Optimization of Turning Parameter of Composite Materials Using Response Surface Method in Minitab

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ABSTRACT

This paper represents the optimization method utilized in machining process for figuring out the most advantageous manner design. Typically, the technique layout parameters in machining procedures are noticeably few turning parameters inclusive of reducing velocity, feed and depth. The optimization of speed, feed depth of cut is very tough because of several other elements associated with processing situations and form complexities like surface Roughness, material removal rate (MRR) that are based Parameters. On this task a new fabric glass fibre composite is introduced through which could lessen costing of manufacturing and time and additionally it will boom the technique of productiveness. Composite substances have strength, stiffness, light weight, which gives the large scope to engineering and technology. The proposed research work targets to analyze turning parameters of composite material. The machining parameters are very important in manufacturing industries. The present research work is optimized surface roughness of composite material specifically in turning procedure with the aid of changing parameter including intensity of reduce, slicing velocity and feed price and additionally expect the mechanical houses of composite material. The RSM optimization is important because it evaluates the effects of multiple factors and their interactions on one or more responsive variables. It is observed that the material removal rate increases and surface roughness decreases as per the increase of Spindle speed and feed rate.

Keywords: Response surface method, Composite material, Optimization, Machining parameter, Mechanical property

1 Introduction

From the literature survey it is observed that the best qualities materials are composite materials as compared to the traditional materials. They unite the properties of many traditional materials. A composite material include includes reinforcement and matrix of two different components. The matrix is used for binding the reinforcement. Also, it is used together for merging the benefits of both the original components. In many industries, composites have more demand because of their all best properties. The demand is increasing in each year composites due to which traditional materials will get replaced. As composites have the less cost and more design flexibility fibre reinforced composites like carbon fibre and fibreglass gives huge opportunities for research [1]. Composite materials are manufactured by many methods like stir casting, powder metallurgy, squeeze casting, spray deposition etc. Metal matrix composites gives improved mechanical properties as compared to regular metals and composites are light weight application materials. Because the composite materials have the more strength to weight ratio, more tensile strength, toughness, huge wear resistance. Hence many applications of composite materials are in the field of automobile, aerospace, sports, and many more fields.[2]

Machining of composite materials is hard to perform because of the anisotropic and non-homogeneous structure of composites and to the better abrasiveness of their reinforcing elements. Plastic deformation is metallic operations reducing mechanism. machining of composite material is difficult because the

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composite material is soft and the tool is hard. [3]. Because of the anisotropy and not homogenous nature of their microstructure and reinforcement components are abrasive, hence it is very difficult to machine the fibre reinforced plastic composite materials. Cutting tool wear development undergoes rapidly during the machining. And the damage is created always on the surface of machined parts. Hence the important thing in machining is to select the perfect tool and machining conditions. Machining parameters are very much important in machining of composite materials.[4] In metal cutting heat is generated after the energy of the cut. It's difficult for CFRP for dissipating this heat. CFRP has low thermal conductivity. During machining no chip is generated to remove heat away. Due to the heat, there can be dander of melting. In some of the composite parts machining the matrix coolant are not allowed. Hence the tool and the tool path be heated during machining. One of the keys to accomplish this is the sharp angles. In machining of composite material, sharp angle tools having high positive rake angles and a quick sharp clean cut keeps less heat. These tools also contain clearance angles that are sufficient to prevent the durability of the tool from rubbing. [5]

