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Effect of Process Parameters on MRR and Surface Roughness in Turning Operation using Taguchi Method

Piyush Pant*, Kunwar Laiq Ahmad Khan[1], Rupesh Chalisgaonkar[1] and Shobhit Gupta[1]

Department of Mechanical Engineering, KIET Group of Institutions, Ghaziabad, India

Abstract

In present study, effect of process parameters in turning of mild steel has ben investigated. The process parameters speed, feed and depth of cut are considered. Material removal rate and surface roughness are taken as the response variables. Taguchi method is employed and signal to noise ratio is calculated using L9 orthogonal array. The combination of optimum levels of process parameters to achieve simultaneous maximization of material removal rate and minimization of surface roughness, is found out and also checked experimentally.

***Keywords*:** Process Parameters; Material Removal Rate; Surface Roughness; Taguchi Method

I. Introduction

In current scenario, machining industries have a challenging task to obtain high quality with respect to dimensional accuracy, surface finish, low wear, machining economy. Surface roughness of the machined workpiece is the most important criteria to judge the quality of machining. The literature survey has revealed that several researchers have attempted to calculate the optimum cutting conditions in a turning operation. Now a day's more attention is given to accuracy and surface roughness. Surface roughness is the most important criteria in determining the machinability of the material .Surface roughness and dimensional accuracy are the major factors needed to predict the machining performances of any machining operation. Optimization of machining parameters increases the utility for machining parameters increases the utility for machining economics and also increases the product quality to greater extent.

II. Literature Review

Kothiyal et al (2013) performed optimization of parameter using Taguchi methodology and ANOVA. The L9 Orthogonal array is used in MINITAB 15 which shows the percentage contribution of each influencing factor on MRR. The material used for experiment is (100 × 34 × 20 mm) blocks of aluminium cast heat-treatable alloy. Chandrasekaran et al (2013) studied the machinability of AISI 410 on CNC lathe for SR using taguchi method. The effect and optimization of machining parameters on SR is investigated. L27 0rthogonal array, analysis of variance was used in this investigation. The experiment was conducted on CNC lathe. Work material of Ø32 mm and length 60 mm was used. Joshi et al (2012) investigated the SR response on CNC milling by Taguchi technique. Analysis of variance was used in this investigation. The material used for the experiment is (100 × 34 × 20 mm) 5 blocks of aluminium cast heat-treatable alloy. The output characteristic, surface finish is analysed by software Minitab 15 and ANOVA is formed, which shows the percentage contribution of each influencing factor on surface roughness. Zhang et al (2012) investigated the Taguchi design application to optimize surface quality in a CNC face milling operation. An orthogonal array of L9 was used and ANOVA analyses were carried out to identify the significant factors affecting surface roughness. CNC Mill : Fadal VMC-40 vertical machining centre was used for this experiment and 19. 1×38. 1×76. 2 mm aluminum blocks as a work piece. The experimental results indicate that in this study the effects of spindle speed and feed rate on surface were larger than depth of cut for milling operation. Oenafdos et al (2011) used neural network modelling approach for the prediction of surface roughness in CNC face milling. Taguchi design of experiments method is used and MATLAB version 5. 3. 0. 10183 (Rll) program is used to create, train and test the ANNs. Gologlu et al (2011) Studied about pocket milling which is often encountered in plastic mould manufacture. The implementation and selection of cutting path strategies with appropiate cutting parameters have significant effect on surface roughness. The aim of this tudy is to investigate optimum cutting speed of DIN 1.2738 mould steel using high-speed steel end mills. Reddy et al (2010) optimized the parameters for surface roughness using response surface methodology and genetic algorithm. The work piece material used for the present investigation is P20 mould steel of flat work pieces of 100mm x100mm x10 mm. Pre-hardened steel (p20) is a widely used material in the production of moulds/dies due to less wear resistance and usedforlarge components. The experiments were conducted using Taguchi's L50 orthogonal array using design of experiments by considering the machining parameters such as nose radius, cutting speed, feed, axial depth of cut and radial depth of cut. Kromanis et al (2010) developed a technique to predict a surface roughness of part to be machined. 3D surface parameters gave more precise picture of the surface, therefore it is possible to evaluate more precisely the surface parameters according to technological parameters. In result of the study, the mathematical model of end-milling is achieved and qualitative analysis is maintained. Achieved model could help technologists to understand more completely the process of forming surface roughness. Routara et al (2010) performed the optimization of parameters using response surface methodology using three different materials 6061-T4 aluminium, AISI 1040 steel and medium leaded brass UNS C34000, ANOVA approach and F test. Newman et al (2009) studied the role of CNC in industries. CNC has an efficient role in production. He studied that CNC is basically the platform for industries, which is basic function of CAD/CAM/CM. In this research, author depicts the working of CNC in manufacturing system.

