Optimization of Machining Parameters of 20mncr5 Steel in Milling Machine by Use of Taguchi Method

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Abstract— Increasing profitability and quality of the machined parts are the fundamental difficulties of metal cutting industry during milling processes. Optimization methods in milling processes, considered assuming a fundamental part for continual improvement of output quality in product and processes include modeling of input-output and in-process parameters relationship and determination of optimal cutting conditions. This Project exhibits an Experimental study to streamline the impacts of Cutting Parameters on Surface roughness and Material Removal Rate of 20MnCr5 Steel alloy work material by utilizing Taguchi strategy. The orthogonal exhibit, signal to noise ratio and Analysis of Variance were utilized to study the performance characteristics in milling operation. Four parameters have been picked as process variables: viz. Cutting Speed, Feed, Depth of cut, Width of cut. The experimentation arrangement is outlined utilizing Taguchi's L18 Orthogonal Array (OA) and Minitab statistical software V17 is used for optimization of parameters. In this research we target to obtain Optimal cutting parameters for minimum surface roughness (SR) and maximum material removal rate are obtained. At long last, the relationship in the factors and the perfomance measures were created by utilizing multiple regression analysis.

Key words: CNC Vertical Milling Machine, L18 Orthogonal Array, Taguchi Method

I. INTRODUCTION

For success of the manufacturing organization finding the optimum balance between higher production rate and improved quality is most important. Productivity can be interpreted in terms of material removal rate in the machining processes and quality represents product characteristics as desired by the customers which will give competitative edge over the competitors. Both these criterions are conflicting but important for the success of the organization. Quality can be expressed in terms of different attributes such as higher dimensional accuracy, form stability, surface smoothness and fulfillment of functional requirements for specific applications etc. Thus improvement in the quality of a product ensures its demand from the costumer thus helping the organization for achieving the higher revenue.

Literature [1-9] indicated different researchers tried to optimize various machining processes for improving the quality of the product. Among different quality attributes surface finish of the component obtained after various machining processes is considered to be most important.

Surface milling is widely used in most of the manufacturing industries due to its capability of producing complex geometric surfaces with reasonable accuracy and surface finish. However, with the inventions of CNC milling machine, the flexibility has been adopted along with versatility in surface milling process. Cutting parameters as spindle speed, feed, depth of cut, type and flow of cutting fluid affects the surface finish of the product. Thus optimizing the parameters for the minimum surface roughness is important in CNC surface milling process. The Taguchi method is a powerful experimental design tool uses simple, effective, and systematic approach for deriving of the optimal machining parameters in lower time.

II. LITERATURE REVIEW

Many investigators have recommended various methods to explain the effect of machining parameter on surface roughness and MRR in CNC milling process.

Various machining processes were optimized by the researchers for improving the quality of the product G. Akhyar et al. [1] applied Taguchi optimization method to optimize cutting parameters in turning Ti-6%Al-4%V extra low interstitial with coated and uncoated cemented carbide tools under dry conditions and high cutting speeds for improved surface finish. L27 orthogonal array including four factors such as Cutting speed, feed rate, depth of cut and tool grades with three levels for each factor was used to identify the optimal combination. ANOVA is used to determine the cutting speed and tool grade to be significant factors affecting the surface finish.

M. Y. Noordin et al.[2] used RSM to study the performance of a multilayer tungsten carbide tools while turning AISI 1045 steel under dry conditions with constant depth of cut. Face centered CCD is used to study the effects of three factors such as cutting speed, feed and side cutting edge angle (SCEA) on surface roughness and the tangential force. Feed is found to be most significant parameter.

Mohammed T. Hayajneh et al.[3] build a multiple regression model for surface roughness to study the effects of spindle speed, cutting feed rate, depth of cut and their two way interactions. The cutting parameters were selected as four levels of cutting speed, seven levels of feed rate and three levels of depth of cut.

The results showed the cutting feed as the most dominant factor and interactions cutting feed-depth of cut, and cutting feed-spindle speed the most significant.

