International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 04, April-2015

Analysis of Process Parameters for Material Removal Rate During Dry Turning of FG 260 Grey Cast Iron

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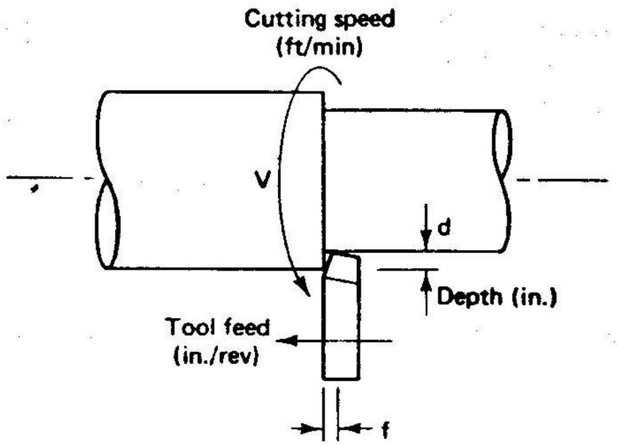
Abstract:- **This paper investigates the effect of process parameters in dry turning of grey cast iron FG 260 in a CNC lathe. The parameters namely the spindle speed, feed rate and depth of cut are varied to study their effect on material removal rate.The study reveals that material removal rate is directly influenced by the spindle speed feed rate and depth of cut. It is observed that material removal increases with increased feed rate and is higher .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 rate 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 CNC lathe machine. From the investigation It concludes that feed rate is most influencing parameter followed by depth of cut and speed on MRR.**

Keywords: Dry turning, NOVA, Taguchi, MVLR analysis, MMR

INTRODUCTION

Turning is the process whereby a single point cutting tool removes unwanted material from the cylindrical work piece and the tool is fed parallel to the axis of rotation. It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not. Turning, in which material is removed from the external surface of a rotating workpiece, is one of the most basic material removal processes. Therefore, turning is the first Choice for machining cylindrical parts.



Turning is used to produce rotational, typically axi-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed.

Turning, like any other machining process, is greatly influenced by independent input variables cutting speed, feed rate, and depth of cut commonly known as cutting conditions. These cutting conditions are also believed to have significant effects on the quality of the machined parts. Since these cutting parameters can be chosen and controlled by the user and are reflected in the quality of machined parts, they are the appropriate parameters for investigating their effects on the quality of turned parts. In turning, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the workpiece material, tool material, tool size, and more.

Cutting feed - The distance that the cutting tool or workpiece advances during one revolution of the spindle, measured in inches per revolution (IPR). In some operations the tool feeds into the workpiece and in others the workpiece feeds into the tool. For a multi-point tool, the cutting feed is also equal to the feed per tooth, measured in inches per tooth (IPT), and multiplied by the number of teeth on the cutting tool.

Cutting speed - The speed of the workpiece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).

Spindle speed - The rotational speed of the spindle and the workpiece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the workpiece where the cut is being made. In order to maintain a constant cutting speed, the spindle speed must vary based on the diameter of the cut. If the spindle speed is held constant, then the cutting speed will vary.

Feed rate - The speed of the cutting tool's movement relative to the workpiece as the tool makes a cut. The feed rate is measured in inches per minute (IPM) and is the product of the cutting feed (IPR) and the spindle speed (RPM).

The performance of a turning operation is greatly influenced by the application of cutting fluid, and, in this regard, turning operations can be classified into different types, such as dry turning, turning with minimum quantity lubrication (MQL), flood turning, and cryogenic turning. Of these, flood turning is the most traditional technique and by far the most widely used in industry. However, the advantages caused by the cutting fluids have been questioned lately, due to the several negative effects they cause. When inappropriately handled, cutting fluids may damage soil and water resources, causing serious loss to the environment. Therefore, the handling and disposal of cutting fluids must obey rigid rules of environmental protection. On the shop floor, the machine operators may be affected by the bad effects of cutting fluids, such as by skin and breathing problems [1].For the companies, the costs related to cutting fluids represent a large amount of the total machining costs. Several research workers [2-4]. State that the costs related to cutting fluids are frequently higher than those related to cutting tools. Technological evolution has provided some options for the use of cutting fluids in machining processes. Tool material properties have been improved and new tool materials have been developed in order to avoid or minimize the use of cutting fluids. Therefore, properties such as resistance against abrasion and diffusion, hot hardness and ductility have been greatly improved with the new tool materials. Tool coatings have provided high hardness, low friction coefficient and chemical and thermal stability to the tool. Tool geometries have been optimized to better break chips and also to produce lower surface roughness values in the workpiece. New concepts of machine tool design have allowed machining speeds to become faster, and increased rigidity enables more severe cutting operations to be used [5-6]. However, with the increasing demand for higher productivity and decreasing manufacturing costs, requirements have to be put forward on developing cutting tools capable of operating at higher machining speeds and larger depth-of-cut which induces higher working temperature and higher tool failure rate. For dry and hard machini-ng, high hardness and high oxidation resistance at elevated temperature of more than 1000oC are of utmost importance [7-8]. Numerous studies have shown that the cubic fcc-TiN structured coatings with high aluminum content (such as TiAlN or AlTiN) can provide higher hardness, higher thermal stability (900ºC) as well as higher oxidation resistance than aluminum-free nitride or carbide coatings (such as CrN, TiN and TiC) [9-12].

