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Experimental Investigations into CNC Lathe Turning operation by using Taguchi Methods

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ABSTRACT

CNC Turning Operation on P20 Material by Taguchi Method attempts on optimizing turning process under various machining parameters by Taguchi Method to develop or implement the quality of machined product. Taguchi optimization technology is applied to optimize cutting parameters in turning P20 material. The CNC turning machine is use to conduct experiments based on the Taguchi design of experiments (DOE). Signal to noise ratio (S/N) and analysis of variable (ANOVA) were implied to find the maximum material removal rate (MRR) and minimum surface roughness. The experiments results shows that the optimal combination of parameters for surface roughness are at variable speed, variable feed rate, variable depth of cut while for material removal rate are at variable spindle speed, variable feed rate, variable depth of cut. The optimum value of surface roughness (Ra) comes out to be 1µm. While the optimum value of the material removal rate (MRR) comes out to be mm3/min. Optimum results are finally varied with the help of conformation experiments.

Keywords: ***ANOVA, MRR, DOE, Ra,CNC.***

1. INRODUCTION

Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment. Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. The desired cutting parameters are determined based on experience or by hand book. Cutting parameters are reflected. Traditional experimental design methods are very complicated and difficult to use. Additionally, these methods require a large number of experiments when the number of process parameters increases [16, 17, and 18]. In order to minimize the number of tests required, Taguchi experimental design method, a powerful tool for designing high-quality system, was developed by Taguchi. This method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only.

2. REVIEW OF LITERATURE

Feng. Cang-Xue (Jack) studied the impact of turning parameters on surface roughness. He studied the impact of Feed, Speed and Depth of Cut, Nose radius of tool and work material on the surface roughness of work material. He found that the feed have most significant impact on the observed surface roughness and also observed that there were strong interactions among different turning parameters.

Jafar Zare and Afsari Ahmad the performance characteristics in turning operations of Df2 (1.2510) steel bars using TiN coated tools. Three cutting parameters namely, cutting speed, feed rate, and depth of cut, will be optimized with considerations of surface roughness.

Rajmohan T. et al. have studied on optimization of machining parameters in electrical discharge machining of 304 stainless steel. Author experimented that the effect of electrical discharge machining parameter such as pulse on time, pulse off time, voltage and current on material removal rate in 304 stainless steel was studied. The experiment was carried out as per design of experiments approach using L9 orthogonal array. The results were analyzed using analysis of variance and response graphs. From this study, it is found that different combination of EDM process parameters is required to achieve higher MRR for 304 stainless steel. Signal to noise ratio and analysis of variance is used to analyze the effect of parameters towards the MRR is also identified.

Vishal parashar et al. have studied Investigation and Optimization of Surface Roughness for Wire Cut Electro Discharge Machining of SS 304L using Taguchi Dynamic Experiments. Optimization of surface roughness using Taguchi's dynamic design of experiments is proposed for WEDM operations. Experimentation was planned as per Taguchi's L'32 mixed orthogonal array. Each experiment has been performed under different cutting conditions of gap voltage, pulse ON time, pulse OFF time, wire feed and dielectric flushing pressure. Stainless

Steel grade 304L was selected as a work material to conduct the experiments. From experimental results, the surface roughness was determined for each machining performance criteria. Signal to noise ratio was applied to measure the performance characteristics deviating from the actual value. Finally, experimental confirmation was carried out to identify the effectiveness of this proposed method.

A.Rehman et al. have studied KERFs width analysis for wire cut electro discharge machining of SS 304L using design of experiments. Statistical and regression analysis of KERF width using design of experiments is proposed for WEDM operations. Experimentation was planned as per Taguchi's L'32 mixed orthogonal array. Each experiment has been performed under different cutting conditions of gap voltage, pulse ON time, and pulse OFF time, wire feed and dielectric flushing pressure. Stainless steel grade 304L was selected as a work material conduct the experiments. From experimental results, the KERF width was determined for each machining performance criteria. Analysis of variance (ANOVA) technique was used to find out the variables affecting the KERF width. Assumptions of ANOVA were discussed and carefully examined using analysis of residuals. Variation of the KERF width with machining parameters was mathematically modelled by using the regression analysis method.

S. Sivakiran et al. studied of Effect of Process Parameters on MRR in Wire Electrical Discharge Machining of En31 Steel. To study the influence of various machining parameters Pulse on, Pulse off, Bed speed and Current on metal removal Rate (MRR). The relationship between control parameters and Output parameter (MRR) is developed by means of linear regression. Taguchi's L16 (4*4) Orthogonal Array (OA) designs have been used on EN-31 tool steel to achieve maximum metal removal rate.

