

VALUE ENGINEERING APPROACH FOR OPTIMIZATION OF THE MANUAL TURNING OPERATION FOR ENHANCED SURFACE FINISH

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Introduction

Turning is one of the most significant machining operations used for removing unwanted material for the purpose of generating an external surface of a rotating cylindrical workpiece by the action of single point cutting tool [ASM Hand Book, 2004]. Since turning is among the primary operations in many of the production processes that is very much significant to achieve quality, dimensional accuracy, surface finish, high production rate, less wear on the cutting tool and economy of machining. Surface finish is one of the most important considerations in determining the quality of the product. It is noted that the surface finish in turning operation varies due to a number of factors and cutting speed, feed rate and depth of cut are the main parameters that determine surface roughness [Kirby, 2010].

In order to analyze the turning process it is necessary to understand the impact of each of the variables and the interaction between them [Pavel *et al*, 2002]. However, it is difficult and it is also time consuming and costly to determine the effect of each and every variable on the output. Therefore, only most significant variables were considered in the analysis which includes cutting speed, feed rate and depth of cut while remaining other

factors such as tool geometry, setup conditions and associated effects like chatter, tool wear and workpiece materials constant.

It has proven that Taguchi Method is a quite successful tool in experimental analysis because Taguchi parameter design is a powerful and efficient method for optimizing quality and performance output of manufacturing processes [Zhang *et al*, 2007]. Also, Taguchi design conducts the orthogonal experimental combinations and it is more effective than a factorial design. In addition, the statistical tool, MINITAB is popular software that is used for the analysis of design of experiments.

Methodology

A mild steel workpiece and a high speed steel (HSS) tool was the experimental work-tool combination. The experiments were carried out in a conventional lathe machine "Harrison M300 series" and a SV400 profilometer was used to measure surface roughness at consecutive stages. Three levels for each parameter were considered, spindle speed: 540, 370 and 260 rpm, feed rate: 0.03, 0.06 and 0.09 mm/rev and the depth of cut: 0.5, 0.7 and 0.9 mm. Turning operation was carried out while other affected parameters remained constant and the optimal cutting combinations

were obtained with Orthogonal Array (L₉) of Taguchi design method. Note that each of the above parameters was chosen within the recommended ranges of M300 lathe machine which suits the work and the tool materials. During the experimental process a 65mm sampling length of a 24 mm diameter mild steel rod was turned with different cutting conditions while supplying a consistent flow of coolant throughout the operation. According to the combinations of the cutting parameters 9 observations were recorded during experiment and process was continued for number of replicates. The statistical software MINITAB 13 was used as the aid tool

for statistical analysis and the analysis was continued with specific setup to determine the critical values of feed rate, cutting speed and depth of cut for optimize the surface finish while optimizing the tool life and the cost associated with the turning operation.

Results and Discussion

In this experiment signal to noise ratio (S/N) ratio was selected as smaller the better and all the calculation was carried out using MINITAB 13. Calculated S/N ratios for different cutting combination are mentioned in Table 1.

Table 1. Experimental results for surface roughness represented with S/N ratio

Spindle Speed (rev/min)	Feed rate (mm/rev)	Depth of Cut (mm)	of Surface Roughness (µm)	S/N Ratio	Standard Deviation	Mean
540	0.03	0.5	3.18	-10.89	0.43841	3.490
540	0.06	0.7	4.62	-10.94	1.94454	3.245
540	0.09	0.9	5.65	-12.20	3.18198	3.400
370	0.03	0.7	4.66	-13.99	0.47376	4.995
370	0.06	0.9	7.51	-15.03	3.40118	5.105
370	0.09	0.5	5.21	-11.81	2.41123	3.505
260	0.03	0.9	5.66	-16.59	1.44250	6.680
260	0.06	0.5	7.11	-15.15	2.29103	5.490
260	0.09	0.7	9.64	-16.92	5.14067	6.005

In the computation of the best cutting combination, it is required to determine the maximum S/N ratio; at the maximum S/N ratio the optimal cutting conditions can be achieved for the range of values that the experiment was carried out. In this experiment the tabulated S/N ratios (Table 1) suggest that the 1st cutting regime (S/N ratio = -10.89) corresponds to produce the surface

which has the lowest surface roughness. Significance of the machining parameters can be determined by examining the above results obtained from Taguchi analysis, considering the smaller the better S/N ratio, means of response, standard deviation of response the feed rate shows the higher influence to the surface roughness rather than spindle speed and depth of cut.

Developed Model

The regression equation derived in MINITAB 13 is,
Surface Roughness = 5.46 - 0.00962 (Spindle speed) + 38.9 (Feed rate) + 2.77 (Depth of cut)

To achieve 95% accuracy of the model it is required to have the probability; p value less than 0.05. From the analysis of variance (ANOVA) table, it was found that the probability, p of this model is 0.042. Therefore, it is clear that the model is well within the significant level of 0.05. Besides the control factor "Depth of cut" the p values of all other individual coefficients of control factors are less than significance level of 0.05 that means the all the coefficient values of these factors are significant at significance level of 0.05. It was also found that the value of the model adequacy (R^2) is equal to 78% at the significance level of 0.05. According to the above results the model is suitable to predict the surface roughness of manual turning operations with an accuracy of 78% at the significance level of 0.05.

Conclusion

Results obtained using Taguchi analysis clearly indicates that the feed rate plays a very important role for producing lower surface roughness and the spindle speed is the most insignificant factor on surface roughness. Furthermore, following cutting regime (when S/N Ratio = -10.89) is the setting expected to produce the surface which has lower surface roughness.

Spindle speed = 540 rpm, Feed rate = 0.03 mm/rev, Depth of cut = 0.5 mm
According to the results, the developed model using regression analysis was successful and it can be predicted the surface roughness values (R_a) with 78% accuracy for mild steel in M300 lathe machine at the 0.05 significance level.

References

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