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MULTI RESPONSE OPTIMIZATION IN TURNING OF AISI 8620 ALLOYSTEEL WITH PVD TOOL USING TAUGHI AND ANOVA AND GREY RELATION ANALYSISCOMPARITIVE STUDY

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Abstract:
The challenge of modern machining industries in mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less ware on the cutting tool, economy of machining in terms of cost saving and increase the performance of the product with reduce environmental impact. Surface roughness plays an important role in many areas and is a factor of great importance in the evaluation of machining accuracy and to have high productivity MRR plays a vital role. Optimization of multi criteria problems is a great need of manufactures to produce precision Parts with low cost.Optimization of multi performance characteristics is more complex compared to optimization of single performance characteristics. Various turning parameters, such as spindle speed, feed related depth of cut were considered. For the purpose of experimentation L9 orthogonal array is used as per Taguchi design of experiments. The work piece used is AISI 8620 alloy steel and PVD coated tool inserts used. Optimal machining parameters will be determined by the Grey relational grade obtained from the Grey relational analysis for multi performance characteristics (The surface roughness and the MRR). Finally a comparison is drawn between tools for better performance.

KeyWords:*AISI 8620 ALLOY STEEL,PVD coated tool,Surface roughness, Material removal rate(MRR), Grey Relation Analysis, ANOVA, CNC Lathe.*

1. INTRODUCTION:

The important goal in the modern industries is to manufacture the product with lower cost and with high quality in short span of time. There are two main practical problems that engineers face in a manufacturing process, the first is to determine the values of process parameters that will yield the desire product quality (meet technical specifications) and the second is to maximize manufacturing system performance using the available resources. The challenge of modern machining industry is mainly focused on achievement of high quality ,in terms of work piece dimensional accuracy, surface finish ,high production rate, less wear on the cutting tools ,economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact.

1.1 Turning Operation:

Turning is a form of machining or material removal process which is used to create rotational parts by cutting away unwanted material as shown in fig 1.1,the turning process requires a turning machine or a lathe ,work piece ,fixture and cutting tool .the work piece is a piece of re-shaped material that is secured to the fixture ,which itself is attached to the turning machine the cutting tool feeds into the rotating work and cuts away material in the form of small chips to create the desired shapeThe work piece used is AISI 8620 alloy steel and PVD coated tool inserts used. Optimal machining parameters will be determined by the Grey relational grade obtained from the Gray relational analysis for multi performance characteristics (The surface roughness and the MRR). Finally a comparison is drawn between tools for better performance.

2. LITERATURE REVIEW:

High speed machining is broadly defined as machining at cutting speeds much higher than those of conventional machining. The cutting speeds and feed rates change the process characteristics such as material removal rate, heat build-up, forces developed, surface finfish and material removal rate.

Krishnakan, Molit Bector et al [1] has focused "Application of Taguchi Method for optimizing Turning process by the effects of machining parameters". This paper reports on an optimization of turning process by the effects of machining parameters applying Taguchi Method.G.Akhyar, C.H.Che Haron et al [2] has focused "Application of Taguchi Method in the optimization of turning parameters for surface roughness". The quality of design can be improved by improving quality and productivity in company-wide activities Taguchi's Parameter design is an important tool for robust design which offers a simple and systematic approach to optimize the process parameters.

M.V.R.D.Prasad, G.RangaJanardhana et al [3] has focused "Experimental Investigation to study the influence of process parameters in dry machining". This paper influences the process parameters like speed, feed and depth of cut in dry machining are Studied as simple roughness as an output response variable. The concept of Design of Experiments (DOE) is used for necessary experimentation.AdeelH.Suhail, N.Ismail et al [4] has focused "Optimization of cutting parameters based on surface roughness and assistance of work piece surface temperature in Turning Process". The focus of the paper is to optimize the cutting parameters using two performance measures – work piece surface temperature and surface roughness. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation.

