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Multi-Objective Optimization of Machining Parameters by using Response Surface Methodology EN-19Alloy Steel Metal

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Abstract - The experimental analysis of the metal removal rate in turning EN-19 steel with a cemented inorganic compound coated atomic number 74 insert tool under different cutting parameters is presented in this paper. Each manufacturing industry strives to produce a large number of goods in a reasonable time. As a result, it becomes important to find out how to machine it quickly and cheaply. The cutting parameters, namely feed rate, cut depth and spindle speed, were changed to see what effect they had on the EN-19 steel. The experimental setup consisted of nine different samples, each of which weights were recorded before and after machining. Then, for nine samples, the cut depth, feed rate, and spindle speed were modified. Then the duration of each experiment is recorded, as well as how much metal is extracted during each experiment and at what time. The main goal of the experiment is to find out which parameters have the highest metal extraction rate.

Key Words: Centre lathe, EN-19 alloy steel, Material removal rate, Machining time, Carbide tools.

1. INTRODUCTION

Current Experimental Studies for the Bridge between Quality and Productivity High Light Center Lathe Machine Method Parameter as high temperature removal rate to produce sensible surface end. The surface end and the material removal rate are known as quality characteristics and square measurements, which are considered to be directly associated with unproductively. This experimental study presents an efficient approach for the improvement of shaping machine adsorption MINITAB 18 and the Taguchi technique under various conditions. Knowledge related to machining of inauspicious cutting materials is inadequate and difficult. So an experimental study needs to be done to come out with an optimal study. Among the various parameters that can be considered because the production target, material removal rate (MRR) was thought for this work because the factor directly affects the value of machining and therefore the rate of machining hours. Particularly the cutting speed, feed rate and cut depth were considered in the machining parameters. The aim was to seek an optimized set of values to maximize MRR by the Taguchi technique. Therefore the present work focuses on finding a combination of optimal parameters of cutting speed, feed and depth to maximize the rate of material removal during machining.

2. LITERATURE SURVEY

Many research workers have investigated and demonstrated the effect of various cutting parameters viz. Spindle speed, feed, depth of cut etc. on the surface roughness and the MRR in orthogonal turning. The literature Explain the effect of above mentioned variable has been discussed below:

Dileep Kumar C., et al (2014) [4] focused on an experimental study to find the effects of cutting parameters on surface finish and optimize them for better surface finish and high Material Removal Rate (MRR) during turning of Ti-6Al-4V. Uncoated WC/Co inserts are used for the machining purpose. A combined Taguchi method and Grey Relational Analysis (GRA) is used for the optimization. Analysis of Variance (ANOVA) is employed to find out contribution of each parameter.

Basim A. K. et al (2015) [6] have experimented to develop a predictive model for surface roughness and temperature in turning operation of AISI 1020 mild steel using cemented carbide in a dry condition using the Response Surface Method (RSM). In this work, the input cutting parameters are cutting speed, feed rate and depth of cut. From the experiment it is found that Feed rate is the most significant factor on surface roughness.

Mohan S., Dharmpal D., et al (2010) [12] have investigated the robust design technique to minimize the variance of the response and orthogonal arrays. Experiments are designed and conducted based on Taguchi's L9 Orthogonal array design. This study discusses the use of Taguchi Parameter Design for optimizing surface roughness generated by a CNC turning operation.

J.B.Shaikh, J.S.Sidhu, et al (2014**)** [14] have determined the influence of lubricant on surface roughness and material removal rate (MRR) by using CNC LATHE Machine with AISI D2 steel as a work material and TiAIN coated carbide tool as a tool material. Different lubricant used on this experiment are Cotton seed oil, Servo cut and soya bean oil and machining parameters are cutting speed, feed rate and depth of cut. Experiments are designed and conducted basedon Taguchi's L9O rthogonal array design

M. Gupta, et al (2015) [15] they investigated the machinebility of unidirectional glass fiber reinforced plastics (UD-GFRP) composite while carrying out turning operation.

The parameters used to investigate their effect on output responses are tool nose radius, tool rake angle, feed rate, cutting speed, cutting environment (dry, wet and cooled) and depth of cut. Experiment are designed and conducted based on Taguchi's L18 Orthogonal array design.

S. A. Rizvi, et al (2015) [16] have analyzed that an effort was made to optimize the cutting parameters to achieve better surface finish and to identify the most effective parameter for cost evolution during turning by using CNC LATHE MACHINE with IS 2062 steel rods (35 mm diameter) as a work material and Chemical Vapor Deposition (CVD) coated carbide inserts as a tool material. In this work, the input parameters are cutting speed, Feed Rate and Depth ofcut.

