Optimization of vertical milling machine process parameters of EN8 steel for MRR Using Taguchi Method

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Abstract— Material removal rate is an important factor that greatly affects production rate and cost. Therefore, it is necessary to estimate the surface roughness and material removal rate before machining. In machining tasks, achieving the desired surface quality characteristics of mechanical innovation is a really exciting task. This is because these quality structures are highly correlated and are expected to be directly or indirectly influenced by the process parameters or their interactive effects, although the magnitude of the main effects of the process parameters varies for different parameters. This paper present the vertical milling of EN8 steel .Taguchi method has been used to plan and analyse the experiment. Three input parameters namely spindle speed; feed rate and depth of cut were varied to study their effect on the quality of cut in en8 steel. the machining characteristic that are being investigated are MRR (material removal rate) ANOVA analysis and Signal to Noise ratio method has been proposed and used to optimise machining parameters of vertical milling machine. it is found that the significant variable effect the MRR is the spindle speed, feed rate and depth of cut. The study shows that the Taguchi method is suitable to solve the stated problem with minimum number of trials as compared with a full factorial design.

Keywords: ANOVA: EN8,Taguchi method: MRR: Parameter optimization:

I. INTRODUCTION

. EN8 steel is a popular grade of medium carbon steel, which readily machinable in any condition which best suitable for high tensile strength and wear resistance components. It is available in heat treated forms possess good homogeneous metallurgical structure and gives consistent machining and mechanical properties.[1].Milling is the process of using a rotary cutter to remove material (or feeding) from a work piece at an angle along the axis of the tool. It covers a wide variety of operations and machines, from small individual parts to large, heavy gang milling operations. This is one of the most commonly used processes in industry and machine shops today for machining parts for exact parts and sizes[2] .The quality of the metal cutting obtained depends on the process parameters of the machine tool; these process parameters affect the output response or performance characteristics, so proper selection of process parameters is an important task in machining operations. Poor process parameter selection results in optimal non-machine running, resulting in lower material removal rate, lower surface finish, higher machining time, reduced tool life, increased tool wear, increased power consumption and more. [3]In the last two decades were instigated many numerical techniques applied to the optimization of machining parameters being the most frequently used the fuzzy logic, the genetic algorithms and the Taguchi method. In this work is implemented the Taguchi method for material removal rate optimization in an end-milling operation.[4]

A. Literature Review

Guo et al. [1] Cells forming materials reinforced by wire-EDM at high travel speeds were investigated. Al2O320% particle reinforced materials with 6061 mixtures were used in this experiment. Regardless of high or low power, the experiment resulted Different machining processes were optimized by the researchers to improve the quality of the material.M.SivaSuryaa et al [5] used taguchi method to optimize the multi-response objectives (material removal rate and surface roughness) while machining EN19 steel using Grey Relational analysis. Cutting speed, feed rate and depth of cut are the process parameters affecting material removal rate (MRR) and surface finish.

Ghhani J. A. et al. [6] optimized The hardened steel AISI H13 with TN Coated P10 Carbide Insert Tool provides optimized cutting parameters in the machining process, machining semi finish and high speed cutting finishing conditions. Milling parameters such as cutting speed, feed rate and depth of cut, as well as their interactions on this process are studied using the Taguchi method of experimental design (DOE). This study indicated the suitability of the Taguchi method to at least address the mentioned problem. The number of tests compared to the full actual design.**Ngoc-Chien Vu. et al. [7]**used to conduct the multi-objective optimization of the surface roughness (*Ra*) and the resultant cutting force (*Ft*) in hard milling of SKD61 steel by Taguchi method and Response Surface Methodology (RSM).Values of the input parameters for milling tests are chosen through the stability lobe diagram of a machine tool simulated by the use of Cutpro software. The Taguchi method is used for designing all of the milling experiments.

