

Analysis of Optimal Selection of Machining Parameters in CNC Turning Process on MRR and Surface Roughness of Al Using Taguchi Method

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ABSTRACT:The challenge of recent machining industries is to reduce lead time and increase production rate in order to maintain their competitiveness and to increase the product accuracy. This paper investigates the analysis of cutting parameter in CNC machine of Aluminium. In the present paper, an effective approach for the optimization of turning parameter based on the Taguchi method with Analysis of Variance is presented for minimizing required surface roughness and maximizing the Material Removal Rate (MRR) in machining of Aluminium. Experiment were conducted based on Taguchi's technique L9 orthogonal array. Three machining parameters are chosen as process parameter - Cutting speed, Feed Rate and Depth of cut. The orthogonal array and analysis of variance are employed to study the performance characteristics in CNC Turning operation. The main aim of this work is to save a power, useful machining time, maximize the productivity

KEYWORDS:Machining Surface Roughness, Material Removal Rate, Taguchi's Technique, Design Of Experiment, ANNOVA, MINITAB.

I. INTRODUCTION

Primary objective of machining operation is the efficient production of accurate parts. Turning is the most widely used among all the cutting process. Surface finish is the method of measuring the quality of products and is an important parameter in machining process. It is one of the prime requirements of customer for machining part. Productivity is also necessary to fulfil the customer demand for this purpose quality of product and productivity should be high. 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 production, less time. In case of CNC Turning process particularly, significant research has focused on the way to increase Material Removal Rate without sacrificing work piece accuracy. MRR can be improved by varying the three parameters- Feed rate, Speed and Depth of cut. The CNC Turning machine is highly used in industries for various machining operations for obtaining high accuracy and in order to increase the machining efficiency, reduce machining cost and improve the quality of machined parts. In order to achieve this desired performance measures in machining operation proper selection of machining parameter is essential. The Aluminium are the most widely used non-ferrous material in engineering application owing to their attractive properties such as high strength to weight ratio, good ductility, excellent corrosion resistance, availability and low cost. However their application have often been restricted in aircrafts fittings, gear and shafts, missile parts keys, bike frames and all-terrain vehicle sprockets because conventional Aluminium are soft and high strength material. This paper explains an optimal setting of turning parameters (Cutting Speed, Feed, Depth of cut) which results in an

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optimal value of surface roughness and maximum Material Removal Rate (MRR) while machining of Aluminium bar with HSS tool.

II. LITERATURE REVIEW

U D Gulhane¹ presented an optimization method of cutting parameters cutting speed, depth of cut, feed on shaping process parameters on MRR and Surface roughness of Al6061 using Taguchi Method to achieve lower value of surface roughness and maximise the MRR by considering three independent parameters, feed rate depth of cut and cutting speed. And concluded optimum MRR with smooth surface finish.

Sourabh Sighvi² investigate material removal rate in turning operation by using Taguchi technique considering three parameters rake angle, feed, spindle speed, where rake angle and feed uses at different levels. After analysis of data it is clear that effect of feed is more than rake angle on material removal rate.

Mohammed Nooruddin³ investigate the effect of process parameters in dry turning of grey cast iron FG 260 in a CNC lathe. The parameters namely the spindle speed, feed rate and depth of cut are varied to study their effect on material removal rate and concluded depth of cut and speed was most influencing parameters on MRR.

S.V.Alagarsamy⁴ worked on an effective approach for the optimization of turning parameters based on the Taguchi's method with Response surface methodology (RSM) is presented. This paper discusses the use of Taguchi's technique for minimizing required surface roughness and maximizing the material removal rate in machining Aluminium Alloy 7075 using TNMG 115 100 tungsten carbide tool and conclude that input parameter feed rate most influencing on quality of surface roughness and depth of cut on material removal rate.

Ghan H R⁵ 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 Minitab 16 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.

Tayab⁶ 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 minitab 17 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. METHODOLOGY

Taguchi's design of experiments is a simple robust technique for analysis and optimizing the process parameters. In this method, main parameters which are assumed to have influence on process results are located at different columns in a designed orthogonal array. The major steps in Taguchi experimental design are: selection of output response, selection of independent variables and the design of orthogonal array (OA). The machining parameters were selected on the basis of the information available in the literature and past experience of the present authors.