S. Sahu, B.B.Choudhury(2015) [17] have analyzed that the performance of multi-layer TiN coated tool in machining of hardened steel (AISI 4340 steel) as a work material under high speed turning uncoated tool use. In this work, the input parameters are cutting speed, Feed Rate and Depth of cut. Experiment are designed and conducted based on Taguchi's L16 Orthogonal Array design. From the Taguchi analysis it has been found that the feed is playing as a main parameter for reducing surface roughness, whereas depth of cut is having significant effect on the surface roughness.

T. Rajasekaran, K. Palanikumar, et al (2013) [19] In this work, the input parameter are cutting speed, feed rate and depth of cutin turning by using conventional Lathe (MakeNAGMATI, INDIA). Experiment are designed and conducted based on Taguchi's L9 Orthogonal Array design. From the Taguchi analysis it has been found that primarily feed rate and secondarily cutting speed has got the greater influence on surface roughness.

Yusuf S., et al (2005) [20] have determined surface roughness model response surface methodology (RSM) with low-carbon steel as a piece material and TiN coated inorganic compound as a tool material. In this work, perform cutting parameters area unit cutting speed, feed rate and depth of cut. From the experiment it's

Ilhan A., et al (2011) [21] have investigate the effect of cutting speed, feed rate and depth of cut using AISI 4140 (51 HRC) steel as a work material and Al_2O_3 and TiC coated carbide as a tool material. Experiment are designed and conducted based on Taguchi's L9 Orthogonal Array design. Through the experiment it is found that Feed rate is the most significant factor on surface roughness.

Ashvin J. M., et al (2013) [23] have investigated the effect of turning parameters such as cutting speed, feed rate, tool nose radius and depth of cut on surface roughness with AISI 410 steel as a work material and ceramic as a tool material using Response Surface Methodology (RSM). In this study Feed rate is the most significant factor on surface roughness.

Tanveer H. B., Imtiaz A. (2014) [24] have experimented a study of cutting parameters of AISI 1040 steel as a work material and uncoated carbide as a tool material using Genetic algorithm and Response Surface Methodology. In this work, the input cooling condition, cutting parameters are cutting speed, feed rate and depth of cut. In this experiment it is found that Feed rate is the most significant factor on surface roughness.

Sayak M., et al (2014) [26] have experimented that to develop the combination of optimum cutting parameters SAE 1020 mild steel as a work material and carbide as a cutting tool using Taguchi technique. In this work, the input cutting parameters are cutting speed, feed rate and depth of cut. Experiment are designed and conducted based on Taguchi's L25 Orthogonal array design. From the experiment it is found that Depth of Cut has the most significant effect on MRR followed by Feed.

Ch. MaheswaraRao et al. [3] optimized the surface roughness in CNC turning using Taguchi method and ANOVA. The material AA7075 was turned using tungsten carbide insert. Experiments were designed using Taguchi technique. ANOVA was performed to study the significance of cutting parameters on surface roughness. The results showed that cutting speed and feed influenced the surface roughness themost.

Ashvin J. Makadia et al. [5] optimized the machining parameters for turning operations based on response surface methodology. Here AISI 410 steel was turned using the turning parameters cutting speed, feed rate, depth of cut and tool nose radius. Design of experiment was used to study the effect of these parameters on surface roughness. The effect of these parameters was investigated by using Response Surface Methodology (RSM). The study revealed that the feed rate followed by the tool nose radius were the main influencing factors on surface roughness.

Sayak Mukherjee et.al [02] conducted experiments on SAE 1020 steel exploitation taguchi methodology to optimize cutting parameters with regard to material removal rate. L25 orthogonal array was employed in conducting experiments. The result shows that Depth of cut had important impact on Material Removal Rate followed by feed and speed.

R. Suresh, et.al [04] to developed a mathematical model correlating cutting parameters with Tool Wear and Surface Roughness. Turning operation was done hardened AISI H13 steel with PVT coated ceramic tool in dry condition. Experiments were conducted exploitation the construct of Response Surface Methodology. For Surface roughness, Feed was the dominating issue followed by Depth of cut and speed. For Tool wear, Speed and feed were them

Krishnakantet.al [07] conducted experiments on EN24 steel to optimize the fabric Removal Rate (MRR). Taguchi technique with L9 orthogonal array is employed with three factors and three levels. Response variation is studied exploitation S/N magnitude relation for larger-the better characteristic. Material Removal Rate will increase with increase in feed, speed and depth of cut.

