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Parametric Optimization during CNC Turning of Aisi 8620 Alloy Steel Using Rsm

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Abstract: *Turning process is one of the method to remove material mainly from cylindrical work materials. The process of turning is influenced by many factors such as the cutting speed, feed rate, depth of cut, nose radius, hardness of tool, cutting conditions etc. The finished product with desired quality targets such as surface roughness and cutting forces developed which are Responses of these input parameters. Properties such as wear resistance, fatigue strength, coefficient of friction, lubrication, wear rate and corrosion resistance of the machined parts are greatly influenced by surface roughness. In many manufacturing processes engineering judgment is still relied upon to optimize the response. Hence The present work demonstrates the optimization process of surface roughness of Computer numerical control lathe machine (CNC) by using Response Surface Methodology (RSM) By using 3 level factorial design in design expert 7.1, the experimental run setup were designed . The process has been successfully modeled by using response surface methodology (RSM) in minitab 17and model adequacy checking is also carried out. the response models have been validated with analysis of variance and response optimizer function.* ***.*** *The objective of this paper is to evaluate the optimal setting of cutting parameters such as cutting Speed, depth of cut, feed of the tool to have a minimum surface roughness. In this experiment the work material of AISI 8620 alloy steel was turned by using CVD(chemical vapor deposit) coated tool insert.*
Keywords - *AISI 8620 Alloy steel, CVD tool, RSM, Surface roughness.*

I. 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. Today metal cutting process places major portion of all manufacturing processes .Within these metal cutting processes the turning operation is the most fundamental metal removal operation in the manufacturing industry. Increase in productivity and the quality of the machined parts are the main challenges of metal based industry. There has been increased interest in monitoring all aspects of machining process. Surface finish is an important parameter in manufacturing engineering it is a characteristic that could influence the performance of mechanical parts and the production costs.

Surface roughness has become the most significant technical requirement and is an index of product quality in order to improve the tribiological properties, fatigue strength, corrosion resistance and aesthetic appeal of the product reasonably good surface finish is required. Now a day's manufacturing industries specially concerned to dimensional accuracy and surface finish In order to obtain better surface finish proper setting of cutting parameters is crucial before the process takes place factors such as spindle speed ,feed rate, depth of cut that control the cutting operation can be set up in advance .However, the factors such as geometry of cutting tool ,tool wear and joint material properties of both tool and work pieces are uncontrollable .one should develop techniques and evaluate the surface roughness of the product before machining in order to determine the required machining parameters such as feed rate, spindle speed, depth of cut for attaining desired surface roughness and product quality.

II. Literature Survey

Author presents a new approach for multi response optimization during turning process. Using AISI 8620 alloy steel that satisfies the chemical composition and required hardness, by machining of CNC turning centre using chemical vapor deposition tool (CVD) approached in this process [1]. Speed of the spindle, feed, depth of cut are three turning parameters used for computing the optimum surface roughness value.[1] [6] .

The approach is based on grey relation analysis and desirability function analysis through this study. The AISI 8620 alloy steel and CVD coated tool combination resulting in the better optimum values in the surface roughness. [1] [3].

R.K.Suresh, P.Venkataramaiah and G.Krishnaiah [2] envisages an experimental investigation on turning of AISI 8620 alloy steel using PVD coated cemented carbide CNMG insert. Nine experimental runs based on Taguchi factorial design were performed to find out optimal cutting level condition. The main focus of present experimentation is to optimize the process parameters namely spindle speed, feed and depth of cut for desired response characteristics i.e. surface roughness, VMRR and interface temperature. To study the performance characteristics in this work orthogonal array (OA), analysis of means (ANOM) and analysis of variance(ANOVA) were employed. The experimental results showed that the spindle speed affects more on surface roughness, feed affects more on VMRR and feed affects more on interface temperature. Confirmation tests also been performed to predict and verify the adequacy of models for determining optimal values of response characteristics.

