Optimization of Process Parameters for Turning of Mild Steel in Minimum Quantity Lubrication (MQL)

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ABSTRACT : *In this experimental study, an attempt is made to obtain optimum cutting parameters for turning of mild steel on the basis of surface roughness and surface temperature. Optimization of cutting parameters is very important to obtain a good machining quality of surface and to inhibit the increase of temperature. Minimum Quantity Lubrication (MQL) has been introduced to avoid excessive use of cutting fluid. The parameters considered here are cutting speed, feed and depth of cut. Optimal cutting parameters for each performance measure were obtained employing Taguchi experimental method. To study the performance characteristics in turning operation Analysis of Variance (ANOVA) was employed. It is found that cutting speed and feed has significant effect on both surface roughness and temperature.*

KEYWORDS - *Analysis of Variance, Cutting parameters, Minimum Quantity Lubrication, Optimum, Taguchi, Turning.*

I. INTRODUCTION

Today's fast changing manufacturing environment requires the application of optimization techniques in metal cutting processes to effectively respond to severe competitiveness and to meet the increasing demand of customizable quality product (low cost, high quality, easily deliverable) in the market. Increasing the productivity and the quality of the machined parts are the main challenges of metal-based industry; there has been increased interest in monitoring all aspects of the machining process.

Surface finish is an important parameter in manufacturing engineering. It is a characteristic that could influence the performance of mechanical parts and the production costs. The cutting temperature is a key factor which directly affects cutting tool wear, work piece surface integrity and machining precision according to the relative motion between the tool and work piece. The amount of heat generated varies with the type of material being machined and cutting parameters especially cutting speed which had the most influence on the temperature, design and develop control system to control the temperature lead to better surface finish . Cutting condition is also very important and so MQL is the mostly used. MQL technique optimizes the use of lubricant or coolant during operation. Taguchi and Analysis Of Variance (ANOVA) can conveniently optimize the cutting parameters with several experimental runs well designed. Taguchi parameter design can optimize the performance characteristics through the settings of design parameters and reduce the sensitivity of the system performance to source of variation. On the other hand, Analysis Of Variance (ANOVA) used to identify the most significant variables and interaction effects [1].

II. PROCESS AND PARAMETER

Minimum quantity lubrication (MQL) is based on the principle that a drop of liquid is split by an air flow, distributed in streaks and transported in the direction of flow of air. In MQL machining, a small amount of vegetable oil or biodegradable synthetic ester is sprayed to the tool tip with compressed air. The consumption oil in industrial applications is in the range of approximately 10 - 100 ml per hour. Conventional cutting fluid can also be used instead of vegetable oil or biodegradable synthetic ester because of its unavailability and expensiveness [2].

Turning is the process whereby a single point cutting tool is parallel to the surface. It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator. The three primary factors in any basic turning operation are speed, feed, and depth of cut. Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. Depth of cut is practically self-explanatory. It is the thickness of the layer being removed from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in inches.

III. MODEL AND EXPERIMENT

Taguchi has developed a methodology for the application of designed experiments. This methodology has taken the design of experiments from the exclusive world of the statistician and brought it fully into the world of manufacturing. Taguchi methods of experimental design provide a simple, efficient and systematic approach for the optimization of experimental designs for performance quality and cost [3]. There are three forms of signal to noise(S/N) ratio that are of common interest for optimization of static problems.

Smaller-the-better :

This is expressed as

S/N= -10 Log_{10} [mean of sum of square of measured data] (1)

Larger-the-better :

This is expressed as

S/N= - Log10 [mean of sum squares of reciprocal of measured data] (2)

This is often converted to smaller-the-better by taking the reciprocal of the measured data and next, taking the S/N ratio as in the smaller-the-better case.

Nominal-the-best :

This is expressed as

n= $-10\ Log10$[square of mean variance] (3)

This case arises when a specified value is the most desired, meaning that neither a smaller nor a larger value is desired.

The workpiece material used is a mild steel bar of 254mm (10 inch) long and 31.75mm (1.25 inch) diameter. A carbide tool has been used for cutting. Soyabean oil has been used as cutting fluid. An infrared thermometer was used for measuring the tempurature of the material during the operation. A TR200 roughness tester was used for measuring the surface roughness after turning the workpiece.

An MQL delivery system has been designed and fabricated for performing this experiment.

Fig1: MQL setup

Compressor used in this purpose is a pneumatic compressor. In MQL system, air-oil mixing is the basic function of the system. For air-oil mixing, it requires three main parts such as compressor, reservoir, mixing chamber. A compressor which is used to supply compressed air to the oil reservoir and mixing chamber. The lubricating oil passes down due to the pressure of compressed air in the reservoir and thus the oil flows through the transmission pipe with pressure from reservoir to the mixing chamber. The compressed air from compressor directly passes through the transmission pipe and reaches the mixing chamber. Thus the compressed air from compressor is divided into two sections by a T-junction, one to supply to the mixing chamber directly and the other to supply to the oil reservoir.

The experiments were carried out on the basis of L9 array which was selected using an array selector depending upon the number of levels. L9 array suggests that a total of 9 experiments are required per cutting environment. A standard L9 array is as shown in table 1.