Gulhane, et.al [08] investigated the surface roughness in turning operation of 316L stainless steel exploitation Taguchi technique. L9 orthogonal array was chosen for conducting

experiments and also the results were verified with ANNOVA. the foremost important issue was feed followed by depth of cut and speed. Conjointly the optimum values for cutting parameters were known.

3. EXPERIMENTAL PROCEDURE

Based on the properties and their application in the manufacturing industry the EN-19 Alloy steel materials of 20mm diameter and 150mm length rolled rod is used for this research work and the machining has been carried out with experimentation on centre lathe machine as shown in figure 1. For this study L9 OA experiments were used. The material removal rate is calculated by using the Equation (1)[9]. MRR=$WWW-WWWWW*W(1)$ Where Wtb, Wta – Weight of workpiece before and after machining in mg t- Machining Time in min, ρ- Density of the steel.

Experiment No.	Spindle Speed RPM	Depth of cut mm	Feed Rate mm/rev	Weight Before machining	Weight After machining	Time seconds	Total metal removed gm	MRR Gm/sec
1	165	0.2	0.1	700	694	98	6	0.051
2	165	0.5	0.2	672	660	49.30	12	0.243
3	165	1	0.3	700	678	98.15	20	0.525
4	330	0.5	0.1	692	680	49.93	12	0.240
5	330	1	0.2	680	660	25.03	20	0.799
6	330	0.2	0.3	685	680	18.81	5	0.265
7	620	1	0.1	700	680	26.38	20	0.758
8	620	0.2	0.2	676	670	13.51	5	0.370
9	620	0.5	0.3	712	700	9.58	12	1.252

Table 4: Experimental Results

3.1 Steps for the Experiments

1) Inspection and preparing the centre lathe machine 12 ready to perform the machining operation.
2) Designing the program with dimension.
3) Cutting EN8 bright bars by power saw to get desired dimension of the workpieces
4) Calculating diameter of each specimen by the high precision vernier caliper.
5) Experiment has been designed using RSM technique of design of experiment.
6) Perform turning operation on work piece in selected cutting process parameters like: cutting speed (A), feed rate (B) and depth of cut(C) on the basis on DOE table.
7) Measured diameter of each machined bar by vernier caliper.
8) Calculate the MRR.
9) Optimize the results with ANOVA technique

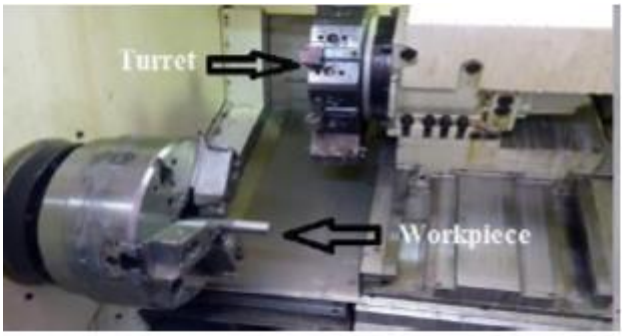

Fig 4: Centre lathe machine

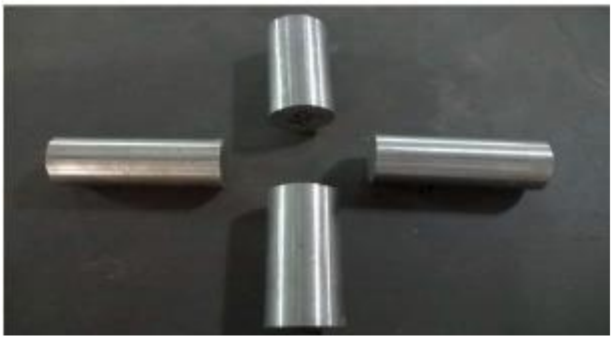

Fig. 4.1: Some of the machined samples

3.1.2. Taguchi Method:

Dr. Genechi Taguchiwas carried out efficient research with DOE techniques in the late 1940's. He spent considerable effort and time to make this experimental technique more users friendly and applied this technique to improve the quality of manufactured products [10]. Dr. Taguchi's standardize form of DOE, popularly known as the Taguchi method or Taguchi's approach was introduced in USA in the early1980's. Today it is one of the most effective and operative quality tools used by engineers in all types of manufacturing activities [6]. Taguchi designs of orthogonal arrays, which estimate the effects of factors on the response MRR. In this experimental study L9 Taguchi's orthogonal array experimental design was used, and the spindle speed, feed rate and depth of cut in three (3) levels were used as input parameters presents in Table 1. Material removal was used as response variables. Taguchi method is a powerful tool in quality Optimization makes use of a special design of Orthogonal Array (OA) to examine. Number of experiments used to design the orthogonal array for 3 parameters and 3 levels of milling parameters.

