EXPERIMENTAL INVESTIGATION AND THE ANALYSIS OF GRINDING ENVIRONMENT

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Abstract-Quality and productivity play significant role in today’s manufacturing market. Therefore, every manufacturing or production unit should concern about the quality of the product. If quality falls down the expected level the controller supplies a feedback in order to reset the process environment. In off-line quality control the method is either to check the quality of few products from a batch or lot (acceptance sampling) or to evaluate the best process environment capable of producing desired quality product. This invites optimization problem which seeks identification of the best process condition or parametric combination for the said manufacturing process. If the problem is related to a single quality attribute then it is called single objective (or response) optimization. If more than one attribute comes into consideration it is very difficult to select the optimal setting which can achieve all quality requirements simultaneously. Otherwise optimizing one quality feature may lead severe quality loss to other quality characteristics which may not be accepted by the costumers. In order to tackle such a multi-objective optimization problem, the present study applied extended Taguchi method through a case study in grinding. In this study main focus to optimize the grinding parameters to achieve good surface finish and better MRR. In this analysis optimum results have obtained for different materials at different machining conditions. For Mild steel the depth of cut 0.10 mm feed 0.30mm and coolant is OFF. For HCHCr steel the depth of cut 0.10 mm feed 0.30mm and coolant is dry. For Die Steel depth of cut 0.08mm feed 0.30mm and coolant condition is also OFF. These results show that the optimum surface finish and MRR is obtained in case of dry conditions.

Keywords- Taguchi method, grinding, roughness, optimization, MRR, Quality

I. INTRODUCTION AND MOTIVATION

Quality and productivity play significant role in today’s manufacturing market. From customers’ viewpoint quality is very important because the extent of quality of the procured item (or product) influences the degree of satisfaction of the consumers during usage of the procured goods. Apart from quality, there exists another criterion, called productivity which is directly related to the profit level and also goodwill of the organization. Every manufacturing industry aims at producing a large number of products within relatively lesser time. The purpose is to check whether quality lies within desired tolerance level which can be accepted by the customers. Therefore, every manufacturing or production unit should concern about the quality of the product. Surface smoothness plays very prominent to measure the quality of the product. Apart from appearance of product manufacturing time which also directly related with cost of the product is a great concern for every manufacturer.

Surface roughness also has large impact on the mechanical properties like fatigue behavior or corrosion resistance, creep etc. It also affects other functional attributes of machine components like friction, lubrication, wear, light reflection, heat transmission and electrical conductivity etc. Surface roughness is also a topic of interest in fluid dynamics. The roughness of the interior surface of pipes affects flow parameters, such as the Reynolds number, which is used to evaluate the flow regime (i.e., laminar or turbulent). The surface smoothness also affect the flow separation over the airfoils and other machine over which high velocity of fluid flow occurs. Specially this flow separation has tremendous effect on the working and efficiency of air vehicles. Because flow separation severely affect the drag and lift of the body. The performance of ships is also affected by roughness in the
form of skin friction, which can account for 80-90% of the total flow resistance. In addition, the power consumption can increase as much as 40% during the service life of a ship as a result of increased surface roughness caused by paint cracking, hull corrosion and fouling. The examples mentioned above are just a few of the applications in which surface roughness has to be carefully considered.

II. LITERATURE REVIEW

Influence of slab milling process parameters on surface integrity of HSLA: a multi-performance characteristics optimization has been published by Pankul Goel et al 2011[01] They investigate the optimal setting of slab milling process parameters. They choose Four process parameters, i.e. cutting fluid, cutting speed, feed and depth-of-cut each at three levels and the cutting fluid at two levels. The multi performance of the processes were measured in terms of surface integrity defined by surface roughness, surface strain and micro-hardness of the work-piece. Eighteen experiments, as per Taguchi’s L18 orthogonal array, were performed on high-strength low-alloy steel. Subsequently, Taguchi response table method and ANOVA were used for data analysis. Confirmation experiment was conducted to determine the improvement in the surface integrity using this approach. Results revealed that machining done in the presence of cutting fluid yield the optimum results. This paper also suggest the use of cutting fluid for good surface finish with other parameters such as cutting speed of 1,800 r.p.m. with a feed of 150 mm/min and depth-of-cut of 0.23 mm etc.