Suresh et. al. [4] adopted a two stage approach towards optimization of surface roughness. First, experimental results were used to build mathematical models for surface roughness by RSM. Then, the second order mathematical model was taken as an objective function and was optimized using genetic algorithm (GA) to obtain the machining conditions for a desired surface finish. Mathematical model was determined to predict surface roughness of 190 BHN steel in end milling in terms of three variables depth of cut, spindle speed and feed rate by using Response Surface Methodology (RSM) by Alauddin et al.

Yang and Tang (1998) [5] completed a trial comprising of 18 mixes on a lathe machine utilizing tungsten carbide with the evaluation of P-10 for the machining of S45C steel bars. The cutting parameters that have been chosen are cutting rate, food rate and depth of cut with the response variable, tool life and surface roughness. Results demonstrate that for surface roughness, all the cutting parameters have the noteworthy impact. The affirmation tests then were led to confirm the ideal cutting parameters. The change of hardware life and surface roughness from the beginning cutting parameters to the ideal cutting parameters is around 250%.

Yang L.J. et al. [6] used Taguchi parameter design approach in process control of individual milling machines. The Taguchi parameter design was used in order to identify the optimum surface roughness performance with a particular combination of cutting parameters in an end-milling operation.

Farhad Kolahan et al. (2011) [7] did study to all the while model and enhance machining parameters and instrument geometry with a specific end goal to enhance the surface roughness for AISI1045 steel. A Taguchi methodology is utilized to accumulate trial information. At that point, in view of S/N proportion, the best arrangements of cutting parameters and apparatus geometry particulars have been resolved. Utilizing these parameters values, the surface harshness of AISI1045 steel parts is minimized. A medium obligation machine with 2 kw shaft force was utilized to perform tests. The device utilized in investigations was HSS (5% Cobalt). This was chosen subsequent to the device points can be actualized just in this sort of cutting apparatuses. The normal surface roughness (Ra) toward the apparatus development was measured in three better places of the machined surface utilizing a surface roughness analyzer, Taylor-Hobson. A few levels of machining parameters and instrument geometry determinations are considered as information parameters. The surface roughness is chosen as procedure yield measure of performance.

Aman Aggarwal and Hari Singh [8] presents that Fuzzy Logic, Genetic Algorithm, scatter search and Taguchi technique are the latest optimization Techniques that are being applied successfully in industrial applications for optimal selection of process variables in the area of machining.

Sreenivasa Murthy et al. (2013) [9] in their work conceive the ideal setting of procedure parameters which impacts the surface roughness during the machining operation of EN41B alloy steel with cermets tools. Examinations have been done utilizing Taguchi outline. The surface roughness is considered as quality trademark while the process parameters considered are speed, feed and depth of cut. Regression equation for surface roughness is gotten utilizing MINITAB 16 as Ra = 3.02 + 0.068 Speed + 0.874 Feed + 0.074 Depth of cut. The consequences of machining analyses were utilized to portray the principle variables influencing surface roughness by the Analysis of Variance. The feed and speed are recognized as the most persuasive process parameters on work piece surface roughness. The ANOVA and F-test uncovered is the dominant parameter took after by rate for surface roughness.

III. METHODOLOGY

A. *Taguchi Method:*

Taguchi defines as the quality of a product, in terms of the loss imparted by the product to the society from the time the product is shipped to the customer. Some of these losses are due to deviation of the products functional characteristic from its desired target value, and these are called losses due to functional variation. The uncontrollable factors, which cause the functional characteristics of a product to deviate from their target values, are called noise factors, which can be classified as external factors (e.g. unit to unit variation in product parameters) and product deterioration. The overall aim of quality engineering is to make products that are robust with respect to all noise factors.