Shokrania [8]et.alanalyzed the study of cryogenic CNC end milling of Inconel 718 nickel-based alloys using TiAN coated solid carbide tools. Experimental research has shown that machine tool has considerable potential to improve surface roughness of cryogenic cooling machine parts compared to dry machining without significant increase in power consumption..**Lohithaksha M Maiyar [9] e**t.al investigated the parameter optimization of end milling operation for Inconel 718 super alloy with multi-response criteria based on the Taguchi orthogonal array with the grey relational analysis. Cutting speed, feed rate and depth of cut are optimized with considerations of multiple performance characteristics namely surface roughness and material removal rate. A grey relational grade obtained from the grey relational analysis is used to solve the end milling process with the multiple performance characteristics. Analysis of Variance is applied to identify the most significant factor**.Reddy Sreenivasulu [10]**focused on the influence of cutting speed, feed rate and depth of cut on the delamination damage and surface roughness on Glass Fibre Reinforced Polymeric composite material (GFRP) during end milling. Taguchi design method is employed to investigate the machining characteristics of GFRP. The obtained results were 5.122µm for surface roughness and 1.692 delamination damage factor.**Qehaja et al. [11],** machining parameters such as the cutting speed, feed rate, and depthof cut widely influence the degree of surface roughness. Anincrease in the cutting speed, feed rate and depth cut duringmachining operations often leads to increase in temperature and rate of chip formation.

.Lou et al. [12] studied surface roughness prediction technique for CNC end milling. Input factors were cutting speed, feed, depth of cut and coolant flow to examine surface roughness and metal removal rate.**Mandeepchahaletal (2013)**are conducted to estimate the range of process parameters for optimization of surface roughness and Material Removal Rate in CNC Milling.They investigated the range of process parameters with optimization of surface roughness and Material Removal Rate in CNC milling process.The optimum parameters of milling is low spindle speed and good surface roughness and MRR in CNC Milling.**Jing et al. [14]** investigated the surface roughness in micro-end-milling of metals, citing chip thickness, too diameterand nature of work piece as variables that influence surfaceroughness in addition to other cutting parameters such as feedper tooth and cutting speed.**Sahin et al.[15]**studied the surface roughness of Al2O3 particle-reinforced aluminium alloy composites with different types of cutting tool; TiN (K10) coated carbide tools and TP30 coated carbide tools at various cuttingspeeds. It was found that the surface roughness is mostly affected by the tool material and geometry of the chipbreaker grooves. It was shown that the machinability of particle-reinforced composites with large sizes and highvolume fractions of composites were poor.

Kok [16]an experimental research was carried out to evaluate the effect of test parameters and properties on the surface roughness of the material when performing the machining MMC workpiece using the Taguchi method and ANOVA. In their research, they found that the average surface roughness value of a triple layer coated cutting tool is less than that of a single layer, TN coated cutting tool. They found that surface roughness increased with increasing cutting speed, but decreased with increasing size and volume fraction of particles for both devices under all cutting conditions.**Reddy et al. [17]**observed surface roughness on the end milling of Al/SiC PMMC using TiAlN coated carbide end millcutters. It was found that the surface roughness increased with an increase in feed rate in all cases under study.When the feed rate increased the chip thickness also increased, resulting in an increase in cutting force. This willincrease the surface roughness value.

II. MATERIALS AND METHOD

A. SELECTION OF MATERIAL

EN8 Steel is a popular grade of medium carbon steel, can easily be machined in any situation that is well suited to high tensile strength and wear resistant components. It is available in heat treatment forms, has good homogeneous metallic texture, and offers convenient machining and mechanical properties.

