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OPTIMISATION OF MACHINE PARAMETERS FOR TURNING OPERATIONS OF AISI 1040CD BY TAGUCHI METHOD AND ANALYSIS OF VARIANCE (ANOVA)

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Abstract

In this research work machining of the AISI 1040 CD with the help of high - speed steel of tool, lath is performed. Analysis of the Material removal rate is done experimentally with specific input values of feed rate, depth of cut, and spindle of speed the optimal condition is found out. The turning parameters are the most important factors affecting the quality, productivity, and cost of turning. A plan of experiments based on the Taguchi technique has been used to acquire the data. An Orthogonal array, signal to noise (S/N) ratio, and analysis of variance (ANOVA) are employed to investigate the turning characteristics of steel optimize the turning parameters. Finally, the conformations tests have been carried out to compare the predicted values with the experimental values to confirm its effectiveness in the analysis of the workpiece surface. Thus, with the proposed optimal parameters it is possible to increase the efficiency of the machining process and decrease production cost in universities and factories.

Keywords: Opitimisation, machine parameters, turning operation, taguchi method, signal to noise

INTRODUCTION

Turning is the process of forming the work mainly in the form of a cylindrical work. Consists of face turning, stripping, threading, internal boring, grooving, Metal Turning. Machine tools that use the lathe is a lathe (Lathe) has a lathe that is controlled. Conventional or manual and automatic controlled lathe (CNC Lathe). As mentioned above Lathes can also able to perform many other tasks such as drilling holes, tapping threads (Tapping). The main factors in lathe production include turning, cutting fluid, coolant, rpm, cutting speed, feed rate, depth of cut operating environment.

Surface roughness plays an important role in many areas and is a factor of great importance in the evaluation of machining accuracy (Palanikumar, L. Karunamoorthy, R. Krathikeyan.,2006). The Taguchi method is statistical tool, adopted experimentally to investigate influence of surface roughness by cutting parameters such as speed, feed and depth of cut (Xue Ping, C. Richard Liu, Zhenqiang Yao.,2007). The Taguchi process helps to select or to determine the optimum cutting conditions for turning process. Many researchers developed many mathematical models to optimize the cutting parameters to get lowest surface roughness by turning process. The variation

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in the material hardness, alloying elements present in the work piece material and other factors affecting surface finish (T. Tamizharasan, T. Selvaraj, A. Noorul Hag. ,2005).

This research, it is important to model and quantify relationships between workpiece surface roughness, impact factors on parameter values, and quantitative analysis. The experimental design in this research uses the Taguchi method to gain confidence under the assumptions. Taguchi technique and analysis of the variance analysis is performed to determine the optimal machining parameters. According (K. Siva Prasad, K.S.V.K. Sainath and B. Vijay Kumar., 2017). the Taguchi method is suitable for a wide range of experiments, especially for testing the optimum values in lathe production. Analysis of Variance is used to find the most important and least significant parameters. Current work is focused on maximizing material removal rates with the aim of improving the efficiency of turning. In this research paper, determining cutting parameters such as rake angle and feed that maximizes material removal rates is a key task in achieving the overall economy of machining. The statistical design of the experiment refers to the process of planning the experiment in order to be able to analyze the appropriate data by statistical methods to obtain accurate and reliable results (Pınar, A.M., Güllü, A.,2010) has mentioned the Taguchi method developed by Genuchi Taguchi is a statistical method used to improve the product quality in industries (Pınar, A.M., Güllü, A.,2010),(Savaşkan, M., Taptık, Y., Ürgen, M. ,2004) the Taguchi method it is possible to significantly reduce the number of experiments. The Taguchi method is not only an experimental design technique, but also a beneficial technique for high quality system design Savaşkan, M., Taptık, Y., Ürgen, M.,2004).

Literature Survey for Taguchi Method

There is a wide variety of researches that have applied the Taguchi method in a wide variety of applications, including:

L. Venugopal. et al., (2012). researched on analysis of tube end forming process using Taguchi design of experiments. Found that, the parameters that affect the process are determined using Taguchi method and the most significant process parameters and their percentage contribution was determined by using ANOVA technique.