Taguchi has empirically found that the two stage optimization procedure involving S/N ratios, indeed gives the parameter level combination, where the standard deviation is minimum while keeping the mean on target .This implies that engineering systems behave in such a way that the manipulated production factors that can be divided into three categories:

1) Control factors, which affect process variability as measured by the S/N ratio.
2) Signal factors, which do not influence the S/N ratio or process mean.
3) Factors, which do not affect the S/N ratio or process mean.

In practice, the target mean value may change during the process development applications in which the concept of S/N ratio is useful are the improvement of quality through variability reduction and the improvement of measurement.

The S/N ratio characteristics can be divided into three categories when the characteristic is continuous: nominal is the best, smaller the better and larger is better characteristics.

IV. MACHINE AND EQUIPMENTS

The following equipments were used in this experimental works:

A. *CNC Vertical Milling Machine:*

CNC Vertical Milling lathe V-500+ which is used for Machining the work material 20MnCr5 is shown in below figure.This machine was used to produce the surface finish and MRR on the surface of the 20Mncr5 steel.


Fig. 1: CNC Vertical Milling Machine

B. *Surface Roughness Tester:*

A Profilometer is a measuring device used to gauge the surface roughness of a given surface profile. Measuring the sharp edges of cutting devices is a testing procedure, on the grounds that it includes a little span, which obliges high horizontal determination and high points. It is likewise vital to have the capacity to quantify a various scope of statures. The study turns out to be more troublesome when the surface has chipping or different sorts of deformation. precision cutting apparatuses by and large oblige a sharp apparatus edge with radii of a few many nanometers or much smaller.


Fig. 2: Surface Roughness Tester

V. WORKPIECE MATERIAL


Fig. 3: 20mncr5 Work Material

1) Work piece material: 20Mncr5
2) Work piece dimensions: 100mm x 75mm x 35mm.
3) Physical properties: Hardness-357BHN, Density- 0.00785(gm/mm3), Tensile Strength- 1482 Mpa.
4) Total specimen -18

Carbon	0.220%
Manganese	1.112%
Silicon	0.244%
Sulphur	0.026%
Phosphorus	0.028%
Chromium	1.154%

Table 1: Composition of 20MnCr5 Steel

VI. RESPONSE PARAMETERS

The response parameters include:

1) Material removal rate (MRR)
2) Surface Roughness (Ra).

A. *Metal Removal Rate (MRR) Measurement:*

The MRR of the work piece was measured by compared the weight of work piece before and after machining (found by weighing method using balance) against the machining time that was achieved. After completion of each machining process, the work piece was blown by compressed air using air gun to ensure for blowing out the debris. A precise balance was used to measure the weight of the work piece required. The following equation is used to determine the MRR value;

$$MRR\,(a) = \frac{[\text{Initial Weight of wirkpiece (gm)} - \text{Final Weight of workpiece (gm)}]}{\text{Density(gm/mm3)} \times \text{Machining Time (min)}}\ mm^3/min$$

B. *Surface Roughness Measurement:*

There are various methods available for measuring the surface roughness of the work piece. The arithmetic surface roughness value (Ra) was adopted and measurements were carried out at the left and at the right side and at the middle of the surface using a profilometer(MITUTOYO SJ 201-P). The Ra values of the surface were obtained by averaging the surface roughness.

VII. EXPERIMENTAL DETAIL AS AND RESULTS

The experiment is carried out on a CNC Vertical Lathe V-400 Installed at PAVAN INNOVATION Tools, Peenya Industrial town, Bangalore-44, India. In this Experiment 18 slabs of 20MnCr5 having 100*75*35mm were milled on CNC Lathe using Coolant IPOL XL.

