

Investigation of Material Removal Rate in Turning Operation

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ABSTRACT:The challenge of recent machining industries is reduce lead time and increase production rate in order to maintain their competitiveness. This paper investigates the machinability of mild steel in turning process perform on conventional lathe machine. Twoparameters like tool rake angle and feed are varied to investigate their effect on material removal rate. An attempt has been made to model the one response variable using Taguchi an ANOVA method. These are techniques of great practical importance in a lot of applications of statistical conclusion in a reliable way. Taguchi L9 orthogonal array is used for experimental design.The main aim of this work is save power and useful production time during manufacturing of product.

KEYWORDS: Turning, material removal rate, Taguchi.

I.INTRODUCTION

Factors such as tool life and wear, cutting forces, material removal rate and power consumption decide the productivity and overall economy of manufacturing a product by machine. In actual practice, there are various parameters like tool material, rake angle, cutting edge geometry, workpiece material, cutting speed, feed and depth of cut which affect these factors. So it is essential to choose the most suitable machining condition in order to improve cutting efficiency.

In turning operation, material removal rate is key aspect, which has need of attention both from industry as well as researcher. In recent industry,one of the trends is to manufacture low cost, high quality productsin less time. On the other hand, material removalrate is another main factor that greatly affects productionrate and cost.

The purpose of this research work is to find theinfluence of cutting parameters on material removal rate in turning operation. This paper presents a Taguchi's L9 orthogonal array for the optimization of thematerial removal rate for turning operation of mild steel as workpiece material by high speed steel as tool material. ANOVA (Analysis of variance) is used to find the most and least significant parameters.

Present work focus on maximize material removal rate with the purpose of improving the performance of turning operation. In this research determining cutting parameters like rake angle and feed that maximize material removal rate is a main task for achieving overall economy of machining. Statistical designof experiment refers to the process of planning the experimental so that the proper data can be analyzed by statistical methods, resulting a in valid and reliable outcome.

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II. LITERATURE REVIEW

Das *et al.*¹ presented an optimization method of the cutting parameters cutting speed, depth of cut and feed in dry turning of AISI D2 steel to achieve minimum tool wear, low work piece surface temperature and maximum material removal rate. For this they use three depth of cut range from 0.5 to 1 mm, three feed range from 0.15 to 0.25 mm/rev and three cutting speed range from 150 to 250 m/min and concluded that depth of cut (51.1%) was only found the significant parameter followed by feed (25.5%) on material removal rate. So the optimal combination of cutting parameters for maximum material removal rate was obtained at 250 m/min cutting speed, 1 mm depth of cut and 0.25 mm/rev feed.

Ghan *et al.*² has developed surface roughness and material removal rate prediction model for machining turning and milling of Al-alloy using multi regression analysis for optimization machining parameter. Design of experiment with orthogonal L9 array has been used for conduct the experiment. The experimental data was analyzed by using Minitab16 software. From this study they concluded that most significant parameter on surface roughness are speed and depth of cut while in case material removal rate, speed is most influencing parameter followed by feed but in case of machining time, speed is most influencing parameter followed by depth of cut.

Gupta and Diwedi³ worked on the effect of insert nose radius and machining parameters including cutting speed, feed rate and depth of cut on surface roughness and material removal rate in a turning operation are investigated by using the Taguchi optimization method. For this work they used three cutting speed range from 100 to 200 m/min, three feed range from 0.25 to 0.3 mm/rev, three depth of cut range from 1 to 2 mm and three nose radius range from 0.4 to 1.2 mm and found that for simultaneous optimization of Surface roughness and material removal rate, depth of cut is the most significant parameter affecting the performance followed by the nose radius.

Gupta and Kumar⁴ investigated surface roughness and material removal rate for turning of unidirectional glass fiber reinforced plastics using principal component analysis and Taguchi method by taking three tool rake angle range from -6 to 6 degree, two nose radius 0.4 and 0.8 mm, three cutting speed range from 55.42 to 159.66 m/min, three feed range from 0.05 to 0.2 mm/rev, three depth of cut range from 0.2 to 1 mm with dry, wet and cooled cutting environment. From this investigation they concluded that surface roughness and material removal rate increases as feed rate increases. Feed rate is the factor, which has great influence on surface roughness, followed by cutting speed.