Ram Kumar. et al.,(2013). researched on optimizing the process parameters of FSW on AZ31B Mg Alloy by Taguchi-Grey Method. Have concluded that. The experiment was carried out by Taguchi (L18) orthogonal array. Grey based Taguchi techniques were utilized to optimize the process parameters. To find out the important parameter that affects mechanical properties, an analysis of discrepancy was used. Later on, for a second order model, response surface methodology helped to develop the process parameters and performance characteristics. The hypothesis for optimal conditions was proven correct after conducting a ratification test.

S. Vijay Kumar.et al., (2013) researched on experimental optimization for CU removal from aqueous solution using neem leaves based on Taguchi method. This research focuses on understanding biosorption process and developing a cost effective technology for treatement of heavy metals-contaminated domastic water. A new biosorbent has been prepared by crushing of neem leaves. The experiments were designed according to Taguchi's (L16) orthogonal array to optimize experimental runs.

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In order to assess the biosorption behavior of neem leaves satisfying multiple performance measure, Taguchi approach has been adopted.

Vijaykumar H.K. et al., (2014) research on experimental investigation of material removal rate and Tool wear in turning of hardened AISI52100 steel using Taguchi Technique. Tried to of this paper is to investigate experimentally the optimum process parameters (cutting speed, feed rate, and depth of cut) resulting in an optimization of material removal rate (MRR) and tool wear while turning of hardened AISI 52100 steel under dry cutting conditions using Taguchi method. A L9 orthogonal array, signal-to-noise(S/N) ratio, and analysis of variances (ANOVA) are applied with the help of Minitab.v.16.2.0 software to study performance characteristics of process parameters with consideration of Material Removal Rate (MRR) and Tool wear. The results obtained from the experiments are changed into signal-to-noise ratio(S/N) ratio and used to optimize the value of MRR and tool wear The ANOVA is performed to identify the importance of parameters. The conclusions arrived at are considerably discussed at the end.

Syed Siraj Ahmed and Prof.S.D.Ambekar (2015) research on experimental analysis of material removal rate in drilling of 41Cr4 by a Taguchi's Approach. Mentioned to in manufacturing industries the largest amount of money spent on drills. Therefore, from the viewpoint of cost and productivity, modeling and optimization of drilling processes parameter are extremely important for the manufacturing industry this paper presents a detailed model for drilling process parameter. The detailed structure includes in the model, are three parameters such as such as spindle speed, feed and depth of cut on material removal rate in drilling of 41 Cr 4 material using HSS spiral drill .We an effect of this three parameters on material removal rate .The detailed mathematical model is simulated by Minitab14 and simulation results fit experiment data very well in this investigation, an effective approach based on Taguchi method, analysis of variance (ANOVA), multivariable linear regression (MVLR), has been developed to determine the optimum conditions leading to higher MRR. Experiments were conducted by varying spindle speed, feed and depth of cut using L9 orthogonal array of Taguchi method. The present work aims at optimizing process parameters to achieve high MMR. Experimental results from the orthogonal array were used as the training data for the MVLR model to map the relationship between process parameters and MMR the experiment was conducted on drilling machine. From the investigation it concludes that speed is most influencing parameter followed by feed and depth of cut on MRR.

A. D. Bagawade and P. G. Ramdasi (2014) research on effect of cutting parameters on material removal rate and cutting power during hard turning of AISI 52100 steel. The turning of hardened steels has been applied in many cases in production. The purpose of this research was to analyze the effect of the cutting parameters on the material removal rate, cutting power and material removal rate per cutting power during turning of AISI 52100 steel when using polycrystalline cubic boron nitride tools. Forces measured resulted in relatively low values, being the radial component the largest of all. The analysis of the result shows that the depth of cut has the greatest influence on material removal rate while cutting speed plays a dominant role in determining the cutting power and material removal rate per cutting power.