III. Procedure of Taguchi's Method

The use of Taguchi's parameter design involves the following steps:

a. Determine the Quality Characteristic to be optimized.
b. Identify the Noise Factors and Test Condition.
c. Identify the Control Factors and their levels.
d. Design the Matrix Experiment and Define the Data Analysis Procedure.
e. Conduct the Matrix Experiment.
f. Analyze the data and determine optimum level of Control Factors.
g. Predict the performance at these level.

IV Taguchi design of experiments (DOE) in MINITAB

Performing a Taguchi design experiment consists of the following steps:

a. Before we start utilizing MINITAB, we have to finish all pre-trial arranging. For instance, you have to pick control factors for the internal exhibit and commotion factors for the external cluster. Control factors will be factors you can control to upgrade the procedure. Commotion factors will be factors that can impact the execution of a framework however are not under control amid the proposed utilization of the item. Note that while you can't control commotion factors amid the procedure or item utilize, you require to have the capacity to control commotion factors for experimentation purposes.
b. Utilize Create Taguchi Design to produce a Taguchi outline (orthogonal exhibit) or, utilize Define Custom Taguchi Design to make an outline from information that you as of now have in the worksheet. Characterize Custom Taguchi Design enables us to determine which segments are our elements and flag factors. We would then be able to effortlessly break down the outline also, produce plots.
c. After we make the outline, you may utilize Modify Design to rename the elements, change the factor levels, add a flag factor to a static outline, overlook a current flag factor (regard the outline as static), and add new levels to a current flag factor.
d. After we make the plan, we may utilize Display Design to change the units (coded or on the other hand un-coded) in which MINITAB communicates the components in the worksheet.
e. Play out the analysis and gather the reaction information. At that point, enter the information in the MINITAB worksheet.
f. Utilize Analyze Taguchi Design to dissect the exploratory information.
g. Utilize Predict Results to anticipate S/N proportions and reaction attributes for chose new factor settings.

S/N Ratio

a. In Taguchi designs, a measure of robustness used to identify control factors that reduce variability in a product or process by minimizing the effects of uncontrollable factors (noise factors). Control factors are those design and process parameters that can be controlled.
b. Noise factors cannot be controlled during production or product use. In a Taguchi designed experiment, you manipulate noise factors to force variability to occur and from the results, identify optimal control factor settings that make the process or product robust, or resistant to variation from the noise factors. Higher values of the signal-to-noise ratio (S/N) identify control factor settings that minimize the effects of the noise factors.

