Optimization of Process Parameters in Turning Operation Using Taguchi Method and Anova: A Review

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Abstract

This paper investigates the parameters affecting the roughness of surfaces produced in the turning process for the various materials studied by researchers. Design of experiments were conducted for the analysis of the influence of the turning parameters such as cutting speed, feed rate and depth of cut on the surface roughness. The results of the machining experiments were used to characterize the main factors affecting surface roughness by the Analysis of Variance (ANOVA) method Taguchi's parametric design is the effective tool for robust design it offers a simple and systematic qualitative optimal design to a relatively low cost. The Taguchi method of off-line (Engineering) quality control encompasses all stages of product/process development. However the key element for achieving high quality at low cost is Design of Experiments (DOE). In this paper Taguchi's (DOE) approach used by many researchers to analyze the effect of process parameters like cutting speed, feed, and depth of cut on Surface Roughness and to obtain an optimal setting of these parameters that may result in good surface finish, has been discussed.

1. Introduction

In order to develop and optimize a surface roughness model, it is essential to understand the current status of work in this area. The need for selecting and implementing optimal machining conditions and most suitable cutting tools has been felt over few decades. Surface roughness has become the most significant technical requirement and it is an index of product quality. In order to improve the tribological properties, fatigue strength, corrosion resistance and aesthetic appeal of the product, a reasonably good surface finish is desired. Nowadays, the manufacturing industries specially are focusing their attention on dimensional accuracy and surface finish. In order to obtain optimal cutting parameters to achieve the best possible surface finish, manufacturing industries have resorted to the use of handbook based information and operators' experience. This traditional practice leads to improper surface finish and decrease in the productivity due to sub-optimal use of machining capability. This causes high manufacturing cost and low product quality [1].

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Surface roughness is mainly a result of process parameters such as tool geometry (i.e. nose radius, edge geometry, rake angle, etc). and cutting conditions (feed rate, cutting speed, depth of cut, etc).Surface roughness is harder to attain and track than physical dimensions are, because relatively many factors affect surface roughness. Some of these factors can be controlled and some cannot. Controllable process parameters include feed, cutting speed, tool geometry, and tool setup. Other factors, such as tool, work piece and machine vibration, tool wear and degradation, and work piece and tool material variability cannot be controlled as easily. The important cutting parameters discussed here are cutting speed, feed and depth of cut. It is found in most of the cases surface roughness decreases with increase in cutting speed and decrease in feed and depth of cut. Since these cutting parameters will decide about the type of chips which we expect at the time of machining of a single constant material thus we have to analyze them for no such built-up edge chips formation.

2. Taguchi Method

Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost . Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment . Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. The desired cutting parameters are determined based on experience or by hand book. Cutting parameters are reflected. Steps of Taguchi method are as follows:

1. Identification of main function, side effects and failure mode.
2. Identification of noise factor, testing condition and quality characteristics.
3. Identification of the main function to be optimized.
4. Identification the control factor and their levels.
5. Selection of orthogonal array and matrix experiment.
6. Conducting the matrix experiment.
7. Analysing the data, prediction of the optimum level and performance.
8. Performing the verification experiment and planning the future action.

3. Analysis Of The Signal-To-Noise Ratio

Taguchi recommends the use of S/N ratio to measure the quality characteristic deviation from the desired values. The term 'Signal' represents the desired value (i.e. mean) for the response and the term 'Noise' represents the undesired value (i.e. SD). Therefore, S/N ratio is the ratio of the mean to SD. Usually there are three categories of quality characteristic in the analysis of S/N ratio, i.e. the larger-the-better, the smaller-the-better, and the nominal the-better. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristic. In this experiment, the S/N ratio for each level of process parameter was computed based on the smaller-the-better S/N analysis for the surface roughness. The experiments were conducted aiming at determining the effect of machine tool condition, in term of vibration amplitude, on surface roughness of the work piece. The values of S/N ratio, η, corresponding to the average surface roughness of each run calculated using the Equation: $\eta = -10 \log [(\Sigma yi\ 2)/n]$ (2) Where η is the S/N ratio, yi is surface roughness measurements in a run, and n is the number of replicates. In many of the cases which study Roughness the S/N ratio is based on the Taguchi smaller the-better loss function, as the idea is to minimize the response, i.e. surface roughness. The S/N ratio is a summary statistic which indicates the value and dispersion of the response. Since the experimental design is orthogonal, it is then possible to separate out the effect of each parameter at different levels. For example, the mean S/N ratio for the vibration amplitude at levels 1-3 can be calculated by averaging the S/N ratio for the Experiments 1-3, 4-6 and 7- 9, respectively. The mean S/N ratio for each of the other parameter can be computed in the similar manner. The mean S/N ratio for each level of the cutting parameters is summarized and called the mean S/N response table for the surface roughness. The S/N response table and S/N response graph are shown in Table 5 and Fig. 3, respectively. The appropriate categories of the S/N ratio are chosen depending on the nature of the quality characteristic. For example, the S/N ratio for smaller-the-better criterion is employed when the aim is to make the response as small as possible. Ideally, the response would be equal to zero. Regardless of the category of the quality characteristics, a greater S/N ratio corresponds to better quality characteristics, that is, to the smaller variance of the output characteristic around the desired (target) value.

4. Analysis Of Variance (ANOVA)

The main aim of ANOVA is to investigate the design parameters and to indicate which parameters are significantly affecting the output parameters. In the analysis, the sum of squares and variance are calculated. F-test value at 95 % confidence level is used to decide the significant factors affecting the process and percentage contribution is calculated [19]. The ANOVA analysis for percentage calibration is shown in Table-5

ANOVA can be useful for determining influence of any given input parameter from a series of experimental results by design of experiments for machining process and it can be used to interpret experimental data. Analysis of variance (ANOVA) is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes *t*-test to more than two groups. ANOVA is used in the analysis of comparative experiments, those in which only the difference in outcomes is of interest. The statistical significance of the experiment is determined by a ratio of two variances. This ratio is independent of several possible alterations to the experimental observations: Adding a constant to all observations does not alter significance. Multiplying all observations by a constant does not alter significance. So ANOVA statistical significance results are independent of constant bias and scaling errors as well as the units used in expressing observations.

The analysis of variance (ANOVA) may be used to investigate which design factors and their interactions affect the response significantly. Taguchi recommends analyzing the mean and S/N ratio using two-dimensional response graphs, instead of ANOVA. The analysis of means (ANOM) is a statistical approach that is based on determining the mean S/N ratios for each design factor and each of its levels.