Table 1 : L9 Orthogonal Array

Speed	Feed	Depth of cut
1	1	1
1	2	2
1	3	3
2	1	3
2	2	1
2	3	2
3	1	2
3	2	3
3	3	1

The levels of the parameters that was selected for the test are given in table 2:

Table 2 : Process Parameters and their Levels

Factor	Unit	Level 1	Level 2	Level 3
Cutting Speed	rpm	280	440	560
Feed	mm/rev	.062	.092	.125
Depth of Cut	mm	.5	.5	.5

IV. RESULT AND DISCUSSION

Here the desirable objectives are lower values of surface roughness. So the lower-the-better type S/N ratio was applied for transforming the observed data.Table 3 shows the experimental results for surface roughness and the corresponding S/N ratio for it . The greater S/N ratio corresponds to the smaller variance of the output characteristic around the desired value. Therefore table 3 with highest mean S/N ratios denotes the optimal level of cutting parameter.

Table 3: Experimental results for surface roughness and S/N ratio

Speed	Feed	DOC	R_a(μm)	S/N ratio
1	1	1	2.325	-7.328
1	2	2	3.527	-10.948
1	3	3	3.862	-11.736
2	1	3	2.127	-6.555
2	2	1	2.352	-7.429
2	3	2	3.283	-10.325
3	1	2	1.939	-5.752
3	2	3	2.213	-6.899
3	3	1	2.621	-8.369

The second quality characteristics on which the analysis is being performed is the workpiece surface temperature. Here the desirable objectives are lower values of temperature. So the lower-the-better type S/N ratio was applied for transforming the observed data.Table 4 shows the experimental results for temperature and the corresponding S/N ratio for it . The greater S/N ratio corresponds to the smaller variance of the output characteristic around the desired value. Therefore following S/N response table with highest mean S/N ratios denotes the optimal level of cutting parameter.

Table 4: Experimental results for temperature and S/N ratio

Speed	Feed	DOC	T(◦C)	S/N ratio
1	1	1	38.3	-31.660
1	2	2	37.8	-31.550
1	3	3	37.5	-31.480
2	1	3	40.4	-32.126
2	2	1	39.9	-32.019
2	3	2	41.2	-32.297
3	1	2	43.8	-32.829
3	2	3	42.6	-32.588
3	3	1	41.5	-32.361

There remains two ANOVA hypothesis. One says that, There is no significant difference between the responses obtained by varying the individual input variables.This is called NULL hypothesis. Another says, There is a significant difference between the responses obtained by varying the individual input variables. The response data obtained by via experimental runs for Temperature and surface roughness were subjected to ANOVA for finding out the significant parameters, at above 95% confidence level and the result of ANOVA thus obtained for the response parameters are shown in table 5.

Table 5 : Analysis of variance for S/N ratios for Surface roughness

Source	Degree of freedom	F-Value	P-Value	% of contribution
speed	2	44.55	0.022	38.25
feed	2	62.75	0.016	53.87
Depth of cut	2	8.19	0.109	7.03
Error	2			.85
Total	8			100

Table 5 shows the effect cutting speed , feed and depth of cut on machined surface.For the speed and feed the null hypothesis is rejected and there is a statistically significant difference in the mean between the different groups of independent variables.This shows that,there is significant effect of cutting speed and feed on surface roughness during turning but the effect of depth of cut is not so important.

Table 6 : Analysis of variance for S/N ratios for temperature

Source	Degree of Freedom	F-value	P-value	% of Contribution
Speed	2	36.91	.026	90.63
Feed	2	1.12	.471	2.74

Depth of Cut	2	1.69	.371	4.16
Error	2			2.45
Total	8			100

Table 6 shows the effect cutting speed, feed and depth of cut on machined surface temperature during turning.For the speed the null hypothesis is rejected but for feed and depth of cut it is accepted. This shows that, only speed has significant effect on temperature variation of machined surface during turning.

The main objective of experimental investigation done was to find the optimal turning parameters for mild steel in MQL condition in terms of surface roughness and temperature. A statistically designed experiment based on Taguchi method was performed using L9 orthogonal array to analyze surface roughness and temperature. ANOVA was also performed to find the effect of selected parameters.

Optimal parameters are provided in table 7 and table 8 for surface roughness and temperature respectively.

On the basis of surface roughness the optimal turning parameters were found where S/N ratio is highest with the lowest surface roughness.

Table 7: Optimal process parameters for surface roughness

Speed Level 3	Feed Level 1	DOC Level 2	R_a
560 rpm	.062 mm/rev	.5 mm	1.939 µm

A different result was found when analysing on temperature. For the lowest temperature the optumal parameter were found .

Table 8: Optimal process parameters for temperature

Speed Level 1	Feed Level 3	DOC Level 3	T
280 rpm	.125 mm/rev	.5 mm	37.5 ◦C

V. CONCLUSION

This study is conducted to find optimum parameters of turning mild steel in minimum quantity lubrication in terms of surface roughness and temperature. Through Taguchi method optimum parameters are found and from ANOVA analysis the effect of speed, feed and depth of cut is observed.

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