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Sahil Sharma. et al., (2017) research on experimental analysis and optimization of process parameters in plasma arc cutting machine of EN-45A material using Taguchi and ANOVA. This paper presents an experimental investigation on the optimization and the effect of the cutting parameters on material removal rate (MRR) in plasma arc cutting (PAC) of EN-45A material using Taguchi L 16 orthogonal array method. Four process variables viz. cutting speed, current, stand-off-distance and plasma gas pressure have been considered for this experimental work. Analysis of variance (ANOVA) has been performed to get the percentage contribution of each process parameter for the response variable i.e. MRR. Based on ANOVA, it has been observed that the cutting speed, current and the plasma gas pressure are the major influencing factors that affect the response variable. Confirmation test based on optimal setting shows the better agreement with the predicted values.

Hinal B.Thakker (2014) research on a review study of the effect of process parameters on weld bead geometry and flux consumption in saw (submerged arc welding process. submerged arc welding is most efficient welding process in any fabrication industry. It is a common arc welding process in which coalescence is produced by heating application with an electric arc or arcs set up model between a bare metal electrode and the work piece. The arc end of the metal electrode and molten pool are invisible. They are invisible being submerged under a blanket of the granular material (flux). Selection of process parameters has great influence on the weld bead geometry. Welding input parameters play a significant role in determining the quality of a weld joint. Here, this joint quality can be defined in terms of properties such as weld bead geometry and flux consumption. All the welding processes are used with the aim of obtaining a welded joint with the desired weld bead geometry and excellent mechanical properties with maximum metal deposition rate and minimum distortion rate. This paper presents the review of the effect of input parameters on weld bead geometry and flux consumption in submerged arc welding process.

Srinivas Athreya1 and Dr Y.D.Venkatesh (2012) research on application of Taguchi method for optimization of process parameters in improving the surface roughness of lathe facing operation. Have concluded that Taguchi method is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. The objective of this study is to illustrate the procedure adopted in using Taguchi Method to a lathe facing operation. The orthogonal array, signal-to-noise ratio, and the analysis of variance are employed to study the performance characteristics on facing operation. In this analysis, three factors namely speed; feed and depth of cut were considered. Accordingly, a suitable orthogonal array was selected and experiments were conducted. After conducting the experiments the surface roughness was measured and signal to noise ratio was calculated. With the help of graphs, optimum parameter values were obtained and the confirmation experiments were carried out. These results were compared with the results of full factorial method.

M. Kaladhar. et al.,(2011) research on application of Taguchi approach and utility concept in solving the multi-objective problem when turning AISI 202 austenitic stainless steel. Have concluded that the traditional Taguchi method is widely used for optimizing the process parameters of a single response problem. Optimization of a single response

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results the non-optimum values for remaining. But, the performance of the manufactured products is often evaluated by several quality characteristics/responses. Under such circumstances, multi-characteristics response optimization may be the solution to optimize multi-responses simultaneously. In the present 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.

P.W. Mason. Et al., (2001) research on iterative Taguchi analysis: optimizing the austenite content and hardness in 52100 steel. According to the research, it was found that Three iterations of Taguchi designed experiments and analyses were used to determine optimal thermal treatments for minimizing retained austenite content while maximizing rockwell hardness (HRC) in AISI 52100 bearing steel. Experimental variables chosen for this study included austenitizing and tempering temperatures, tempering time and cold treatment. After one iteration, tempering temperature and cold treatment were seen to have the greatest effect on austenite content while austenitizing and tempering temperatures had the greatest influence on hardness. After the second and third experimental iterations, two thermal treatments were noted each producing hardness of 58-59 HRC in combination with zero retained austenite as measured by x-ray diffraction.

From related research, many scholars have adopted the Taguchi method. To carry out research get different results depending on which data was used to analyze. The confidence of the data analyzed by Taguchi has made the research more reliable. Therefore, the Taguchi method is one of the quality tools.

EXPERIMENTAL DESIGN

Tools and Techniques Used in the Study

Experiments will be conducted on a selected lathe, selected tools and materials were carbides and mild steel (AISI 1040CD) respectively, the three process parameters as stated above. Spindle of speed (A), feed rate (B) and depth of cut (C) were considered in the study. Spaced five evenly levels within the operating range of the input parameters were selected for each process parameter. By experimenting with the Taguchi method, A L27 (OA) orthogonal array has been developed that includes 27 different experiments at three levels. According (K. Siva Prasad, K.S.V.K. Sainath and B. Vijay Kumar., 2017) the Taguchi method was selected to obtain the most suitable

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solution for material removal rates in a given input range such as rake angle, cutting speed and feed.