Jayaraman *et al.*⁵ used grey relational analysis to performed multi-objective optimization of surface roughness and material removal rate. It investigate the effect of cutting speed, feed and depth of cut on surface roughness and material removal rate in turning of Al6063 aluminium alloy using uncoated carbide insert under dry condition. Experiment were conducted based on Taguchi design of experiment with orthogonal L9 array and then followed by optimization of result using ANOVA to find out maximum MRR and minimum surface roughness. From this study they concluded that feed rate is most influencing factor in grey relation grade followed by depth of cut. Lower cutting speed, lower feed rate and medium depth of cut give minimum surface roughness and maximum material removal rate.

Kaladhar⁶ worked on optimize process parameters on multiple performance characteristics such as, surface roughness and material removal rate during turning of AISI 202 austenitic stainless steel using a CVD coated cemented carbide tool. They investigated the effect of process parameter like cutting speed, feed, depth of cut and tool nose radius on surface finish and material removal rate to obtain the optimal setting of these process parameter. Analysis of variance (ANOVA) and F-tests are used to analyses the influences of cutting parameter during machining. It was found that higher levels of cutting speed, depth of cut, and nose radius and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness.

Pawar *et al.*⁷ worked on the effect of variation of geometric parameter of insert such as nose radius on surface roughness and material removal rate in a CNC turning operation for high speed steel by using Taguchi method. For this work they use three nose radius range from 0.4 to 1.2 mm, three cutting speed range from 150 to 300 m/min, three feed range from 0.15 to 0.28 mm/rev and three depth of cut range from 0.5 to 0.8 mm and concluded that material removal rate and surface roughness values in CNC turning process is greatly influenced

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by feed rate and nose radius. Also the optimal level of process parameters for optimum value of material removal rate parameter values are cutting speed 220 m/min, feed 0.28 mm/rev, depth of cut 0.80 mm, nose radius 0.8 mm.

Ranganath *et al.*⁸ investigated the effect of the rake angles and cutting parameters cutting speed, feed and depth of cut on material removal rate and surface roughness in turning of Aluminium (6061) in dry condition by taking three rake angle range from 2 to 4 degree mm, three speed range from 180 to 710 rpm and three feed range from 0.2 to 0.4 mm/rev. Based on this study they concluded that optimal combination process parameters for maximum material removal are obtained at 2 degree rake angle, 710 rpm speed and 0.4 mm/rev feed with constant depth of cut 0.2 mm.

Tayab⁹ worked on optimize cutting parameters like spindle speed, feed, depth of cut to minimization of surface roughness and maximization of material removal rate in CNC turning of aluminium alloy(AL 6063-T6) using carbon insert tool in dry condition. Taguchi design of experiment with L9 orthogonal array was used for experiment and minitab17 statistical software used to analysis the experimental data. The ANOVA is used to investigate which design factor and their interaction affects the response significantly. The result show that significant factor for surface roughness are feed rate and spindle speed while for material removal rate, depth of cut and spindle speed are most significant factor.

III. EXPERIMENTAL METHODOLOGY

(i) MATERIAL SELECTION

Mild Steel is use in present experimental work due to its durability, light weight, economical properties. The work pieces cut for the experimentwere of similar dimensions and cut from 32mm diameter rod. High speed steel used as tool material due to high hardness, abrasion resistance properties. Mechanical properties of work piece and tool material are given in **Table 1**.

Table 1 Mechanical properties of work piece and tool material

S. No.	Object	Material	Density (kg/m ³)	Elasticity (MPa)	Measurement (mm)
1	Work piece	Mild steel	7861	210,000	32×100
2	Tool	High speed steel	7900	207,000	

(ii) EXPERIMENTAL SETUP

The measurement of material removal rates is done for turning operation perform on the conventional lathe machine shown in **Figure 1** and measured by changing the cutting parameters as rake angle and feed.