A. *Cutting Parameters and their Levels:*

For the present experimental work we have selected four parameters at three levels. It is desirable to have two minimum levels of process parameters to reflect the true behavior of output parameters of study. The cutting parameters are renamed as factors and they are given in the adjacent column. The levels of the individual cutting parameters/factors are given in Table

Symbol	Cutting para-meter	Unit	Level 1	Level 2	Level 3

A	Speed	Rpm	3200	3400	3600
B	Feed	mm/rev	700	800	950
C	DOC	mm	0.1	0.25	0.3
D	WOC	mm	0.1	0.2	0.4

Table 2: Cutting Parameters and Their Levels

Selecting proper orthogonal arrays, degree of freedom (number of reasonable and free correlations required for enhancement of process parameters and is one not exactly the quantity of level of parameter) of exhibit is figured. There are eight degrees of freedom inferable from four machining data parameters, so Taguchi based L18 orthogonal array is chosen. Appropriately, 18 experiments were done to study the impact of machining input parameters. Every investigation was rehashed three times with a specific end goal to reduce experimental errors.

Trail no.	speed (rpm)	feedmm/rev	Doc mm	Width of Cut mm	RA µm	S/N ratio	MMR (mm^3/min)
1	3200	700	0.1	0.1	0.92	0.7242	1954.75
2	3200	800	0.25	0.2	0.87	1.6184	2285.94
3	3200	950	0.30	0.4	0.92	0.7242	2795.30
4	3400	700	0.1	0.2	0.76	2.4987	2481.45
5	3400	800	0.25	0.4	0.80	1.9382	2711.15
6	3400	950	0.3	0.1	0.68	3.3498	2906.85
7	3600	700	0.25	0.1	0.56	6.0206	3232.91
8	3600	800	0.3	0.2	0.70	3.0980	3674.34
9	3600	950	0.1	0.4	0.68	3.7917	4331.21
10	3200	700	0.3	0.4	0.81	1.8303	3064.02
11	3200	800	0.1	0.1	0.85	1.4116	2646.59
12	3200	950	0.25	0.2	0.76	2.3837	2676.83
13	3400	700	0.25	0.4	0.68	3.3498	3069.35
14	3400	800	0.3	0.1	0.75	2.4987	3411.91
15	3400	950	0.1	0.2	0.81	1.8303	2859.74
16	3600	700	0.3	0.2	0.60	4.4369	3780.85
17	3600	800	0.1	0.4	0.85	1.4116	3308.18
18	3600	950	0.25	0.1	0.50	6.0206	4496.06

Table 3: Experimental Results of SR & MRR

VIII. STUDIES RELATED TO SURFACE ROUGHNESS (SR)

A. Regression Model for Surface Roughness:

Using MINITAB statistical software the Regression model has been developed for the surface roughness. The regression equation for surface roughness;
Surface Roughness (µm) = 2.602 - 0.000538
Cutting Speed 'A' (m/min) + 0.0004 Feed 'B'(mm/rev) + 0.432 Depth of Cut 'C' (mm) + 0.274 width of cut 'D'
If the value of Speed, Feed, and Depth of cut and Tool Hardness are known, using the above equation we can predict the corresponding value of Surface Roughness

B. Analysis of Variance for SA:

The experimental results from Table 3 were analyzed with analysis of variance (ANOVA), which is used for identifying the factors significantly affecting the performance measures. The results of the ANOVA with surface roughness are shown in Table 4.

Source	DF	Adj SS	Adj MS	F-Value	p-value
Cutting speed (A)	2	0.13874	0.069372	22.98	0.000
Feed (B)	2	0.02698	0.013489	4.47	0.045
Depth of cut (C)	2	0.04814	0.024072	7.97	0.010
Tool Hardness (D)	2	0.02168	0.010839	3.59	0.071
error	9	0.02717	0.003019		
Total	17	0.26271			

Table 4: Analysis of Variance for Surface Roughness

C. Response Table of Signal to Signal ratios for Surface Roughness:

Table 5 represents the response table for surface roughness. The ranks and Delta values for various parameters in the table show that Cutting speed has the greatest effect on surface roughness and is followed by the depth of cut, tool hardness and feed in that order.