Therefore, modern methods of finding the best results above a given set of inputs can be easily accomplished using the Taguchi method rather than the other conventional methods. This method has a wide application scope in various fields of engineering science. The experimental data were analyzed using Minitab Release 15.00 software. To overcome this problem (A. D. Bagawade and P. G. Ramdasi., 2014) Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. Taguchi thus, recommends the use of the loss function to measure the performance characteristics that are deviating from the desired target value. The value of this loss function is further transformed into signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristics to analyze the S/N ratio. They are: nominal-the-best, larger-the-better, and smaller-the-better.

Steps Involved in Taguchi Method

The use of Taguchi's parameter design involves the following steps (W.T. Foster., 2000).

a. Identify the main function and its side effects.

b. Identify the noise factors, testing condition and quality characteristics.

c. Identify the objective function to be optimized.

d. Identify the control factors and their levels.

e. Select a suitable orthogonal array and construct the matrix

f. Conduct the matrix experiment.

g. Examine the data; predict the optimum control factor levels and its performance.

h. Conduct the verification experiment.

The process of preparing for efficiency

The process of preparing equipment and materials to be tested for efficiency takes the principles of a Taguchi experiment design to determine the optimization in the manufacturing process for lathes. The testing procedure of the machining process for the best value by the Taguchi method is shown in Figure 1 and shown in Table 1 the design factors along with their level.

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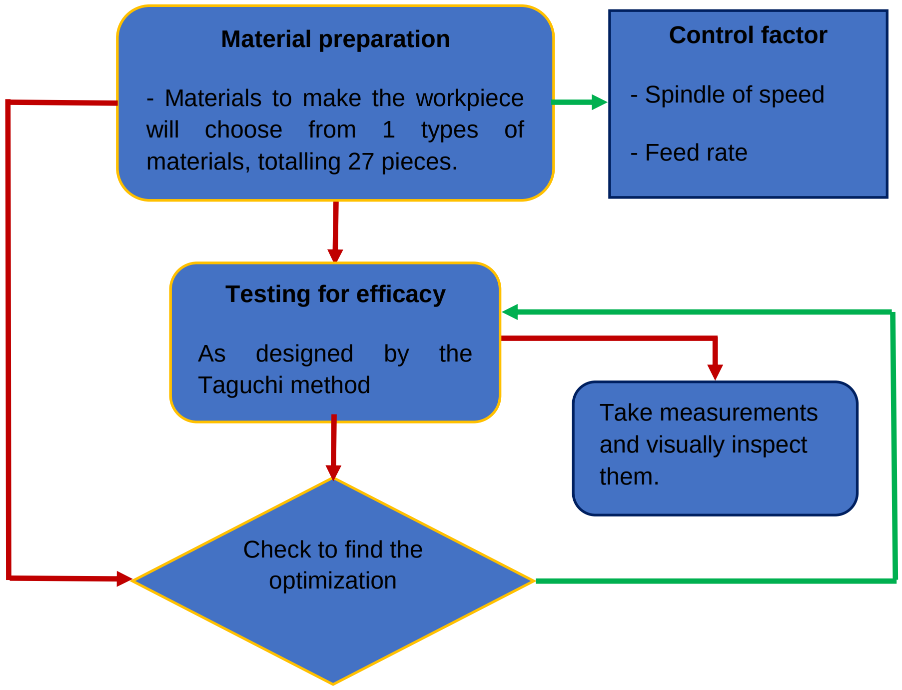

Figure 1 the testing process of the machining process for the optimization by the Taguchi method

The objective function

Objective function: Smaller-the-Better

S/N Ratio for this function:

$$\eta=-10 \log_{10} \left(\frac{1}{n} \sum_{i=1}^{n} y_i^2\right) \quad (1)$$

Where, n= Sample Size, and y= MRR in that run.