Singaram Lakshmanan et al. have studied, Optimization of Surface Roughness using Response Surface Methodology for EN31 Tool Steel EDM Machining. The work piece material was EN31 tool steel. The pulse on time, pulse off time, pulse current and voltage were the control parameters of EDM. RSM method was used to design.

Brajesh Kumar Lodhi and Sanjay Agarwal studied Optimization of machining parameters in WEDM of AISI D3 Steel using Taguchi Technique. In this work, an attempt has been made to optimize the machining conditions for surface roughness based on (L9 Orthogonal Array) Taguchi methodology. Experiments were carried out under varying pulse-on-time, pulse-off time, peak current, and wire feed. An orthogonal array, the signal-to-noise (S/N) ratio, and the analysis of variance (ANOVA) were employed to the study the surface roughness in the WEDM of AISI D3 Steel.

Gaurav Raghav et al. studied Optimization of Material Removal Rate in Electric Discharge Machining Using Mild Steel. In the present work, relationships have been developed between the input decision variables and the desired goals by applying the statistical regression analysis of investigations obtained by Electro Discharge machining process for a considerable variation in the crisp sets of variables. The objectives functions were maximized or minimized by using the generalized Genetic Algorithms and the data are stored for a given set of objectives

Amit Kohli et al. studied Optimization of Material Removal Rate in Electrical Discharge Machining Using Fuzzy Logic. The objective of present work is to stimulate the machining of material by electrical discharge machining (EDM) to give effect of input parameters like discharge current (Ip), pulse on time (Ton), pulse off time (Toff) which can bring about changes in the output parameter, i.e. material removal rate. Experimental data was gathered from die sinking EDM process using copper electrode and Medium Carbon Steel (AISI 1040) as work-piece. It was found that proposed fuzzy model is in close agreement with the experimental results. By Intelligent, model based design and control of EDM process parameters in this study will help to enable dramatically decreased product and process development cycle times.

Zahid A. Khan et al. studied Multi response optimization of Wire electrical discharge machining process parameters using Taguchi based Grey Relational Analysis. This paper presents a study that investigates the effect of the WEDM process parameters on the surface roughness average and the KERF width of the stainless steel (SS 304). Nine experimental runs based on an orthogonal array of Taguchi method are performed and grey relational analysis method is subsequently applied to determine results of the analysis of variance (ANOVA) reveals that the pulse ON time is the most significant controlled factor for affecting the multiple responses in the WEDM according to the weighted sum grade of the surface roughness and the KERF width.

Harpreet Singh and Amandeep Singh studied Effect of Pulse On/Pulse off Time on Machining of AISI D3 Die Steel Using Copper and Brass Electrode in EDM. Electric discharge machining is non conventional machining process. EDM is generally used for machining for those materials which are cannot processed by conventional machining process. In this article we compared the material removal rate achieved using different tool materials. Work piece used is AISI D3 and tool materials used copper and brass electrode with pulse on/pulse off as parameter. The electrolyte used is kerosene oil.

S. A. Sonawane & M.L. Kulkarni studied effect of WEDM machining parameters on output characteristics. Wire Electrical discharge machining [WEDM] is an electro-thermal machining process. It can machine any material irrespective of its hardness, brittleness or toughness with utmost accuracy. As there is no contact between wire and the work piece mechanical stresses are not induced during machining..

Shubhra Paliwal et al. studied parameter optimization of wire electrical discharge machining for minimum surface roughness and KERF width using taguchi method. The cutting of SS302 material using Wire electro discharge machining (EDM) with Molybdenum electrode by using Taguchi methodology has been reported. The Taguchi method is used to formulate the experimental layout and to analyze the effect of each parameter on the machining characteristics. Optimum level of process parameters like current, pulse-on time and pulse-off time that would yield optimum response of surface roughness and KERF width are determined. Percentage contribution of the process parameters is Calculated using ANOVA. It is found that pulse off time is significant factor for surface roughness, while pulse on time is significant factor for KERF width.

M. Durairaj et al. studied Analysis of Process Parameters in Wire EDM with Stainless Steel using Single Objective Taguchi Method and Multi Objective Grey Relational Grade. This paper summarizes the Grey relational theory and Taguchi optimization technique, In this present study stainless steel 304 is used as a work piece, brass wire of 0.25mm diameter used as a tool and distilled water is used as a dielectric fluid. For experimentation taguchi's L16, orthogonal array has been used.