B. WORKPICE AND TOOL DETAILS

- The work piece material chosen for this experiment is EN8.
- There are some of the characteristic features of the alloy including light weight, formability and corrosion resistance which have made is applicable for many industries.
- The test was conducted on vertical milling machine which shown in figure 1.
- Work piece used in the square block of dimension given below and also shown in fig 2**.**
- Work piece were inserted in the jaw and it is perpendicular to the tool axis.
- The milling experiments were carried out for 9 different work piece of each EN8. Shown in Table 1

Fig 1.Vertical Milling Machine

TABLE 1: Material Specification

MATERIAL	LENGTH(mm)	WIDTH(mm)	THICKNESS(mm)
EN8	150	150	10

TABLE 2:Chemical Properties Of En8 Steel(Wt%)

	C	Si	Mn	S	P	Mo
EN8	0.44	1.0	0.05	0.015	0.5	-

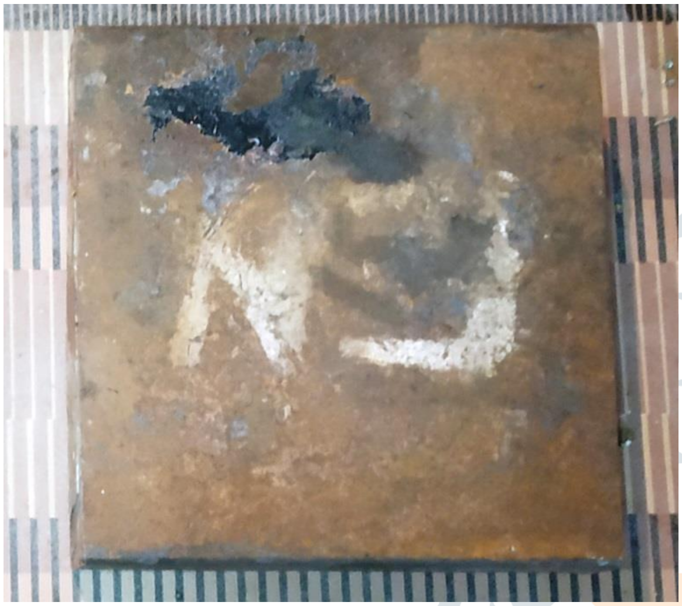

Fig 2: EN8 Steel

Fig 3: End milling cutter

Table 3: Mechanical Properties of EN8 Steel

Maximum stress	**Yield stress**	**Proof stress (0.2%)**	**Elongation**	**Impact strength**	**Hardness value**
850 N/mm–2	465 N/mm2	450 N/mm2	16%	28 j	255 Brinell

C. SELECTION OF CONTROL FACTORS AND LEVELS

A total of three process parameters with three levels are chosen as the control factors such that the levels are sufficiently far apart so that they cover wide range. The process parameter and their ranges are finalized using literature, books and machine operator’s experience. The three control factors selected are spindle speed (A), feed rate (B), depth of cut(C). EN-8 Steel alloy work pieces are used in experimentation. The control levels and their alternative levels are listed in table:

TABLE 4: PROCESS PARAMETERS AND THEIR LEVELS

Process Parameters	Units	Level1	Level2	Level3
Spindle Speed	Rpm	228	317	450
Feed Rate	Mm/Rev	30	48	75
Depth Of Cut	Mm	1	1.5	2.0

I. METHODOLOGY

A TAGUCHI METHOD

Taguchi method provides simple and systematic work to find and evaluate the optimum parameters in the selected process. The Taguchi method uses to find S/N ratio converting the loss function which calculates the deviation between the experimental and desired values.() The Taguchi method is used for effective design and analysis.It uses two major tools which are the orthogonal arrays OA and the signal to noise ratio S/N ()

B .DESIGN OF EXPERIMENTS

L9 orthogonal array was chosen for 3 factors and 3 levels and process parameters selected to conduct this experiment are spindle speed ,feed rate and depth of cut shown in table 4 .The Minitab 18 software was used to carry out the design of experiments .TABLE 4 illustrates the final DOE using L9 orthogonal array. The output responses measured are, material removal rate.