Level	Cutting Speed (m/min) „A"	Feed (mm/rev) „B"	Depth of Cut (mm) „C"	Width of cut (mm) „D"
1	0.8483	0.7100	0.8050	0.7000
2	0.7450	0.7967	0.6783	0.7417
3	0.6333	0.7200	0.7433	0.7850
Delta	0.2150	0.0867	0.1267	0.8050
Rank	1	3	2	4

Table 5: Response Table for Surface Roughness

D. Main Effect Plot for S/N Ratios of Surface Roughness (Ra):

The main effect plots on surface roughness was analyzed with the help of software MINITAB and shown in figure 4. The plots show the variation of individual response with the four parameters; cutting speed, feed depth of cut and hardness of cutting tool separately. In the plots the x-axis indicates the value of each process parameters at three level and y-axis the response value. The main effect plots are used to determine the optimal design conditions to obtain the low surface roughness.

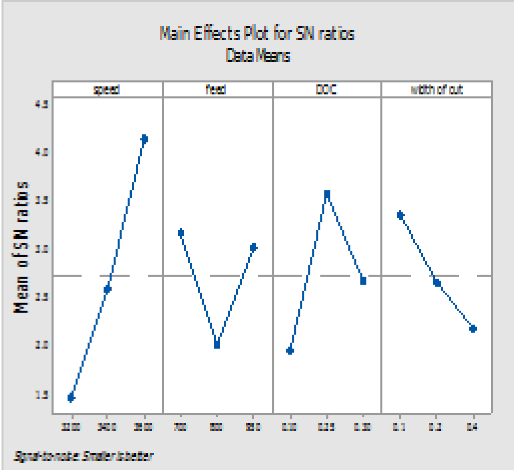

Fig. 4: Effect of Process Parameters on S/N Ratio (Ra)

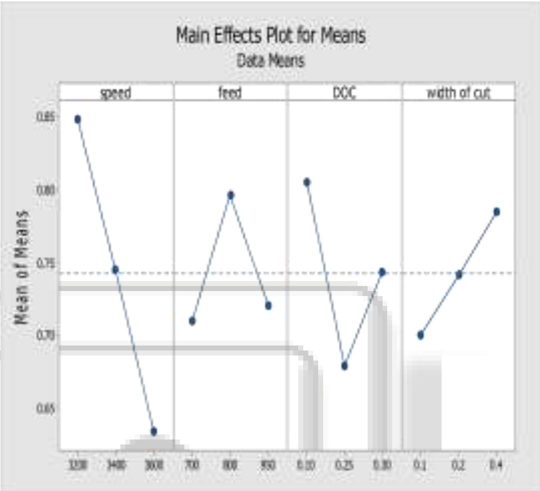

Fig. 5: Effect of Process Parameters on Means (Ra)

Figure 5 shows the Effect of process parameters on main surface roughness. As the surface Roughness is the "Lower the Better" type quality characteristic, from figure it can be seen that first level of cutting speed, third level of feed, second level of depth of cut and third level of tool hardness result in minimum or optimum value for surface roughness.

