Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

An Experimental Study of Influence of Frictional Force, Temperature and Optimization of Process Parameters During Machining of Mild Steel Material

Ankit U [1], D Ramesh Rao [2], Lokesha [3]
[1, 2, 3, 4]Department of Mechanical Engineering,
M S Ramaiah Institute of Technology,
Bangalore

***Abstract* -In the Modern manufacturing, machining is an essential process in order to produce high quality finished parts. Turning process is one such manufacturing process which is affected by many factors such as the cutting velocity, feed rate, depth of cut and geometry of cutting tool. The influence of process parameters on the machined part can be considered as a measure of output parameter. Vibration, temperature, cutting force etc. during machining process of a part are most important factors which influence the quality of the machined part, hence manufacturers are seeking various methods to improve it. Selection and optimization of machining process parameters leading to minimize the effect on output characteristics is an important aspect in a manufacturing process. The objective of the present study is to design and optimize machining parameters in turning operation for mild steel material. In this study, a set of process parameters such as cutting speed, feed rate and depth of cut were selected as input parameters and measurement of frictional force, temperature and surface roughness as output characteristic. The experimental trials were designed with the help of Taguchi's L9 orthogonal array and all the trials were carried out by using tool room lathe with 0.4mm cutting tool insert nose radius. Dynamometer, non contact infrared thermometer and Mitutoyo instruments were used to measure the output characteristics. The frictional forces were calculated with the help of Merchant's circle diagram. Relationship between input and output parameters and the influence of cutting parameters on each of the output parameters were individually studied by using Analysis of Variance (ANOVA) tool.**

Keywords- Machining parameters, optimization, Merchant's circle diagram, Taguchi method, Analysis of variance.

I. INTRODUCTION

In machining process, the quality of the process is mainly affected by machining process input parameters. Among several process parameters cutting speed, feed rate, depth of cut, clearance angle, rake angle, end cutting edge angle and side cutting edge angle are of great importance. Therefore, it is important to study the effects of process parameters on the process response characteristics. Surface roughness, temperature and few other parameters are generally used to indicate the quality of final product which depends on these process parameters. The combination of these process parameters results in an optimized condition for an enhanced productivity and quality of the product. This study mainly focuses on the influence of cutting parameters on frictional force, tool tip temperature and surface roughness during turning process.

Various computing techniques are used to study the Influence of Process Parameters on various outputs. A study on effect of tool vibration on surface roughness in lathe dry turning of medium carbon steel samples reveals that best surface finish is obtained at low feed rate and with smaller tool overhanging [1]. An experimental study on EN 8 steel bars with HSS tool on tool wear monitoring in turning reveals that increase in cutting speed leads to increase in tool wear [2]. A study on MS 1010 material in CNC turning operation with HSS tool type was considered. Optimization of three parameter namely cutting speed, feed rate and depth of cut were considered and experiments were designed by Taguchi's L9 orthogonal array and analyzed using Analysis if Variance and the final results of this study suggested the spindle speed is the key for minimizing the surface roughness [3]. A study on influence of cutting parameters on cutting force and surface finish in turning operation by using ceramic tool and experiments were conducted on CNC lathe for AISI 1050 steel. Here Taguchi L27 design was used and AVONA method was employed and the results indicated that depth of cut had more influence on the cutting force and very less influence on surface roughness [4]. Further, an experimental study of effect of cutting parameters on surface roughness was carried out in CNC lathe using coated carbide tool for aluminium 6063 material. The regression equations were solved using genetic algorithm approach in mat lab 8.0 application. Finally this study revealed the optimum input values in order to obtain best surface finish [5]. A study of CNC turning of AISI stainless steel with CVD coated cemented carbide tool consisted of optimizing process parameters such as speed, feed, depth of cut and nose radius showed that feed rate is the factor that is influencing the surface roughness and then followed by nose radius [6]. A study on Al 6063 aluminium using CCGT-09T30FL turning insert to predict and control of cutting tool vibration in CNC lathe and from the experimental results it was clear that the depth of cut and cutting speed were the main parameter that was influencing the vibration of the cutting tool [7].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