The motive of optimization is to achieve the high-quality design relative to a hard and fast of prioritized standards or constraints. These include maximizing factors which includes productiveness, electricity, reliability, efficiency and usage. There is the extreme significance of obtaining the accurate dimensions in machining of material. There is the extreme significance of achieving an amazing surface in any machining method. A machining method involves many method parameters which directly or in a roundabout way have an impact on the surface roughness and metallic elimination charge of the product in not unusual. Surface roughness and steel removal in turning procedure are varied because of various parameters of which feed, pace, depth of cut are crucial ones. The choice of right mixture of machining parameters yields the desired floor finish and metallic elimination rate the right aggregate of machining parameters is the crucial undertaking as it determines the optimum values of surface roughness and metal removal charge. The preparation of high-quality surfaces is very important process within the engineering and technology. The surface roughness will influence the excellent and effectiveness of the subsequent coatings for safety in opposition to corrosion. There are many optimization techniques like the fractional factorial technique of D.O.E. Techniques. Taguchi & response surface methodology are carried allows to attain higher surface end out to optimize turning procedure parameter. Some analyzing turning parameters are an orthogonal array, sign-to-noise (S/N) ratio, and Pareto analysis of variance (ANOVA). Most important and interaction outcomes of procedure parameters on the excellent characteristics (surface roughness) were analyzed and the outcomes suggests that feed and interplay of slicing speed intensity influences the surface finish substantially. The parameters for purchasing better surface end are slicing speed of 2400 rpm, feed charge 40 mm/min, and intensity of reduce 0.5 mm. [6]. Quality and quantity are two challenging aspects in all manufacturing industries. As per the customers requirement quality is very much important and as per the earning of profit, quantity is important a lot. Hence it should have the middle way of optimization for more material removal rate and less surface roughness. There is the central composite design technique for the optimisation of multi-response CNC turning parameters in 'Response surface methodology'[7] It is observed that in turning of metals, it is difficult to maintain the surface roughness and flank wear of the tool. So for experimental design Taguchi L9 (3)3 orthogonal array has been applied. The important analysis are Sign-to-noise (S/N) ratio (lower the pleasant) and analysis of variance (ANOVA) analyses to become aware of big parameters influencing tool wear and Ra. Device wear (flank wear) is influenced by the slicing velocity and surface roughness is influenced by feed. Mathematical models are used for both response parameters. Through regression analysis,a device put on and Ra had been acquired. By means of Taguchi evaluation the affirmation experiments done at most desirable aggregate of parameters are given predicted. The reaction factors is with less than 5 % blunders. Response surface method (RSM) was implemented in addition to this for the better desirability, to reach on the best setting of input parameters to decrease tool wear and Ra and to evaluate parameters given through Taguchi evaluation. The desirability is achieved by the optimization outcomes with the use of Taguchi analysis. [8]. The large number of researches were done for the parameters affecting the roughness of surfaces for turning of various substances. Design of experiments (DOE) have been conducted for the analysis of of the turning parameters consisting of reducing velocity, feed rate and depth on the surface roughness. The effects of the machining experiments were used to signify the main factors affecting floor roughness by using the DOE strategies like Taguchi, full factorial, reaction surface methodology and different techniques. The major detail for accomplishing high and low value as per requirement is design of Experiments (DOE). Response surface technique (RSM) is an powerful tool for strong design, it gives a simple and systematic qualitative layout to a surprisingly low number of experiments. Many researchers have used RSM as a technique of DOE for analyzing the impact of procedure parameters. To achieve the setting of speed, feed, and depth of cut, these parameters are optimized in good surface finish. [9].

The present paper represents the RSM optimization method for turning parameters Speed, feed and depth of cut by using Minitab19.

2 Experimental Analysis

2.1 Methodology

To clear the major concepts of this project following points are given:

Lathe Machine: In this project work, 'medium duty lathe' machine is used for the turning It has the spindle speed ranging from 6/40 to 470 mm and electric motor power of 2 HP.

Tool used: Uncoated Carbide tool is used. Nose radius of tool is 0.8 mm.

Material: Job material taken is 'Glass fibre composite material' and its chemical composition is enlisted manufacturing of composites. Fibreglass rods are Corrosion, weather, humidity, and insect resistant. Easy to drill, cut, and install Usable during a vast range of industries and environments. More impact resistant than wood. More potent in some methods than metallic, mainly while used as a reinforcement fabric. **Material Removal Rate (MRR) (in cu / min):** Material Removal Rate (MRR) is a volume of chips removed in 1 minute. It is also measure of productivity of metal cutting. The accuracy in calculating MRR is very important.

$$MRR = Vc\ Fm\ d$$

Where Vc = cutting speed, Fm= Feed rate & d= Depth of cut

Surface roughness: Ra is Surface roughness is given in microns unit. By using HANDYSURF E 35 the measurements of average surface roughness (Ra) were conducted. The surface roughness values of this experiment are calculated by taking three measurements with different locations after that the average value of that three was used in the analysis. We get the Ra value in digital form.