Use of cast iron in the automotive industry has grown dramatically in recent years Gray cast iron is considered to have good machinability such as low wear rate, high metal removal rate, relatively low tool forces and low power consumption [13]. A major reason for the continued large scale use of cast iron in engineering is not only the low cost of the material and the casting process but also the economics of machining the finished component [14]. Grey cast iron is widely used to fabricate components such as engine blocks, cylinder heads, motor casings flywheels, and cylinder liners etc.

2. EXPERIMENTAL DETAILS

a) Design of experiments: Taguchi and Konishi had developed Taguchi techniques [15] these techniques have been utilized widely in engineering analysis to optimize the performance characteristics within the combination of design parameters. Taguchi technique is also power tool for the design of high quality systems. It introduces an integrated approach that is simple and efficient to find the best range of designs for quality, performance, and computational cost [16]**.** In this study we have consider 3 factors which affect majorly on quality characteristic such as (A) spindle speed., (B) feed rate (C*)* depth of cut. The design of experiment was carried out by Taguchi methodology using Minitab 14 software. In this technique the main objective is to optimize MMR of turning that is influenced by various process parameters

b) Selection of control factors: From the discussion with company peoples strongly felt that turning bears a direct relationship with MMR. So that MMR is selected as response parameter for experimentation.

c) Selection of orthogonal array: Since 3 controllable factors and three levels of each factor were considered L9 (3**3) Orthogonal Array was selected for this study.

d) Experimental set up: A Series of experiment was conducted to evaluate the influence of parameters on MMR. The experiments were carried out on CNC lathe machine The CNC lathe machine (Figure2.1) has the following specifications:

Chuck size	170mm
Max.Turning Dia.	250mm
Max.Turning Length	350mm
Travel X/Z axes	200mm/350mm
Rapid Feed rateX/Z axes	24m/min
Spindle 30mm/rating	9.25/7KW
Spindle speed Range	50-4500rpm
Tooling System	8st.Servo Turret
Input Voltage	415+or-10%Voltage
Input Power	20KW
Spindle power	05/07KW
Working Temp.	10degree C to 50 degree C
Machine Weight	3000kg.

Figure 2.1 Pictorial View of CNC lathe

e) Work material and Tool:

Work piece material for the present work is grey cast iron (FG260) a bar of dimension 90mm length and 40 mm diameter is used. Chemical composition of the material used is C3.3%, Si2.05%, Mn1.02%, S 0.08%, P 0.09%.

Tool used in the research is CVD — TiN-TiCN-Al2O3 coated carbide carbide tool from WIDIA (CNMG 12 04 08 HK20 CT manufacturer code). Tool geometry is defined by rake angle 5º,clearance angle 11º, tool cutting edge angle 95º, cutting edge inclination angle 0ºand tool nose radius 0.8 mm and a type PCLNL 1616 K12 (ISO) tool holder from WIDIA was used.

f) Weight measurement:

MRR is the rate at which the material is removed from the work piece. Turning operation takes place between the tool and the work piece during the machining process material is removed The MRR is defined as the ratio of the difference in weight of the work piece before and after machining to the machining time.