Minimum experiments = $[(L-1) \text{ X } p] + 1 = [(3-1) \text{ X } 3]+1$ $L9$

3.1.3 Taguchi Approach

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Parameter	Factor	Level1	Level2	Level3
Spindle Speed RPM	A	165	330	620
Depth of cut mm	B	0.2	0.5	1
Feed Rate mm/rev	C	0.1	0.2	0.3

Table 4.1 Control Parameters and their levels

3.1.4. Signal to noise ratio (SNR):

Dr. Taguchi proposed the signal to noise ratio for robust design; it is an appropriate tool to quantify the quality of the product response to noise ratio and signal factor. The signal to noise ratio for the product response can be divided in to three categories, such as smaller the better, higher the better and nominal the best. The material removal rate is considered under higher the better signal to noise ratio, this can be calculated by using equation (2) [4, 5] Signal to noise ratio= -10log[1/MRR2]

Spindle Speed RPM	Depth of cut mm	Feed Rate mm/rev	Machining Time seconds	MRR Gm/sec	S/N ratio
165	0.2	0.1	98.00	0.051	39.8245
165	0.5	0.2	49.30	0.243	33.8569
165	1.0	0.3	98.15	0.525	39.8378
330	0.2	0.2	49.93	0.240	33.9672
330	0.5	0.3	25.03	0.799	27.9692
330	1.0	0.1	18.81	0.265	25.4878
620	0.2	0.3	26.38	0.758	28.4255
620	0.5	0.1	13.51	0.370	22.6131
620	1.0	0.2	9.58	1.252	19.6273

Table 3.2: L9 Orthogonal design and response parameters

3.2. RESULTS ANDDISCUSSION

- Optimization of Machining Parameter of EN 19Steel.
- Main effect plots analysis

The main effect plots of SN ratios for material removal rate of EN-19 steel have been shown in Fig 2.From the Fig 2 it is observed that rotational speed feed rate and depth of cut has direct effect on material removal rate, which means by increasing rotational speed feed rate and depth of cut The maximum material removal of EN-19 alloy steel was done in the experiment 9 where the speed, depth of cut and feed rate are 620 rpm, 0.5 mm and 0.3 mm/ retrospectively.

3.2.1 Main effect plots analysis:

The analysis is made with the help of a software package MINITAB 18. The main effect plots are shown in Figs. 1 and 2. These show the variation of individual response with the four parameters, i.e., cutting speed, feed, depth of cut and nose radius separately. In the plots, the *x*-axis indicates the value of each process parameter at two level and y-axis the response value. Horizontal line indicates the mean value of the response. The main effects plots are used to determine the optimal design conditions to obtain the optimum flank wear. Figure 1 shows the main effect plot for flank wear. According to this main effect plot, the optimal conditions for minimum flank wearare:

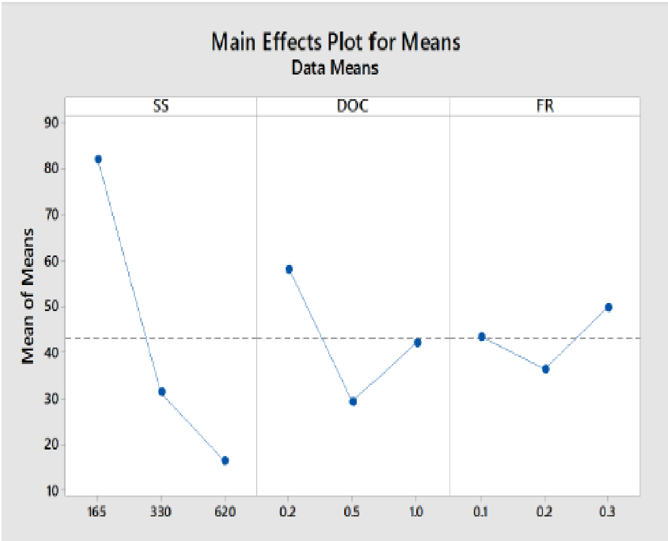

Fig.3.2 Main effects plot for SN ratios (MRR)