RSM: Response surface method (RSM) shows the relationship between the many input variables and one or more response variables. In 1951 with George E. P. Box and K. B. Wilson were studied it. To form a chain of designed experiments RSM approach is important. They recommended the use of the second-degree polynomial version for this approach. They acknowledge that it was easy to handle this this model for an approximation, and also its version is easy to estimate and practice. Statistical approaches inclusive of RSM can be hired to maximise the manufacturing price of a specimen via optimization of operational factors. With the use of statistical techniques, the interaction among method variables can be obtained. A first-degree polynomial model is used for experiment or design. This is sufficient to determine which input variables have an effect on the response variable. After that complicated composite design can be applied to estimate a second polynomial degree. Which is still simplest an approximation at quality. But the second-degree version may be used to optimize (maximize, limit, or acquire a particular target for). Response Surface method (RSM) is one of the best optimization methods for the experimental design. As it permits evaluating the consequences of multiple elements and their interactions on one or greater reaction variables. It is a beneficial method for premier solution. Major objectives of RSM are to optimize, increase and enhance and explore the parameters. It is practical models. As it is conducted from experimental findings included with interactive effects of variables. It also represents the overall effects of the input parameters on the output responses. Major importance of RSM is execution of less number of designed experiments. An appropriate statistical and graphical analysis of multiple responses can be carried out , in corresponding short time. The strategy applied for the present work is as follow

2.2 Experimental procedure

i. Manufacturing of glass fibre composite
ii. Lathe machine is used for the turning operation.
iii. Experiment is conducted on total 9 composites Specimens.
iv. After the turning operation, the surface roughnesses of all the specimens are measured.
v. The table1 is drawn which shows the speed, feed and depth of cut, Surface Roughness & MRR.
vi. After that the Response surface regression, contour plots and optimization curve are obtained using MINITAB19 software

2.3 Manufacturing of composites

Process of manufacturing E - Glass Test Specimen

i. For the initial level we purchase a 12 mm MS shaft from the market. As per testing requirement divided into 9 Parts.
ii. After cutting the shaft we reinforce the E glass fibre on MS shaft for that purpose we prepare a solution made of 90 % Epoxy resin plus 10% Epoxy Hardener.
iii. For reinforcement first we take the MS shaft and apply solution on that with the help of a brush. Apply E - Glass fibre layer on it up to 15 mm.

2.4 Analysis of composites for turning operation on lathe machine

Machining parameters: In the turning operation geometry factors and machining factors are used majorly. Three important machining parameters are studied in this work viz. Velocity, feed and depth of cut. Fig1 represents those 3 parameters. By the combination of those three parameters material removal is obtained. Different input parameters influence the output parameters which includes roughness of surface and MRR.

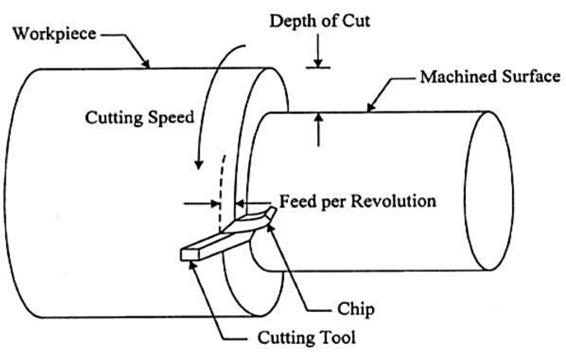

Figure 1: Important Machining parameters in turning [6]

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Cutting Speed

The rate at which the surface of the work piece passes the cutting tool is called as Cutting speed. Surface speed is also called as cutting speed. It is represented in unit of m/min. It can be calculated from the spindle speed. The speed at which the spindle or work piece rotates is called as the spindle speed. Number of revolutions of the work piece per minute i.e. rpm is unit of spindle speed.

$$Vc = \frac{\Pi DN}{1000} \tag{1}$$

Where, D = work piece diameter in mm

N = speed of spindle is rpm

Vc = the cutting speed (in m/min)

Feed

The distance moved by the tool tip throughout its path of travel is called as a feed. This feed for is for each revolution of the work piece. Symbol of feed is Fm and the unit is mm/rev.

$$Fm = f\,N \tag{2}$$

Where, f = Feed in mm/rev

N = Spindle speed in rpm

Depth of cut

The distance from the newly machined surface to the uncut surface is called as the depth of cut (d). The thickness of material which is removed from the work piece is the Depth of cut. It is also defined as the penetration depth of the tool into the work piece measured from the work piece surface before turning of the work piece. This thickness is removed from both sides hence the diameter after machining is reduced by twice of the depth of cut according to the turning of the work.

$$d = \frac{D1-D2}{2} \tag{3}$$

Where, D1 = diameter before turning the job

D2 = diameter after turning the job

d= depth of cut

3 Experimental Findings

The instrument used for experimental analysis in the form of measurement of Surface roughness Surface roughness tester. Material removal of the E Glass epoxy rod specimen with dimensions (1cm X 12 layers) is carried out by turning process. To achieve the optimum Surface roughness by using RSM is done on Minitab 19. Experiments are executed as per the orthogonal matrix given to RSM with three factors at two levels for which following Experimental Readings were taken.