D .SIGNAL TO NOISE RATIO

Signal to noise ratio was design and analysed by Dr Taguchi .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 a(s smaller the better, higher the better and nominal the best.

E .MATERIAL REMOVAL RATE

The material removal rate is calculated based on the machining time and the work piece weight measured before and after the machining process.(Eq1) is used to determine the material removal rate for the given experiment.

Material Removal Rate (MRR) is calculated from the multiplication of cutting speed, feed rate and depth of cut by using the relation:

$$MRR = \frac{\text{before machining- after machining}}{\text{time}\times \text{density}} \quad 1$$

Where, Wb-Weight before machining (Kg) Wa-Weight after machining (Kg) q-Density of material (Kg/mm3) t-

Machining time (seconds)

TABLE 5: TAGUCHI DESIGN

JOB NO1	SPINDLE SPEED	FEED RATE	DEPTH OF CUT
1	228	30	1.0
2	228	48	1.5
3	228	75	2.0
4	317	30	1.5
5	317	48	2.0
6	317	75	1.0
7	450	30	2.0
8	450	48	1.0
9	450	75	1.5

II. RESULTS AND DISCUSSION

Analysing and evaluating results of the experiments using the Taguchi method

A. **Experimental results:**The observed data for MRR has been analysed using the Taguchi optimization method and Analysis of Variance with the help of MINITAB 19 software. The Signal to noise ratio has been calculated based on Taguchi's larger the better approach as it aims to maximise the material removal rate by using the following relation:

η= $-10\boldsymbol{log 1/n 1/yi}$

The following **Table 6** consist of given input process parameters and their levels and experimental results and predicted results.

Sl No	Rotational Speed (rpm)	Feed rate (mm/rev)	Depth of Cut(mm)	MRR(mm3/min)	S/N RATIOS
				EN-8	EN-8
1	228	30	1.0	115.955	-7.2722
2	228	48	1.5	54.047	-7.2346
3	228	75	2.0	274.894	-5.7111
4	317	30	1.5	340.136	-7.3471
5	317	48	2.0	334.190	-7.4950
6	317	75	1.0	231.910	-7.6042
7	450	30	2.0	175.520	-11.2459
8	450	48	1.0	838.360	-11.0777
9	450	75	1.5	911.070	-11.3170

After the generation of the above table, the Response table for Mean S/N ratio for the EN8 are obtained, on the basis of which the corresponding the rank of the different parameters were used to find the level of importance towards affecting the MRR

B. Analysis of response table for S/N ratio

Results from table 3 shows that the main factors that significantly influence that contributing to material removal rate is the spindle speed. Spindle speed was found influencing parameter with highest delta of 1.489 followed by depth of cut with 0.743 delta value. **Figure3, shows** the main effect plot for S/N ratio.The greatest variations on MRR was due to spindle speed

Table 7 :Response Table For S/N Ratio

Level	spindle	feed rate	doc
1	-41.57	-45.60	-49.02
2	-49.47	-47.87	-48.16
3	-54.18	-51.76	-48.05
Delta	12.61	6.16	0.97
Rank	1	2	3