The control factors and parameters used in the experiment

The factors and parameters used in the experiment were determined in the conduct of the experiment and based on the guidelines outlined in the manufacturer's turning operation. In this study spindle of speed, feed rate and depth of cut was selected as control factors and their levels are shown in Table 1.

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Table 1 Factors and parameters used in the experiment.

Level	Spindle of speed (*rpm*)	Feed rate (*mm/rev*)	Depth of cut (*mm.*)
1	200	0.25	0.3
2	220	0.36	0.5
3	270	0.45	0.7

Selection of orthogonal array

To select an appropriate orthogonal array for conducting the experiments, the degrees of freedom are to be computed .The same is given below :
Degrees of Freedom :1 for Mean Value, and 8) =2x4(, two each for the remaining factors
Total degrees of freedom :9
The most suitable orthogonal array for experimentation is L27 array as shown in Table 2 . Therefore, a total twenty-seven experiments.

Table 2 Orthogonal array (OA)27.

Experiment No.	Control factors		
	1	**2**	**3**
1	1	1	1
2	1	1	1
3	1	1	1
4	1	2	2
5	1	2	2
6	1	2	2
7	1	3	3
8	1	3	3
9	1	3	3
10	2	1	2
11	2	1	2
12	2	1	2
13	2	2	3
14	2	2	3
15	2	2	3
16	2	3	1
17	2	3	1
18	2	3	1
19	3	1	3
20	3	1	3
21	3	1	3
22	3	2	1
23	3	2	1
24	3	2	1
25	3	3	2
26	3	3	2
27	3	3	2

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Analysis of Variance (ANOVA)

ANOVA is a statistical tool used to test differences between two or more means. It may seem odd that the technique is called analysis of variance (ANOVA) rather than analysis of means. The analysis of variance is obtained by dividing the measured the sum of the squared deviations from the total mean S/N ratio into contributions by each of the control factors and the errors (Duan, Wei Ran, Dai, Yi Fan, Shu, Yong, Sherrington, Ian., 2013) analysis of variance identify the percentage of contribution of controlled process parameters.

ANALYSIS OF EXPERIMENTAL RESULTS

Table 3 shown the experiment results for the MRR and corresponding S/N ratios were obtained with the help of Minitab release19.00 software.

Cause of Spindle of Speed, Flow Rate and Depth of Cut on MRR

From the response Table 3, it is clear that cutting speed is the most influencing factor followed by spindle of speed, depth of cut, and flow rate for MRR. The optimum for MRR is a spindle of the speed of 220 rpm, a flow rate of 0.25 mm/rev, and a depth of **cut of 0.5 mm respectively.**

Material Removal Rate Measurement

The Material removal rate is employed to work out the quantity of material removed per second. It's given by the Formula

MRR = N FR DC

Where N = Spindle of speed (rpm)

FR = Flow rate (mm/rev)

DC = Depth of cut (mm)

MRR = Material removal rate (mm3/ min)

As the conditions for feed, cutting rate and depth of cut area unit mounted therefore, this formula is employed to calculate the MRR rather than hard the initial and also the final weight, the higher than formula was won’t to calculate the MRR (Hardeep Singh, Rajesh Khanna, M.P. Garg., 2011).

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Table 3 Factors and parameters used in the experiment.

Level	Spindle of speed (*rpm*)	Feed rate (*mm/rev*)	Depth of cut (*mm.*)	MRR	Level	Spindle of speed (*rpm*)	Feed rate (*mm/rev*)	Depth of cut (*mm.*)	MRR
1	200	0.25	0.3	9.653	15	220	0.36	0.7	24.570
2	200	0.25	0.3	9.747	16	220	0.45	0.3	28.736
3	200	0.25	0.3	9.542	17	220	0.45	0.3	29.240
4	200	0.36	0.5	11.792	18	220	0.45	0.3	28.571
5	200	0.36	0.5	24.390	19	270	0.25	0.7	9.542
6	200	0.36	0.5	23.866	20	270	0.25	0.7	9.506
7	200	0.45	0.7	26.525	21	270	0.25	0.7	18.975
8	200	0.45	0.7	13.021	22	270	0.36	0.3	28.902
9	200	0.45	0.7	13.333	23	270	0.36	0.3	31.447
10	220	0.25	0.5	4.845	24	270	0.36	0.3	30.675
11	220	0.25	0.5	4.757	25	270	0.45	0.5	34.722
12	220	0.25	0.5	4.836	26	270	0.45	0.5	34.483
13	220	0.36	0.7	25.253	27	270	0.45	0.5	34.602
14	220	0.36	0.7	24.876					

