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ANALYTICAL STUDY OF TOOL WEAR IN TURNING OPERATION THROUGH S/N RATIO AND ANOVA

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Abstract- Tool Wear measurement of great apprehension in machining industries and it effects the surface quality, dimensional accuracy and production cost of the materials components. In the present study twenty seven experiments were conducted as per 3 parameter 3 level full factorial design for turning operation of a mild steel specimen with high speed steel (HSS) cutting tool. An experimental investigation on cutting tool wear and a mathematical model for tool wear estimation is reported in this paper and SN Ratio calculation was made and an optimized combination was determined.

Keywords: Tool Wear, feed rate, depth of cut, spindle speed, factorial design etc.

I. INTRODUCTION

Machining operations have been the core of the manufacturing industry since the industrial revolution. 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. Turning is the most widely used among all the cutting processes. The most important process parameters (cutting speed, feed rate, depth of cut) accelerate tool wear affects the surface finishing. The tool wear is directly related to the machining parameters. The objective of this work is to find out the best set of combination of process parameters for minimum tool wear in turning operation through S/N Ratio and ANOVA Analysis to improve quality of machined products and to improve the tool life.

II. EXPERIMENT

The experiments were designed by following full factorial design of experiments. Design of experiments is an effective approach to optimize the process parameters in various manufacturing related process, and one of the best intelligent tool for optimization and analyzing the effect of process variable over some specific variable which is an unknown function of these process variables. The selection of such points in design space is commonly called design of experiments (DOE). In this work related to turning of Mild steel, the experiments were conducted by considering three main influencing process parameters such as spindle speed, Feed Rate and Depth of Cut at three different levels namely Low, Medium and High. So according to the selected parameters a three level full factorial design of experiments ($3^3 = 27$) were designed and conducted. The level designation of various process parameters are shown in table 2.

Table 1.Limits and levels of control parameters

Control Parameters	Limits		
	Low(1)	Medium(2)	High(3)
Spindle Speed (V) rpm	250	590	930
Feed Rate (f) mm/rev	0.16	0.40	0.64
Depth of cut (d) mm	0.6	0.8	1.0

Table 2. Experimental Data

Exp. No.	Spindle Speed (v) RPM	Feed Rate (f) mm/rev	Depth of Cut (d) mm	Response (T = Tool Wear) mm
1.	250	0.16	0.6	0.03
2.	250	0.16	0.8	0.06
3.	250	0.16	1.0	0.08
4.	250	0.40	0.6	0.05
5.	250	0.40	0.8	0.07
6.	250	0.40	1.0	0.09
7.	250	0.64	0.6	0.07
8.	250	0.64	0.8	0.08
9.	250	0.64	1.0	0.10

10.	590	0.16	0.6	0.04
11.	590	0.16	0.8	0.06
12.	590	0.16	1.0	0.08
13.	590	0.40	0.6	0. 06
14.	590	0.40	0.8	0.08
15.	590	0.40	1.0	0.10
16.	590	0.64	0.6	0.08
17.	590	0.64	0.8	0.09
18.	590	0.64	1.0	0.11
19.	930	0.16	0.6	0.05
20.	930	0.16	0.8	0.08
21.	930	0.16	1.0	0.10
22.	930	0.40	0.6	0.07
23.	930	0.40	0.8	0.09
24.	930	0.40	1.0	0.12
25.	930	0.64	0.6	0.09
26.	930	0.64	0.8	0.11
27.	930	0.64	1.0	0.16

III. S/N RATIO CALCULATION

Taguchi uses the loss function to measure the performance characteristic deviating from the desired value. The value of loss function is then further transformed to S/N ratio. Usually, there are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, the higher-the-better, and the nominal-the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis and the smaller S/N ratio corresponds to the better performance characteristic for minimum tool wear calculation. Therefore, the optimal level of the process parameter is the level with the highest S/N ratio. S/N ratio calculation is done to find influence of the control parameters.