II. DESIGN OF EXPERIMENT (DOE)

Design of experiments is a series of tests or experiments carried out, in which the input variables of a system or a process are purposefully varied and then their effects on the response variables are measured. Design of experiments is applicable to both physical processes and computer simulation models. DOE is an effective tool which maximizes the amount of information gained from a study while minimizing the amount of data to be collected. Factorial design and Taguchi orthogonal array are the most frequently used design of experiments method in experimental studies. [8]

A. Factorial design

Factorial designs are more efficient for experiments which involve the study of effects of two or more factors. In factorial design, each factor is associated with discrete possible values or "levels", and experiments are performed for all possible combinations of these levels across all such factors. Based on these factors they are classified as 2k factorial design and 3k factorial design.

2k factorial design consists of k factors, each at only two levels. The levels of each factors are always called as "low" and "high" and it is customary to denote the low and high levels of the factors by the signs – and +, respectively. Here 22 is the simplest 2k factorial design having two factors A and B, each at two levels and it requires 4 runs or tests.
Similarly 3k factorial design consists of k factors, each at three levels. 32 is the simplest 3k factorial design having 2 factors, each at three levels and it requires 9 runs or tests. As the number of factors increases, the runs or test trials increase and finally results in investment of more money and time. [9]

B. Taguchi orthogonal array

As the number of factors increases, a large number of experiments have to be carried out in full factorial design which becomes laborious and complex. In order to overcome the above problem Taguchi suggested a specially designed method called the Taguchi method which makes use of orthogonal array to study the entire parameter with lesser number of experiments to be conducted. Taguchi also recommended the use of the loss function to measure the performance characteristics that are deviating from the desired target value. Finally this value of loss function is further transformed into signal-to-noise (S/N) ratio. To analyze this (S/N) ratio, there are three categories of the performance characteristics. They are: nominal-the-best, larger-the-better, and smaller-the-better. [10]

III. MERCHANT'S CIRCLE DIAGRAM

Merchant's circle diagram is a graphical or diagrammatic representation of various forces acting at the tool, chip and at the work piece interface during cutting operation. During orthogonal cutting, it mainly helps to analyze various cutting forces and by constructing Merchant circle diagram, one can easily determine various relevant forces and machining characteristics without considering large equations and calculations. In this study Merchant's circle diagram is mainly used to determine the frictional force. Below figure 1 shows Merchant's circle diagram with all forces.

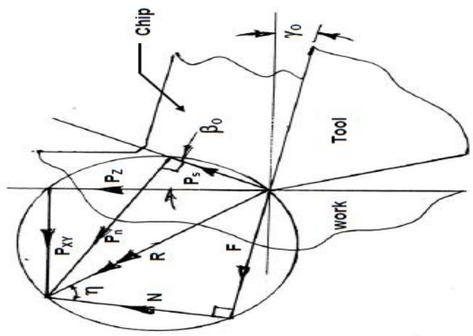

Figure 1: Merchant's Circle Diagram with all forces

Forces displayed in Merchant's circle diagram are: Shear force (Ps), Frictional force (F), Normal force (N) and Pz which is main force acting in the direction of cutting velocity. The force components PX, PY, PZ are normally obtained by direct measurement.

Calculation of frictional force can be done either graphically or with the help of the equation.