5. Literature Review

Ilhan Asiltürk.et.al.,[2011] have presented a paper on title "Determining The Effect Of Cutting Parameters On Surface Roughness In Hard Turning Using The Taguchi Method" [Ref 5] The study focuses on optimizing turning parameters based on the Taguchi method to minimize surface roughness (Ra and Rz). Experiments have been conducted using the L9orthogonal array in a CNC turning machine. Dry turning tests are carried out on hardened AISI 4140 (51 HRC) with coated carbide cutting tools. Each experiment is repeated three times and each test uses a new cutting insert to ensure accurate readings of the surface roughness. The statistical methods of signal to noise ratio (SNR) and the analysis of variance (ANOVA) are applied to investigate effects of cutting speed, feed rate and depth of cut on surface roughness. Results of this study indicate that the feed rate has the most significant effect on Ra and Rz. In addition, the effects of two factor interactions of the feed rate-cutting speed and depth of cut-cutting speed appear to be important. S/N ratios and level values were calculated by using Eq. ''the smaller-the better'' in the MINITAB 14 Program. The results obtained in this study are as below:

- L9 orthogonal array was selected for three different levels of cutting speed, feed rate and depth of cut, which were cutting factors, by using the Taguchi method. Asa result, nine experiments were conducted instead of the full factorial 27 experiments. Ra and Rz' S/N ratios were found as a result of experiments conducted according to the L9 orthogonal array. The maximum value was found by using the S/N ratio equation of ''the smaller-the better,'' the maximum S/N ratio yielded optimum cutting parameters. Optimum cutting conditions-which correspond to maximum 2.32 S/N value of the smaller Ra value for the smaller surface roughness in hard turning operation (2 1 2) were found to be 120 m/min for the cutting speed, 0.18 mm/rev for the feed rate and 0.4 mm for the depth of cut. Optimum cutting conditions-which correspond to maximum 18.75 S/N value of Rz value (3 1 1) were found to be120 m/min for the cutting speed, 0.18 mm/rev for thefeed rate and 0.4 mm for the depth of cut.
- Variance analysis was applied to S/N ratios to discover interactions between cutting parameters relating to Ra and Rz. According to the ANOVA analysis, the feed rate has an effect on Ra and Rz at a reliability level of 95%. Any difference (variance) was not observed for the cutting speed and the depth of cut at the reliability level of 95%.
- The numbers of experiments in the same or similar area in hard turning operations were reduced by using the Taguchi experimental design to determine optimum cutting conditions. Satisfying results were obtained so that they may be used in future academic and industrial studies.
- Their study suggest that developed model can be used in the metal machining industries in order to determine the optimum cutting parameters for minimum surface roughness.

M Kaladhara .et.al.[2012], have presented a paper on title "Determination Of Optimum Process Parameters During Turning Of AISI 304 Austenitic Stainless Steels Using Taguchi Method ANOVA" [Ref 9].They have tried to Investigate the process parameters on surface finish and Material Removal Rate to obtain the optimal setting of these parameters. They have used ANOVA to analyze the influence of cutting parameters during machining. In their work AISI 304 Austenitic Stainless Steels work pieces were turned on CNC lathe by using physical vapour deposition coated ceramic insert (TiCN-TIN) of 0.4, and 0.8 Nose Radii. The analysis has been made with the help of a software package MINITAB 14.Their result revealed that the feed and Nose radius is the most significant process parameter on work piece surface roughness and the depth of cut and feed are the significant factor on MRR. They have also predicted optimal range and optimal level of parameters for responses with TAGUCHI Approach.

Ananthakumar.P et.al.,[2013] have presented a paper on title "Optimization Of Turning Process Parameters Using Multivariate Statistical Method-PCA Coupled With Taguchi Method[Ref 3]The work applies to optimize the process parameter for turning medium carbon steel bar using HSS tool bit via conventional machining. Optimizing one quality attribute may lead to loss of other quality attribute. Hence in order to simultaneously satisfy all the three quality requirements a multi objective optimization is required. To achieve this exploration of grey relational theory, utility concepts are attempted. To meet the basic assumption of taguchi method that quality attributes should be uncorrelated the study applies PCA based multivariate statistical method and eliminates correlation that exists in between the responses. Experiments have been conducted based on taguchi's L9 Orthogonal array design with different combinations of process control parameters: (Cutting speed, Feed, Depth of cut). Surface roughness, Material removal rate, Tool Flank wear are the response parameters that will be optimized. The obtained result will be verified through confirmatory test. This work highlights the effectiveness of proposed method for solving multi objective optimization of turning process. The above said methodology has been found fruitful in the cases where simultaneous optimization of huge responses is required. Back rack angle 10°,Side rack angle 12°,Side relief angle 07°,End relief angle 07°,Major cutting edge 15°,Minor cutting edge 15°,Nose radius 0.8 mm, Size of square tool bit 12 *12 mm2,Length of tool bit 100 mm. In this experiment HSS TOOL BITS with 10% Cobalt (SAE T42) is used. This quality of tool bits retains its hardness even at very high temperatures and is recommended where the generation of heat is very high and the tool should not get blunt at high temperatures. Work piece of standard dimensions was used for machining. Diameter of work piece: 38 mm, length of work piece: 100 mm. length of turning: 40 mm. AISI: 1040(ISO 683-1:C40) medium carbon steel is selected for work piece material because it is used wide variety of general purpose engineering.

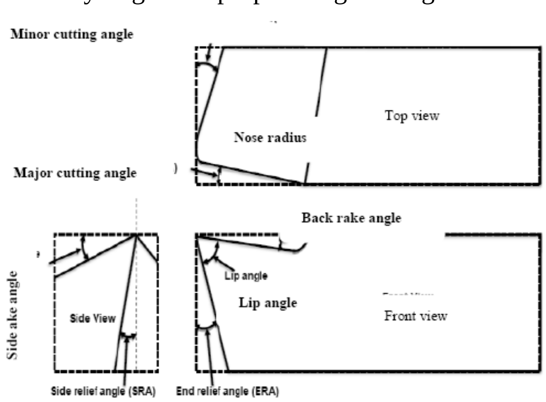


Fig.1 Cutting Tool Nomenclature [Ref 3]

These steels are of particular importance because of unique combination of strength and toughness after heat treat treatment. Medium Carbon Steels are similar to low carbon steel except that the carbon ranges from 0.30 to 0.60 & the manganese from 0.50 to 0.90%. The instrument used to measure surface roughness was "Time surface roughness tester TR 100". Surface roughness readings were recorded at three locations on the work piece and the average value was used for analysis Specifications of Instrument used: Tracing length 6 mm, tracing speed 1 mm/sec, cutoff lengths 0.25 mm/0.8 mm/ 2.5 mm. Measuring range Ra:0.05-10µm, Rz:0.1-50µm. Metzer tool maker's microscope is used to measure the cutting tool flank wear. All statistical works and including principal component analysis with proposed algorithm are performed with the help of MINITAB R14 statistical software. At the end, results of proposed algorithm are compared with the results of confirmatory test and existing methods. Here larger the better criterion is used for optimizing the overall MP Index.