For Calculating S/N Ratio for Smaller-the-Better for Tool Wear, the Equation is

$[Y_i] = - 10 \log_{10}[(X_i^2)/ n]$

Where Y_i = S/N Ratio for Respective Result

X_i = Total Tool Wear for each experiment I = 1 to 27

n = no. of results for each experiment for experiment no i

Table 3: S/N Ratio for Smaller the Better

Exp. No.	Spindle Speed (v) RPM	Feed Rate (f) mm/rev	Depth of Cut (d) mm	Response (T = Tool Wear) mm	S/N Ratio for Smaller is Better
1.	250	0.16	0.6	0.03	30.4576
2.	250	0.16	0.8	0.06	24.4370
3.	250	0.16	1.0	0.08	21.9382
4.	250	0.40	0.6	0.05	26.0206
5.	250	0.40	0.8	0.07	23.0980
6.	250	0.40	1.0	0.09	20.9151
7.	250	0.64	0.6	0.07	23.0980
8.	250	0.64	0.8	0.08	21.9382
9.	250	0.64	1.0	0.10	20.00
10.	590	0.16	0.6	0.04	27.9588
11.	590	0.16	0.8	0.06	24.4370
12.	590	0.16	1.0	0.08	21.9382
13.	590	0.40	0.6	0. 06	24.4370
14.	590	0.40	0.8	0.08	21.9382
15.	590	0.40	1.0	0.10	20.00
16.	590	0.64	0.6	0.08	21.9382
17.	590	0.64	0.8	0.09	20.9151
18.	590	0.64	1.0	0.11	19.1721
19.	930	0.16	0.6	0.05	26.0206
20.	930	0.16	0.8	0.08	21.9382
21.	930	0.16	1.0	0.10	20.00
22.	930	0.40	0.6	0.07	23.0980
23.	930	0.40	0.8	0.09	20.9151
24.	930	0.40	1.0	0.12	18.4164
25.	930	0.64	0.6	0.09	20.9151
26.	930	0.64	0.8	0.11	19.1721
27.	930	0.64	1.0	0.16	15.9176

Table 4: Overall Mean of S/N Ratio

Level	Average SN Ratio by Factor Level			Overall Mean of S/N Ratio (Y_0)
	Spindle Speed (v)	Feed Rate (f)	Depth of cut (d)	
Low	23.5447	24.3473	24.8827	22.2622
Medium	22.5261	22.0987	22.0877	
High	20.7159	20.3407	19.8108	
Delta = Larger - Smaller	2.8288	4.0066	5.0719	
Rank	3	2	1	

The values obtained in the above table 4 are represented graphically in figure 3.1, figure 3.2 and figure 3.3

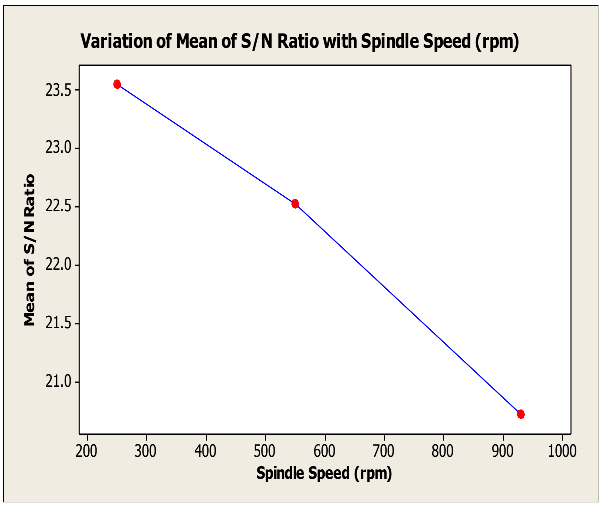

Figure 3.1: variation of mean of S/N ratio with spindle speed

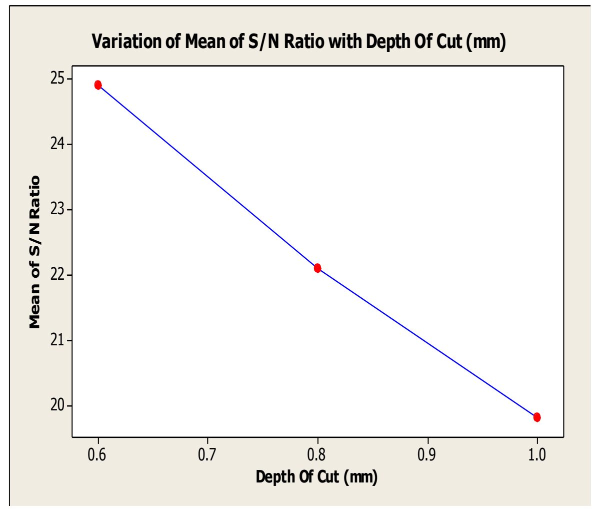

Fig3.2: variation of mean of S/N ratio with depth of cut

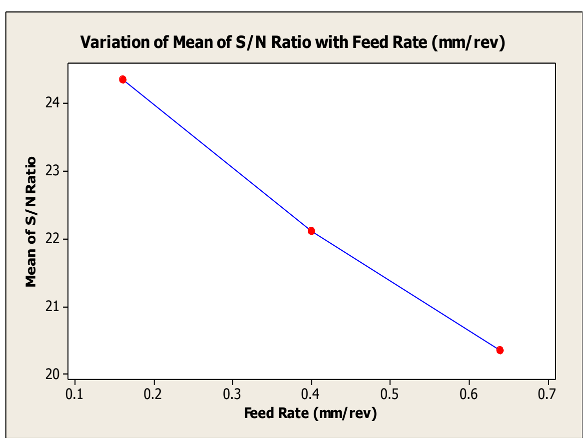

Fig 3.3: variation of mean of S/N ratio with feed rate

From the calculations and the graphs it is found Depth of cut is the most influencing parameter followed by feed rate and Spindle Speed.