A. Calculation of frictional force – Graphically

1. First we need to determine Pxy. Where Pxy = sqrt(Px^2 + Py^2)
2. Next we need to draw the tool and the chip in orthogonal plane with the given rake angle.
3. Then it is important to choose a suitable scale (e.g. 1000 N = 1 cm) for representing Pz and Pxy in cm.
4. By using the above selected scale we need to draw Pz and Pxy normal to each other.
5. Next is to draw the cutting force R as a resultant of Pz and Pxy.
6. Now by considering R as the diameter, draw a circle (Merchant's Circle).
7. Next extend the tool rake surface to get F and N as intercepts in the circle by joining the tips of F and R.
8. Finally the value of F is measured. [11]

B. Calculation of frictional force – Analytically

$F = Fc \sin\alpha + Fv \cos\alpha$ (1)

Where,
F – Frictional force in Newton
Fc – Cutting force in Newton
Fv – Feed force in Newton
α – Rake angle of the insert in Degree.

In this study, the above equation is used to calculate the frictional force.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

IV. ANALYSIS OF VARIANCE (ANOVA)

The analysis of variance which is frequently referred to as ANOVA is a statistical technique which is specially designed to test whether the means of two or more quantitative populations are equal.

Basically, ANOVA consists of classifying and cross-classifying statistical results in which testing is carried out to check whether the means of specified classification differ significantly. In this way ANOVA is helpful in determining whether the given classification is important in affecting the results and also helps us to analyze the total variation of our data into components which may be attributed to various sources or causes of variation.

ANOVA are classified into two types namely one way and two way ANOVA.

In general, one way ANOVA technique is used to study the effects of a single factor over a variety of levels. But this technique cannot be used for multi factor analysis.

When two or more independent factors have an effect on response variable which is of interest, then it is possible to design the test so that analysis of variance can be used to test for the effects of two or more factors simultaneously. Such a test is called two-way analysis of variance which is made use of in the present study. The F-test in ANOVA is used to assess whether the expected values of a variable is within several pre-defined factors and levels differ from each other. Based on this F-test in ANOVA the factors affecting the output of the experiment and to amount of which these factors affect can be determined. [12]

V. EXPERIMENTAL SETUP

In the present study, experiments have been carried out under different combinations of machining parameters in a HMT LT 20 lathe. The machining parameters considered are cutting speed, feed rate and depth of cut. Machining of mild steel specimens under different machining conditions was carried out and the cutting forces, tool temperature and surface roughness were measured. Using this data analysis was carried out using ANOVA method in Statistica software.

The different combination of machining parameters for each trial has been developed by using Taguchi's orthogonal array. Table 1 and 2 provide the level of parameter and the number of experimental trial respectively.

Table 1: Process parameters and their levels

Levels	Cutting Speed (A) (RPM)	Feed Rate (B) (mm/rev)	Depth of Cut (C) (mm)
1	420	0.05	0.5
2	710	0.11	0.75
3	1200	0.22	1.0

Table 2: Number of trials as per Taguchi L9 orthogonal array

Trial	Coded Factor			Natural Factor		
	x1	*x2*	*x3*	*Cutting Speed (rpm)*	*Feed Rate (mm/rev)*	*Depth of cut (mm)*
1	1	1	1	420	0.05	0.5
2	1	2	2	420	0.11	0.75
3	1	3	3	420	0.22	1
4	2	1	2	710	0.05	0.75
5	2	2	3	710	0.11	1
6	2	3	1	710	0.22	0.5
7	3	1	3	1200	0.05	1
8	3	2	1	1200	0.11	0.5
9	3	3	2	1200	0.22	0.75

The experimental work was carried out on HMT LT 20 lathe with dry run condition using a tungsten carbide insert of 0.4mm corner radius for mild steel material. The rake angle for the insert is 17°. Figure 2 shows the experimental setup.