M.Kaladhar, K.VenkataSubbaiah et al [5] this paper deals with the optimization of machining parameters in turning of AISI 202 austenitic stainless steel using CVD coated cemented carbide tools. During the experiment, process parameters such as speed, feed, depth of cut and nose radius are used to explore their effect on the surface roughness of the work piece. The experiments have been conducted using full factorial design in the Design of Experiments (DOE) on Computer Numerical Controller (CNC) lathe. Further, the analysis of variance (ANOVA) was used to analyze the influence of process parameters and their interactive during machining. LB.Abhang and M.Hameedullah [6] has focused "Optimal machining parameters for achieving the desired surface roughness in Turning of Steel", the prediction of optimal manufacturing conditions for good surface finish and dimensional accuracy plays a very important role in process planning. In this paper experimental investigations have been conducted to determine the effect of tool geometry (effective tool nose radius) and metal cutting condition (cutting speed, feed rate and depth of cut) on surface finish during turning of En-31 Steel. The surface roughness is prediction model has been optimized to obtain the surfaceroughness values by using LINGO solver programs. The lingo solver program is global optimization software which gives minimum values of surface roughness and their respective optimal conditions.

3. OBJECTIVES OF THE PRESENT WORK:

1.To conduct experiments in dry turning process using Taguchi design of Experiments.
2.To perform statistical analysis using ANOVA technique.
3.To determine the optimum machining parameters using Grey relation analysis algorithms.
4.To identify the best optimization method in finding the optimum machining parameters based on the minimum surface roughness and maximum material removal rate.

4. EXPERIMENTAL PROCEDURE AND METHODOLOGY:

An engine lathe was used for conducting the experiments. AISI 8620 alloy steel was used as the work material and PVD coated cemented carbide was used as the cutting tool. The average surface roughness on the work piece was measured using Mitotoyo SJ-201P surface roughness measuring instrument. The experimentation of this work was based on Taguchi's design of experiments have to be carried out when the number of the process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. In this work, three cutting parameters namely, spindle speed, depth of cut and feed rate were considered for experimentation, accordingly there are three input parameters and for each parameter three levels were assumed. For three factors, three level experiments, Taguchi had specified L9 orthogonal array experimentation was recorded and further analyzed. Table1 shows the parameters and their levels considered for experiment. The tests were carried for a work piece bar of 40mm Diameter and 300mm length in a CNC Lathe.

4.1 The Process Parameters and Their Levels:

Cutting Parameters	Level 1	Level 2	Level 3
Spindle Speed(rpm)	450	580	740
Feed(mm/rev)	0.05	0.07	0.09
Depth of cut(mm)	0.10	0.20	0.25

2 Design of experiments [DOE]

A design of experiment is a structured, organized method for determining the relationship between factors affecting a process and the output of that process

Design of experiment techniques

1) Factorial designs
2) Response surface methodology
3) Mixture design
4) Taguchi design

4.2Taguchi Approach:

The objective of the robust design is to find the controllable process parameters setting for which Noise or variation as a minimal effect on the product or process functional characteristics. It is to be noted that the aim is not to find the parameter setting for the uncontrollable noise variables but the controllable design variables. To attain this objective, the control parameter also known as inner array variables, are systematically varied as stipulated by the inner orthogonal array.

4.3 Analysis Of Variance (Anova):

Analysis of variance (ANOVA) is a statistical method of determining the existence of several While the aim of ANOVA is to detect the difference among several populations means the technique requires the analysis of different forms of variance associated with random samples under the study hence it is called ANOVA.

The original idea of ANOVA was devolved by the English statistician sir Ronald A fisher during the first part of this century. most of the early work in this area deal with the agricultural experiments where crops were given different treatments, such as being grown using different kinds of fertilizes. The researchers wanted to determine whether all treatments under study were equally effective or whether some treatments were better than others.

4.4 Grey Relation Analysis:

In the procedure of GRA, the experimental result of surface roughness and material removal rate are normalized at first in the rangebetween zeros to one due to different measurementunits. This data pre-processing step is termed as ‘greyrelational generating’. Based on the normalizedexperimental data, grey relational coefficient iscalculated to correlate the desired and actualexperimental data using equations. The overall GreyRelational Grade (GRG) is determined by averagingthe grey relational coefficient corresponding to selected responses using equation. This approach converts amultiple response process optimization problem into asingle response optimization by calculating overall greyrelational grade. The normalized experimental results can be expressed as follows.

