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A Review on Optimal Selection of Machining Parameters in Turning Operations on MRR and Surface Roughness

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Abstract - *The concerned work aims to investigate the influence of cutting parameters on MRR and surface roughness of the work material with various parameters, an approach to streamline the turning parameters, depending upon optimizing strategies is proposed. The venture examines the utilization of optimization techniques for limiting required surface roughness [Ra] and maximizing material removal rate [MRR] after machining. Due to optimized parameters achieved in machining process, tool life and productivity will attain its best optimum value. In this paper a review on influence of cutting parameters like speed, feed, coolant, rake angle and depth of cut on MRR and surface roughness value was studied to identify the best suitable method to achieve optimization amongst the above mentioned parameters.*

***Key Words*: surface roughness [Ra], material removal rate [MRR], optimization, etc.**

1. INTRODUCTION

The prime requirement of the customers for the material is its surface finish. For this purpose the surface finish should be maintained properly by minimizing the surface roughness as minimum as possible. Along with the surface roughness, material removal rate plays a key role to increase the productivity of the machined component. To achieve the required properties proper selection of the machining parameters should be done [1]. In turning process three process parameters were chosen like speed, feed, and depth of cut. These parameters have maximum influence on the surface roughness and the material removal rate. As a result on the basis of the material used for the work piece, type of tool used and the material used for the tool machining parameters were selected for various operations [4]. After the selection of the process parameters the optimization of these parameters is required to be done to achieve maximum productivity. The term optimization is generally referred as a process of selecting best suitable design satisfying certain criteria among many feasible solutions available. There are various optimization techniques used now a days for the optimization of the machining parameters like Taguchi's optimization Techniques, Genetic Algorithm (GA), Simulated Annealing (SA), Fuzzy logic, etc. these techniques have already proven their significance in other parameter optimization of the various manufacturing process. Industries have been adopted these techniques for their manufacturing optimization [21]. It was observed that the Taguchi's optimization technique is the mostly used optimization technique during machining.

Taguchi method suggest to use a specially designed method called the use of the orthogonal array to study the entire parameter space with lesser number of experiments. This method also recommends the use of the loss function. The value of the loss function is further transformed into S/N ratio. Mainly there are three categories to analyse the S/N ratio, they are nominal-the-better, larger-the-better and the smaller-the-better [16]. From the literature survey it was observed that L-9, L-18 and L-27 array were selected from the array selector. For example for the three number of parameters and for three levels L-9 orthogonal array was selected. Taguchi method cannot judge and determine the effect of the individual parameter on the entire process while percentage contribution on the individual parameter can be determined with the help of the Minitab software. Software of ANOVA module should be employed to investigate the effect of the process parameters selected during machining operation [2]. In addition with this ANOVA also helps to evaluate significance of factor to find the contribution of each factor to attain the process outcome [1]. ANOVA helps to identify which parameter is the most significant for the given input parameter [10]. The results obtained from the Minitab software, ANOVA and S/N ratio can be used to predict the best suitable optimal combination amongst the various combinations selected during machining. Once the optimal combination is found for the selected process parameter, confirmatory experiments can be performed to justify the selection of the combination of optimal parameter [13]. To analyse the effect of the process parameter on surface roughness and material removal rate the review of literature has been carried out.

2. THEORETICAL ANALYSIS

Analytical solution's was applied to determine MRR and Signal to Noise ratio (S/N). Since the values of the surface roughness of every machined job is determined using the various surface roughness measuring instruments. Mostly surface roughness tester is preferred to determine the roughness values. Therefore in this section theoretical treatment on MRR and S/N ratio is included.

2.1 Analysis of Signal to noise ratio

The S/N ratio was proposed [1] due to the fact that it is appropriate tool to quantify the quality of the product response to noise ratio and signal factor. The signal to noise ratio for the product response divided in to two categories viz. smaller the better, higher the better.

2.1.1 Smaller is the better

In this work the surface roughness is considered under the category of smaller is the better, the equation (1) has been used for the calculation of S/N ratio for surface roughness. Signal to noise ratio= -10log [Ra] (1)

S/N ratio is the tool utilized for investigation which measures the performance of particular process parameters towards the surface roughness and material removal rate. The S/N Ratio for surface roughness was calculated using smaller the better characteristics [6] by using the formula stated below.

$$\frac{s}{N_{SMALLER}} = -10Log\left[\frac{1}{n}\sum_{i=1}^{n} {y_i}^2\right]$$

Where,

n = number of measurement in a trail/row

Y_i = measured value in the trail/row.