Figure 2: Experimental Setup

A 20mm diameter mild steel specimen was machined for a length of 25mm in each trial. The temperature was measured at the tool tip or at the cutting zone during machining operation and maximum temperature during each trail was recorded using a Beetech infrared non-contact thermometer and the cutting forces for each trail was recorded using a lathe tool dynamometer and frictional force was calculated from the above forces using a equation which is derived from the Merchant circle diagram. The calculation of frictional force for single trial is shown below. Surface roughness of machined surface of the specimen was measured by using Mitutoyo SJ-201 instrument. The measured and calculated values of cutting forces, frictional forces, tool temperature and surface roughness are listed in table 3. The effect of these output parameters were further studied using Analysis of Variance (ANOVA) tool. Figure 3, 4 and 5 shows the temperature measurement setup, surface roughness setup and cutting forces measurement setup respectively.

Calculation of frictional force for first trial from equation (1):

$F = F_c \sin\alpha + F_v \cos\alpha$

$F = 166.7 * \sin(17°) + 78.4 * \cos(17°)$

$F = 123.5$ N

Similarly frictional force is calculated for all the trials.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

Table 3: Measured and calculated output values

Trial	Cutting force (N)	Feed force (N)	Thrust force (N)	Frictional force (N)	Tool tip Temperature (°C)	Surface roughness (μm)
1	166.7	78.4	19.6	123.5	37	5.83
2	618	294.3	29.4	462.1	41	4.62
3	1952.1	804.4	78.4	1339.9	46	6.45
4	294.3	137.3	9.81	217.3	41	3.96
5	725.9	333.5	29.4	531.1	38	3.09
6	480.6	255	58.8	384.4	40	3.96
7	412	176.5	9.81	289.3	40	2.88
8	274.6	137.3	49	211.6	42	1.24
9	765.1	402.2	78.4	608.3	49	2.75

Figure 3: Temperature measurement setup

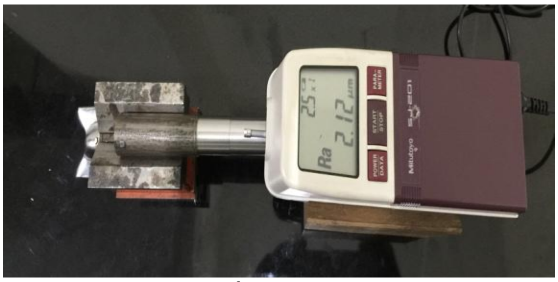

Figure 4: Surface measurement setup

Figure 5: Force measurement setup

VI. RESULTS AND DISCUSSION

The analysis is carried out to determine the relationship between the input and output parameters using an ANOVA tool. The software application namely, Statistica, is used to carry out the data analysis. The Statistica software has a built in ANOVA, in which the analysis is carried out. First a data sheet is generated for the selected number of input (namely Cutting Speed, Feed rate and Depth of Cut) and output parameters (namely Temperature, Frictional force and Surface roughness) according to Taguchi's orthogonal array and the respective data or values was inserted in the data sheet. Then this data sheet was further submitted for the analysis by defining the input parameters as the independent variables and the output parameters as the dependent variables or the factors with the experimental design option, individually for each output parameter against the same input parameter. In the ANOVA results, F-test values were used at 95% confidence level to decide the significance factor affecting the process and percentage of contribution. As per ANOVA the least value of 'p' and the maximum value of 'f' indicate the influence of machining parameter on the output.

Below table 4 indicates the analyzed values for Taguchi design on frictional force, tool tip temperature and surface roughness. And from table 4 it is also clear that feed rate is influencing the increased frictional force and temperature at the cutting zone and the cutting speed influences the surface roughness of the machined part.

Table 4: ANOVA results

Effect	Sum of Square (SS)	Degree of freedom (DOF)	Mean of square (MS)	Frequency (F)	Percentage of Contribution (p)
FRICTINAL FORCE					
Cutting Speed	143991.1	2	71995.5	1.927524	0.341586
Feed Rate	499865.2	2	249932.6	6.691403	0.130015
Depth of Cut	350946.5	2	175473.3	4.697916	0.175503
Residual	74702.6	2	37351.3		
TOOL TIP TEMPERATURE					
Cutting Speed	24.22222	2	12.11111	2.224490	0.310127
Feed Rate	54.88889	2	27.44444	5.040816	0.165541
Depth of Cut	24.22222	2	12.11111	2.224490	0.310127
Residual	10.88889	2	5.44445		
SURFACE ROUGHNESS					
Cutting Speed	16.93696	2	8.468478	1891.223	0.000528
Feed Rate	3.53362	2	1.766811	394.573	0.002528
Depth of Cut	0.35669	2	0.178344	39.829	0.024493
Residual	0.00896	2	0.004478		