In a journal named “Optimization of Grinding Parameters for Minimum Surface Roughness by Taguchi Parametric Optimization Technique” presented by Deepak Pal et al 2012[2]. The Experiments are conducted on universal tool and cutter grinding machine with L9 Orthogonal array with input machining variables as work speed, grinding wheel grades and hardness of material. The developed model can be used by the different manufacturing firms to select right combination of machining parameters to achieve an optimal surface roughness (Ra). The results reveals surface roughness (Ra). The predicted optimal values for Ra for Cylindrical grinding process is 1.07 Ra respectively.

In 2013, Sudhansu Ranjan Das et al. investigate turning of hardened steels using a single point cutting tool has replaced by the cylindrical grinding as it offers attractive benefits in terms of lower equipment costs, shorter set up time, fewer process setups, higher material removal rate, better surface quality and elimination of cutting fluids compared to cylindrical grinding. In order to obtain desired surface quality by machining, proper machining parameters selection is essential. This can be achieved by improving quality and productivity in metal cutting industries. The study is to investigate the effect of machining parameters such as cutting speed, feed and depth of cut on surface roughness during dry turning of hardened AISI 4340 steel with CVD (TiN+TiCN+Al2O3+ZrCN) multilayer coated carbide inserts. A full factorial design of experiment is selected for experimental planning and the analysis of variance (ANOVA) has been employed to analyze the significant machining parameters on surface roughness during turning. This journal showed that feed (60.85%) is the most influencing parameter followed by cutting speed (24.6%) at 95% confidence level. And the two-level interactions of feed-cutting speed (F*V), depth of cut feed (D*F) and depth of cut-cutting speed (D*V) are found the significant effects on surface roughness in this turning process. Moreover, the relationship between the machining parameters and performance measure i.e. surface roughness has been modeled using multiple regression analysis.

III. METHODOLOGY

The key factors which mainly affect the surface roughness are:

a. Feed
b. Grinding wheel
c. Types of Material
d. Types of Coolant
e. Coolant condition.

i. ON

ii. OFF

We have used here Taguchi’s method of optimization. Taguchi recommends the following procedure for designing the experiments and analysis. The Taguchi method is a traditional approach for robust experimental design that seeks to obtain best parametric combination and the levels with the lowest cost and higher quality to achieve customer satisfaction. In the Taguchi design, the factors that can be controlled by designers called as control parameters and noise factors are considered to be influential on process output.

➢ Determine the quality characteristics to be optimized
➢ Identify the noise factors and test conditions.
➢ Identify the control factors and their alternative levels.
➢ Select orthogonal matrix.
➢ Analysis the data and determine optimum levels for control factors.
➢ Predicting the performance at these levels.

![Figure: 1 Showing Hill and Valley.](image)

IV. RESULT AND DISCUSSION

Table 1: Machine settings used in the experiments

| Factor Identifier | Factor          | Unit | Level 1 | Level 2 | Level 3 |
|-------------------|-----------------|------|---------|---------|---------|
| A                 | Depth of Cut    | Mm   | 0.05    | 0.08    | 0.10    |
| B                 | Feed            | Mm   | 0.30    | 0.15    |         |
| C                 | Cutting Fluid   | __   | Dry     | Water   | Oil     |

4.1 SIGNAL-TO-NOISE RATIO

Taguchi’s method is one of the simplest and effective approaches for parameter design and experimental planning [Ross PJ (1988) Taguchi techniques for quality engineering. McGraw-Hill, New York]. In this method, the term ‘signal’ represents the desirable value (mean) for the output characteristic and the term ‘noise’ represents the undesirable value (S.D.) for the output characteristic. Therefore, the S/N ratio is the ratio of the mean to the S.D. There are three types of S/N ratio depending on the type of characteristics—the lower the better, the higher the better, and the nominal the better.

Table 4.1.1 : S/N Ratio

| S.No. | Material-1 | Material-2 | Material-3 |
|-------|------------|------------|------------|
|       | Roughness  | MRR        | Roughness  | MRR        | Roughness  | MRR        |
| 1     | 9.37040    | 5.460      | 8.4042     | 5.460      | 10.1728    | 5.460      |
| 2     | 13.2868    | 5.460      | 9.8970     | 5.460      | 8.9954     | 5.460      |
As better surface finish means the lower the irregularity. Hence optimum S/N ratio is “lower the better” e.g. For reading No. of material-1 i.e. Mild steel

\[ \eta = -10 \log \left( \frac{0.34^2}{1} \right) = 9.3704 \]

The S/N ratio with a “the higher the better” characteristic can be expressed as [13. Siddiquee AN, Khan ZA, Mallick Z (2010)]