From the analyses, the following conclusions have been given

1. Here the application of PCA with grey or utility based taguchi method has been recommended for the optimization of manufacturing processes like turning processes which are having correlated multiple responses to find the optimum combination of process parameters with experimental objectives.
2. PCA has been utilized here to eliminate the correlation between the responses by converting correlated responses in to uncorrelated quality indices called principal components to meet the basic assumption of taguchi optimization.
3. By comparing the existing taguchi based multi response optimization method the proposed approach meet the objectives of multiple responses simultaneously and produce best optimum combination of process parameter.
4. Over all multi response performance index based on PCA serves as a single response for solving multi response problem, really it will helpful where large number of responses to be optimized simultaneously.
5. From the experimentation and analysis depth of cut and feed showing greater influence than speed on surface roughness tool flank wear & material removal rate simultaneously.
6. The proposed approach can be recommended for off line quality control of process and product to improving the quality.

Muhammad Munawar.et.al.,[2009] have presented a paper on title "Optimization Of Surface Finish In

Turning Operation By Considering The Machine Tool Vibration Using Taguchi Method" [Ref 13] have carried out experimentation to investigate the effect of machine tool condition on surface roughness. Variable used to represent machine tool's condition was vibration amplitude. Input parameters used, besides vibration amplitude, were feed rate and insert nose radius. Cutting speed and depth of cut were kept constant. Based on Taguchi orthogonal array, a series of experimentation was designed and performed on AISI 1040 carbon steel bar at default and induced machine tool's vibration amplitudes. In their study ANOVA (Analysis of Variance), reveals that vibration amplitude and feed rate had moderate effect on the surface roughness and insert nose radius had the highest significant effect on the surface roughness. The working was done with C type negative, multi layers coated inserts CNMG 120404, CNMG 120408 and CNMG 120412 each having grade CA5525 [20]. These inserts have chip breaker geometry of type CQ, which has a broader range of applications. The insert has rake angle of -6º and inclination angle of -6º the tool holder used for the inserts was PCLNL2020K12.

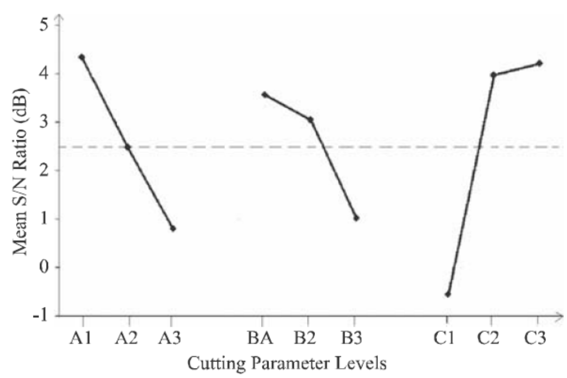


Fig: 2. S/n ratio graph for surface roughness

The experimentation was carried out on slant bed EMCO Concept turn 345-series CNC lathe machine having maximum power of 21KW, maximum spindle speed of 6000 rpm, and maximum feed rate of 8000 mm/min. The surface roughness was measured with surface texture meter by Taylor Hobson, UK as shown in Table 2. For measurement of the surface roughness of the machined work pieces, cut off length and evaluation length were set to 0.8 and 4mm respectively. Their study shows that a machine tool with low vibration amplitude produced better surface roughness and Insert with larger nose radius produced better surface roughness at low feed rate. The design had yielded an optimum condition for the input parameters using ANOVA and S/N ratio. The verification process was then performed using the predictive equation, which indicated that deviation between actual and predicted S/N ratio of surface roughness was small. The improvement of the surface roughness from initial cutting parameters to the optimal cutting parameters was about 100%.

E. Daniel Kirby [2006] have presented a paper on title" A Parameter Design Study In A Turning Operation Using The Taguchi Method" [Ref 4]This study utilized an efficient method for determining the optimum turning operation parameters for surface finish under varying noise conditions, through the use of the Taguchi parameter design process. Conclusions have been given as below:

The use of a modified L8 orthogonal array, with three control parameters and one noise factor, required only sixteen work pieces to conduct the experimental portion, half the number required for a full factorial design.

Feed rate had the highest effect on surface roughness, spindle speed had a moderate effect, and depth of cut had an insignificant effect. This would indicate that feed rate and spindle speed might be included alone in future studies, although the literature review would caution against ruling out depth of cut altogether. The noise factor, "damaged" and new chuck jaws, was not found to have a statistically significant effect here, although the inclusion of this noise could still help make this experiment robust.

A parameter design yielded an optimum condition of the controlled parameters, as well as a predictive equation. A verification procedure was then performed, which indicated that the selected parameter and predictive equation were accurate to within the limits of the measurement instrument. has demonstrated that this method of machining parameter optimization can be accomplished with minimal down time, the practical application of this requires more research.

This area of research would benefit from future studies taking place in an industrial environment, such as a manufacturing plant. Additionally, the addition of more representative conditions and materials, such as steel bar stock, coolant, and cutting tool variations would provide a more robust and applicable study. Addressing issues such as numerous uncontrolled noise factors and time constraints for experimentation and implementation would be important in demonstrating Taguchi Parameter Design as a valuable and manageable tool for off-line quality engineering and production optimization.

Yigit Kazancoglu1.et.al., [2011] have presented a paper on title " Multi-Objective Optimization Of The Cutting Forces In Turning Operations Using The Grey-Based Taguchi Method, [Ref 17] Their study investigates the multi-response optimization of the turning process for an optimal parametric combination to yield the minimum cutting forces and surface roughness with the maximum material-removal rate (MRR) using a combination of a Grey relational analysis (GRA) and the Taguchi method. Nine experimental runs based on an orthogonal array of the Taguchi method were performed to derive objective functions to be optimized within the experimental domain. A Phynix TR-100 model surface-roughness tester was used to measure the surface roughness of the machined samples. The cut-off length (_) was chosen as 0.3 for each roughness measurement. An average of six measurements of the surface roughness was taken to use in the multi-criteria optimization. They have selected objective functions in relation to the parameters of the cutting process: cutting force, surface roughness and MRR. The Taguchi approach was followed by the Grey relational analysis to solve the multi-response optimization problem. They have also evaluated quantitatively using the analysis-of-variance method (ANOVA)the significance of the factors on the overall quality characteristics of the cutting process Optimal results were verified through additional experiments. They concluded that a proper selection of the cutting parameters produces a high material-removal rate with a better surface roughness and a lower cutting force.