Analysis of Signal to Noise Ratio and Means

Smaller is better performance characteristic was selected to obtain material removal rate.

Table 4 Response table for signal to noise ratios (smaller is better).

Level	SS	FR	DC
1	-23.84	-18.63	-26.18
2	-23.59	-27.98	-23.60
3	-27.66	-28.48	-25.31
Delta	4.07	9.84	2.58
Rank	2	1	3

Table 5 Response table for signal for means.

Level	SS	FR	DC
1	15.763	9.045	22.946
2	19.520	25.086	19.810
3	25.873	27.026	18.400
Delta	10.109	17.981	4.546
Rank	2	1	3

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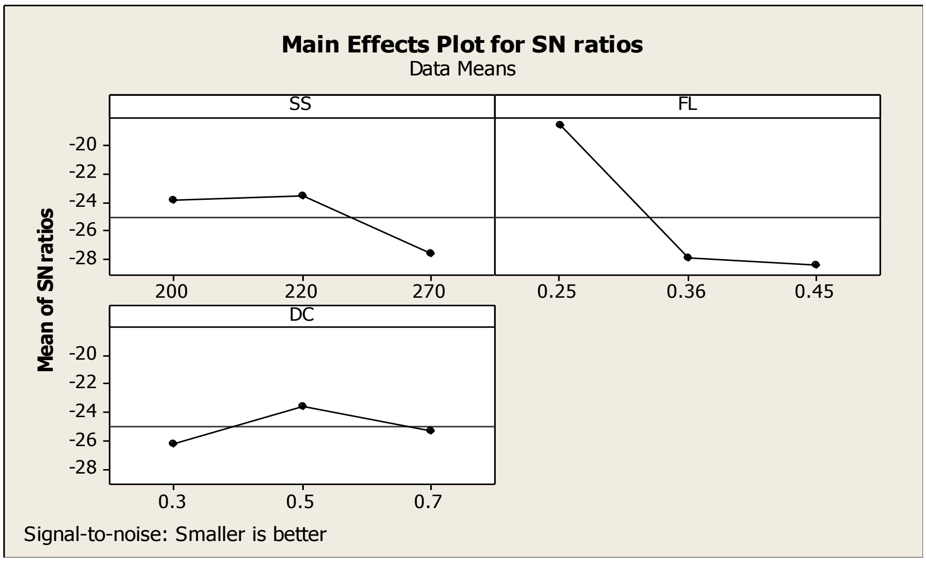