Signal-to-noise ratio	Goal of the experiment	Data characteristics
Larger is better	Maximize the response	Positive
Nominal is best	Target the response and you want to base the signal-to-noise ratios on standard deviations only	Positive, zero or negative
Nominal is best (default)	Target the response and you want to base the signal-to-noise ratios on means and standard deviations	Non-negative with an absolute zero in which the standard deviation is zero when the mean is zero
Smaller is better	Minimize the response	Non-negative with a target value of zero

Table 4.1 Signal to Noise ratios

V. Experimental Details

a. Material used: Mild Steel E250a
b. Machine tool used(turning process): Lathe Machine
c. Cutting Tool: Single Point HSS (High Speed Steel)
d. Type of Coolant: Water-oil Emulsifier
e. Surface Roughness Tester by Mituyoto.
f. Length of Workpiece (before machining):4000 mm

g. Total Workpiece used: 9*3 (9 experiments)
h. Three runs per experiment
i. Diameter of workpiece: 30 mm
j. Number of repeats for each experiment = 3
k. Taguchi's Orthogonal array used = L9

After every machining operation, the cutting tool is grinded so as to get new cutting edges

Chemical Composition of workpiece

C	Si	Mn	N	P	S
0.23 max	0.40 max	1.50	0.012 max	0.045 max	0.045 max

Table 5.1 Chemical Composition

Mechanical Properties

Grade	Thickness (mm)	Min. Yield (MPa)	Tensile (MPa)	Elongation (%)
IS2062 E250A	<20	250	410	23
	20-40	240	410	23
	>40	230	410	23

Table 5.2 Mechanical Properties

SPINDLE SPEED (REV/MIN)
Range Available- 25, 35, 55, 80, 120,170, 235, 350, 525, 700, 1100, 1600.

FEED RATE (1DIV=0.1MM)
Automatic feed given, Range- 0-8, Feed given (mm) - 0.096, 0.382, 0.764
DEPTH OF CUT (1DIV=0.05MM)
Range Available - 0-17

LEVELS	**SPEED (RPM)**	**FEED (mm/rev)**	**DEPTH OF CUT(mm)**
1	120	0.096	0.8
2	700	0.382	1.6
3	1100	0.764	2.4

Table 5.3 Process Parameters

EXP. NO.	SPINDLE SPEED (RPM) ,N	FEED RATE (mm/rev) ,f	DEPTH OF CUT (mm) ,d	SR (µm) ,Ra	MRR (mm^3/sec)
1	120	0.096	0.8	3.34	11.46
2	700	0.096	1.6	4.48	131.37
3	1100	0.096	2.4	2.26	309.19
4	120	0.382	1.6	12.02	85.66
5	700	0.382	2.4	2.73	732.53
6	1100	0.382	0.8	3.65	442.43
7	120	0.764	2.4	6.25	238.48
8	700	0.764	0.8	31.91	531.82
9	1100	0.764	1.6	29.33	1626.36

Table 5.4 Experimental Results

GRAPHS VIA MINITAB SOFTWARE

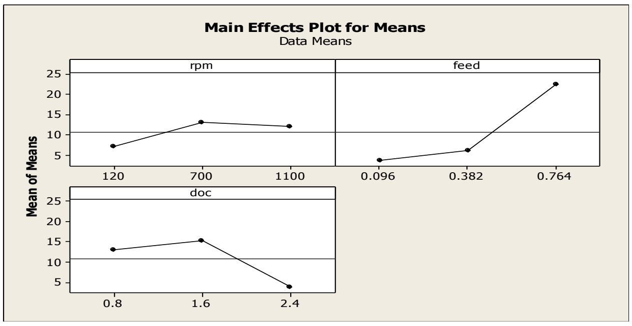

Fig. 5.1 Main Effects Plot for Means for SR

The main effect plot is useful when a few elements impact the machined surface property (i.e. feed rate, depth of cut, speed). These plots were utilized to look at the adjustments in the mean level. Plots are drawn and then, the mean of means are calculated to have a clear graphical representation.

The value of rpm was less than the mean value at 120 rpm which then rises above the base value at 700 rpm (maximum is attained) and then falls to just above the mean line.

Likewise in feed graph, the value of feed mean values continuously increases at various feed increments and finally, it attains a maximum value much above the mean feed.