The paper states that the Surface roughness and metal removal rate are significantly improved by cutting factors. The results are concluded by desirable function analysis (DFA). The DFA is used to change the multi response characteristic the work were accomplished by CNC lathe. [3].

The higher spindle speed, The higher feed, the higher depth of cut are optimum conditions of the process parameters for turning AISI 8620 alloy steel. Study of investigation of [4].states that cutting speed contributes more percentile of surface roughness while comparing feed and depth of cut [5]. Author presents result In an optimal value of surface roughness by using AI 6351 – T6. alloy with uncoated carbide tool inserts. Regression techniques were used to predict the surface roughness value and also taguchi techniques was used in this process. [5]. Environmental parameters are included in this investigation which are dry cutting and wet cutting. S-N ratios (signal to noise) states the surface roughness in the graphical point of view.

The residual plots are helps in resulting the graphical values, that helps in finding the easy solution for roughness average (Ra). the testing investigation highlights that the anova and F-test revealed that the feed is dominant parameter followed by speed for surface roughness [6].

The surface roughness resulting in tool geometry, cutting conditions etc & the optimal valve of surface roughness occurs in highest speed [7].

Author (Ranganathan) states the RSM model of cnc turning of aluminium work material by CVD. Coated tool were the results states that feed is the major factor were surface roughness increased by the improving of feed. Mini tab software helps in computing RSM model and surface and contour plots helps in predicting the significant factor.[8].

Using CNC lathe analyzing of surface finishing of copper work piece material with coated ceramic tool. Using parameters such as speed, feed, doc. The process uses the taguchi based approach for resulting .the process includes MINI TAB 15. Software. Through this study the residual plots of surface roughness states that least depth of cut value was significant effect on the process [9].

Surface finishing was an wide index of product quality in turning. therefore there is a need to develop a methodology to determine the optimal machining parameters such as speed, feed and depth of cut for obtaining a desired surface roughness and product quality. Author states the best optimal value for the set of parameters by RSM by using Central composite design model in design experts software.[10]

From the literature survey, it is evident that no work has been reported on AISI 8620 alloy steel work with combination of CVD coated tool with machining of CNC machine. Also little work has been reported on RSM method on various machining operations. Hence the experimentation is done on above said combination of work piece and tool and optimization by response surface methodology .

III. EXPERIMENTAL DETAILS

WORK PIECE MATERIAL

The AISI 8620 alloy steel work piece material was selected for investigation. The work piece material is a cylindrical rod with dimensions of 30mm x 70mm was taken and it was machined in CNC turning center. The chemical composition of the AISI 8620 alloy steel is as follows:

Elements	C	Si	Mn	Cr	P	S	Ni	M	Al	B
%	2.179	0.511	0.511	12.634	0.027	0.021	0.050	0.178	0.042	0.065

Table 1: Chemical Composition Of AISI 8620 alloy Steel

Fig 1 work material (AISI 8620 alloy steel)

MACHINING PROCESS

The Turning Operation was performed on MICROMATIC (ACE-Designers) model CNC lathe (fig 2).

Fig 2 MICROMATIC (ACE-Designers) model CNC lathe

MEASUREMENT OF SURFACE ROUGHNESS

A surface profile measurement is made with a profilometer that but more generally can be contact (typically a diamond stylus) or optical (e.g. a white light interferometer). The roughness average, Ra was measured in perpendicular direction to the cutting direction using a Surface Roughness tester. In this investigation the Surface roughness values are obtained from SV-C4500 surface roughness measuring instrument for each run.

Fig 3 SV- C4500 Surface roughness measuring device.