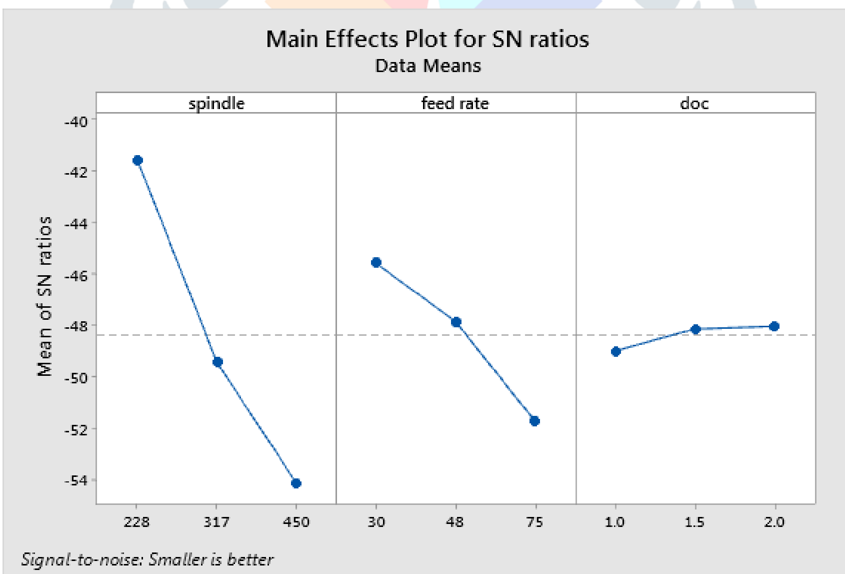

Figure 3: Main Effect Plot for S/N ratio

C. Analysis of main effects for SN ratios

The productivity of machining can be determined through MRR, so it necessary to know the influence of the machining parameters on the MRR during vertical milling of EN8 steel.

During process of milling process, the influence of various machining parameters like spindle speed, feed rate and depth of cut has significant effect on MRR. The mail effect plot shown in figure are S/N ratio of the experimental responses are in given in table and the value of MRR for each process parameters and the respective levels are plotted.

The optimal machining performance for MRR was obtained as228 rpm, feed rate and depth of cut. The material removal rate rapidly decreases with increases of spindle speed and from 228rpm to 450rpm and it gradually decreases from 30mm/rev to 48mm/rev and rapidly decreases from 48mm/rev to 75mm/rev from 1mm to 1.5mm gradually increases and from 1.5 to2mm,itdecreasesrapidly.

TABLE 8.Analysis of Variance for Material removal rate

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value
spindle	2	382353	51.37%	382353	191176	1.91
feed rate	2	112089	15.06%	112089	56045	0.56
doc	2	49616	6.67%	49616	24808	0.25
Error	2	200213	26.90%	200213	100106	
Total	8	744271	100.00%			

D. ANALYSIS OF VARIANCE

The purpose of ANOVA is to investigate which milling parameter significantly affects performance index and to establish the mathematical link between the responses and machining parameters of milling process, test has been performed to test the accuracy of experimental error. The relative importance of the machining parameters by using ANOVA. The results of ANOVA for material removal rate signal ratio and material removal rate are presented in TABLE 7,8 and 9.

From Table 9, it ANOVA can be seen and analysed that associated p value of less than 0.05 for the model which shows that the model are statistically significant. In this study, the contribution of each of the machining parameters and their interaction was determined. The table also represent % contribution of the parameters on the response MRR. It observed that spindle speed is major influencing factor (51.37%), followed by feed rate (15.06%) and depth of cut is 6.67%.

CONCLUSIONS

Experimental investigation of end milling operation on EN8 a has been done and experiments were conducted according to L9 Orthogonal Array design .The optimum parameters value combining was found which would yield maximum material removal rate(MRR) ,following conclusion have been drawn are written below:

- Both the response and S/N ratio are used to derive the optimum conditions. Since for quality characteristic, MRR larger the better approach is desirable, the largest response is the ideal level for a parameter. The S/N ratio is always highest at the optimum condition.
- Analysis of variance (ANOVA) is also employed to identify the level of importance of the machining parameters on the multiple performance characteristics namely material removal rate and surface roughness. Assumptions of ANOVA are tested using residual analysis. ANOVA results showed that SPINDLE SPEED AND FEED RATE are the powerful control parameters for the material removal rate
- The most influencing factor on Material removal rate is the spindle speed.
- Depth of cut is statistically insignificant factors influencing the material removal rate in milling process.
- The result of the optimization for maximum material removal rate are based on the optimization results, it has been found that Spindle speed 450 rpm ,30 mm/rev as feed rate, and depth of cutat1.5mm.

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