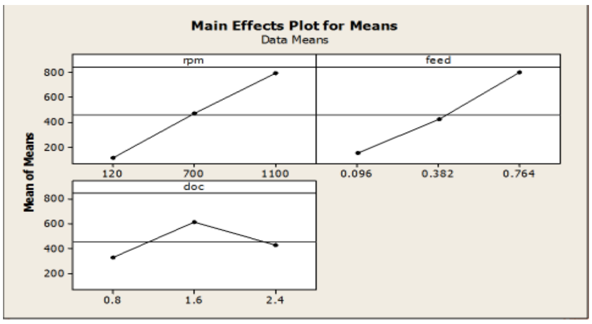

Fig. 5.2 Main Effects Plot for Means for MRR

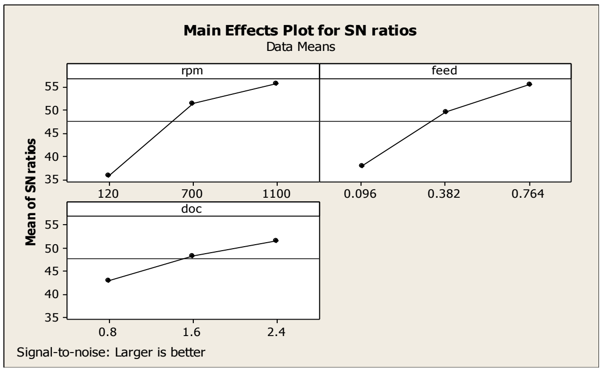

Fig. 5.3 Main Effects Plot for S/N ratios for MRR

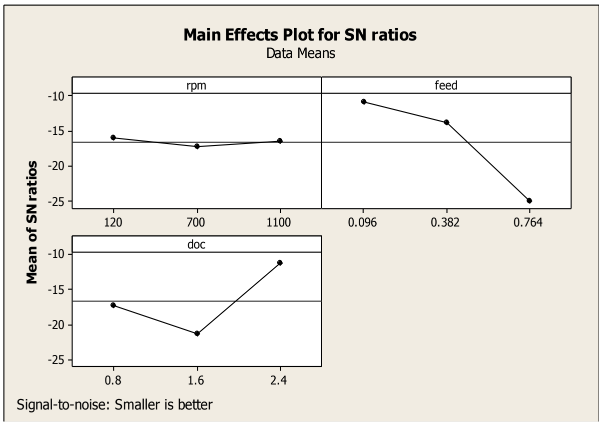

Fig. 5.4 Main Effects Plot for S/N ratios for SR

Exp No.	RPM	Feed	DOC	MRR	Ra	SNRA1	SNRA2
1	120	0.096	0.8	11.6	3.34	21.28	-10.47
2	700	0.096	1.6	131.17	4.48	42.35	-13.02
3	1100	0.096	2.4	309.19	2.86	49.80	-9.12
4	120	0.382	1.6	85.66	12.02	38.65	-21.59
5	700	0.382	2.4	732.53	2.73	57.29	-8.72
6	1100	0.382	0.8	442.43	3.65	52.91	-11.24
7	120	0.764	2.4	238.48	6.25	47.54	-15.91
8	700	0.764	0.8	531.82	31.91	54.51	-30.07
9	1100	0.764	1.6	1626.36	29.33	64.22	-29.34

Table 5.5 S/N Ratios

The above table is found using MINITAB software.

SNRA1 represents the first output parameter representing MRR with repect to the given input parameters using larger the better.

SNRA2 represents the second output parameter representing Surface Roughness (Ra) with respect to the given input parameters using smaller the better.

The plots demonstrate the variety of reaction with the adjustment in cutting parameters. In the plots, the X-axis demonstrates the estimation of each procedure parameters at three levels and y-axis gives the response value. These fundamental effect plots are utilized to decide the optimal design conditions to acquire the low surface roughness.