Jitendra Verma.et.al., [2012] have presented a paper on title "Turning Parameter Optimization for Surface Roughness of ASTM A242 Type-1 Alloys Steel by Taguchi Method" [Ref 6]. This research paper is focused on the analysis of optimum cutting conditions to get lowest surface roughness in turning ASTM A242 Type-1 ALLOYS STEEL by Taguchi method. Experiment was designed using Taguchi method and 9 experiments were conducted by this process. The results have been analyzed using analysis of variance (ANOVA) method. Taguchi method has shown that the cutting speed has significant role to play in producing lower surface roughness about 57.47% followed by feed rate about 16.27%. The Depth of Cut has lesser role on surface roughness from the tests. The results obtained by this method are concluded to be useful to other researches for similar type of study and may be eye opening for further research on tool vibrations, cutting forces etc .In this study ASTM A242 TYPE-1 ALLOY steel and 250 mm long with 50 mm diameter was used as work material for experimentation using a lathe turning machine. Cutting speed, feed rate and depth of cut were selected as the machining parameters to analyze their effect on surface roughness. A total of 9 experiments based on Taguchi's orthogonal array were carried out with different combinations of the levels of the input parameters. Among them, the settings of cutting speed include 100, 125 and 150 rpm; those of feed rate include 0.05, 0.1, 0.15 mm rev-1; the depth of cut is set at 0.5, 1.0 and 1.5 mm.

Table: 1. Cutting parameters [Ref 6]

Symbol	Parameters/Level	Level 1	Level 2	Level 3	Units
A	Cutting speed	-18.30	-20.28	-15.78	m/min
B	Feed rate	-16.46	-18.85	-19.05	mm/rev.
C	Depth of cut	-16.78	-18.5	-19.09	mm

Table: 2. Experimental Results [Ref 6]

Test. No	Cutting Speed	Feed rate	DOC	Mean Surface Roughness Ra (μm)	Signal to Noise Ratio (S/N)
1	100	0.05	0.5	5.62	-14.99
2	100	0.1	1.0	10.04	-20.03
3	100	0.15	1.5	09.88	-19.89
4	125	0.05	1.5	10.25	-20.21
5	125	0.1	0.5	9.30	-19.36
6	125	0.15	1.0	11.60	-21.29
7	150	0.05	1.0	5.04	-14.18
8	150	0.1	1.5	6.93	-17.18
9	150	0.15	0.5	6.27	-15.99

Table 3 Result of ANOVA for Surface Roughness contribution [Ref 6]

Symbol	Parameter	DOF	Sum of Square	Mean Square	Percentage Contribution
A	Cutting Speed	2	30.5208	15.2604	57.47%
B	Feed Rate	2	12.4602	6.2301	23.46 %
C	Depth of Cut	2	8.6427	4.3213	16.27 %
Error		2	1.4823	0.74115	2.79 %
Total		8	53.106	26.553	

The conclusions drawn based on the tests conducted from the ANOVA, Table and the P value, the cutting speed is the only significant factor which contributes to the surface roughness i.e. 57.47 % contributed by the cutting speed on surface roughness. The second factor which contributes to surface roughness is the feed rate having 23.46 %. The third factor which contributes to surface roughness is the depth of cut having 16.27%. The Validation experiment confirms that the error occurred was less than 2.79% between equation and actual value. It is recommended from the results that cutting of 18.30 to 15.78 m/min can be used to get lowest surface roughness. Taguchi gives systematic simple approach and efficient method for the optimum operating conditions. This research has also suggested using Taguchi's parameter design to obtain optimum condition with lowest cost, minimum number of experiments and industrial engineers can use this method.

Marinković Velibor et.al.,[2011] have presented a paper on title "Optimization Of Surface Roughness In Turning Alloy Steel By Using Taguchi Method" [Ref 12] In this study the Taguchi robust parameter design for modelling and optimization of surface roughness in dry single-point turning of cold rolled alloy steel 42CrMo4/AISI 4140 using TiN-coated tungsten carbide inserts has been presented. Three cutting parameters, the cutting speed (80, 110, 140 m/min), the feed rate (0.071, 0.196, 0.321 mm/rev), and the depth of cut (0.5, 1.25, 2 mm), have been used in the experiment. Each of the other parameters was taken as constant. The average surface roughness (Ra) was chosen as a measure of surface quality. The experiment was designed and carried out on the basis of standard L27 Taguchi orthogonal array. The data set from the experiment was employed for conducting the optimization procedures, according to the principles of the Taguchi method. The results of calculations were in good agreement with the experimental data. A certain discrepancy between the experimental results and calculations could be interpreted as the presence of measurement errors, many irregularities and deficiencies in the turning process, as well as environmental effects. The results presented in this work confirm the effectiveness of Taguchi's technique in optimization of cutting processes. For that purpose, the experimental results should be transformed into the S/N ratios. There are three categories of the S/N ratio (Phadke, 1989; Taguchi et al., 2005):

(a) Smaller-the-better,

(b) Larger-the-better,

(c) Nominal-the-best,

The S/N ratio for smaller-the-better criterion is employed when the aim is to make the response as small as possible. Ideally, the response would be equal to zero. The statistical analysis was also performed by using ANOVA. This analysis was prepared using software MINITAB. The response graphs and ANOVA results show that the effects of two-way interactions of these cutting parameters are statistically insignificant, that is, can be neglected. As shown in this study, the Taguchi method provides a systematic, efficient and easy-to-use approach for the cutting process optimization.