Table 1: Experimental readings

SR.NO.	SPEED (RPM)	FEED (mm/rev)	DEPTH OF CUT (mm)	Surface Roughness (Micron)	MRR mm^3/min
1.	730	0.33	0.5	0.3	120.45
2.	730	0.24	1	8	175.2
3.	730	0.22	1.5	3.5	240.9
4.	459	0.52	0.5	1	119.34
5.	459	0.38	1	2	174.42
6.	459	0.34	1.5	1.5	234.09
7.	284	0.86	0.5	0.5	122.12
8.	284	0.625	1	3.5	177.5
9.	284	0.568	1.5	7.5	241.968

4 RSM Optimization

In Optimization our aim is of creating 'Maximum' or 'Minimum' based on circumstances. Optimization is system, or procedure, or method of forming something as perfect, functional, or accurate as much as possible. Importance of Optimization is efficient, decreases the product development costs, reduce the production time etc.

Steps for RSM optimization by Minitab19 is to enter data for analyze response surface design, then specify the model terms for Analyze Response Surface Design, Specify the options for Analyze Response Surface Design, Specify the options to use to analyze your response surface design. For example, Low & High Factors of speed & Feed are selected. Select the graphs to display for analyze response surface design, Store statistics for Analyze Response Surface Design.

The steps applied for RSM optimization in this study are presented in fig.2

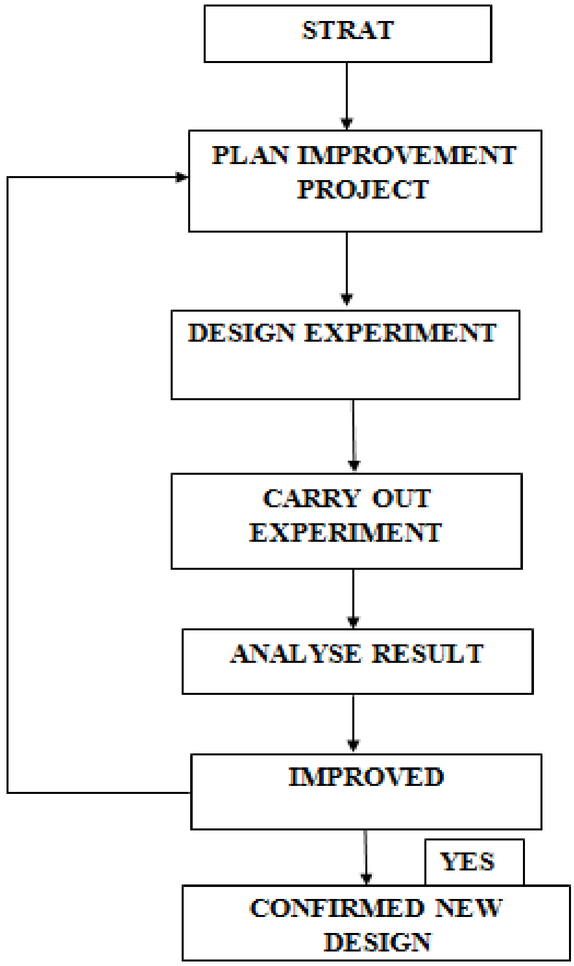

Figure 2: Steps applied in RSM optimization design procedure [6]

5 Results and discussions

A counter plot is a graph for representing a 2dimensional surface. It uses steady z variable called as contours to plot the graph on a 2-dimensional layout. It's easy to read contour plot.

5.1 Contour plot of MRR vs. Feed (mm/rev), Speed (RPM)

In this counter plot (Figure3) the effect on MRR is plotted against speed and feed of the turning tool

In this plot it is observed that as the spindle speed increase with feed of the tool the material removal rate is also increased and as the spindle speed and feed decreases it will decrease MRR rate also.