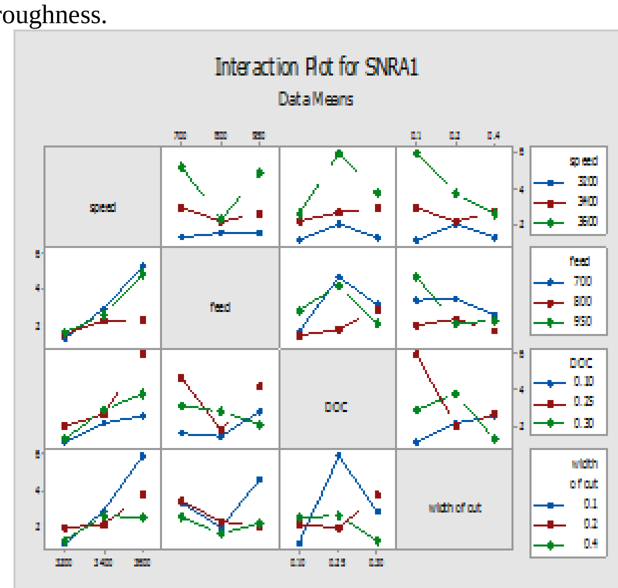

Fig. 6: Interaction S/N Ratio for Surface Roughness With Smaller Is Better

IX. Studies Related to Material Removal Rate (MRR)

A. *Regression Model for MRR:*

Using MINITAB statistical software the Regression model has been developed for the Material Removal Rate.
The regression equation for MRR is given by:
MRR (a) mm3/min = 9227 + 3.083 cutting speed 'A' (m/min) +1.702 feed 'B' (mm/rev) + 1543 depth of cut 'C' (mm) – 481 Width of cut 'D'(mm)
If the value of Speed, Feed, and Depth of cut and width of cut are known, using the above equation we can predict the corresponding value of Material Removal Rate.

B. *Analysis of Variance for MRR:*

Source	DF	Adj SS	Adj MS	F-value	P-value
Cutting speed (A)	2	4878217	2439109	14.72	0.001
Feed (B)	2	582373	291157	1.76	0.227
Depth of cut (C)	2	352705	176353	1.06	0.385
Width of cut (D)	2	194423	97212	0.59	0.579
error	9	1491014	165668		
Total	17	7498734			

Table 6: Analysis of Variance for MRR

The experimental results from Table 5 were analyzed with analysis of variance (ANOVA), which is used for identifying the factors significantly affecting the performance measures. The results of the ANOVA with Material Removal Rate are shown in Table 6.

C. *Response Table of Signal to Signal ratios for MRR:*

Level	Cutting Speed (m/min) "A"	Feed (mm/rev) "B"	Depth of Cut (mm) "C"	Width of cut (mm) "D"
1	68.11	69.15	69.07	69.58
2	69.23	69.44	69.56	69.27
3	71.54	70.28	70.24	70.03
Delta	3.43	1.12	1.17	0.76
Rank	1	3	2	4

Table 7: Response Table for MRR

The ranks and Delta values for various parameters in the table 7 show that cutting speed has the greatest effect on MRR and is followed by the feed, Depth of cut and Tool hardness in that order.

D. *Main Effect Plot for S/N Ratios of MRR:*

The main effect plots on surface roughness was analyzed with the help of software MINITAB and shown in figure 6. The plots show the variation of individual response with the four parameters; cutting speed, feed depth of cut and hardness of cutting tool separately. In the plots the x-axis indicates the value of each process parameters at three level and y-axis the response value. The main effect plots are used to determine the optimal design conditions to obtain the maximum Material Removal Rate.

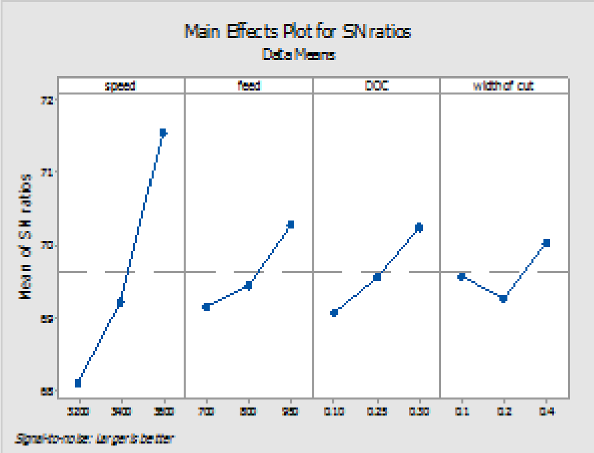

Fig. 7: Effect of Process Parameters on S/N Ratio (MRR)

Figure 7 shows the effect of process parameters on Material Removal Rate. As MRR is the "Higher the Better" type quality characteristic from figure 7 it can be seen that third level of cutting speed, third level of feed, third level of depth of cut and first level of tool hardness result in maximum or optimum value for MRR.