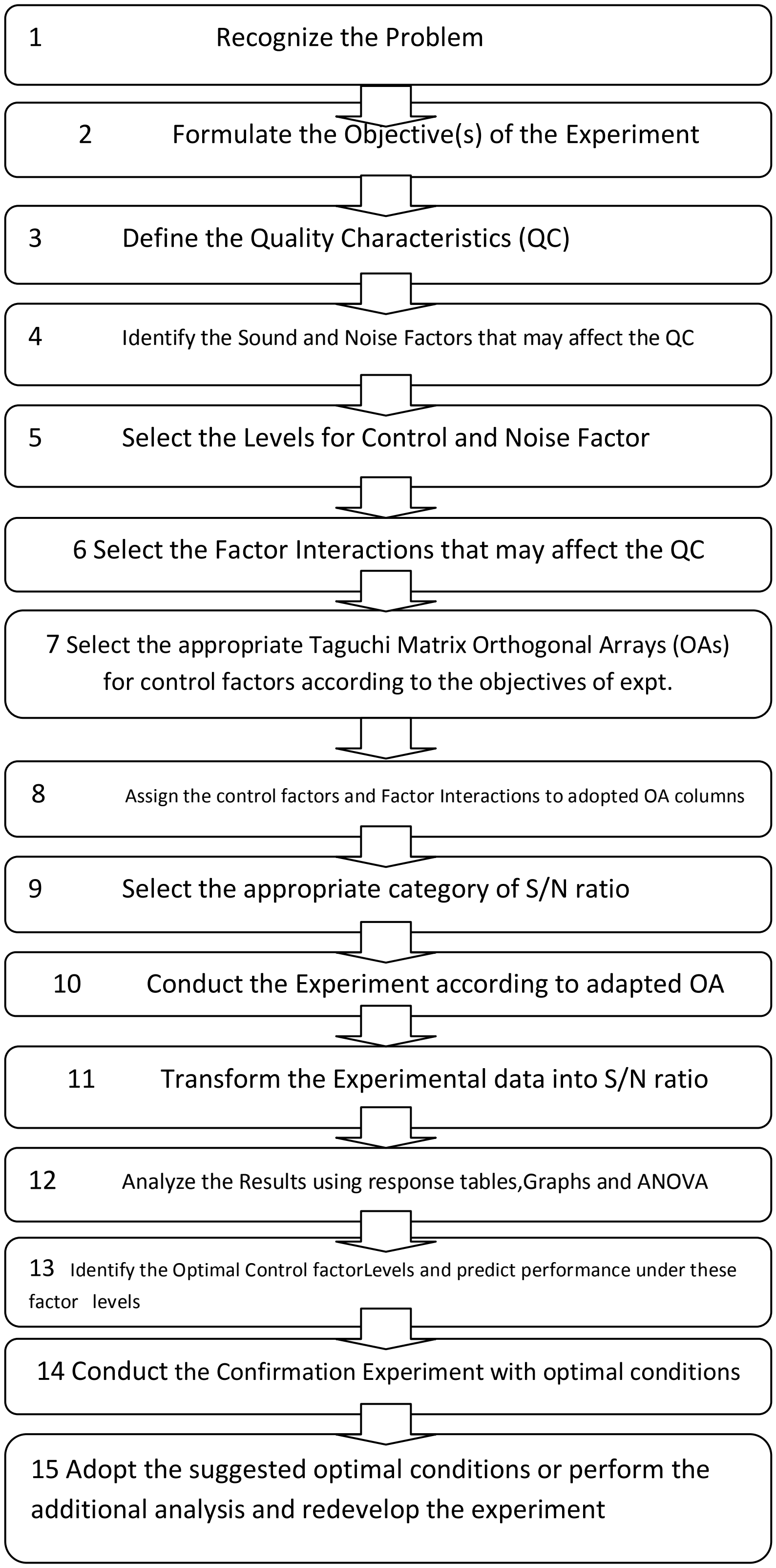


Fig: 2. Steps in the Taguchi method. [Ref 12]

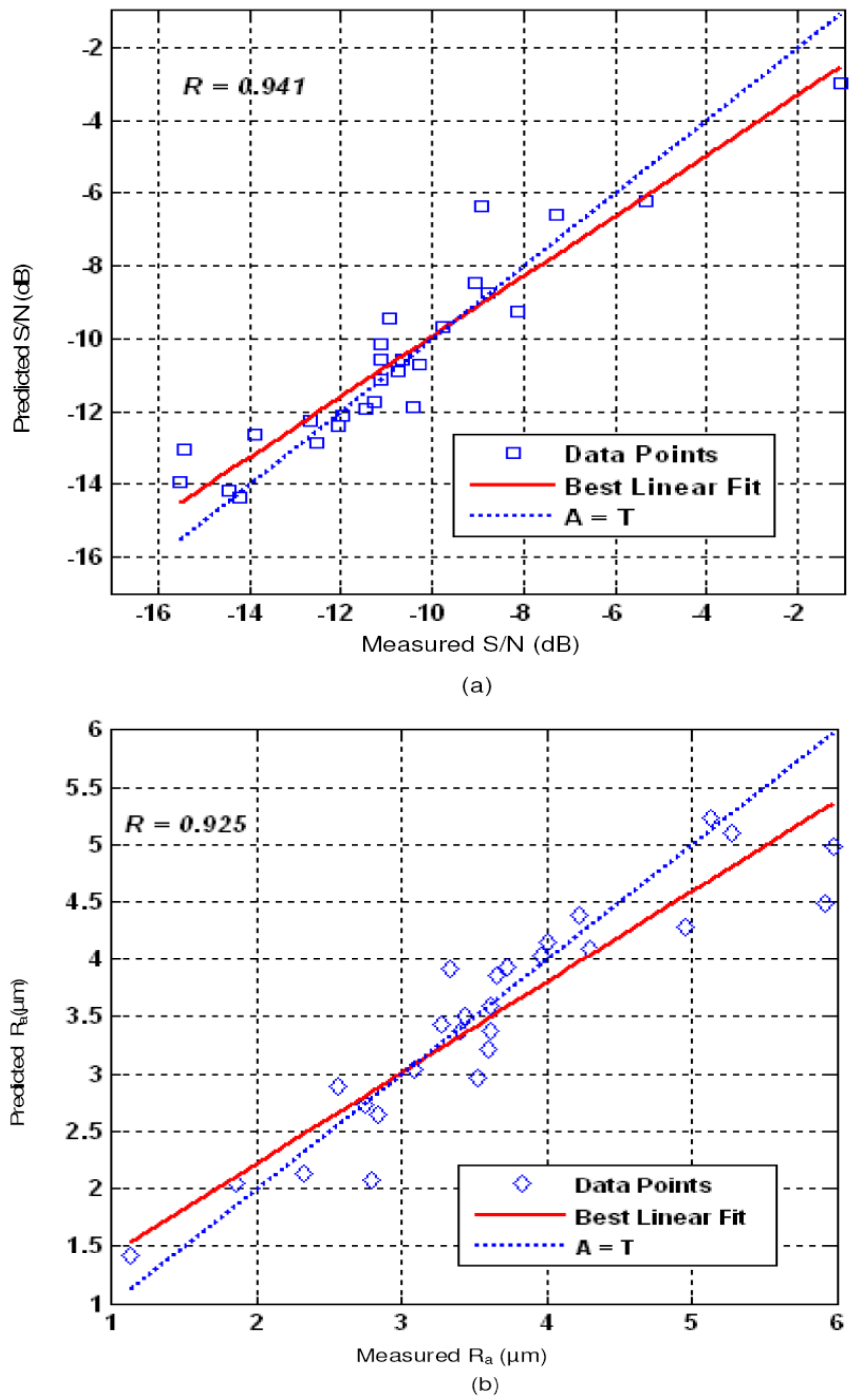


Fig: 4. Comparison of measured and predicted values : [Ref 12]
(a) For S/N ratio; (b) For Ra

Rodrigues L.L.R et.al.,[2012] have presented a paper on title "Effect Of Cutting Parameters On Surface Roughness And Cutting Force In Turning Mild Steel" [Ref 15] They studied the effect of speed, feed and depth of cut on surface roughness (Ra) and cutting force (Fc) in turning mild steel using high speed steel cutting tool. Experiments conducted on a precision centre lathe and the influence of cutting parameters were studied using analysis of variance (ANOVA)based on adjusted approach. Based on the main effects plots obtained through full factorial design, optimum level for surface roughness and cutting force were chosen from the three levels of cutting parameters considered. Linear regression equation of cutting force has revealed that feed, depth of cut, and the interaction of feed and depth of cut significantly influenced the variance. In case of surface roughness, the influencing factors were found to be feed and the interaction of speed and feed. As turning of mild steel using HSS is one among the major machining operations in manufacturing industry, the revelation made in this research significantly contribute to the cutting parameters' optimization.