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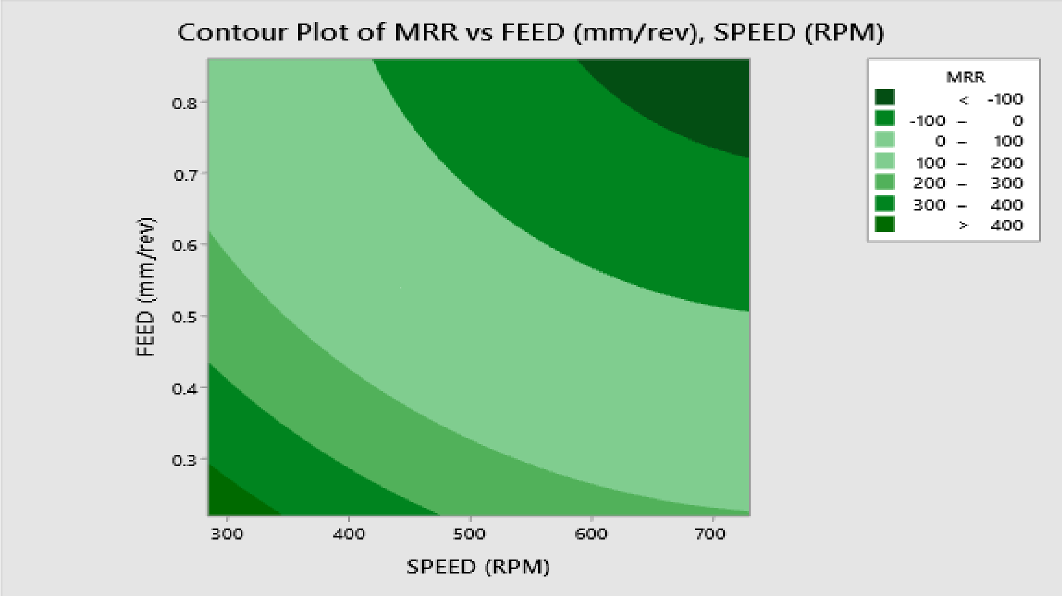

Figure 3: Contour plot of MRR vs Feed (mm/rev), Speed (RPM)

5.2 Contour plot of MRR vs Feed (mm/rev), Speed (RPM)

In this counter plot (Figure 4) the values of surface roughness are plotted against spindle speed and feed rate of the tool.

As the spindle speed increases and feed increases accordingly it will minimize the surface roughness value and as the spindle speed decreases, with the feed it will maximize the surface roughness value.

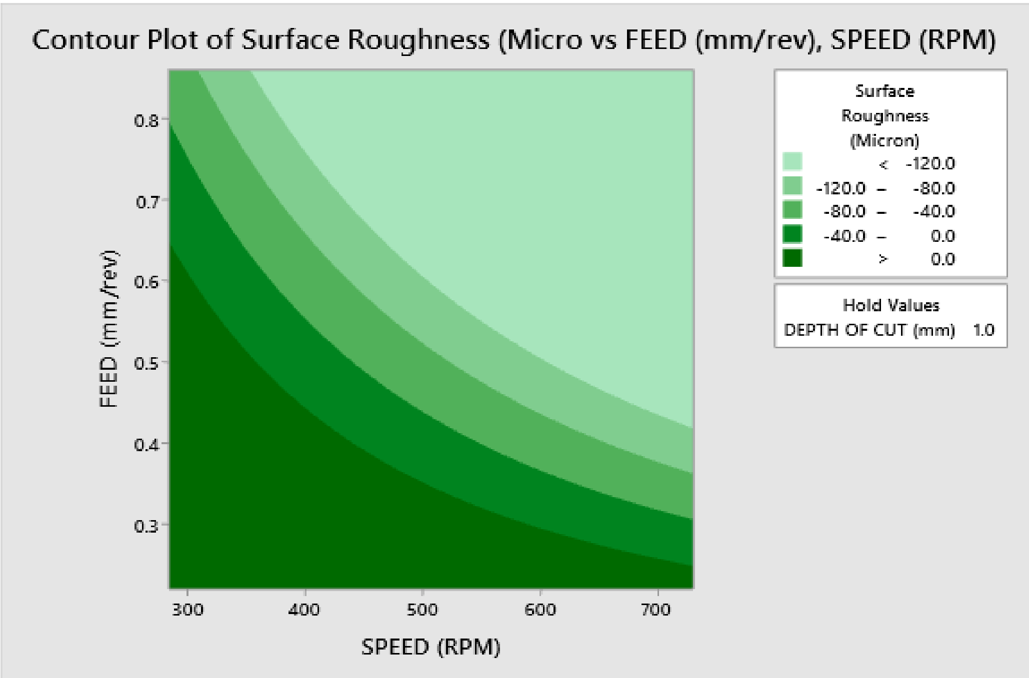

Figure 4: Contour plot of Surface Roughness (Micron) vs Feed (mm/rev), Speed (RPM)