2.1.2 Higher the better

The material removal rate is considered under higher the better signal to noise ratio, this can be calculated by using equation (2)

Signal to noise ratio= -10log $[\frac{1}{MRR}]$ (2)

The S/N Ratio was also determined using larger the better characteristics for MRR [6].

$$\frac{s}{N_{larger}} = -10Log\left[\frac{1}{n}\sum_{i=1}^{n} \frac{1}{{y_i}^2}\right]$$

Where,

n = number of measurement in a trail/row

Y_i = measured value in the trail/row.

2.2 Mean Squared division

The S/N ratio was also proposed [4] using the formulas as given below,

S/N = -10 log10 (MSD).

Where, MSD =Mean Squared Division.

$$MSD=\frac{\left[\frac{1}{{y_1}^2}+\frac{1}{{y_2}^2}+\cdots+\frac{1}{{yn}^2}\right]}{n}$$

Where,

$y_1, y_2, \ldots, y_n$ = Responses.

n = Number of tests in a trial.

MSD = Target value of the result.

The level of a factor with the highest S/N ratio was the optimum level for responses measured.

2.3 Analysis of the MRR

Material Removal rate (MRR) in turning operation is the material or metal that is removed per unit time in mm^3/sec. For each revolution of the work piece, a ring shaped layer of material is removed [22].Material Removal Rate is given by the formula as given below,

MRR = v×f×d mm^3/sec

Where,

v = cutting speed in mm/sec

d = depth of cut in mm

f = feed in mm/rev.

Material removal rate was determined using the formula shown below [1],[6].

$$MRR=\frac{(D^2-d^2)*\frac{\pi}{4}*L}{machining\ time}$$

Where,

D= diameter of the work piece before machining in mm

d= diameter of the work piece after machining in mm

L= length of work piece machining in mm

3. EXPERIMENTAL ANALYSIS

In this section of experimental analysis various machines, tool, material, methods, and parameters were analysed from the selected papers. The results obtained from the study are specified in tabular form in table 1. This table contains the data about various tool used, parameters selected, method selected etc.

Table -1: summary of the experimental analysis

Machine used	Parameter	Method	Tool	Material
CNC, Lathe, End mill cutter, Shaper	Speed, feed rate, depth of cut, rake angle, coating angle, tool material, cutting fluid ratio, coolant, etc.	Taguchi, ANOVA, Regression analysis, RSM, full factorial method	HSS, carbide, tungsten, tungsten carbide tool, etc.	Alu-minum, Al alloy, steel, spring steel, etc.

3.1 Selection of array

To perform the experiments, selection of the appropriate array is to be done. Therefore this section includes the selection criteria of the orthogonal array. The array can be selected from the array selector chart shown in table 2.

Table -2: Array selector chart [23].

	parameters				
		2	3	4	5
levels	2	L4	L4	L8	L8
	3	L9	L9	L9	L18
	4	L16	L16	L16	L16
	5	L25	L25	L25	L25

Here, for the selection of Array considering three levels and three parameters L-9 orthogonal Array can be selected from the Array selector chart [23]. Thus it can be concluded that the selection of array depends on the number of parameters and the number of levels selected. In the table 2 only basic array are shown.

It is obvious that as the number of parameters and the number of the level increases there is change in the Array. Thus the numbers of experiments to be perform also increases based on the Array selected. It results in increase in the cost of material as well as the time. Increase in the Array tends to give appropriate optimal solution for the selected input parameters.

It is thus on ones view towards using a particular array after selecting level of operations and number of input parameters depending on the cost and to get best optimal solution. Since both are inversely proportional to each other.

4. SIMULATION STUDIES:

RESPONSE PLOTS FOR SURFACE ROUGHNESS AND MRR

To understand the significance of S/N ratio on surface roughness and material removal rate main effect plot graphs were studied. The graphs were obtained using Minitab software. The figure1 shows an example of the graph of main plot for S/N ratio.