A.V.N.L.Sharma.et.al., [2013]" have presented a paper on title Parametric Analysis And Multi Objective Optimization Of Cutting Parameters In Turning Operation Of EN353 – With CVD Cutting Tool Using Taguchi Method" [Ref 1] This paper discusses an investigation into the use of Taguchi parameter Design and Regression analysis to predict and optimize the surface roughness and metal removal rate in turning operations using CVD cutting tool. In this study EN353 work material, with 300 mm long and 50mm diameter was used for experimentation using a lathe machine. 50 mm was held in the chuck and 250 mm was turned in dry condition. During measuring 5mm was set as the cut of length.
The results obtained in this study lead to following conclusions

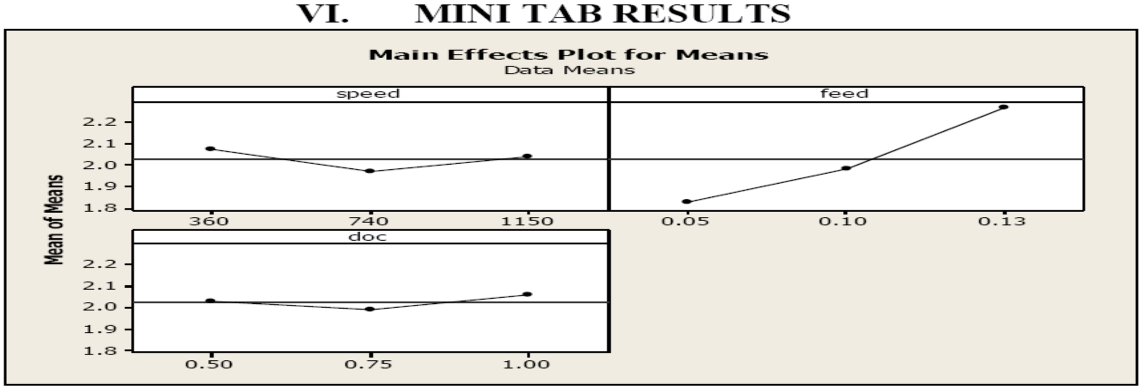
1. From the results obtained by experiment, the influence of surface roughness (Ra), and Material Removal Rate (MRR) by the cutting parameters like speed, feed, DOC is (a) the feed rate has the variable effect on surface roughness, cutting speed and depth of cut an approximate decreasing trend. (b) Cutting speed, feed rate and depth of cut for Material Removal Rate have increasing trend.
2. The design of experiments (DOE), Taguchi method is applied for optimization of cutting parameters and Analysis of Variance (ANOVA) is done and found that (a) The optimal combination of process parameters for minimum surface roughness is obtained at 580 m/min cutting speed, 0.07 mm/rev feed, 0.20 mm of depth of cut. (b) The optimal combination of process parameters for maximum material removal rate is obtained at 740 m/min cutting speed, 0.09 mm/rev feed, 0.25 mm of depth of cut.
3. ANOVA shows that the depth of cut has great influence for the response surface roughness (Ra), cutting speed has great influence for the response Material removal rate (MRR) .The percentage contribution values for the responses Ra, and MRR are as follows: (a) In case of Ra response the depth of cut 87.68% is significant one followed by cutting speed. (b) In case of MRR response the cutting speed 48.03% is significant one followed by depth of cut.
4. The interaction of cutting parameters is also studied for the three responses Ra, and MRR as follows: (a) The interaction for the cutting parameters is found that speed and depth of cut have great influence on the response Ra and the percentage contribution of speed and depth of cut is 4.84% followed by feed and depth of cut with 0.66%, speed and feed with 0.26%. (b) The interaction for the cutting parameters is found that speed and depth of cut have great influence on the response MRR and the percentage contribution of speed and depth of cut is 6.80% followed by speed and feed with 2.46%, feed and depth of cut with 1.23%.
5. Using the experimental data, a multi linear regression model is developed and the values obtained for the responses Ra and MRR are compared with measured values. A graph was plotted between Regression predicted values and experimentally measured values and shows that the models are adequate without any violation of independence or constant assumption.

Vipin.et.al.,[2009] have presented a paper on title "Surface Roughness Prediction Model By Design Of Experiments For Turning Leaded Gun Metal" [Ref 16]In this study The surface roughness models have been developed for turning leaded gun metal under dry conditions. The models have been developed in terms of cutting speed, feed rate and depth of cut obtained experimentally. The Experimental data has been used to develop the models with the aid of regression analysis. The effects of cutting variables (cutting speed, feed and depth of cut) on surface roughness have been investigated by Central composite Design. The first-order model was developed by an experimental design consisting of 12 experiments. Twelve experiments constitute Eight experiments (23 factorial designs) and Four experiments (an added centre point repeated four times) as shown in Fig.2. This was done to predict the 'b' parameters as used in the Equation. The blocks provide the confidence interval of the parameters and help in the analysis of variance. A second-order model is developed by adding six augment points to the factorial design. Depending on the capacity of the machine, an augment length of ±1 was chosen. The independent variables denoted by -1, 0, and 1. These six experiments were repeated twice to develop the second-order model. The resulting 12 or 24 experiments form the central composite design Fig. 2 shows 23 designs. The results conclude that the surface roughness equation shows that the feed is the main influencing factor on the surface roughness, followed by cutting speed and depth of cut in the operation model. Increasing any of these three cutting variables increases the surface roughness. Dual-response contours provide useful information about the maximum attainable surface roughness for a given metal removal rate as a function of all three independent cutting variables.