IV. MATERIAL SELECTION

Aluminium is use in present experimental work. The aluminium are most widely used in engineering operation because of their attractive properties like high strength to weight ratio, good ductility excellent corrosion resistance, light in weight and it is non-ferrous and soften material. The 9 work pieces cut for the experiment were of similar dimensions and cut from 25mm diameter rod. High speed steel used as tool material due to high hardness, abrasion resistance properties. Mechanical properties of work piece shown in Table 1

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Table 1: Mechanical properties of work piece

Physical properties	Mechanical properties
Density-2.70g/cm ³	Young modulus-38.2GPa
Melting point -660 ⁰ C	Tensile strength-82.7MPa
Poisson's ratio-0.33	Yield strength-75.8MPa
Modulus of elasticity-68.9GPa	Ultimate tensile strength-110MPa

V. EXPERIMENTATION

Turning operation was carried out on CNC Machine (CNC Lathe Trainer Power Turn SS-PT-100) using high speed steel tool. Al was used as a work material for experimentation. The chemical composition of Al is shown in Table2, Properties of the material are shown in the following table1. Long Circular bar of the material was cut in the required size of 80×25 mm² using hacksaw & then ends of specimens were turned on file for proper aligning and removal of extra waste material. The tool, High speed steel (HSS has point angle is 118°. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness. The composition of high speed steel are carbon (0.6%to0.75%), tungsten (14%to20%), Chromium (3%to5%), vanadium (1%to1.5%), Cobalt (5%to10%) and remaining is iron. CNC machine used is 1.5 H.P.,3000rpm, The input parameters are depth of cut, Speed, feed rate as shown in table and the responses considered are material removal rate (MRR) and surface roughness (Ra).

Initially the weights of work pieces were measured before machining on the high precision digital balance meter. Weight is required for calculating the MRR. Work piece was fixed in the vice firmly. Before fixing care should be taken for alignment & horizontal surface of work piece. According to the combination of OA as shown in table 4, proper feed, speed & depth of cut were set on the machine. After checking all the arrangements, machining was started. Simultaneously time for the machining is noted down. On completion of machining on first specimen, it was removed from the vice. File was used for removing burr present on it & then its weight is measured on the balance. In this way all 9 work pieces were machined with their parameter levels. Care should be taken while fixing the specimen on the vice & while setting the required feed on it. Before starting the machine, it must be confirmed that depth of cut is not so large The surface roughness is measured using Surface Tester SJ-210 Mitutoyo — Portable Surface Roughness Tester with 10mm of measuring range. The MRR Step Turning was calculated on the basis of theoretical formula.

TABLE 2: COMPOSITION OF AL

SAE Designation	%Al	% Cr	% Fe	% Mg	% Mn	% Si	% Zn	% Ti	Other
Al (Actual)	99.60	-	0.35	0.03	0.03	0.25	0.05	0.03	0.03

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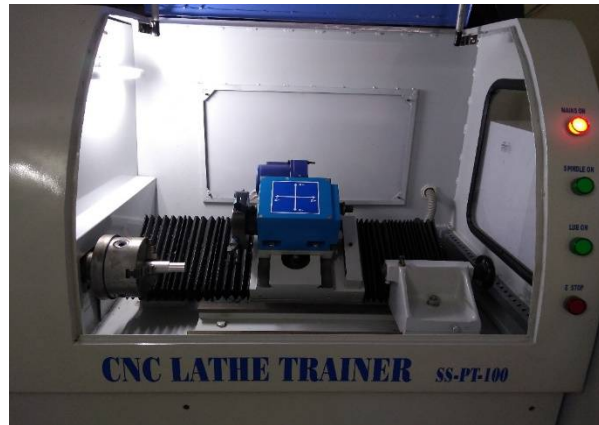


Figure1: Pictorial view of CNC lathe trainer power turn SS-PT-100

We are conduct the experiment of step turning on CNC lathe trainer power turn SS-PT-100 machine (Figure 1) with the help of G codes and M codes programing. With the advent of CNC technology, the machining processes are automated through which high quality of the machined component, high material rate can achieved with high surface finish. In general CNC machine operated with several controllable factors such as spindle speed, feed rate, depth of cut etc. The optimization of CNC turning process is often achieved by trial and error method based on the shop floor experiences by determining certain parameters of the process, but neither guarantee the quality nor the machine economics. Therefore a general optimization plan is required to avoid cumbersome trial runs on machine and wastages.

TABLE 3: MACHINING PARAMETERS AND LEVELS

Machining Parameters	Low	Medium	High
Cutting speed (rev/min)	2000	2500	3000
Depth of cut (mm)	0.3	0.5	0.7
Feed rate (mm/rev)	25	30	35

VI. RESULTS AND DISCUSSION

Table 4 shows orthogonal array and response values calculations for AI. S/N ratio is calculated using Lower the better characteristics for surface roughness and larger the better characteristics for MRR. Responses for Signal to Noise Ratios of both responses are shown in Table 5 & 6

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 smaller is better" was chosen to reach the optimization condition for minimum Surface Roughness, and "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.