The graphs predicting the behavior of various cutting parameters on frictional force, tool tip temperature and surface roughness are shown below in figure 6, 7 and 8 respectively. The curve from figure 6 and 7, indicate that signal to noise ratio is more in case of feed rate than the other two parameters and hence confirming the influence of feed rate on frictional force and tool tip temperature. Similarly the curve from figure 8 indicates that signal to noise ratio is more in case of cutting speed than the other two parameters and hence confirming the influence of cutting speed is more on the surface roughness.

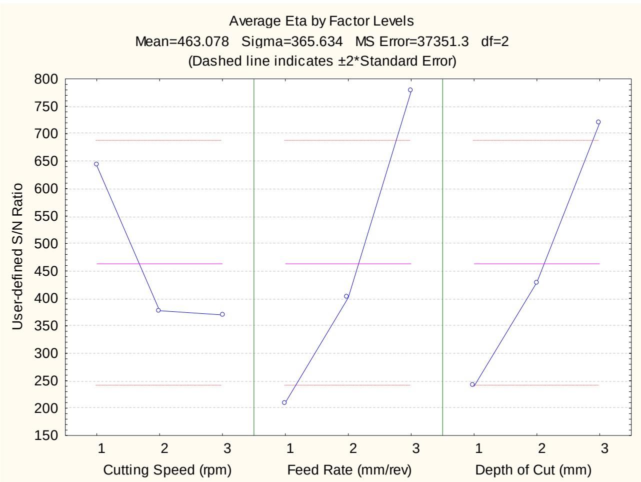

Figure 6: Graph representing the influence of cutting parameters on frictional force