S. S. Mahapatra et al. studied Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method. Rough cutting operation in WEDM is treated as a challenging one because improvement of more than one machining performance measures viz. metal removal rate (MRR), surface finish (SF) and cutting width (KERF) are sought to obtain a precision work. Using Taguchi's parameter design, significant machining parameters affecting the performance measures are identified as discharge current, pulse duration, pulse frequency, wire speed, wire tension, and dielectric flow.

2.1 Literature gap

1. In most of the time the authors try to optimize the turning process.
2. After that they give their focus to optimize the following process and maximum time mild steel,
3. Copper, aluminum these type materials can optimized

2.2 Objective

1. To study of CNC machining operation.
2. To Study optimization Of Taguchi Method
3. To find out the minimum machining time required
4. To find the maximum MRR.
5. To find out minimum surface roughness.

3. METHODOLOGY

3.1 Taguchi method

Traditional experimental design methods are very complicated and difficult to use. Additionally, these methods require a large number of experiments when the number of process parameters increases [16, 17, 18]. In order to minimize the number of tests required, Taguchi experimental design method, a powerful tool for designing high-quality system, was developed by Taguchi. This method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only. Taguchi recommends analyzing the mean response for each run in the inner array, and he also suggests analyzing variation using an appropriately chosen signal-to-noise ratio (S/N).

There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems;

(I) SMALLER-THE-BETTER:

n = -10 Log_{10} [mean of sum of squares of measured data]This is usually the chosen S/N ratio for all undesirable characteristics like " defects " etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined (like maximum purity is 100% or maximum Tc is 92K or minimum time for making a telephone connection is 1 sec) then the difference between measured data and ideal value is expected to be as small as possible. The generic form of S/N ratio then becomes, n = -10 Log_{10} [mean of sum of squares of {measured - ideal}

(II) LARGER-THE-BETTER:

n = -10 Log_{10} [mean of sum squares of reciprocal of measured data] This case has been converted to SMALLER-THE-BETTER by taking the reciprocals of measured data and then taking the S/N ratio as in the smaller-the-better case.

(III) Nominal –The -Best:

$$n = 10 \, Log_{10} \frac{\text{Square of means}}{\text{Variance}}$$

This case arises when a specified value is MOST desired, meaning that neither a smaller nor a larger value is desirable.

3.2 DESIGN OF EXPERIMENT

In this study, three machining parameters were selected as control factors, and each parameter was designed to have three levels, denoted 1, 2, and 3 (Table). The experimental design was according to an L9 array based on Taguchi method, while using the Taguchi orthogonal array would markedly reduce the number of experiments. A set of experiments designed using the Taguchi method was conducted to investigate the relation between the process parameters and delamination factor. DESIGN EXPERT @ 16 Minitab software was used for regression and graphical analysis of the obtained data.

3.3 Design of experiment parameters and Levels

Symbol	Turning Parameters	Level 1	Level 2	Level 3
A	Cutting speed, (mm/min)	1000	1400	1800
B	Feed rate, (rev/min)	0.10	0.15	0.20
C	Depth of cut, (mm)	0.5	1	1.5

3.4 Material Used

Medium Steel alloy (P20) of Ø: 50 mm, length: 100 mm were used for the turning experiments in the present study. The chemical composition and mechanical and physical properties of P20 can be seen in table. The turning tests were carried out to determine the material removal rate under various turning parameters.

Chemical composition of P20 (Medium Steel alloy)

Sr. No	**Property**	**Value**
1	Density	7861 kg/m^3
2	Specific Gravity	7.86
3	Machinability	60-65 %
5	Thermal Conductivity	41.5 W/m/^{0}K
4	Melting Point	2600 ^{0}F
6	Modulus of Elasticity	207 GP
7	s of Elasticity Tension	29 MPa

4. EXPERIMENTAL DETAIL

4.1 Material Removal Rate

Expt No.	Spindle Speed (rpm)	Feed rate (mm/rev)	Depth Of Cut (mm)	Machining Time sec	Initial Weight Before Cutting (Kg)	Final Weight Before Cutting (Kg)	MRR=Initial Wt. - Final Wt./Machining Time mm³/sec
1	1000	0.10	0.5	34	1.019	0.985	0.990
2	1000	0.15	1	24	**1.021**	**0.961**	**0.981**
3	1000	0.20	1.5	18	1.018	0.939	0.966
4	1400	0.10	0.5	25	1.018	0.987	0.979
5	1400	0.15	1	18	1.018	0.965	0.964
6	1400	0.20	1.5	14	1.014	0.939	0.947
7	1800	0.10	0.5	20	1.014	0.986	0.965
8	1800	0.15	1	14	1.019	0.963	0.950
9	1800	0.20	1.5	12	1.017	0.938	0.939