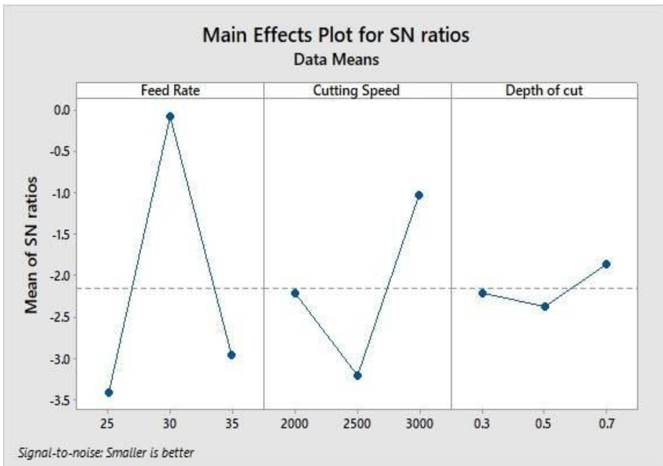

Figure 1. Effect of Feed, Speed & Depth of cut on Ra[2]

Significance of machining parameters of surface roughness indicates the individual parameter which significantly contributes towards the machining performance as difference gives higher values [2].

Plot for S/N ratio shown in Figure 2 explains the variation in machining parameters [2].

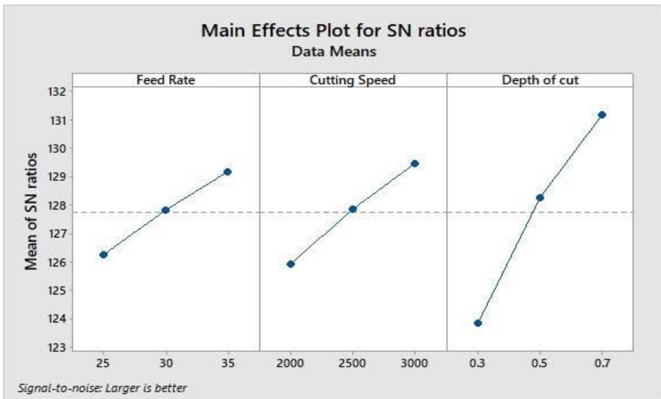

Figure 2. Effect of Feed, Speed & Depth of cut on MRR[2]

From the simulation studies it is observed that smaller the better characteristics gives optimal results for the surface roughness and the larger the better characteristics was employed to predict the optimal combination for material removal rate.

5. RESULTS AND DISCUSSION

Array	Parameters used	material used	tool used	machine used	method used
L-9	speed, feed, depth of cut, rake angle, coating material, tool material, cutting fluid ratio.	Alum-inium, mild steel, GCI-FG 260, Aluminium alloy, S-45 Steel bar, high chromium alloy tool steel	HSS-tool, Tin-TICN-Al203 coated carbide tool, carbide tool, tungsten carbide tool	CNC, Lathe, end mill cutter, shaper	Taguchi, ANOVA, Regression analysis, Grey relation analysis, full factorial method
L-16	Speed, feed, depth of cut	AISI-1045	coated carbide tool	Lathe	Taguchi, ANOVA
L-18	Speed, feed, depth of cut, coolant	stainless steel, spring steel	carbide tool	CNC Lathe	Taguchi, ANOVA, Regression analysis
L-25	Speed, feed, depth of cut	SAE-1020	carbide tool	CNC Lathe	Taguchi, ANOVA
L-27	Speed, feed, depth of cut	Aluminium alloy AA-7075, mild steel, Aluminium alloy AA-6062, AISI-austentic stainless steel	Tungsten carbide tool, coated carbide tool	CNC, Lathe	Taguchi, ANOVA, Regression analysis, Responce surface methodology (RSM), full factorial method

6. CONCLUSIONS

The study aims towards compiling turning process parameters for optimization of the machining parameters. To prepare the turning process with improved quality and cost effective, the study of relationship between the various input parameters and the output parameters is done in order to optimize the process parameters. From this investigation it was observed that with help of suitable optimization methods and eligible software like (Minitab, ANOVA), it is possible to gain optimum output response parameters like surface roughness (Ra), metal removal rate (MRR).this study can also be applicable for existing component's in determining machining parameters to obtain optimum surface roughness and material removal rate.

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