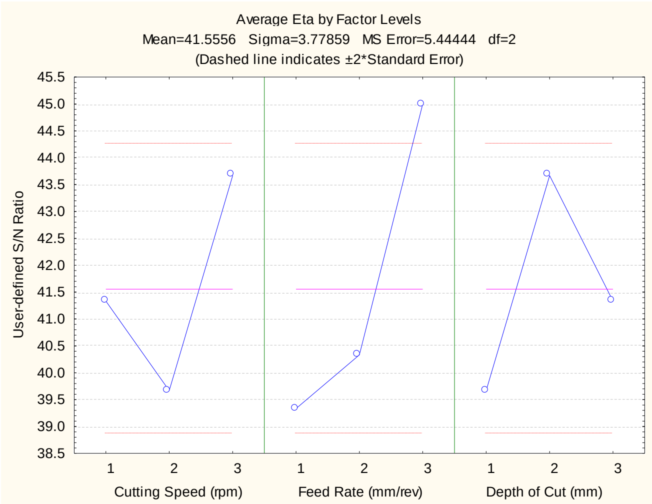

Figure 7: Graph representing the influence of cutting parameters on

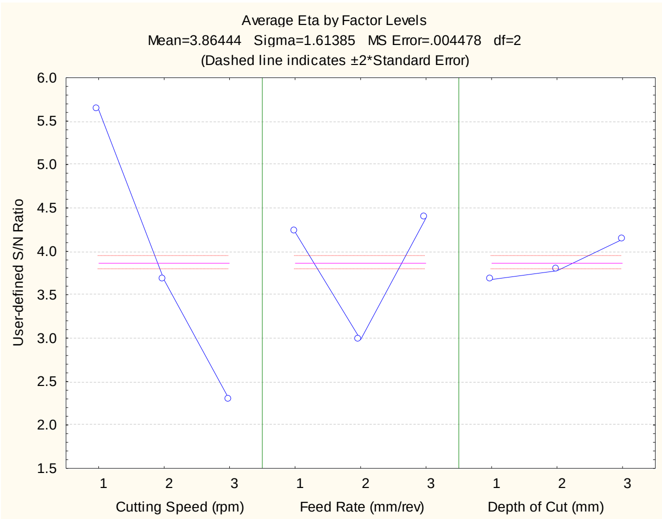

Figure 8: Graph representing the influence of cutting parameters on surface roughness

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

VII. CONCLUSION

This study describes the use of Taguchi technique to optimize the cutting parameters such as cutting speed, feed rate and depth of cut in lathe for mild steel material in dry condition by using a 0.4mm nose radius insert. Taguchi's orthogonal array and Analysis of Variance are effectively used in this study to select the optimum experimental trials and to analyze the relationship between input and output parameters. This study reveals that feed rate has more influence on frictional force and tool tip temperature while cutting speed has more influence on surface roughness than other input parameters.

REFERENCES

[1] Safeen Y. Kassab, Younis K. Khoshnaw, The Effect of Cutting Tool Vibration on Surface Roughness of Workpiece in Dry Turning Operation. No.7, University of Salahddin, Erbil : Eng. & Technology, 2007, Vol. Vol.25.

[2] Vikas B. Magdum, Vinayak R. Naik.Evaluation and Optimization of Machining Parameter for turning of EN 8 steel. International Journal of Engineering Trends and Technology (IJETT), May 2013, Vol. 4. ISSN: 2231-5381.

[3] Harish Kumar, Mohd. Abbas, Dr. Aas Mohammad, Hasan Zakir Jafri. Optimization of cutting parameters in CNC Turning. International Journal of Engineering Research and Applications (IJERA), May-Jun 2013, Vol. 3. ISSN: 2248-9622.

[4] Dr. C. J. Raoa, Dr. D. Nageswara Raob, P. Sriharic, Influence of cutting parameters on cutting force and surface finish in turning operation.. Odisha, India : ELSEVIER, 2013. 1405 – 1415.

[5] Zeelan Basha N, Selva Ganesh Kumar and Endalkachew Mosisa, Determining the Effect of Cutting Parameters on Surface Roughness Using Genetic Algorithm. Science, Technology and Arts Research Journal, Oct-Dec 2013, Vol. 2.

[6] M. Kaladha, K. Venkata Subbaiah, Ch. Srinivasa Rao and K. Narayana Rao, Optimization of process parameters in turning of aisi202 austenitic stainless steel. ARPN Journal of Engineering and Applied Sciences, SEPTEMBER 2010, Vol. 5. ISSN 1819-6608.

[7] S. S. Abuthakeer, P.V. Mohanram and G. Mohan Kumar, Prediction and Control of Cutting Tool Vibration in Cnc Lathe with Anova and Ann. International Journal of Lean Thinkin, June 2011, Vol. 2.

[8] A Brief Introduction to Design of Experiments. Telford, Jacqueline K. 3, s.l. : Johns Ho pkins APL Technical Digest, 2007, Vol. 27.

[9] Montgomery, Douglas C. Design and Analysis of Experiments. s.l. : Wiley, 2009.

[10] Srinivas Athrey, Dr Y.D.Venkatesh, Application Of Taguchi Method For Optimization Of Process Parameters In Improving The Surface Roughness Of Lathe Facing Operation. International Refereed Journal of Engineering and Science (IRJES), November 2012, Vol. 1. 2319-1821.

[11] Mechanics of machining, Lesson 8 – Machining forces and Merchant's circle diagram, Version 2, ME, IIT, Kharagpur.

[12] S.P.Gupta, Statistical Methods, Volume 2, Chapter 5, f-test and analysis of variance, page number 1009 – 1020.