5. RESULT & DISCUSSION

5.1 MRR Experiment results and Taguchi analysis

A series of turning tests was conducted to assess the influence of turning parameters on material removal rate in turning P20. Experimental results of the material removal rate for turning of P20with various turning parameters are shown in table. Also gives S/N ratio for material removal rate. The S/N ratios for each experiment of L9 (3^13) was calculated. The objective of using the S/N ratio as a performance measurement is to develop products and process insensitive to noise factor. Table 5 shows average effect response table. Response Table For Means Response table signal to noise ration larger is better.

Level	Spindle speed (rpm)	Feed Rate (mm/rev)	Depth of cut (mm)
1	0.9789	0.9777	0.9624
2	0.9633	0.9652	0.9661
3	0.9512	0.9505	0.9650
Delta	0.0277	0.0272	0.0037
Rank	1	2	3

Analysis of Variance Table

Source	Df	Adj Ss	Adj Ms	F-Value	P-Value
Regression	3	0.002271	0.000757	178.68	0
Spindle Speed (Rpm)	1	0.00115	0.00115	271.43	0
Feed Rate (Mm/Rev)	1	0.001111	0.001111	262.24	0
Depth Of Cut (Mm)	1	0.00001	0.00001	2.36	0.185
Error	5	0.000021	0.000004		
Total	8	0.002293			

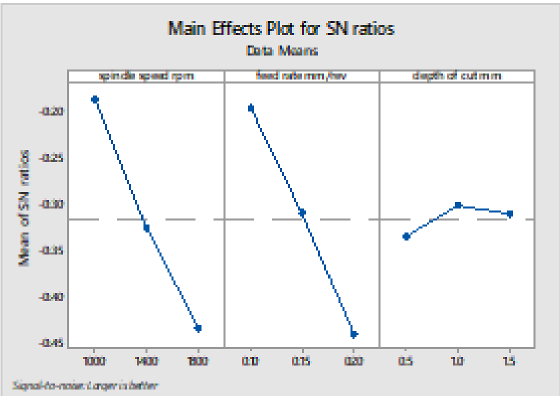
Model Summary

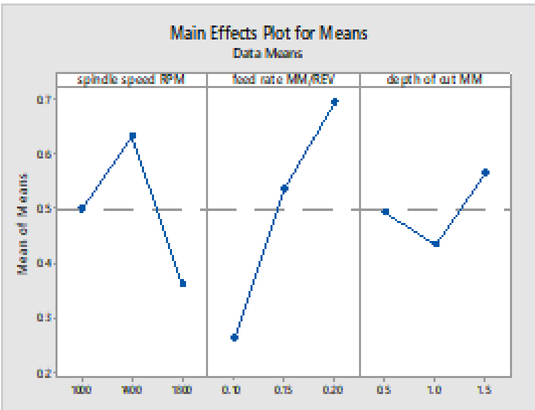
S	R-sq	R-sq.(adj)	R-sq(pred)
0.0020585	99.08%	98.52%	97.36%

Regression Equation

MRR mm^3/sec = 1.05119- 0.000035 spindle speed rpm - 0.2722 feed rate mm/rev + 0.00258 depth of cut mm

MAIN EFFECTS PLOT FOR SN RATIOS





Result analysis of MRR

Minitab statistical software has been used for the analysis of the experimental work. The Minitab software studies the experimental data and then provides the calculated results of signal-to-noise ratio. The objective of the present work is to minimize machining time and maximize the MRR in turning process optimization. The effect of different process parameters on material removal rate and machining time are calculated and plotted as the process parameters changes from one level to another. The average value of S/N ratios has been calculated to find out the effects of different parameters and as well as their levels. The use of both ANOVA technique and S/N ratio approach makes it easy to analyze the results and hence, make it fast to reach on the conclusion. Table shows the experimental results for material removal rate and machining time and corresponding S/N ratios. Larger-the-better performance characteristic is selected to obtain material removal rate. From the response Table and Fig.it is clear that cutting speed is the most influencing factor followed by feed rate and depth of cut for MRR. The optimum for MRR is cutting speed of 1000 rpm. Feed rate of 0.15mm/rev and depth of cut of 1.5mm.