5.3 Contour plots of Surface Roughness values

The optimization curve (Figure 5) provides the high speed and feed value for better MRR and surface roughness. The maximum MRR value we are getting at 730 spindle speeds, 0.860 Feed and 1 mm of depth of cut is about 3095 while the surface roughness value as -10 micron.

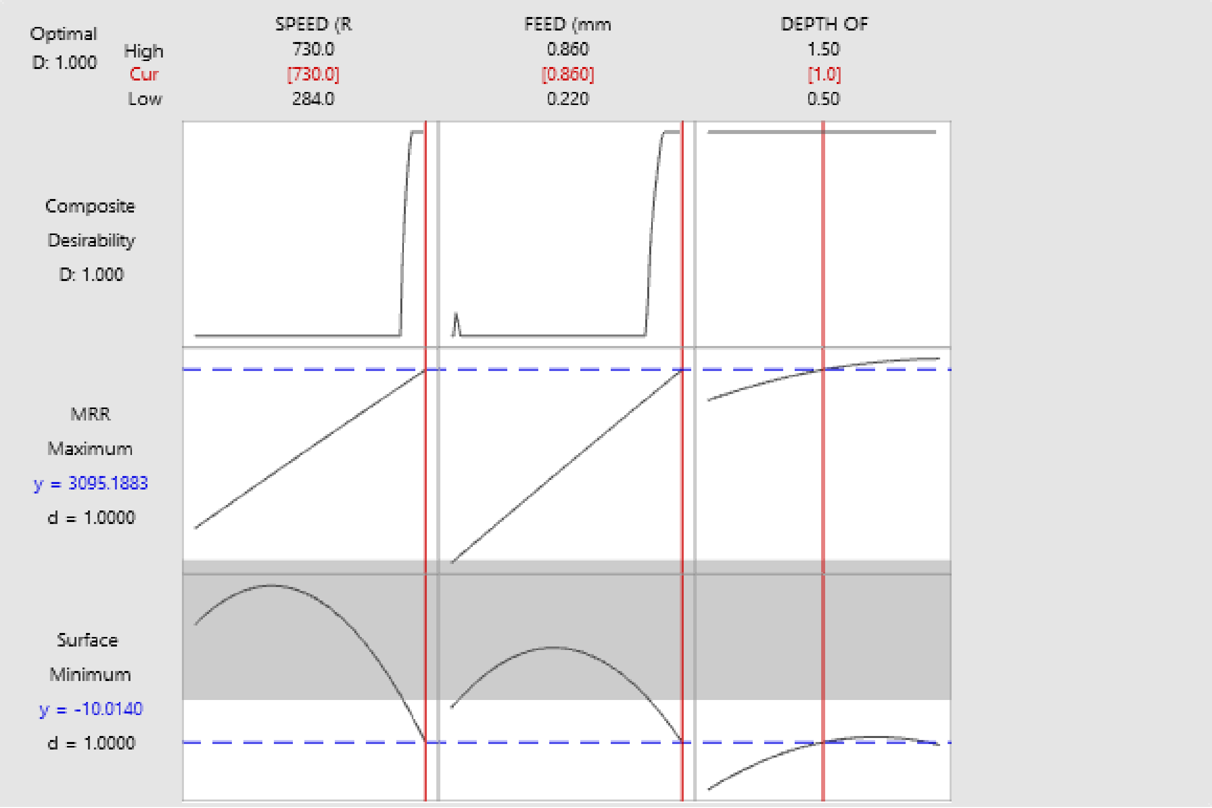

Figure 5: Contour plots of Surface Roughness values

6 Conclusion

The optimization curve provided by Minitab shows the high speed and feed value for better MRR and surface roughness. The maximum MRR value we are getting at 730 spindle speed, 0.860 Feed and 1 mm of depth of cut is about 3095 while the surface roughness value as -10 micron. MRR maximizes and Surface roughness minimizes when Spindle speed and feed rate are increased. Hence we got the optimized result.

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