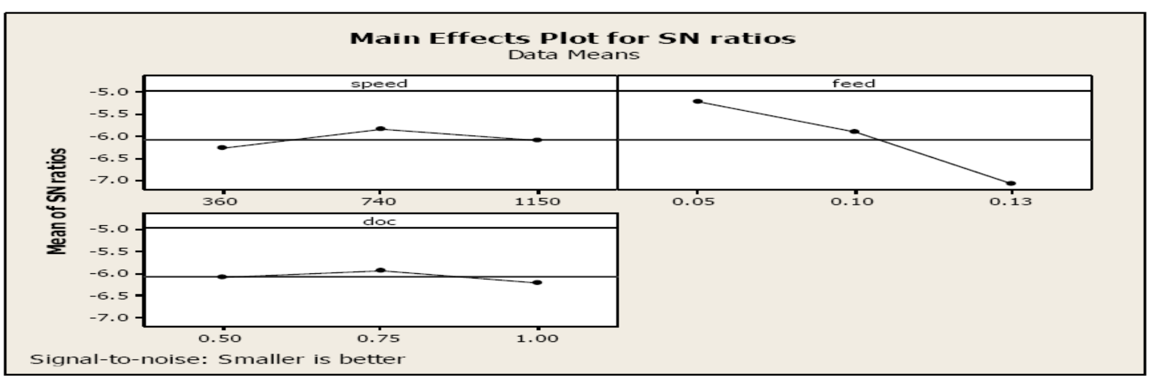
K. Mani Lavanya1.et.al.,[2013] have presented a paper on title "Optimization Of Process Parameters In Turning Operation Of AISI-1016 Alloy Steels With CBN Using Taguchi Method And Anova" [Ref 7]This study investigates the parameters affecting the roughness of surfaces produced in the turning process for the material AISI-1016 Steel. Design of experiments have been conducted for the analysis of augment points consist of three levels for each of the

the influence of the turning parameters such as cutting speed, feed rate and depth of cut on the surface roughness. The results of the machining experiments for AISI-1016 have been used to characterize the main factors affecting surface roughness by the Analysis of Variance (ANOVA) method. The experiment was conducted using work piece material AISI-1016. The cutting tool used was Cubic Boron Nitrite. CBN is the second only to diamond in the hardness. The tests were carried for a length of 300mm in a PSGA141 Conventional lathe.AISI-1016 steel is used as a work piece material for carrying out the experimentation to optimize the surface roughness. The bars used are of 50mm diameter and 300mm length. From ANOVA Table and Response Table for Signal to noise ratios, based on the ranking it can be concluded that Speed has a greater influence on the Surface Roughness followed by Feed. Depth of Cut had least influence on Surface Roughness. Conclusion says that the feed rate is found to be the most significant parameter influencing the surface roughness in the turning process.

VI. MINI TAB RESULTS



Effect of Turning Parameters on Surface Roughness



S/N Ratio values for Surface Roughness

Fig: 5. MINI Tab Results: [Ref 7]

Philip Selvaraj.et.al., have presented a paper on title " Optimization Of Surface Roughness Of Aisi 304 Austenitic Stainless Steel In Dry Turning Operation Using Taguchi Design Method " [Ref 14] This paper presents the influence of cutting parameters like cutting speed, feed rate and depth of cut on the surface roughness of austenitic stainless steel during dry turning. A plan of experiments based on Taguchi's technique has been used to acquire the data. An orthogonal array, the signal to noise (S/N) ratio and the analysis of variance (ANOVA) are employed to investigate the cutting characteristics of AISI 304 austenitic stainless steel bars using TiC and TiCN coated tungsten carbide cutting tool. Finally the confirmation tests that have been carried out to compare the predicted values with the experimental values confirm its effectiveness in the analysis of surface roughness the cutting tests were made on medium duty Kirloskar Turn master-35 Lathe. A tool holder with a general specification PSBNR 2525M12 was used in this experiment. Carbide insert (Tagutec make) with a general specification of SNMG 120408 MT TT5100 coated with TiC and TiCN was used as the cutting tool insert. The experiments were conducted as per the orthogonal array and the surface roughness for various combinations of parameters was measured using TR-100 surface roughness tester. The measurement accuracy meets the ISO and DIN standards. The Piezoelectric stylus and cut-off (2.5 mm) was used for taking the surface roughness measurements. The experimentations were conducted without the application of cutting fluid (dry turning). The experiments were planned using Taguchi's orthogonal array in the design of experiments, which helps in reducing the number of experiments. The experiments were conducted according to a 3-level L9 orthogonal array. The cutting parameters identified were cutting speed, feed and depth of cut. The results of the cutting experiments were studied using the S/N and ANOVA analyses. Based on the results of the S/N and ANOVA analyses, optimal cutting parameters for surface roughness were obtained and verified. They have concluded that the Taguchi optimization method was applied to find the optimal process parameters, which minimizes the surface roughness during the dry turning of AISI 304 Austenitic Stainless Steel. A Taguchi orthogonal array, the signal to noise (S/N) ratio and the analysis of variance (ANOVA) were used for the optimization of cutting parameters. ANOVA results shows that feed rate, cutting speed and depth of cut affects the surface roughness by 51.84%, 41.99% and 1.66% respectively. A confirmation experiment was also conducted and verified the effectiveness of the Taguchi optimization method.

M. Kaladhar.et.al., [2011] have presented a paper on title "Application Of Taguchi Approach And Utility Concept In Solving The Multi-Objective Problem When Turning AISI 202 Austenitic Stainless Steel" [Ref 10] In this work, a multi-characteristics response optimization model based on Taguchi and Utility concept is used to optimize process parameters, such as speed, feed, depth of cut, and nose radius on multiple performance characteristics, namely, surface roughness (Ra) and material removal rate (MRR) during turning of AISI 202 austenitic stainless steel using a CVD coated cemented carbide tool. Taguchi's L8 orthogonal array (OA) is selected for experimental planning. The experimental result analysis showed that the combination of higher levels of cutting speed, depth of cut, and nose radius and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness. The ANOVA and F-tests are used to analyze the results. Further, the confirmation tests are conducted and the results are found to be within the confidence interval. Coated carbide tools have shown better performance when compared to the uncoated carbide tools [14]. For this reason, commonly available Chemical Vapor Deposition (CVD) of Ti (C, N) +Al2O3 coated cemented carbide inserts of 0.8 and 0.4mm as nose radius are used in the present experimental investigation. They have concluded that based on the ANOVA and F-test analysis, the most statistical significant and percent contribution of the process parameters for multiple performances are depth of cut, cutting speed, whereas feed and nose radius are less effective. In both the stages the interaction effect of process parameters is negligible. Table12 shows the results comparison. The validation experiment confirmed that the adequacy of law of additively is justified. It is also found that the proposed model based on Taguchi approach and Utility concept is simple, useful and provides an appropriate solution for multi-response optimization problems.