5.2 SURFACE ROUGHNESS

The surface roughness is one of the most commonly used criteria to determine the quality of turned steel. The surface roughness of a turned surface is an important response parameter. The quality of product such as laptops, cell phones made by injection molding greatly depends on finishing of the moulds. Surface roughness is one of the important factors for the materials used for making moulds and dies such as P20 steel. This paper optimize the cutting parameters such as feed rate, depth of cut and cutting speed for the turning process of AISI P20 steel (mould steel) for better surface finish. Taguchi's technique has been used to accomplish the objective of the experimental study. L-9 Orthogonal array, Signal to noise (S/N) have been used for conducting the experiments. A surface roughness tester of Mitutoyo Surface SJ-201P was used for measuring the surface roughness. The Surface roughness tester was capable of measuring Ra value up to 3 reading taken.

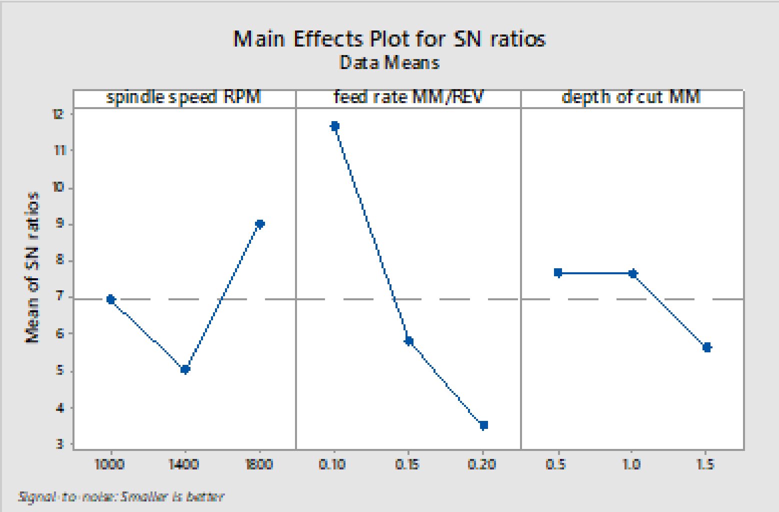
Anova table for surface roughness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	**3**	0.315938	0.105313	3.55	0.103
spindle speed RPM	**1**	0.028153	0.028153	0.95	0.375
feed rate MM/REV	**1**	**0.279936**	**0.279936**	**9.43**	**0.028**
depth of cut MM	**1**	0.007848	0.007848	0.26	0.629
Error	**5**	0.148394			
Total	**8**	0.464332			

Surface Ra µm =0.018 - 0.000171 spindle speed RPM
+ 4.32 feed rate MM/REV
+ 0.072 depth of cut MM

Level	Spindle Speed (rpm)	Feed Rate (mm/Rev)	Depth Of Cut (mm)
1	6.915	11.630	7.680
2	5.024	5.803	7.629
3	8.978	3.485	5.608
Delta	3.955	8.145	2.072
Rank	2	1	3

MAIN EFFECTS PLOT FOR SN RATIOS



The Taguchi method is used in this study to optimize the high speed CNC turning conditions of AISI P-20 steel. The cutting parameters optimization is carried out through experiments with minimum number of trials as against full factorial design. The results are summarized as follows:

(1) The factor/level combinations of A2 B1 C3 are the recommended optimum parameters, for high speed CNC turning.

(2) It can be concluded that the combination of the high level of cutting speed (1400 rpm) and low level feed of (0.10mm/rev) and a middle value of depth of cut 1.5mm yield the optimum result

6. CONCLUSION

The present study was carried out to study the effect of input parameters on the material removal rate. The following conclusions have been drawn from the study:

1. The Material removal rate is mainly affected by cutting speed and feed rate. With the increase in cutting speed the material removal rate is increases & as the feed rate increases the material removal rate is increases.
2. From ANOVA analysis, parameters making significant effect on material removal rate feed rate, and interaction between feed rate & cutting speed were found to be significant to Material removal rate for reducing the variation.
3. The parameters considered in the experiments are optimized to attain maximum material removal rate. The best setting of input process parameters for defect free turning (maximum material removal rate) within the selected range is as follows:

a. Cutting speed i.e. 1000m/min.
b. Feed rate i.e. 0.15mm/rev.
c. Depth of cut should be 1.5mm.

4. The Taguchi method is used in this Study to optimize the high speed CNC Turning conditions of AISI P-20 steel.
5. The factor/level combinations of A2 B1 C3 are the recommended optimum Parameters, for high speed CNC Turning.
6. It can be concluded that the combination of the high level of cutting speed (1400 rpm) and low level feed of (0.10mm/rev) and a middle value of depth of cut 1.5mm yield the optimum result

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