3. EXPERIMENTAL CONDITIONS

The experiments were carried out on CNC lathe for MMR there are three input controlling factors selected having three levels. Details of parameters and their levels used shown in the table 3.1

Table 3.1: Process parameters and levels

A	SPEED (m/min)	230	260	290
B	FEED (rev/min)	0.10	0.25	0.40
C	DOC (mm)	0.5	1	1.5

Table 3.2: Layout for Experimental Design according to L9 Array

Sr.N0	SPEED (m/min)	FEED (rev/min)	DOC (mm)
1	230	0.10	0.5
2	230	0.25	1.0
3	230	0.40	1.5
4	260	0.10	1.0
5	260	0.25	1.5
6	260	0.40	0.5
7	290	0.10	1.5
8	290	0.25	0.5
9	290	0.40	1.0

4. RESULTS AND DISCUSSION

a) S/N Ratio Analysis-

In the Taguchi method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value for the output characteristic. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available depending on type of characteristic: lower is better (LB), nominal is best (NB), or larger is better (LB). Larger is better S/N ratio used here. Larger -the-better quality characteristic was implemented and introduced in this study.

Larger the better characteristic

S/N = -10 log10 (MSD)

Where MSD= Mean Squared Division

$$MSD = (1/Y_1^2 + 1/Y_2^2 + 1/Y_3^2 + \cdots\cdots\cdots)/n$$

Where Y1, Y2, Y3 are the responses and n is the number of tests in a trial and MSD is the target value of the result. The level of a factor with the highest S/N ratio was the optimum level for responses measured. Table 4.1 and Figure 4.1 depict the factor effect on material removal rate. The higher the signal to noise ratio, the more favorable is the effect of the input variable on the output.

Table4.1Summary Report for different trials conducted during experimentation

SPEED	FEED	DOC	MRR
230	0.10	0.5	1.991
230	0.25	1.0	7.867
230	0.40	1.5	18.660
260	0.10	1.0	3.785
260	0.25	1.5	12.210
260	0.40	0.5	9.224
290	0.10	1.5	5.746
290	0.25	0.5	4.869
290	0.40	1.0	14.653

Table 4.2Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	P
Constant	17.1294	0.1715	99.881	0.000
SPEED 230	-0.6908	0.2425	-2.848	0.104
SPEED 260	0.4020	0.2425	1.657	0.239
FEED 0.10	-6.2194	0.2425	-25.643	0.002
FEED 0.25	0.6704	0.2425	2.764	0.110
DOC 0.5	-4.1199	0.2425	-16.987	0.003
DOC 1.0	0.4693	0.2425	1.935	0.193

Summary of Model-

S = 0.5145   R-Sq = 99.8%   R-Sq (adj) = 99.3%

4.3 Response Table for Signal to Noise Ratios Larger is better

Level	SPEED	FEED	DOC
1	16.44	10.91	13.01
2	17.53	17.80	17.60
3	17.42	22.68	20.78
Delta	1.09	11.77	7.77
Rank	3	1	2

From the Table 4.1 and Figure 4.1 it is clear that, the optimum value levels for higher MMR are at speed (230), feed (0.40), and depth of cut (1.5). Also, for MMR, from it can be seen that, the most significant factor is feed rate (B), followed by Depth of cut (C), and Speed (A).

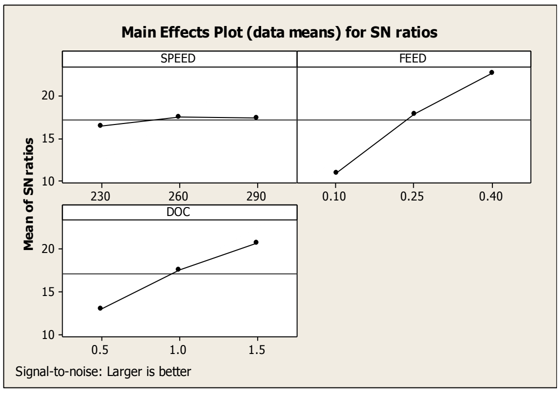


Figure 4.1: Effect of process parameters on S/N Ratio

Table 4.4 Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SPEED	2	2.383	2.383	1.192	0.37	0.732
FEED	2	161.286	161.286	80.643	24.76	0.039
DOC	2	70.261	70.261	35.130	10.79	0.085
Residual Error	2	6.513	6.513	3.257		
Total	8	240.444				

b) Analysis of Variance (ANOVA): Analysis of variance is a standard statistical technique to interpret experimental results. It is extensively used to detect differences in average performance of groups of items under investigation. It breaks down the variation in the experimental result into accountable sources and thus finds the parameters whose contribution to total variation is significant. Thus analysis of variance is used to study the relative influences of multiple variables, and their significance.