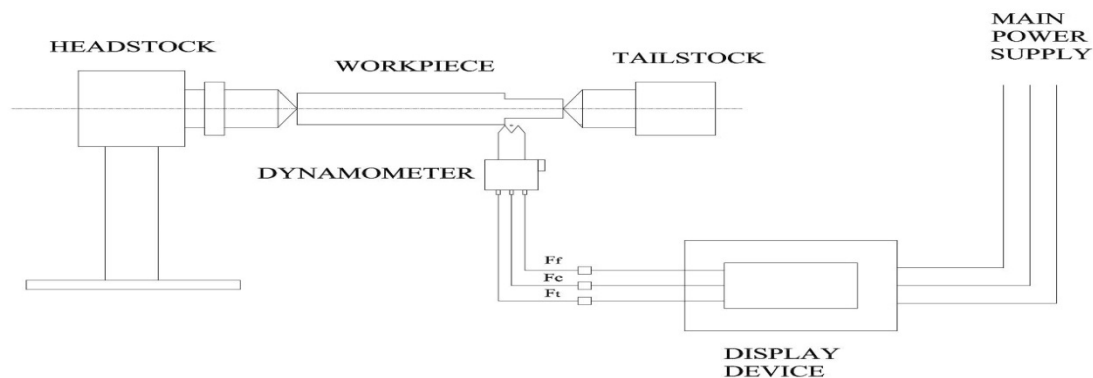


Figure 1: Line diagram of experimental setup

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(iii) DATA COLLECTION AND ANALYSIS

The experiment involves two cutting parameters (rake angle and feed) and one response variable (material removal rate) is show in **Table2**.

Table 2 Cutting parameters and their different level

Cutting Parameter	Unit	No. of Levels	Values For Each Level		
			Level 1	Level 2	Level 3
Rake angle	degree	3	6	9	12
Feed	mm/rev	3	0.05	0.07	0.10

The experimental work is divided basically into two phases. In the first phase, the experiments are performed for different combination of parameters and all the data are collected. In the final phase, analysis task is performed over the collected data using various numerical and statistical tools for optimization of the results.

To determine the effect of each variable on the output, the signal-to-noise (S/N) ratio calculated for each experiment by using Taguchi method in Minitab 17 statistical software and result of total 9 (3x3) runs are given in **Table 3**.

Table 3 Material removal rate for different independent parameters

Independent parameter			Dependent variable		
Rake angle (degree)	Feed (mm/rev))	Spindle speed(rpm)	Material removal rate (mm ³ /min)	S/N ratio	Mean
6	0.05	52	377	51.52683	377
6	0.07	52	467	53.38634	467
6	0.10	52	654	56.31155	654
9	0.05	52	282	49.00498	282
9	0.07	52	392	51.86572	392
9	0.10	52	548	54.77561	548
12	0.05	52	233	47.34712	233
12	0.07	52	322	50.15712	322
12	0.10	52	451	53.08353	451

(a) **Taguchi method:** In Taguchi method, there are three categories for analysis of S/N Ratio i.e. the smaller is better, the larger is better and the nominal is best. For this experimental analysis, the second category 'The larger is better' was chosen to reach the optimization conditions for maximization of material removal rate which is the desired condition for turned machined parts.

Main effects plot for S/N ratio and for Means generated by using MiniTab-17 statistical software as shown in **Figure 2** and **Figure 3** respectively.

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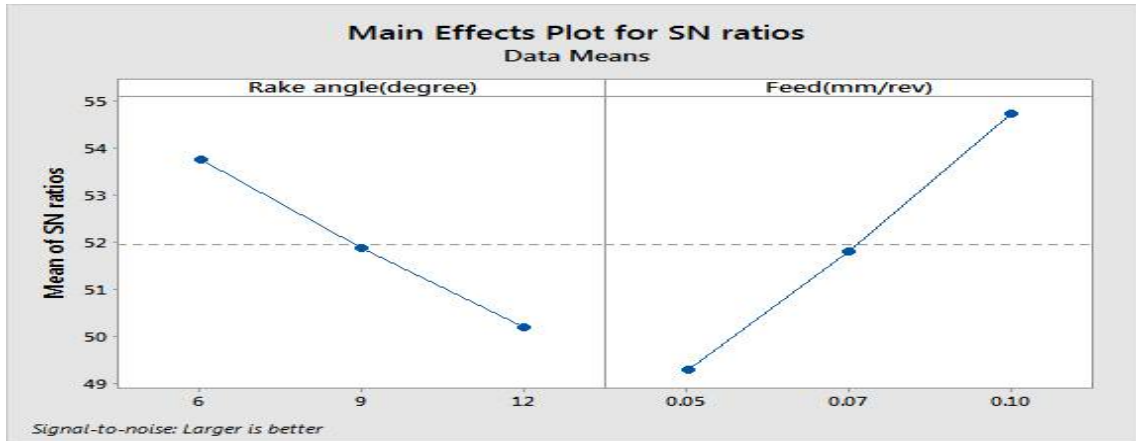