IV. DESIGN OF EXPERIMENTS

RESPONSE SURFACE DESIGN

An important face of RSM is to design a plan of experiments after identification of problem several designs such as fractional factorial design, full factorial design central composite design, boxbehnken, D optimal,
V optimal design, A optimal designs and G optimal designs are available in the literature. Each design is useful for a particular practical problem depending on the user requirements and user constraints. Response surface methods are used to examine the relationship between a response variable and a set of experimental variables of factors. These methods are often employed that optimize the responses. By conducting experiments and applying regression analysis, a model of response to some independent variables can be obtained. In RSM it is possible to represent independent process parameter in quantitative form. In This work 3- level factorial design used to conduct experiments. And analysis is carried out by means of Response surface methodology in MINITAB 17 software.

In design optimization using RSM, the first task is to determine the optimization model, such as the identification of the interested system measures and the selection of the factors that influence the system measures significantly. To do this, an understanding of the physical meaning of the problem and some experience are both useful. After this, the important issues are the design of experiments and to improve the fitting accuracy of the response surface models. DOE techniques are employed before, during, and after the regression analysis to evaluate the accuracy of the model.RSM also quantifies relationships among one or more measured responses and the vital input factors.

RSM can be used in the following ways :

1) To determine the factor levels that will simultaneously satisfy a set of desired specifications,
2) To determine the optimum combination of factors that yields a desired response and describes the response near the optimum,
3) To determine how a specific response is affected by changes in the level of the factors over the Specified levels of interest,
4) To achieve a quantitative understanding of the system behavior over the region tested,
5) To predict product properties throughout the region, even for a factor combinations not actually run,
6) To find the conditions necessary for process stability (insensitive spot).

3-LEVEL FACTORIAL DESIGN

In Design-Expert 7.1, the proposed designs was located under the Miscellaneous design option. Full factorial 3-level designs are available for up to 4 factors. The number of experiments will be 3^k plus some replicates of the center point. Since there are only 3 levels for each factor, the appropriate model is the quadratic model. For more than 2 factors these designs force you to run many more experiments than are needed to estimate the coefficients in a quadratic model. A Box-Behnken design also requires only three-levels, and is a more efficient alternative to the full three-level factorial.

Process parameter	units	levels		
		-1	0	1
speed	m/min	50	75	100
feed	mm/rev	0.02	0.04	0.06
Depth of cut	mm	0.1	0.2	0.3

Table 2 : Parameters and their levels for experiment

METHODOLOGY

After identification of significant process control variables the measurement of responses were found by the experiments. The corresponding data were analyzed in Response surface methodology in MINITAB V17 software. Results and regression equation were calculated and corresponding plots are generated. In otherwise among the several process variables involved in finished turning operation the significant variables found out based on the pilot experiments and the literature survey are considered in the proposed work as the inclusion of in significant variables excessively increases the computational complexity of the models. In view of the costly process and the material design of experiments are used which reduces the number of experiments needed to carry out the analysis with MINITAB 17 software for accuracy and precession.

S.no	Run oder	Speed	Feed	Depth of cut	Ra
1	1	50	0.02	0.1	0.456
2	10	75	0.02	0.1	0.500
3	19	100	0.02	0.1	0.56
4	2	50	0.02	0.2	0.54
5	11	75	0.02	0.2	0.53
6	20	100	0.02	0.2	1.01
7	3	50	0.02	0.3	0.594
8	12	75	0.02	0.3	0.74
9	21	100	0.02	0.3	1.32
10	4	50	0.04	0.1	0.531
11	13	75	0.04	0.1	0.340
12	22	100	0.04	0.1	0.590
13	5	50	0.04	0.2	0.680
14	14	75	0.04	0.2	0.517
15	23	100	0.04	0.2	0.651
16	6	50	0.04	0.3	0.730
17	15	75	0.04	0.3	0.500
18	24	100	0.04	0.3	0.860
19	7	50	0.06	0.1	0.711
20	16	75	0.06	0.1	0.400
21	25	100	0.06	0.1	0.340
22	8	50	0.06	0.2	0.464
23	17	75	0.06	0.2	0.450
24	26	100	0.06	0.2	0.476
25	9	50	0.06	0.3	0.610
26	18	75	0.06	0.3	0.800
27	27	100	0.06	0.3	0.624