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TABLE 4: ORTHOGONAL ARRAY & CALCULATIONS FOR RESPONSE VARIABLES

Specimen No	Feed Rate (mm/rev)	Cutting Speed (rpm)	Depth Of Cut (mm)	Surface Roughness (Ra) μm	S/N Ratio of Ra	Material Removal Rate (mm^3/min)	S/N Ratio of MRR
1	25	2000	0.3	1.633	-4.2597	1060287	120.50
2	25	2500	0.5	1.646	-4.3286	2208932	126.88
3	25	3000	0.7	1.212	-1.6700	3710738	131.38
4	30	2000	0.5	1.003	-0.0260	2120575	126.52
5	30	2500	0.7	1.196	-1.5546	3711006	131.39
6	30	3000	0.3	0.853	1.3810	1908517	125.61
7	35	2000	0.7	1.311	-2.3520	3463605	130.79
8	35	2500	0.3	1.543	-3.7673	1855503	125.36
9	35	3000	0.5	1.375	-2.7660	3710014	131.38

Taguchi method cannot judge and determine effect of individual parameters on entire process while percentage contribution of individual parameters can be well determined using ANOVA. MINITAB software of ANOVA module was employed to investigate effect of process parameters (cutting speed, Depth of Cut, Feed rate).

RESPONSE TABLES FOR SURFACE ROUGHNESS AND MRR

TABLE 5: SIGNAL TO NOISE RATIOS OF SURFACE ROUGHNESS, SMALLER IS BETTER

Level	Feed Rate	Speed	Depth of Cut
1	1.497	1.316	1.343
2	1.017	1.462	1.341
3	1.410	1.1147	1.240
Delta	0.480	0.315	0.103
Rank	1	2	3

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Table 5 Shows that feed rate is more significant on surface roughness as compare to other parameters, and depth of cut is less significant on surface roughness. Theory suggests that surface roughness is function of feed rate. In practice it is more like directly related to feed rate.

TABLE 6: SIGNAL TO NOISE RATIOS OF MRR, LARGER IS BETTER

Level	Feed Rate	Speed	Depth of Cut
1	2326742	2214822	1608102
2	2580033	2591814	2680171
3	3010038	3110176	3628539
Delta	683296	895354	2020437
Rank	3	2	1

Table 6 Shows that depth of cut is more significant on material removal rate as compare to other parameters and feed rate is less significant on material removal rate. Therefore depth of cut is directly related to the material removal rate. Utilizing right approach for tool can result in prolonged tool life, minimizing the rate of normal tool wear.

RESPONSE PLOTS FOR SURFACE ROUGHNESS AND MRR

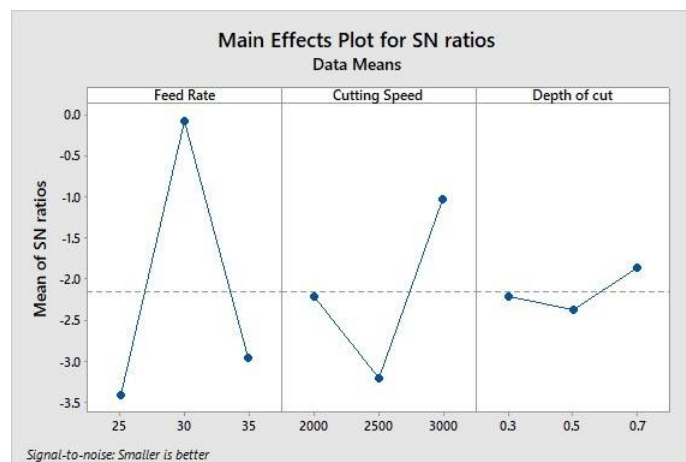


Figure 2. Effect of Feed, Speed & Depth of cut on Ra

Significance of machining parameters of surface roughness indicates that feed is significantly contributing towards the machining performance as difference gives higher values. Plot for S/N ratio shown in Figure 2 explains that there is less variation for change in depth of cut where as there is significant variation for change in feed rate.