Alexandru STANIMIR.et.al., [2011] have presented a paper on title "Regressions Modelling Of Surface Roughness In Finish Turning Of Hardened 205cr115 Steel Using Factorial Design Methodology"[Ref 2] In this study, in order to find out a mathematical relation of polynomial second degree type which describe, in finish turning of hardened 205 Cr115 steel, the roughness parameter Ra dependence on cutting edge wear, depth of cut, feed rate and cutting speed, a factorial design methodology was used. The experimental tests were done according to a composed, central, four-factor five-level factorial program.

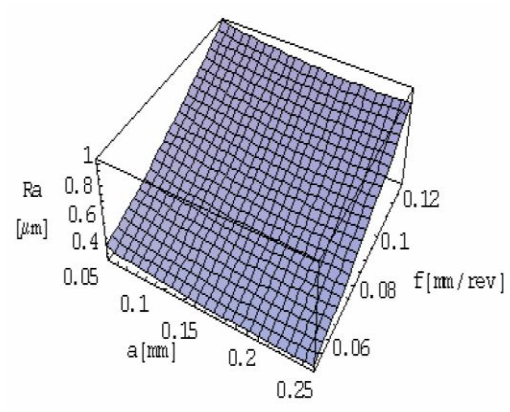


Fig: 6. Roughness surface variation with depth of cut and feed rate

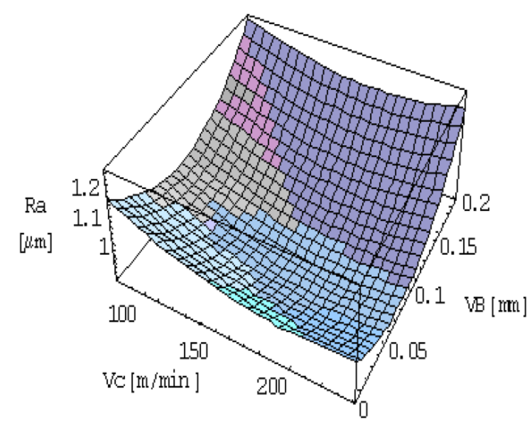


Fig: 7. Roughness surface variation with cutting speed and flank wear

The established second degree polynomial relationship for the Ra calculus as a function of the cutting conditions and the flank wear approximate in a satisfactory way the studied phenomena. The main influence on the surface roughness is exerting by the feed rate and flank wear. However, we have to notice that the cutting speed and the depth of cut influence indirectly the roughness surface because the increase of this parameters result in increased chemical wear of PCBN cutting tool. Also, the interactions of some parameters as feed rate and flank wear have a great influence on the roughness values of the machined surface.

Karin Kandananond [2009] have presented a paper on title " The Determination Of Empirical Model For Surface Roughness In Turning Process Using Design Of Experiment" [Ref 8] The purpose of this research is to determine the empirical model for surface roughness in a turning process. This process is performed in the final assembly department at a manufacturing company which supplies fluid dynamic bearing (FDB) spindle motors for hard disk drives (HDDs). The work pieces used were the sleeves of FDB motors made of ferritic stainless steel, grade AISI 12L14. A 2k factorial experiment was used to characterize the effects of machining factors, depth of cut, spindle speed and feed rate on the surface roughness of the sleeve. The results show that the surface roughness is minimized when the spindle speed and feed rate are set to the highest levels while the depth of cut is set to the lowest level. Even though the results from this research are process specific, the methodology deployed can be

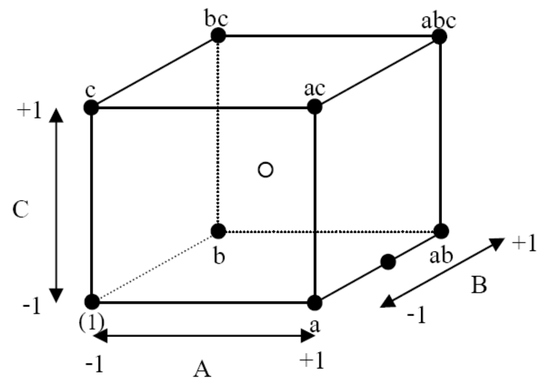


Fig.7 Geometric view of 23 factorial designs

readily applied to different turning processes. As a result, practitioners have guidelines for achieving the highest possible performance potential. The purpose of this research is to quantify the effect of depth of cut, spindle speed and feed rate on surface roughness of the FDB sleeve in HDD. The factorial design was utilized to obtain the best cutting condition which leads to the minimization of the surface roughness. The half normal plot and ANOVA indicate that the feed rate (C) is the most significant factor followed by spindle speed (B) and feed rate (A). Moreover, it is interesting to note that there are interactions among these three factors with the highest order term, ABC. Regarding the model validation, the regression model developed proves to be accuracy and has the capability to predict the value of response within the limits of factors investigated. After the optimal cutting condition is implemented, the surface roughness is significantly reduced about 8 percent. In addition to the factorial design experiment, the RSM and Taguchi design are proved to be potential methodologies to develop an empirical model and optimize the surface roughness of the metal work pieces.

Manish Kumar Yadav.et.al.,[2009] have presented a paper on title " Paper On A Comparative Study Of Surface Roughness In Multi Tool Turning With Single Tool Turning Through Factorial Design Of Experiments" [Ref 11] The paper focus on embryonic a few criterion on the basis of which a range of control parameters can be selected in order to attain the desired level of the surface finish on the material for development of techniques using factorial design of experiments for acquiring appropriate surface finish by multi tool machining. Throughout real machining process there are different factors which unfavorably impinge on the finish and therefore, the proper mythological concern of these factors appear to be most crucial for achieve the appropriate and preferred level of surface finish. The present paper will attempt to a comparative study of surface roughness in Multi tool turning with single tool turning through factorial design of experiments on AISI-1018.The conclusions made from their experimental investigation shows that Surface finish obtained at low cutting feeds is better than higher cutting feed and Higher depth of cut gives less surface finish with respect to at lower depth of Cut. There is fluctuation in surface roughness with cutting speed. Surface finish Obtained at higher cutting speed is better than lower cutting speed. Surface finish obtained at low shear plane area is better than higher shear Plane area.

6. Conclusions

On the basis of the experimental results and derived analysis, one can conclude that cutting speed has the most dominant effect on the observed surface roughness, followed by feed rate and depth of cut, whose influences on surface roughness are smaller. The surface roughness is continuously improved with the increase in cutting speed, but increase in feed rate and depth of cut causes a significant deterioration of surface roughness. The results obtained using the Taguchi optimization method revealed that cutting speed should be kept at the highest level, while both feed rate and depth of cut should be kept at the lowest level. The response graphs and ANOVA results show that the effects of two-way interactions of these cutting parameters are statistically insignificant, that is, can be neglected. As shown in this study, the Taguchi method provides a systematic, efficient and easy-to-use approach for the cutting process optimization.

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