Table 3: Experimental observation Details

V. Result And Discussion

Using Minitab 17 software, the response surface method were carried out. The Response surface methods which is used to examine the relationship between a response variable and a set of experimental variables of factors. These methods are often employed that optimize the responses. For the proposed method ANOVA (Analysis of variance) are calculated and tabulated. Also respective regression equation was found for the design. The smaller the better phenomenon is chosen for surface roughness because surface quality will be high when the surface roughness values will be small. Using response optimizer the above criteria were satisfied.

ANALYSIS OF VARIANCE (ANOVA)

Source	DF	Adj SS	Adj MS	F- value	p-value
Model	9	0.91999	0.102221	8.08	0.001*
Linear	3	0.47815	0.159384	12.60	0.001
Speed	1	0.06783	0.067835	5.36	0.033
Feed	1	0.10351	0.103513	8.18	0.011
Depth of cut	1	0.30681	0.306806	24.25	0.001
square	3	0.09656	0.032186	2.54	0.090
Speed*Speed	1	0.08825	0.088250	6.98	0.017
Feed*Feed	1	0.00186	0.001861	0.15	0.706
Depth of cut *Depth of cut	1	0.00645	0.006446	0.51	0.285
2-Way Interaction	3	0.34528	0.115093	9.10	0.001
Speed *Feed	1	0.22277	0.222769	17.61	0.001
Speed *Depth of cut	1	0.09684	0.096840	7.66	0.013
Feed *Depth of cut	1	0.02567	0.025669	2.03	0.172
Error	17	0.21505	0.012650		
Total	26	1.000			

Table 4: ANOVA TABLE

An ANOVA table is commonly used to summarize the tests performed. it is evident that speed ,feed and doc are significant at 95% confidence level thus affects mean value and varaiation around the mean value of the Ra.the feed is the most significant factor in the anova for and thus affects the mean value of Ra followed by Depth of cut.