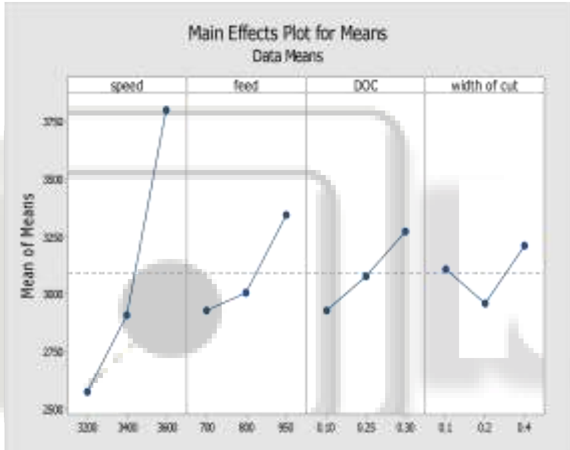

Fig. 8: Effect of Process Parameters on Means (MRR)

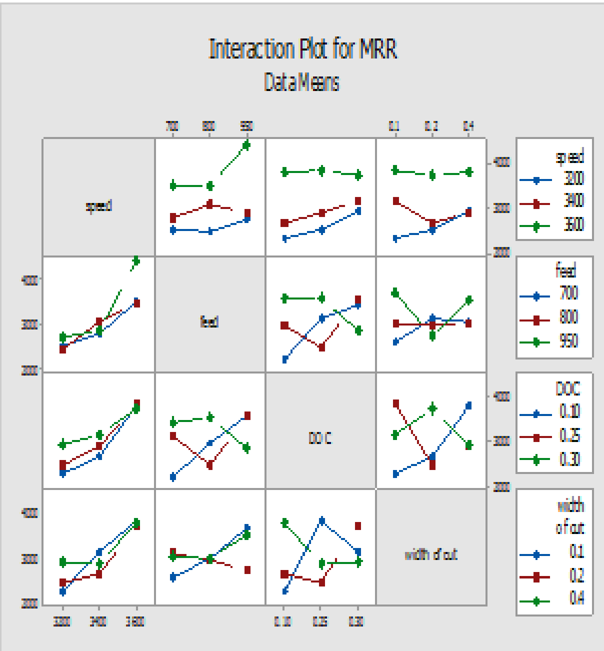

Fig. 9: Interaction Plot for Means Data (MRR)

X. SUMMARY

This study evaluates the machining perfomance of 20MnCr5 Steel utilizing CNC Milling Machine which utilized carbide End Mill cutting tool. All the experiment trials, arranging and investigation were executed utilizing Taguchi design of experiment. The reasons of DOE system connected in this study were to focus the optimum condition of machining parameters and the significance of each parameter to the perfomance of machining characteristics. The total experiment runs performed in this study was 18 trials utilizing randomized parameters which done by MINITAB 17 software.The work to be specific surface roughness (Ra) and material removal rate (MRR).

XI. CONCLUSIONS

Based on results obtained, the following conclusions can be drawn:

1) The experiment results demonstrated that the Taguchi parameter design is a successful method for deciding the optimal cutting parameters for accomplishing low surface roughness and maximum material removal rate.
2) The relationship between cutting parameters (cutting speed, feed, depth of cut and Width of Cut) and the performance measures (surface roughness and material removal rate) are shown by multiple regression equation which can be used to estimate the expressed values of the performance level for any parameters levels.
3) ANOVA recommends that cutting speed is the most significant factor and Width of cut is most insignificant factor for surface roughness and cutting speed is the most significant factor and width of cut is the most insignificant factor for MRR.
4) Optimum parameter level for minimum surface roughness are third level of cutting speed, first level of feed, second level of depth of cut and first level of width of cut.
5) This implies that the levels of parameters at designated levels as A3, B1, C2 and D1 are the best combination to get minimum surface roughness.
6) Optimum parameter level for maximum MRR are third level of cutting speed, third level of feed, third level of depth of cut and third level of tool hardness.
7) This implies that the levels of parameters at designated levels as A3, B3, C3 and D3 are the best combination to get maximum MRR.

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