5.0STEPS IN SOLVING GREY RELATION ANALYSIS EQUATIONS:

In the grey relational analysis, experimental results were first normalized and then the grey relational coefficient was calculated from the normalized experimental data to express the relationship between the desired and actual experimental data. Then, the range is too large, or when the directions of the target in the sequences are different.

In the study, a linear data pre-processing method for the yarn tenacity is the “higher-the-better” and is expressed as:

$$x_i(k) = \frac{y_i(k) + min yi(k)}{max y_i(k) - min y_i(k)} \qquad \text{.........................} (1)$$

Which is the lower-the-better can be expressed as:

$$x_i(k) = \frac{max y_i(k) - y_i(k)}{max y_i(k) - min y_i(k)} \qquad \text{..................} (2)$$

Where x_i (k) is the value after the grey relational generation, min y_i (k) is the smallest value of yi (k) for the k^{th} response, and max y_i(k) is the largest value of y_i(k) for the k^{th} response.

An ideal sequence is x_0(k) (k=1, 2, 3) for three responses. The definition of the grey relational grade in the grey relational analysis is to show the relational degree between the twenty-seven sequences ($x_0(k)$ and xi(k), i=1, 2, . . . , 9; k=1, 2, 3). The grey relational coefficient ξi(k) can be calculated as:

$$\xi_i(k) = \frac{\Delta_{min} + \varsigma\Delta_{max}}{\Delta_{0i}(k) + \varsigma\Delta_{max}} \quad \text{...............(3)}$$

Where ? $_{0i}$ (K) = | | x_0 (k) – x_0 (k) | | is the difference of Data pre-processing of each performance characteristic. Distinguishing coefficient (0_1); ? min, small value of absolute value between $x_0(k)$ and $x_i(k)$; ? = 0i; and ? max, largest value of ? $_{0i}$.. After averaging the grey relational coefficients, the grey relational grade ?i can be obtained as:

$$\lambda^{i} = \frac{n}{1}\sum_{n}^{K=1} \xi^{i}(K) \quad \text{..................(4)}$$

Where n is the number of process responses. The higher value of the grey relational grade represents the stronger relational degree between the reference sequence $x_0(k)$ and the given sequence x_i (k). As mentioned before, the reference sequence $x_0(k)$ is the best process response in the experimental layout. The higher value of the grey relational grade means that the corresponding cutting parameter is closer to optimal. In other words, optimization of the complicated multiple process responses is converted into optimization of a single grey relational grade.

5.1Results and Discussion:

Manufacturing companies are trying to drastically reduce coolant consumption and, if possible, eliminate it altogether. Machining with non-geometrically defined cutting edges such as grinding and honing requires coolant, and potential of dry operation is limited. Machining using geometrically defined cutting edges such as, milling, turning, and boring has been the good candidate for dry operation. For any production facility, it is important to use their machines at an optimum level. Here, optimality is defined in terms of an objective to minimize surface roughness and material removal rate (i.e. minimize production costs or maximize production rate). The analysis has several stages.

5.2 Evaluation of Optimal Setting Physical Vapour Deposition:

Experimental data of all L9 OA experimental observations AISI 8620 WITH PVD TOOL have been furnished in Table 4.14. For surface quality characteristics Lower-the-Better (LB) and material removal rate Higher-the-better (HB) criterion has been selected

S.NO	Spindle Speed	Feed	Depth of cut	Surface roughness(Ra)	Material Removal Rate(MRR)
1	450	0.05	0.10	1.9125	101.890
2	450	0.07	0.20	1.543	279.851
3	450	0.09	0.25	1.378	401.309
4	580	0.05	0.20	1.425	233.966
5	580	0.07	0.25	1.335	407.963
6	580	0.09	0.10	1.292	259.634
7	740	0.05	0.25	1.434	368.372
8	740	0.07	0.10	1.283	267.527
9	740	0.09	0.20	1.188	538.604