MODEL SUMMARY

S	R-sq	R-sq(adj)	R-sq(pred)
0.112473	81.05%	71.02%	52.44%

Table 5: Model Summary

RESIDUAL AND INTERACTION PLOT FOR Ra

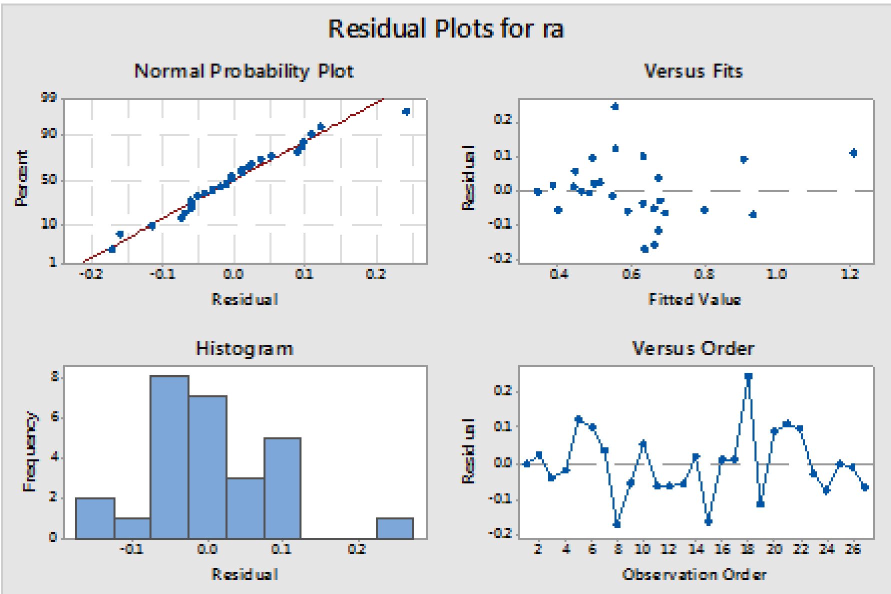

Fig 4: Residual Plots for Ra

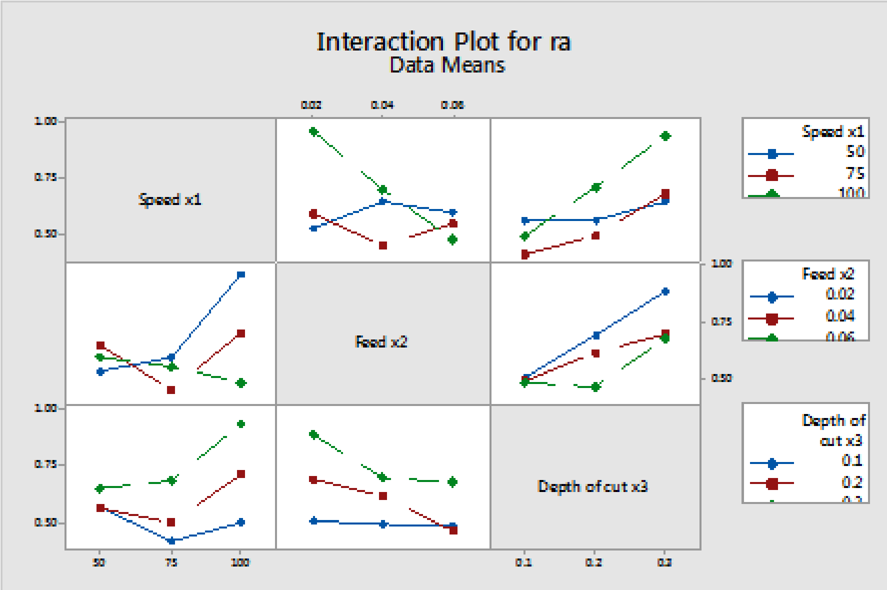

Fig 5 : Interaction Plots for Ra

The normal probability plots of the residuals for Ra reveals that the residuals generally fall on a straight line implying that errors are distributed normally also fig 4 showing residuals versus order for Ra reveals that they have no obvious pattern and unusual structure were found. This implies that the models proposed are adequate and there is no reason to suspect any violation of the independent or constant varaiation assumption. Fig 5 shows the interaction plots of Ra for three parameters