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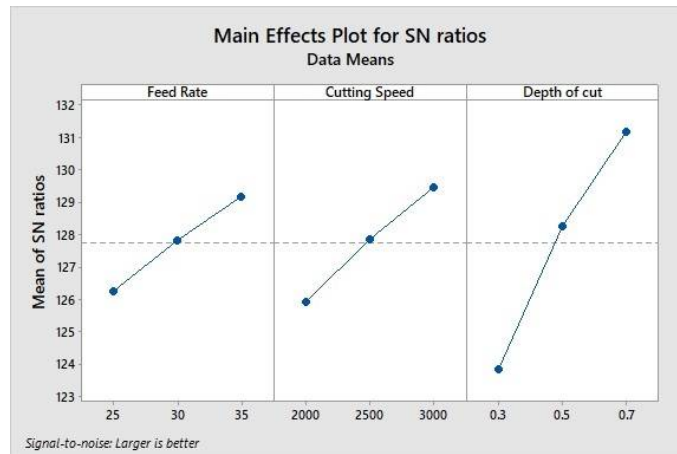


Figure 3. Effect of Feed, Speed & Depth of cut on MRR

Significance of machining parameters of material removal rate indicates that depth of cut is significantly contributing towards the machining performance as difference gives higher values. Plot for S/N ratio shown in Figure 3 explains that there is less variation in feed rate where as there is significant variation for depth of cut.

ANALYSIS OF VARIANCE FOR S/N RATIOS OF SURFACE ROUGHNESS AND MRR

Table 7: Surface Roughness Analysis

Source	DF	Adj SS	Adj MS	F	P
Feed Rate	2	0.39163	0.19582	9.88	0.092
Cutting Speed	2	0.14910	0.07455	3.76	0.210
Depth Of Cut	2	0.02102	0.01051	0.53	0.654
Error	2	0.03965	0.01983		
Total	8	0.60140			

Table 5 & 6 shows S/N ratios for responses. Now from surface roughness analysis (table 7), F value (9.88) of parameter indicates that feed rate is significantly contributing towards surface finish & machining performance. F value (0.53) of parameter indicates that depth of cut is contributing less towards surface finish. It can be observed from rough surface for the specimen No. 2 (cutting speed:- 2500 rpm; depth of cut:- 0.5 mm; feed :- 25 mm/rev) and smooth surface for the specimen No. 6 (cutting speed:- 3000 rpm; depth of cut:- 0.3 mm; feed :- 30 mm/rev) as shown in Table4.

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Table 8:MRR Analysis

Source	DF	Adj SS	Adj MS	F	P
Feed Rate	2	7.15E+11	3.57E+11	4.43	0.184
Cutting Speed	2	1.21E+12	6.06E+11	7.50	0.118
Depth Of Cut	2	6.13E+12	3.06E+12	37.9	0.026
Error	2	1.61E+12	8.08E+10		
Total	8	8.22E+12			

From MRR analysis (table 8), F value (37.9) of parameter indicates that Depth of Cut is significantly contributing towards MRR & machining performance. F value (4.43) of parameter indicates that Feed Rate is contributing less towards Material removal rate. The specimen No. 5 (cutting speed - 2500 rpm; depth of cut – 0.7 mm; feed – 30 mm/rev) has highest Material removal rate and the specimen No. 1 (cutting speed – 2000 rpm; depth of cut – 0.3 mm; feed – 25 mm/rev) has lowest MRR (table 4)

VII. CONCLUSION

Based on the scope and limitations of the present work, the following conclusions may be drawn from the results of the experiments and analysis of the experimental data in connection with CNC turning of aluminium. Taguchi method of experimental design has been applied for optimizing multi response process parameter for CNC turning Al are optimized with L9 orthogonal array. Results obtained from Taguchi method closely matches with ANOVA

1) In the study, the Taguchi method and ANOVA was applied for analyzing to get a minimum surface roughness and maximum material removal rate for turning process of Aluminium using CNC machine via considering three influencing input parameters- Speed, Feed and Depth of Cut.

2) Best parameters found for surface finish machining are cutting speed:- 3000 rpm; depth of cut:- 0.3 mm; feed :- 30 mm/rev. The parameters found for rough machining are cutting speed:- 2500 rpm; depth of cut:- 0.5 mm; feed :- 25 mm/rev. Feed is most influencing parameters corresponding to the quality characteristics of surface roughness.

3) Best parameters found for MRR are cutting speed - 2500 rpm; depth of cut – 0.7 mm; feed – 30 mm/rev. The parameters for very less MRR are cutting speed – 2000 rpm; depth of cut – 0.3 mm; feed – 25 mm/rev. Depth of cut being most affecting parameter on MRR.

4) By observing table 4, the surface roughness value corresponding to highest MRR of specimen no 5 is 1.196. This value of surface roughness is nearer to the Ra value of smooth surface (0.853). Hence Combination of parameters of specimen no 5 gives optimum MRR with smooth surface finish. Desired values of parameters are cutting speed - 2500 rpm; depth of cut – 0.7 mm; feed – 30 mm/rev. As a result, the optimisation of complicated multiple performance characteristics can be greatly simplified using this approach.

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