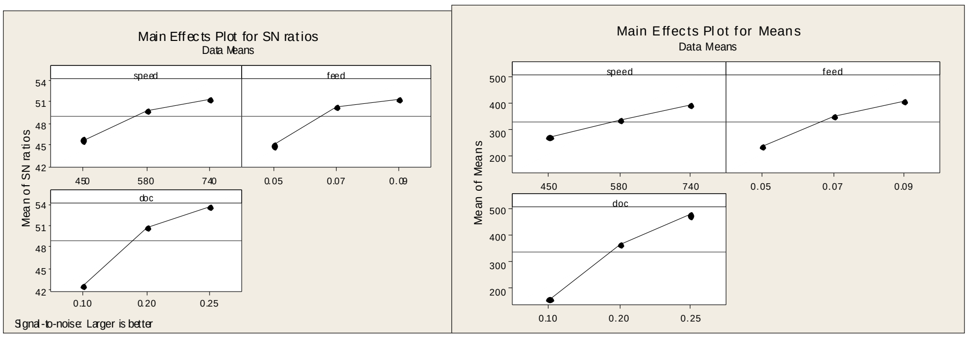
5.3Taguchi Analysis and Discussion of Results:

The experiments were conducted by using the parametric approach of the Taguchi's method.

The effect of individual Turning process parameters, on the selected quality characteristics – material removal rate, has been discussed in this section. The average value and S/N ratio of the response characteristics for each variable at different levels were calculated from experimental data. The main effects of process variables both for raw data and S/N data were plotted. The response curves (main effects) are used for examining the parametric effects on the response characteristics. The analysis of variance (ANOVA) of raw data is carried out to identify the significant variables and to quantify their effects on the response characteristics. The most favourable values (optimal settings) of process variables in terms of mean response characteristics are established by analysing the response curves and the ANOVA tables.

1. Selection of optimal levels surface roughness (Ra):

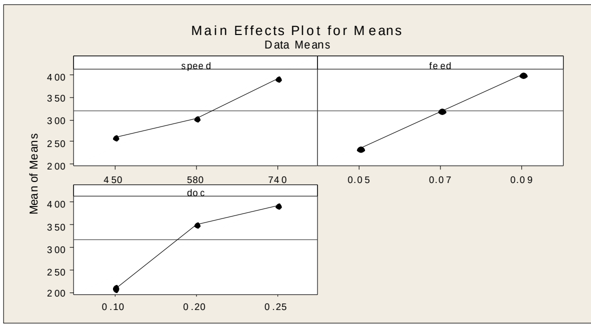
In order to study the significance of the process variables towards surface roughness, analysis of variance (ANOVA) was performed. It was found that depth of cut is to be non-significant process parameters for surface roughness.

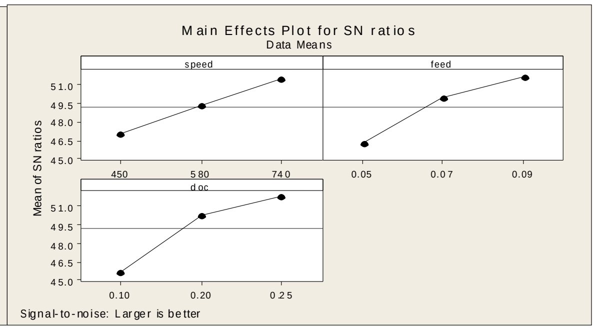


The ranks and the delta values show that feed have the greatest effect on material removal rate and is followed by speed depth of cut in that order. As surface roughness is the “higher the better? type quality characteristic, it can be seen from Graph 4.4 that the third level of speed (A3), third level of feed (B3), third level of depth of cut (C2), provide maximum value of surface roughness. The S/N data analysis (Figure 4.3) also suggests the same levels of the variables (A3, B3, C2) as the best levels for maximum MRR in Dry turning

2.Selection of optimal levels Material removal rate (MRR):

In order to study the significance of the process variables towards material removal rate, analysis of variance (ANOVA) was performed. It was found that depth of cut is to be non-significant process parameters for material removal rate. Non-significant parameters were pooled and the pooled versions of ANOVA for material removal rate are given in Tables 4.14 respectively. From these tables, it is clear that feed and speed significantly affect both the mean and the variation in the MRR values.