The purpose of ANOVA is to investigate which process parameters significantly affect the quality characteristic. The analysis of the experimental data is carried out using the software MINITAB 14 specially used for design of experiment applications. In order to find out statistical Significance of various factors like speed (A), feed (B), and depth of cut (C), and their interactions on MMR, analysis of variance (ANOVA) is performed on experimental data. Table 4.2 shows the result of the

ANOVA with the MMR. The last column of the table indicates p-value for the individual control factors. It is known that smaller the p-value, greater the significance of the factor. The ANOVA table for S/N ratio (Table 4.4) indicate that, the speed (s=230), feed (p= 0.40) and depth of cut (doc=01.5) in this order, are significant control factors effecting MMR. It means, the feed rate is the most significant factor and the depth of cut has less influence on the performance output.

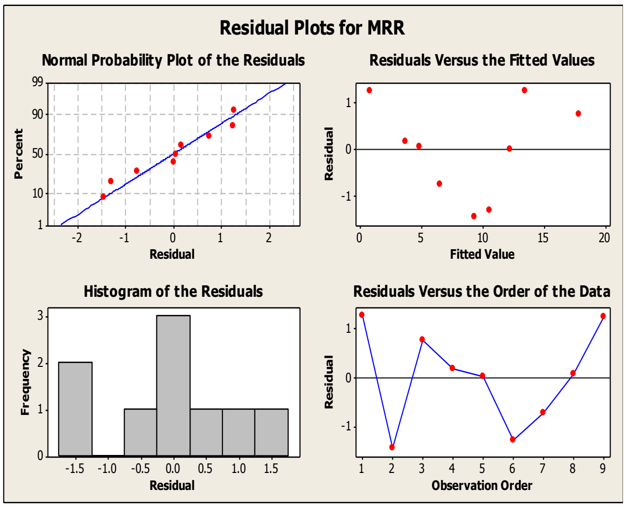


Figure 4.3: Residual Plots for MMR

C) Regression Analysis- Regression analysis is used for explaining or modeling the relationship between a single variable Y, called the response, output or dependent variable, and one or more predictor, input, independent or explanatory variables Mathematical models for process parameters such as speed . , feed and depth of cut were obtained from regression analysis using MINITAB 14 statistical software to predict MMR.

The regression equation is

Y = - 1.99 + 6.84 DOC + 34.5 FEED - 0.0181 SPEED

S = 1.27288 R-Sq = 96.6% R-Sq (adj) = 94.6%

Where,
Y = Response i.e. MMR (gm/sec)
A = Speed (m/min), B = Feed rate (mm/rev), C = depth of cut (mm),

If we put optimum parameters which are drawn by ANOVA in equation 1 it will give optimum value of quality characteristic which will maximum MMR.

Yopt = - 1.99 + 6.84 DOC + 34.5 FEED - 0.0181 SPEED

Yopt = -1.99+6.84*1.5+34.5*0.4-0.0181*230

Yopt = 17.907 gm/sec

(Predicted by Regression Equation)

In multiple linear regression analysis, R2 is value of the correlation coefficient and should be between 0.8 and 1. In this study, results obtained from MMR in good agreement with regression models (R2>0.80).

Observation	Optimum Experimental value of MRR	Optimum Predicted Value	S/N Ratio
	18.660	17.907	25.4182

5. CONCLUSIONS:

The Taguchi method was applied to find an optimal setting of the material removal rate parameters process. The result from the Taguchi method chooses an optimal solution from combinations of factors if it gives maximized normalized combined S/N ratio of targeted outputs. The L-9 OA was used to accommodate three control factors and each with 3 levels for experimental plan selected process parameters are Speed. (230,260, 290), Feed rate (0.10, 0.25, 0.40), Depth of cut (0.5, 1, 1.5). The results are summarized as follows:

- Among three process parameters Feed rate followed by Depth of cut and Speed was most influencing parameters on MMR
- The Optimal level of process parameter were found to be **A1B3C3**
- The prediction made by Taguchi parameter design technique is in good agreement with confirmation results
- The result of present investigation are valid within specified range of process parameters
- Also the prediction made by Regression Analysis is in good agreement with.
- The optimal levels of MMR process parameters for optimum MMR are:

Speed.	(m/min)	230
Feed rate	(mm/rev)	0.40
Depth of cut	(mm)	1.5

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