.0	320	80	0.13	0.15	5.613	6.57
14	2.0	320	100	0.20	0.17	8.213	8.10
15	2.0	320	120	0.24	0.15	5.237	6.38
16	2.0	400	80	0.16	0.19	6.519	7.21
17	2.0	400	100	0.33	0.25	13.300	9.04
18	2.0	400	120	0.16	0.26	6.562	7.60
19	3.0	260	80	0.37	0.28	6.275	6.46
20	3.0	260	100	0.37	0.24	6.551	7.66
21	3.0	260	120	0.05	0.17	6.374	5.60
22	3.0	320	80	0.25	0.33	5.988	4.23
23	3.0	320	100	0.19	0.33	4.701	5.72
24	3.0	320	120	0.29	0.28	5.789	3.95
25	3.0	400	80	0.46	0.43	5.579	5.20
26	3.0	400	100	0.43	0.46	4.093	6.98
27	3.0	400	120	0.54	0.44	5.944	5.50

The average values of induced vibration and surface roughness (Ra) result were also plotted on a graph to give a better understanding of the results. The relationship between depth of cut (F₁), Cutting speed (F₂) and work- piece overhang (F₄) with acceleration amplitude and the surface roughness of work piece for cutting condition is plotted in Figs. 8 and 9 respectively. The actual amplitude of the induced vibration between tool and work-piece was measured using a displacement sensor.

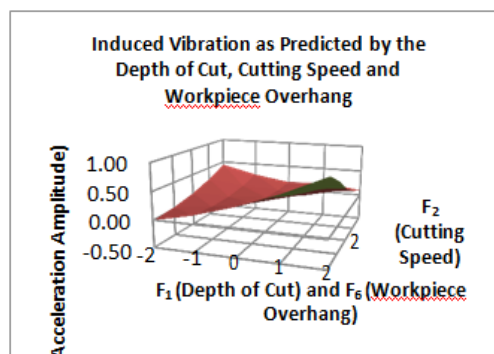


Figure 8: Response Surface plot of the induced vibration data

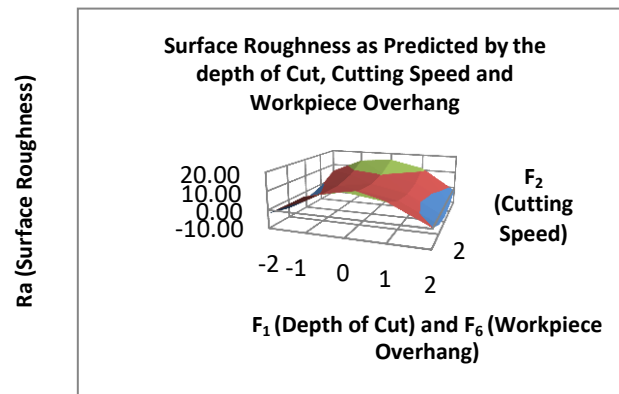


Figure 9: Surface Roughness Data

IV. CONCLUSION

From the experimental results, turning parameter (dept of cut, cutting speed and work piece overhang) has significant effect on the surface roughness of work piece and to a relative degree influences induced vibration. It also shows that the induced vibration and surface roughness of work-piece is proportional to the depth of cut, cutting speed and work piece overhang.

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