The ranks and the delta values show that feed have the greatest effect on material removal rate and is followed by speed depth of cut in that order. As MRR is the “higher the better? type quality characteristic, it can be seen from Graph 4.4 that the third level of speed (A3), third level of feed (B3),third level of depth of cut (C3), provide maximum value of material removal rate. The S/N data analysis (Figure 4.3) also suggests the same levels of the variables (A3, B3, C3) as the best levels for maximum MRR in Dry turningEvaluation of grey relational grade.

S.NO	Spindle Speed	Feed	Depth of cut	GRG	RANK
1	450	0.05	0.10	0.3333	9
2	450	0.07	0.20	0.4814	8
3	450	0.09	0.25	0.6349	3
4	580	0.05	0.20	0.5228	7
5	580	0.07	0.25	0.6685	2
6	580	0.09	0.10	0.6081	5
7	740	0.05	0.25	0.5788	6
8	740	0.07	0.10	0.6191	4
9	740	0.09	0.20	1.0000	1

Calculation of Average relational grade

FACTORS			
Level	**Spindle speed**	**Feed**	**Doc**
1	0.4832	0.4783	0.5202
2	0.5998	0.5897	0.6681
3	0.7326	0.7476	0.6274
Maximum	0.2494	0.2693	0.1479
Rank	2	1	3

Optimum ConditionSpindle speed = 740 rp
Feed = 0.09 mm/rev
Depth of cut = 0.20 mm

5.4analysis of Variance (Anova):

SOURCE	DOF	SUM OF SQUARES	MEAN OF SQUARES	F RATIO	% OF CONTRIBUTION
Speed(S)	2	0.1693	0.0846	7.2618	47.529
Feed(F)	2	0.1369	0.0684	5.8755	38.433
DOC(D)	2	0.0267	0.0133	1.1459	7.4957
Error	2	0.0233	0.0116		6.5412
TOTAL	8				100

5.5Anova based on Material removal rate for PVD Tool:

SOURCE	DOF	SUM OF SQUARES	MEAN OF SQUARES	F RATIO	% OF CONTRIBUTION
Speed(S)	2	26864.11	13432.05	5.895	21.084
Feed(F)	2	40892.77	20446.38	8.974	32.095
DOC(D)	2	55097.46	27548.73	12.091	43.243
Error	2	4556.63			3.576
TOTAL	8				100

5.6 Anova based on grey relation grade for PVD Tool:

SOURCE	DOF	SUM OF SQUARES	MEAN OF SQUARES	F RATIO	% OF CONTRIBUTION
Speed(S)	2	0.0939	0.04695	7.5725	36.39
Feed(F)	2	0.1162	0.0588	9.3709	45.03
DOC(D)	2	0.0355	0.01775	2.8629	13.75
Error	2	0.0124	0.0062		4.806
TOTAL	8				100

The experimental results were analyzed with the analysis of variance (ANOVA), which is used to investigate which design parameters significantly affect the quality characteristic. This is too accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the design parameters and the error.

6.0 CONCLUSION:

The process of cutting requires the determination of the speed, feed, and depth of cut. These factors affect the material removal rate and surface quality and also several other performance characteristics and therefore play important roles in the economics of the machining process. The foregoing study deals with optimization of multiple surface roughness material removal rate characteristics of AISI 8620 Alloy Steels obtained in straight turning operation in search of an optimal parametric combination (favourable process environment). The study proposes an integrated optimization approach using Grey Relational Grade Analysis (GRA) in combination with Taguchi's robust design methodology.

	PVD		
Responses/Factors	**Ra**	**MRR**	**GRG**
Spindle speed	47.529	21.084	36.39
Feed	38.433	32.095	45.038
Depth of cut	7.4957	43.243	13.75
Residual Error	6.5412	3.576	4.806

7.0 REFERANCES:

[1]Krishnakan, Molit Bector et al has focused "Application of Taguchi Method for optimizing Turning process by the effects of machining parameters".
[2]G.Akhyar, C.H.Che Haron et al has focused "Application of Taguchi Method in the optimization of turning parameters for surface roughness".
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