Figure 2 Main effects plot for SN ratios

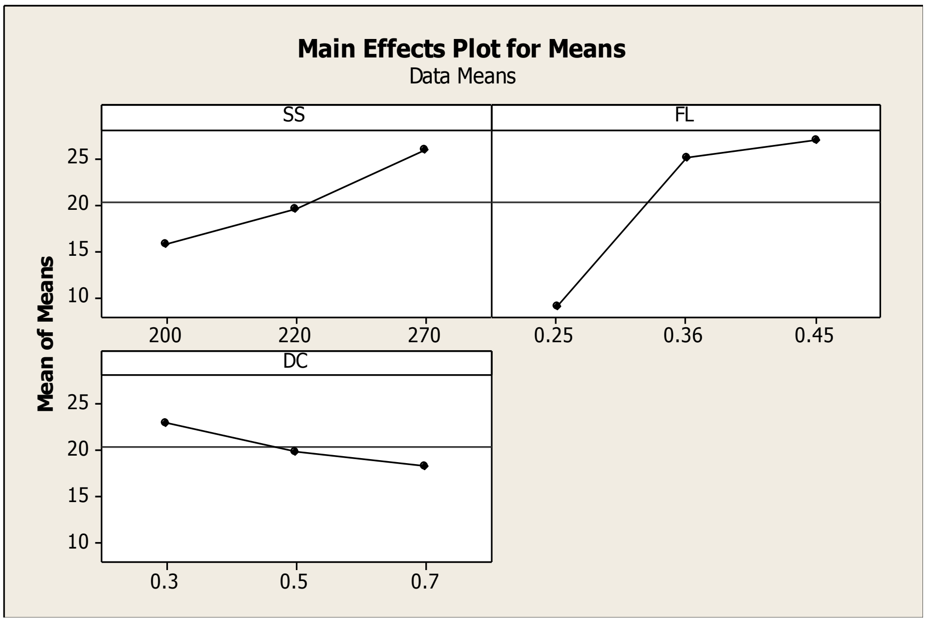

Figure 3 Main effects plot for means

From Tables 4, 5, and Figure 2, and 3 above that flow and edge condition after that spindle of speed plays an important role for MRR, a spindle of speed = 220 rpm, feed rate = 0.25 mm/rev and depth of cut = 0.50 mm respectively.

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Analysis of Variance (ANOVA) and Estimated Model Coefficients

Minitab release 19.00 was used to investigate the process parameters. Analysis of variance and estimate coefficient defines the percentage of contribution for each process parameters.

Table 6 Analysis of variance for means.

Source	DF	Seq SS	Adj SS	MS	F	P
SS	2	156.66	156.66	78.33 3	3.50	0.222
FR	2	584.40	584.40	292.20	13.07	0.071
DC	2	32.48	32.48	16.24	0.73	0.579
Residual Error	2	44.73	44.73	22.36		
Total	8	818.28				

Table 7 Estimated model coefficients for means.

Term	Coef	SE Coef	T	P
Constant	20.3854	1.576	12.932	0.006
SS 200	-4.6221	2.229	-2.073	0.174
SS 200	-0.8651	2.229	-0.388	0.735
FR 0.25	-11.3407	2.229	-5.087	0.037
FR 0.36	4.7002	2.229	2.108	0.170
DC 0.3	2.5603	2.229	1.148	0.370
DC 0.5	-0.5749	2.229	-0.258	0.821
S =4.729	R-Sq =94.5 %		R-Sq(adj) =78.1 %	

Taguchi Analysis: MRR versus SS, FR, DC for predicted values shown in Table 8.

Table 8 Predicted values.

S/N Ratio	mean	StDev	Ln(StDev)
-18.5878	6.9828	2.42075	-0.85332
-18.5878	6.9828	2.42075	-0.85332
-18.5878	6.9828	2.42075	-0.85332
-25.3620	19.8885	5.32258	0.69578
-25.3620	19.8885	5.32258	0.69578
-25.3620	19.8885	5.32258	0.69578
-27.5628	20.4185	7.19412	1.88494
-27.5628	20.4185	7.19412	1.88494
-27.5628	20.4185	7.19412	1.88494
-15.7664	7.6047	-0.46591	-3.19197
-15.7664	7.6047	-0.46591	-3.19197
-15.7664	7.6047	-0.46591	-3.19197

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Table 8 (Cont.) Predicted values.

S/N Ratio	mean	StDev	Ln(StDev)
-26.8239	22.2352	2.66021	0.35211
-26.8239	22.2352	2.66021	0.35211
-26.8239	22.2352	2.66021	0.35211
-28.1850	28.7211	-1.45606	-2.32285
-28.1850	28.7211	-1.45606	-2.32285
-28.1850	28.7211	-1.45606	-2.32285
-21.5465	12.5465	3.65251	0.42878
-21.5465	12.5465	3.65251	0.42878
-21.5465	12.5465	3.65251	0.42878
-31.7644	33.1331	0.79083	0.10874
-31.7644	33.1331	0.79083	0.10874
-31.7644	33.1331	0.79083	0.10874
-29.6818	31.9382	2.43807	-0.69707
-29.6818	31.9382	2.43807	-0.69707
-29.6818	31.9382	2.43807	-0.69707

ANOVA for Material Removal Rate (MRR)

Results obtained for the material removal rate (MRR) square measure shown in Table 3. The results for material removal rate (MRR) were obtained from the nine experiments performed of Taguchi. The experimental results analyzed with multivariate analysis square measure shown in Table 6. The F worth calculated through Minitab release 19.00 computer code is shown within the second last column of multivariate analysis table that suggests the importance of the factors on the required characteristics. Larger is that the F worth higher is that the significance (considering confidence level of 95%). The results show that solely feed is that the most vital issue. The results are consistent with the research of (Musunuru, et al., 2018).