SURFACE AND CONTOUR PLOT FOR Ra

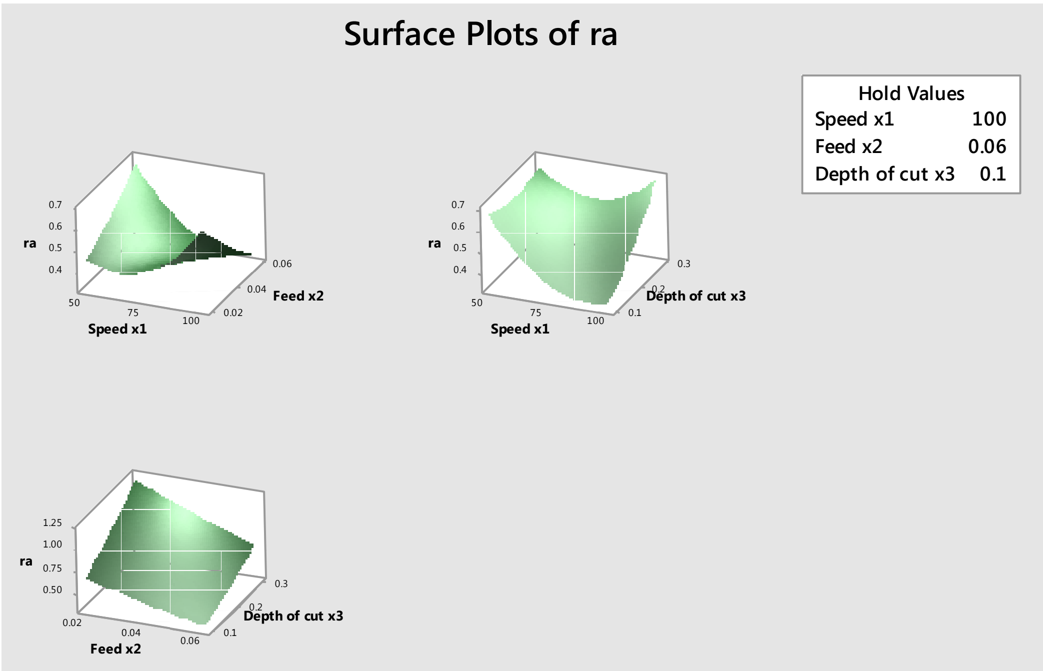

Fig 6: 3D surface plot for Ra

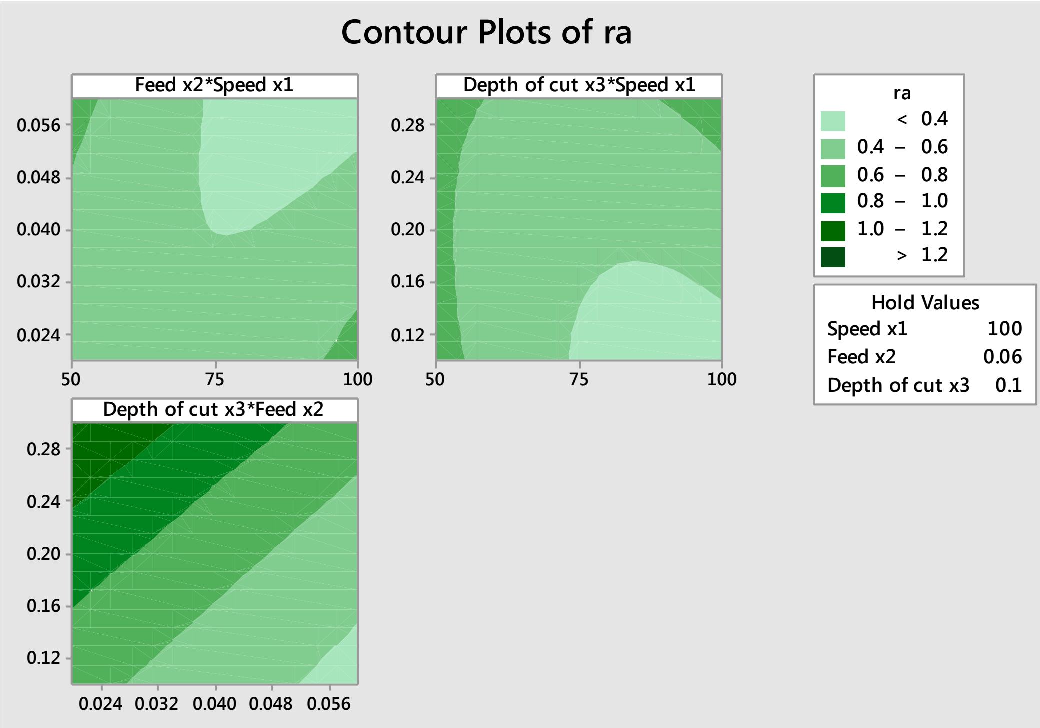

Fig 7 : contour plot for Ra.

The entire 3d surface graph for surface roughness has curvilinear profile in accordance to the model fitted.fig 6 shows 3d surface plot graph of the effect of speed, feed and depth of cut on the surface roughness. it has a curve linear shape according to the model fitted. The contour plot and surface plot are shown in the fig 7 represents the surface roughness increase with increasing feed followed by depth of cut.