IV. ANOVA CALCULATION

The test results analyzed using Computer Simulation and S/N Ratio were again analyzed by using ANOVA (Analysis of Variance) for identifying the significant factors and their relative contribution on the outcome or results. By using S/N Ratio it is not possible to judge and determine the effect of individual parameter where by using ANOVA percentage contribution of individual parameters can be determined. The analysis was carried out with a confidence level of 95% (α=0.05) which means we are 95% sure that our prediction is right or in the other hand there is a chance of type-1 error is only 5% which means rejecting null hypothesis while it is true. Our null hypothesis is that the control parameters are not significant. Therefore alternative hypothesis is that they are influencing the outcome.

The decision rule for accepting the null hypothesis or rejecting is that – at a α level of confidence, reject H_0 if P ($F_{k-1,n-k}$> $F_{computed}$)$<\alpha$. Do not reject if H_0 if P $>\alpha$

Statistically the two hypotheses can be written as-
H_0 = null hypothesis = control factors are not significant = 0
H_A = alternative hypothesis = control factors are significant $\neq 0$

Effect of each parameter can be determined by subtraction of each value of table no.4 to the overall average of S/N ratio (22.2622).After subtraction, the effect of each parameter obtained as follows:

Table 5: Effect of each parameter

	Spindle Speed (r.p.m)	Feed Rate (mm/rev)	Depth of Cut (mm)
Low	1.2825	2.0851	2.6205
Medium	0.2639	-0.1635	-0.1745
High	-1.5463	-1.9215	-2.4514

The analysis was carried out in MINITAB software. The following table shows ANOVA table-

Table 6.ANOVA Results

Factors	DOF	Seq. SS	Adj. SS	Adj. MS	F Value	P	Contribution
Spindle Speed (rpm)	2	0.0033852	0.0033852	0.0016926	30.88	0.000	18.06 %
Feed Rate (mm/rev)	2	0.0053407	0.0053407	0.0026704	48.72	0.000	28.50 %
Depth of Cut (mm)	2	0.0089185	0.0089185	0.0044593	81.35	0.000	47.59 %
Error	20	0.0010963	0.0010963	0.0000548			5.85%
Total	26	0.0187407					

S = 0.00740370 R-sq = 94.15% R-sq (Adj.) = 92.40%

From the above table it can be seen that the percentage contribution of the factor d i.e. depth of cut as high as 47.59%. The next contributing factor is Feed Rate with percentage of contribution 28.50%. Spindle Speedhas a relatively low contribution. From the values of F ratios it can be concluded that Depth of Cut is (p=0.000) is more significant factor than the Feed Rate (p=0.000) and Spindle Speed (p=0.000), which again validate the findings of Taguchi S/N ratio conclusions. As the p value of the factor all three factor (p=0.000) is less than theα (0.05) value so it can be said that all the three factors are statistically significant.Another term appeared in the ANOVA table is R-Sq& R-Sq (adj) where R-sq is a statistical measure of how close the data are to the fitted regression line. This is also known as co-efficient of determination or the co-efficient of determination for multiple regressions. R-sq. is always between 0% to 100%. 0% indicates that the model explains none of the variability of the response data around its mean and 100% indicates that the model explains all the variability of the response data around its mean. In general higher the R-sq. better the model fits your data. R-Sq(adj) is the modified version of R-sq. that has been adjusted in for the number of predictors in the model. The adjusted R-sq increases only if the new term improves the model more than would be expected by chance. It decreases when a predictor improves the model by less than expected by chance. The R-squared can be negative, but usually not. It is always lower than the R-squared.

V. CONCLUSION

From the Taguchi S/N Ratio calculation and graph analysis the optimum set of combination of process parameter for tool wear is Spindle Speed (v) 250 RPM, Feed Rate (f) 0.16 mm/rev&Depth of Cut (d) 0.6 mm. this optimality has been proposed within the experimental working range of v (250 rpm to 930 rpm), f (0.16 mm/rev to 0.64 mm/rev) & d (0.60 mm to 1.0 mm).

It has also been proposed by Taguchi S/N Ratio calculation that Depth of Cut (d) is the most influencing process parameter on Tool Wear followed by Feed Rate (f) and Spindle Speed (v). ANOVA analysis also indicates that Depth of Cut is the most influencing process parameter on Tool Wear with 47.59% contribution followed by Depth of Cut (d) with 28.50% contribution & Spindle Speed with 18.06% contribution.
Results obtained from Taguchi S/N Ratio analysis and ANOVA analysis both are bearing same trend.

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