Signal –to - Noise Ratio

Parameters that effect on the output are often divided into 2 parts: governable (or design) factors and uncontrollable (or noise) factors. The worth of governable factors is often adjusted by the designer however the worth of uncontrollable factors can't be modified as a result of they're the sources of variation as a result of operational surroundings. The most effective set of management factors as they influence the output is set by performing arts experiments. Smaller-the-Better is employed for material removal rate shown in Figure 2 and 3 respectively. The values were consistent with the research of (Musunuru, et al., (2018).

Regression Equation

The regression equation for material removal rate as shown by Equation (1) is calculated in minitab release 19.00 software. The regression Equation shows the significant effect of each process parameter on the material removal rate. From this equation, it is cleared that the current and pulse on time have positively affected the material removal rate whereas spindle of speed, feed rate, and depth of cut effect on

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response i.e. material removal rate.

$$MRR = +20.3854 - 4.6221(SS200) - 0.8651(SS200) - 11.3407(FL0.25) + 4.7002(FL0.36) + 2.5603(DC0.3) - 0.5749(DC0.5) \quad (2)$$

Conclusion and Further Research

From the Experimental results as we observed that the optimum condition for our input data to get maximum material removal rate (MRR) is 9 degrees of the spindle of the speed of 220 rpm, 0.25 mm/rev of feed rate, and depth of cut of 0.5 mm. The maximum material removal rate that we get from our experiment and the Taguchi method is 4.757 grams. The minimum material removal rate that we get from our experiment by the Taguchi method is 4.757 grams. This concludes that spindle of speed, flow rate, and depth of cut is consumed and from analysis, we got the minimum material removal rate conditions which would directly save power in small-scale productions. This would also save the lead time in the industrial production process.

The main aim of this research was to find optimum values of process parameters for the minimum values of material removal rate by using spindle of speed, feed rate, and depth of cut as the process parameters. From this research, the following conclusions are drawn:

1. The material removal rate increases with the decrease in the spindle of speed. As we decrease the feed rate and depth of cut within a becomes less than which results to less than material removal rate.
2. As the spindle of speed and feed rate increases, the material removal rate decreases.
3. The spindle of speed, feed rate, and depth of cut has a significant effect on material removal rate.
4. The material removal rate is minimum at the third level of the spindle of speed (220 rpm.), flow rate (0.25 mm/rev), and depth of cut 0.5 mm.) respectively.
5. The response table mean analysis of MRR. The most effecting factors on MRR is the spindle of speed followed by depth of cut.
6. The response table signal to noise ratio analysis of MRR. The most effecting factors on MRR is the spindle of speed followed by depth of cut.
7. The regression equation the output parameters can be optimized for any turning machine with different combination of input parameters.
8. The coefficient of determination, R2, is defined as the ratio of the explained variation to the total variation according to its magnitude. It is also the proportion of the variation in the response variable attributed to the model and was suggested that for a good fitting model, R2 should not be more than 75 % (this research is R2(adj.) is 78.1%).
9. The p-value was 0.222, 0.071, and 0.579 for SS, FR, and DC respectively which means there is no significant difference between the level of the spindle of speed, flow rate, and depth of cut factor. This suggests that the temperature no significant effect on material removal rate significantly affects the production process of the turning

machine.

10. The use of the Taguchi method to analyze it gives confidence in this research. The Taguchi method is widely used in many academic fields.

11. The future will be extended from this project further by considering the approach to creating innovations for the community using the same Taguchi method, but by changing the analytical approach.

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