PREDICTION OF OPTIMAL SOLUTION BY RESPONSE OPTIMIZER

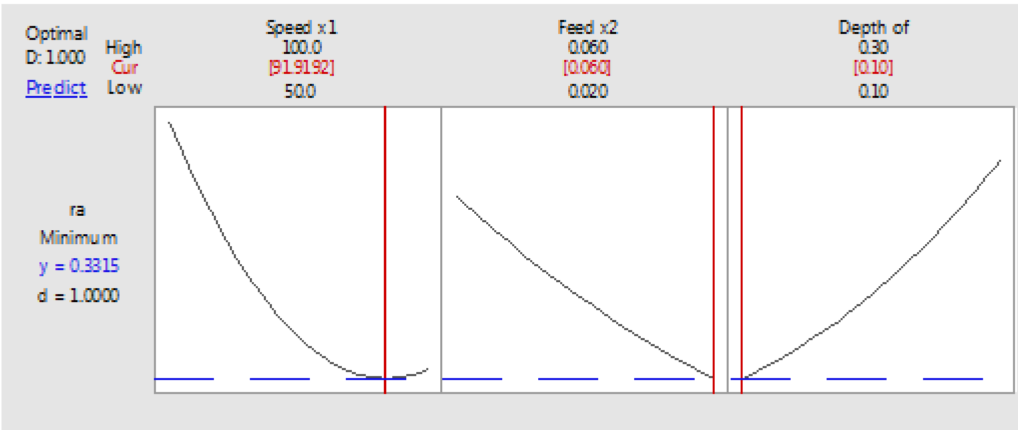

Fig 8 : Response Optimizer Plot.

The influence of each control factor can be clearly presented with response graphs (Fig 8). These figures reveal the level to be chosen for the ideal turning parameters. response optimization helps in identifying the combination of input variable settings that jointly optimize a single response or a set of responses. Joint optimization must satisfy the requirements for all the responses in the set, which is measured by the composite desirability. Minitab calculates an optimal solution and draws a plot. The optimal solution serves as the starting point for the plot. This optimization plot allows to interactively change the input variable settings to perform sensitivity analyses and possibly improve upon the initial solution.

For surface roughness (Ra). The optimal parameter setting combination for AISI 8620 alloy steel is shown in table 6

Control factors	Speed	Feed	Doc
Surface roughness (Ra) µm	100	0.06	0.1

Table 6. Optimized table obtained for AISI 8620 alloy steel

ANALYSIS OF REGRESSION FOR PREDICTION OF SURFACE ROUGHNESS (SR):

Regression equation is the best fit equation between the input factors output response. That is to say the relationship between surface roughness and machining independent variables In order to facilitate the determination of constants and parameters the mathematical model of Experiment for the response (Surface Roughness) are shown below.
Ra=1.033-0.0229speed+17.7feed-1.78Doc+0.000194speed*speed+44Feed*feed+3.28Doc
0.2725Speed*feed+0.0359speed*doc-23.1 Feed*doc.

VI. Conclusion

1. The ANOVA shows that the percentage contribution of Feed is the dominant parameter followed by depth of cut for surface roughness.
2. From table of model summary R^2 for Ra is found to be 0.8105. This shows that the second-order model can explain the variation in Surface roughness up to the extent of 81.05%. similarly, adjusted R^2 is found as 71.02% Predicted R^2 value is 52.44%.
3. The surface and contour plots reveals the parameter increase in feed increases the surface roughness. Hence The input parameter Feed, has a major effect on surface roughness
4. The optimized parameters for minimum surface roughness are speed (100 rpm), Feed (0.06 mm/rev), Depth of cut (0.1mm).
5. The optimized minimum surface roughness is 0.340µm.

The present work states the one type of CVD coated tool which is analyzed by the RSM method. Future plan is there to accomplish the comparison of different style of inserts and all by adding the parameter level more than present work.

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