Figure 2: Main effects plot for S/N ratios

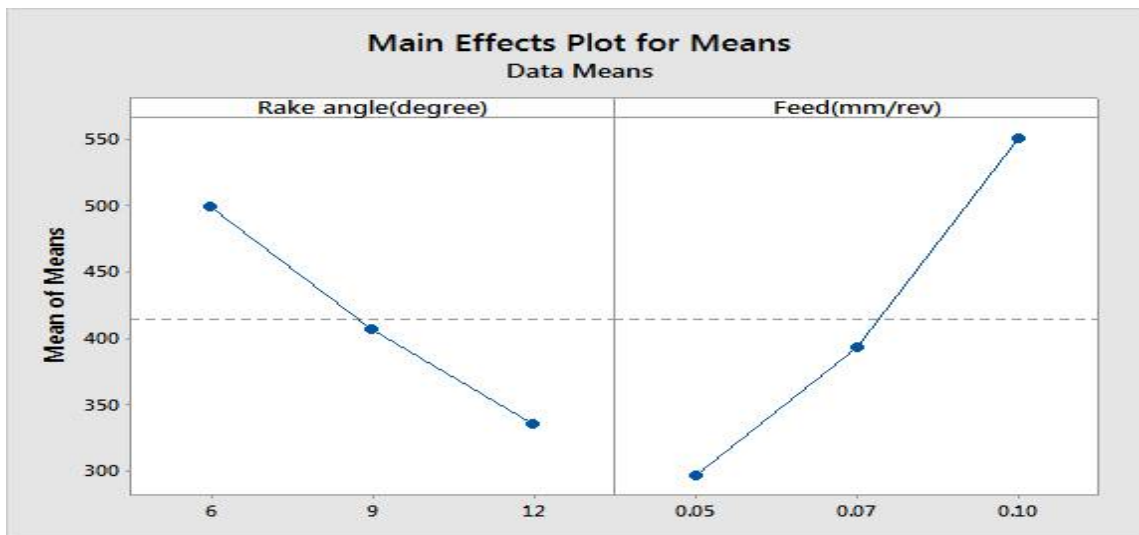


Figure 3: Main effects plot for Means

(b) ANOVA (Analysis of Variance): ANOVA (Analysis of variance) table generated for determined percentage contribution of different independent parameters on response variable by using Minitab 17 statistical software is shown in Table 4.

Table 4: Analysis of Variance

Source value	DF	Seq.SS	Contribution	Adj.SS	Adj.MS	F value	P value
Rake angle (degree)	2	40544	28.91%	40544	20272.0	61.84	0.001
Feed(mm/rev)	2	98381	70.15%	98381	49190.3	150.05	0.000
Error	2	1311	0.94%	1311	327.8		
Total	6	140236	100%				
S= 18.1062		R-sq=99.06%		R-sq(adj)= 98.13%			

It is clear from this table that the effect of feed and rake angle on material removal rate is 70.15% and 28.91% respectively. R-sq represents the significance of experiment work.

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Regression: Regression equation is formulated to predict the desired material removal rate value. This term is use for finding out the correlation between the data. In the present work, regression equation was obtained by Minitab 17 statistical software.

$$\text{Material removal rate (mm}^3/\text{min)} = 287.0 - 27.33 \text{ Rake angle (degree)} + 5087 \text{ Feed (mm/rev)} \quad (I)$$

IV. RESULT AND DISCUSSION

The result shows that both two parameters have their effect on the measured material removal rate. The effect of feed is more than rake angle. Feed is the distance that tool travel in per revolution of work piece, so it indicates the time for cut the material from work piece. Hence for more feed, less time required for cut the material for desired length which increase material removal rate.

It is clear from given data in **Table 3** for a constant rake angle and spindle speed, but varying the feed shows more variation in material removal rate. For example, for constant spindle speed 52 rpm and rake angle 6 degree, changing the feed from 0.05 mm/rev to 0.10 mm/rev show increment in material removal rate from 377 mm³/min to 654 mm³/min, which is more significant. There is less effect of rake angle on material removal rate as the increase in rake angle leads to a less increment in material removal rate.

After analysis of data, it is clear that maximum material removal rate developed at 0.10 mm/rev of feed and at 6 degree of rake angle which save energy and useful production time.

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