Spindle Speed RPM	Depth of cut mm	Feed Rate mm/rev	Machining Time seconds	MRR Gm/sec	S/N ratio	MEAN 1
165	0.2	0.1	98.00	0.051	39.8245	6
165	0.5	0.2	49.30	0.243	33.8569	12
165	1.0	0.3	98.15	0.525	39.8378	20
330	0.2	0.2	49.93	0.240	33.9672	12
330	0.5	0.3	25.03	0.799	27.9692	20
330	1.0	0.1	18.81	0.265	25.4878	5
620	0.2	0.3	26.38	0.758	28.4255	20
620	0.5	0.1	13.51	0.370	22.6131	5
620	1.0	0.2	9.58	1.252	19.6273	12

Table 4.3 Taguchi Analysis: Main effect plot for means for MRR

3.3 Taguchi Analysis: Main effect plot for S/N ratio for MRR

3.3.1 Analysis of Variance(ANOVA):

The analysis of variance estimates the significance of machining parameters on material removal rate. The significance of process parameters are identified by comparing α=0.05 level of 95% confidence level with p-value column, if p-value is less than 0.05 then the process parameter is said to be significant and p value is more than 0.05, then the process parameters is said to be insignificant and also ANOVA table gives the influencing parameters on response [9]. The analysis of variance presents the significance of process parameter on response variable for EN-19 material, From Table 1 it is conclude that rotational speed and depth of cut , feed rate is insignificant, also from the F- test value can conclude that rotational speed is most influencing parameters followed by feed rate ,rotational speedand.

Source	DF	Adj SS	Adj MS	F - Value	P - Value	Remark
SS	2	0.4255	0.21276	2.32	0.301	Insignificant
DOC	2	0.1683	0.08415	0.92	0.522	Insignificant
FR	2	0.3522	0.17609	1.92	0.343	Insignificant
Error	2	0.1835	0.09173	-	-	-
Total	8	1.1295	-	-	-	-

Table1. 4.4 Analysis of Variance of material removal rate for EN-19 steel

4. CONCLUSION & FUTURE SCOPE

This paper has presented an application of parameter design of the taguchi method in the optimization of turning operations in centre lathe machine. The following conclusions will be drawn supported the experimental results of this study:

- Taguchi's robust orthogonal array design method is suitable to analyze the machining time (metal cutting) as well as material removal rate problem.
- It is additionally found that the various constant quantity style supported the Taguchi methodology provides a straightforward, systematic and efficient methodology for the optimization of the machining parameters.
- It can be concluded that spindle speed and depth of cut are the main parameters among the three controllable factors (spindle speed, feed rate, and depth of cut) that influence material removal rate during centre lathe machine.
- This experiment additionally suggests that the material removal rate is very influenced first by the feed rate so depth of cut followed by spindle speed. It is clear from analysis that the effect of Feed rate spindle speed and Depth of cut on material removal rate (MRR) is 41.47%, 37.11% and 21.42.68%respectively.
- In turning for maximum material removal rate, use of medium cutting speed (165rpm), higher depth of cut(0.5mm) and higher feed rate(0.3mm/rev) are recommended to obtain better material removal rate (MRR) for the specific range.
- When we looking for higher material removal rate, smaller cutting speed (165rpm), higher depth of cut (0.5mm) and higher feed rate (0.3mm) can be employed to get optimized result.
- It is clear from above table that the effect of spindle speed, Depth of cut and Feed rate on machining time (MT) is 75.33%, 16.54% and 3.94%respectively

5. FUTURE SCOPE

Although the CNC turning has been thoroughly investigated for EN-19 alloy steel work piece, still there is a scope for further investigation. This paves a way for following future work: It can be also done for L27 orthogonal array. We can also do for more process parameters such as nose radius and rake angle of cutting tool which we have taken constant. On economical aspect of view it can be also done for it.

The above study can be carried out using other heuristic techniques and the results can be compared. In this paper machining time & material removal rate of EN31Alloy steel specimen has been optimized by Taguchi Method. Other researchers can perform optimization of more machining parameters like material removal rate (MRR), cutting force, etc. Furthermore, other types of nonconventional optimization methods, such as Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC) Optimization, etc. can also be studied.

The developed mathematical model can be used for direct evaluation or machining time material removal rate under various combinations of machining parameters during the turning process.

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