CONCLUSIONS ON SURFACE ROUGHNESS

Dependence of surface roughness on the information factors speed, feed and depth of cut is to be resolved keeping in mind the end goal to control the nature of machined surface.

1. Strong cooperation’s were seen among the turning parameters. Most noteworthy associations were found between cutting pace, sustain and profundity of cut .An efficient approach was given to plan and investigate the analyses, and to use the information got to the greatest expand.
2. By utilizing methods to decide the ideal level of process parameters. It has been watched that depth of cut is the most basic parameter when complete is the standard. Complete gets poor as the Depth of cut expands, along these lines the normal surface harshness esteem increments with increment in Depth of cut. The test uncovered that the depth of cut is overwhelming parameter took after by nourish and speed for surface unpleasantness.

CONCLUSIONS ON MRR

The present investigation was done to study the impact of input parameters on the material removal rate. The following conclusions have been drawn from the examination:

1. The Material removal rate is essentially influenced by cutting velocity and feed rate. With the expansion in cutting speed, the material removal rate increments and as the feed rate increases, the material removal rate also increments.
2. The parameters influencing critical impact on material removal rate to feed rate, and interaction between feed rate and cutting speed were observed to be critical to Material removal rate for diminishing the variation.

VI. Optimum Results

The optimum results were calculated on the basis of signal to noise ratio calculations. The conclusion result is that quality can be measured regarding the particular item's response to noise factors and signal factors. The perfect item will just react to the operator signal and will be unaffected by irregular noise factors (climate, temperature, moistness, and so on.). In this way, the objective of our quality improvement can be expressed as attempting to maximize the signal to noise (S/N) ratio for the individual item. The S/N proportions portrayed in the accompanying sections have been proposed by Taguchi. These S/N proportions can be registered with the Taguchi vigorous outline choices in the Experimental Design module.

OPTIMUM RESULT FOR MRR

As per S/N ratio curve, we have selected the larger the value of MRR and the smaller the value of surface roughness for optimum value of output result. The value of MRR on curve basis was 309.19mm3/sec.

However when we have further machined the workpieces. The output comes out as follows:

$$MRR = 2450.1\ mm^3/sec,\ R_a = 31.68\ \mu m$$

As the calculated MRR value is higher for this combination of rpm, feed and doc. This shows that this combination gives the optimum result at which machining should be done.

The values of input parameter at which optimum output is obtained are as follows:

RPM = 1100 mm/rev, FEED = 0.764 mm, DOC = 2.4 mm

OPTIMUM RESULT FOR SURFACE ROUGHNESS

From S/N ratio curve, the smaller the value of surface roughness is most suited for the optimum output. It was found that the better finish is obtained when material removal rate has the higher value (larger the surface roughness, better the surface finish). The smaller the value of surface roughness via minitab was found to be 2.86µm.

However when we have performed machining on the workpiece, the obtained output are as follows:

$$MRR = 33.01\ mm^3/sec,\ R_a = 3.40\ \mu m$$

As the calculated Ra value is closer to the minimum Ra for this combination of rpm, feed, doc. This shows that this combination gives the optimum result at which machining should be done for best finishing.

The input parameters selected at which the optimum output is obtained are as follows:

RPM = 120 mm/rev, FEED = 0.096 mm, DOC = 2.4 mm

DISCUSSION OF RESULTS

The impact of cutting parameters on surface roughness and MRR during machining of mild steel was inspected. In like manner, the following conclusions can be drawn: It was fascinating to take note of spindle speed and depth of cut an approximate diminishing pattern. The feed rate has the variable impact on surface roughness. It is interesting to take note of that spindle speed, feed rate and depth of cut for Material Removal Rate have an increasing pattern. In addition to this, when the combination of rpm, feed and depth of cut was precisely investigated, we found that these combinations do not form an array as required. So, we repeated the experiment again until an orthogonal array was attained for the conformity.

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