### 4.2 DATA PRE-PROCESSING

In Grey relational analysis, the function of factors is neglected in situations where the range of the sequence is large or the standard value is enormous. However, this analysis might produce incorrect results if the factors, goals and directions are different. Therefore, one has to pre-process the data which are related to a group of sequences, which is called “Grey relational generation” [13. Siddiquee AN, Khan ZA, Mallick Z (2010)]. The normalization can be done from three different approaches [14]. If the target value of original sequence is infinite, then it has a characteristic of “the larger the better”. The original sequence can be normalized as follows [Khan ZA, Kamaruddin S, Siddiquee AN (2010)]

\[ x_i^*(k) = \frac{x_i^*(k) - \min x_i^0 (k)}{\max x_i^0 (k) - \min x_i^0 (k)} \]

If the expectancy is “the smaller the better”, then the original sequence should be normalized as follows:

\[ x_i^*(k) = \frac{\max x_i^0 (k) - x_i^0 (k)}{\max x_i^0 (k) - \min x_i^0 (k)} \]

However, if there is a definite target value to be achieved, the original sequence will be normalized in the form:

| S.No. | Material-1 | Material-2 | Material-3 |
|-------|------------|------------|------------|
|       | Roughness  | MRR        | Roughness  | MRR        | Roughness  | MRR        |
| 1     | 0.8544     | 0.5033     | 1.0000     | 0.5033     | 0.7239     | 0.5033     |
| 2     | 0.5039     | 0.5033     | 0.8242     | 0.5033     | 0.8243     | 0.5033     |
| S.No. | Material-1 Roughness | Material-1 MRR | Material-2 Roughness | Material-2 MRR | Material-3 Roughness | Material-3 MRR |
|-------|----------------------|----------------|----------------------|----------------|----------------------|----------------|
| 1     | 0.1456               | 0.4967         | 0.0000               | 0.4967         | 0.2761               | 0.6967         |
| 2     | 0.4961               | 0.4967         | 0.1758               | 0.4967         | 0.1757               | 0.4967         |
| 3     | 0.8174               | 0.4967         | 0.7841               | 0.4967         | 1.0000               | 0.4967         |
| 4     | 0.03888              | 0.8943         | 0.0136               | 0.8943         | 0.3004               | 0.8943         |
| 5     | 0.2344               | 0.8943         | 0.4082               | 0.8943         | 0.4164               | 0.8943         |
| 6     | 0.0489               | 0.8943         | 0.2766               | 0.8943         | 0.3703               | 0.8943         |
| 7     | 0.1806               | 0.1600         | 0.0136               | 0.1600         | 0.0000               | 0.1600         |
| 8     | 0.3846               | 0.1600         | 0.6068               | 0.1600         | 0.3895               | 0.1600         |
| 9     | 0.6259               | 0.1600         | 0.4702               | 0.1600         | 0.4179               | 0.1600         |
| 10    | 0.0192               | 0.6602         | 0.0412               | 0.6602         | 0.3128               | 0.6602         |
| 11    | 0.6259               | 0.6602         | 0.5909               | 0.6602         | 0.2763               | 0.6602         |
| 12    | 0.4494               | 0.6602         | 0.7092               | 0.6602         | 0.8650               | 0.6602         |
| 13    | 0.0000               | 0.0000         | 0.0842               | 0.0000         | 0.4972               | 0.0000         |
| 14    | 0.0389               | 0.0000         | 0.4470               | 0.0000         | 0.3635               | 0.0000         |
| 15    | 0.5351               | 0.0000         | 0.3384               | 0.0000         | 0.3979               | 0.0000         |
| 16    | 0.00953              | 0.5000         | 0.0842               | 0.5000         | 0.3515               | 0.5000         |
| 17    | 1.0000               | 0.5000         | 0.6400               | 0.5000         | 0.7433               | 0.5000         |
| 18    | 0.7030               | 0.5000         | 1.0000               | 0.5000         | 0.8309               | 0.5000         |
4.3 Grey relational coefficient and Grey relational grade

Following data pre-processing, a Grey relational coefficient is calculated to express the relationship between the ideal and actual normalized experimental results. The Grey relational coefficient can be expressed as follows:

Table 4.3.1: Gray Relational Grade And Order for Material-1 i.e. Mild Steel

| S.No. | G.R.Coff. Roughness | GR Coeff.MRR | GR Grade | Order |
|-------|---------------------|--------------|----------|-------|
| 1     | 0.6442              | 0.4478       | 0.546    | 8     |
| 2     | 0.74                | 0.4478       | 0.5939   | 7     |
| 3     | 0.3333              | 0.4478       | 0.39055  | 17    |
| 4     | 0.6246              | 0.3333       | 0.47895  | 12    |
| 5     | 0.5457              | 0.3333       | 0.4395   | 15    |
| 6     | 0.5745              | 0.3333       | 0.4539   | 13    |
| 7     | 1                   | 0.7365       | 0.86825  | 1     |
| 8     | 0.5621              | 0.7365       | 0.6493   | 5     |
| 9     | 0.5447              | 0.7365       | 0.6406   | 6     |
| 10    | 0.6152              | 0.4038       | 0.5095   | 11    |
| 11    | 0.6441              | 0.4038       | 0.52395  | 10    |
| 12    | 0.3663              | 0.4038       | 0.38505  | 18    |
| 13    | 0.5014              | 1             | 0.7507   | 4     |
| 14    | 0.579               | 1             | 0.7895   | 2     |
| 15    | 0.5569              | 1             | 0.77845  | 3     |
| 16    | 0.5872              | 0.4794       | 0.5333   | 9     |
| 17    | 0.4022              | 0.4794       | 0.4408   | 14    |
| 18    | 0.3757              | 0.4794       | 0.42755  | 16    |

Table-4.3.2: Gray relational grade and Order for Material -2 i.e.HCHCr Steel

| S.No. | G.R.Coff. Roughness | GR Coeff. MRR | GR Grade | Order |
|-------|---------------------|--------------|----------|-------|
| 1     | 0.7744              | 0.4478       | 0.6111   | 9     |
| 2     | 0.502               | 0.4478       | 0.4749   | 13    |
| 3     | 0.3795              | 0.4478       | 0.41365  | 17    |
| 4     | 0.9279              | 0.3333       | 0.6306   | 8     |
| 5     | 0.6808              | 0.3333       | 0.50705  | 12    |
| 6     | 0.9109              | 0.3333       | 0.6221   | 10    |
| 7     | 0.7346              | 0.7365       | 0.73555  | 4     |
| 8     | 0.5652              | 0.7365       | 0.65085  | 7     |
| 9     | 0.4408              | 0.7365       | 0.58865  | 11    |
| 10    | 0.963               | 0.4038       | 0.6834   | 6     |
| 11    | 0.4408              | 0.4038       | 0.4223   | 16    |
| 12    | 0.5266              | 0.4038       | 0.4652   | 14    |
| 13    | 1                   | 1             | 1        | 1     |
| 14    | 0.9279              | 1             | 0.96395  | 2     |
| 15    | 0.483               | 1             | 0.7415   | 3     |
| 16    | 0.9813              | 0.4794       | 0.73035  | 5     |
| 17    | 0.3333              | 0.4794       | 0.40635  | 18    |
| 18    | 0.4156              | 0.4794       | 0.4475   | 15    |
Here 13th observation shows the optimum results. Its mean best results are obtained for conditioned which are used in 13th experiment i.e. Feed=0.30 mm. Depth of Cut=0.10 mm. Coolant=Dry

The best optimum result is obtained for experiment No.13. Its mean that the best of all observation when material removal rate and surface finish is considered is obtained.

Best machining conditions are:
Feed=0.30 mm Depth of cut=0.10 mm And Coolant OFF i.e. dry condition.

Table 4.3.3: Gray Relational grade and Order material -3 i.e.Die Steel
Here, From above table it is clear that best results and machining conditions are obtained for experiment no.7. i.e. optimum machining parameters are
Feed= 0.30mm Depth of cut=0.08mm coolant Dry

V. CONCLUSION

In this project work we have studied the effect of various grinding parameters on surface finish and metal removal rate (MRR). By optimization the experiments in our study with the help of Taguchi’s optimization method it is concluded that the coolant condition is also play a vital role in grinding operation. As in all of three study on different-2 three material show that optimum grinding condition achieve for dry condition i.e. no coolant is used.

Same optimum grinding parameters has obtained for High Carbon and High Carbon High Chromium steel, but only difference for Die Steel is for depth of cut. The papers that have carried out in this regard, show that the best surface finish is obtained for grinding with coolant. And also they suggest the best coolant for grinding is oil not the water. But in our study optimum conditions has obtained for dry condition. The reason of this difference, due to consideration of “Material Removal Rate” (MRR).In our best knowledge this parameter has not considered for optimization or experiment. Material Removal Rate affect the optimization results large extent and that is why the best optimum conditions are obtained for dry condition. Hence by this it can ascertain that for better Metal Removal dry condition is best. Hence in sort it can be concluded from our work that for optimum metal removal, there is no need for coolant.

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