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Analysis Of Cutting Forces of Lathe Threading Operation Using Dynamometer on Aluminium 6063

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Abstract: In this paper we use the Taguchi technique for the optimization of parameters on aluminium 6063 workpiece. The three significant parameters which are depth of cut, feed rate and spindle speed are used as a input parameters for experiment. These three parameters are at three levels. The number of experiments has been selected using Orthogonal array in the design of experiments. And to identify the effects of parameters on workpiece the analysis of variance is used. By using minitab software the mean plot effect and anova table is generated.

***Index Terms* -** Thread Turning, Threading, Lathe, Taguchi method, Annova, Cutting forces, aluminium 6063, dynamometer.

I. INTRODUCTION

In industry lathe machine is used for different purposes and variety of operation can be perfomed on lathe machines. In this work the thread turning operation are done on lathe machine. Tools used in lathe operation is 4.5ISO ER and HSS and the workpiece is aluminium 6063 of cylindrical round shape Lathe parameters that affect the tool life are Spindle speed, feed and depth of cut are selected. Feed rate means the speed of the cutting tool's movement relative to the workpiece as the tool makes a cut. Spindle speed is the rotational speed of the spindle and the workpiece in revolutions per minute (rpm). Depth of cut is the depth of the tool along the axis of the workpiece as it makes a cut. Design of experiments are used to analyze the result. With the help of MINITAB statistical software, the Anova table and mean effect plot were generated. And the three forces in X,Y and Z direction can be measured using lathe tool dynamometer.

II. Experimental details and procedure

1. Experimental setup

The experimental setup used in the lathe threading are as shown in below figure

Figure 1: Lathe machine

The machining experiments were performed on a aluminium 6063 round bar and the two cutting tool were used first is HSS and another one is carbide PVD coated tool. The lathe machine used was all geared lathe machine having spindle speed of 40-1200 rpm.

2. *Material and methodology*

a. Material

In our experiment two types of tools are used one is non-coated which is High-speed steel (HSS) and another one is Pvd coated. The tool used in these are have two components mainly first is thread insert and second is tool holder. The thread insert used in this operation are 22ER 4.5 ISO of carbide Pvd coated. Aluminium round bar was selected as workpiece material of length 150mm and 50mm diameter.

Fig 2: Tool Holder

b. Methodology

In this work the feed force, cutting force and radial force which were acting on tool were measured using lathe tool dynamometer. And an experimental design based on Taguchi L9 orthogonal array is used to find the relation between the factors. The lathe tool dynamometer has been designed so that it can be directly fixed on to the tool post using the hole provide on the dynamometer. The dynamometer can measure three forces in mutually perpendicular directions, horizontal, vertical and thrust force and is provided with three connector sockets. Instrument comprises of three digital display to display force using dynamometer. This instrument compute respective force value for direct display in kgf units. Instrument operates on 230v, 50c/s AC main.

Taguchi Orthogonal Array (OA) design is a type of common fractional factorial design. It is a highly fractional orthogonal design that is based on a design matrix proposed by the Dr. Genichi Taguchi and allows you to consider a selected subset of combinations of multiple factors at multiple levels. In order to select a suitable orthogonal array for the experiments, the total degrees of freedom need to be calculated. The selection of orthogonal array based on number of factors to be studied, number of levels for each factor and Number of interactions to be estimated.

Degree of freedom (DOF) for Speed = (3-1) = 2

Degree of freedom (DOF) for Feed = (3-1) = 2

Degree of freedom (DOF) for Depth of cut = (3-1) = 2

The total degree of freedom = 2 + 2+ 2 = 6

Therefore, Minimum number of experiments = Total DOF for parameters +1 = 6 + 1

Minimum number of experiments = 7

L9 orthogonal array of Taguchi is selected. L9 orthogonal array designed as shown in below table.

Table 1: Cutting parameters and their levels

Factor	Depth of cut(mm)	Feed rate(mm/rev)	Spindle speed(rpm)
Level 1	0.125	0.47	40
Level 2	0.25	0.54	60
Level 3	0.37	0.61	75

Table 2: Experimental table

Trial No.	Depth of Cut(mm)	Feed Rate(mm/rev)	Spindle Speed(rpm)
1	0.125	0.47	40
2	0.125	0.54	60
3	0.125	0.61	75
4	0.25	0.54	40
5	0.25	0.61	60
6	0.25	0.47	75
7	0.37	0.61	40
8	0.37	0.47	60
9	0.37	0.54	75

3. Result and discussion

a.Experimental Result Table: -

The L9 orthogonal array was selected, and experiments are performed accordingly. All process parameters and their levels are given in the below table. The output parameters were forces which were measured using dynamometer.

Table 3: Result table for Coated tool

Trial No.	Depth of Cut(mm)	Feed Rate(mm/rev)	Spindle speed(rpm)	Fx	Fy	Fz
1	0.125	0.47	40	2	23	11
2	0.125	0.54	60	3.5	40	24

3	0.125	0.61	75	4.5	33	21
4	0.25	0.54	40	7	80	45
5	0.25	0.61	60	24	72	31
6	0.25	0.47	75	5	60	31
7	0.37	0.61	40	33	122	44
8	0.37	0.47	60	13	87	40
9	0.37	0.54	75	10	105	58

Table 4: Result table for Uncoated tool

Trial No.	Depth of Cut(mm)	Feed Rate(mm/rev)	Spindle speed(rpm)	Fx	Fy	Fz
1	0.125	0.47	40	5	44	23
2	0.125	0.54	60	6	25	20
3	0.125	0.61	75	2	23	18
4	0.25	0.54	40	8.5	38	29
5	0.25	0.61	60	2.5	48	33
6	0.25	0.47	75	4.5	60	36
7	0.37	0.61	40	4	98	63
8	0.37	0.47	60	18	95	60
9	0.37	0.54	75	12	76	52

b. Analysis experimental data: -

In Taguchi method, the term 'signal' represents the desirable effect(mean) for the output characteristics and the term 'noise' represent the undesirable effect (signal disturbance) for the output characteristics. The preferred parameter settings are then determined through analysis of the "signal-to-noise" (SN) ratio where the factor Levels that minimize the appropriate SN ratio are optimal. To determine the effect of each variable on the output, the signal-to-noise ratio, needs to be calculated for each experiments conducted. The calculation of SN for the experiment in the above array is shown below for the specific target value of the performance attribute. In the equations below, yi is the mean value and si is the variance. yi is the value of the performance attribute for a given experiment.

$$SN_i = 10 \log \bar{y}^2_i / s_i^2$$

For the case of minimizing the performance characteristic, the following definition of the SN ratio should be calculated:

$$SN_i = -10\log\left(\sum_{u=1}^{Ni} y^2/N_i\right)$$

The main effect plot for Fx, Fy and Fz direction for Coated tool are given below:

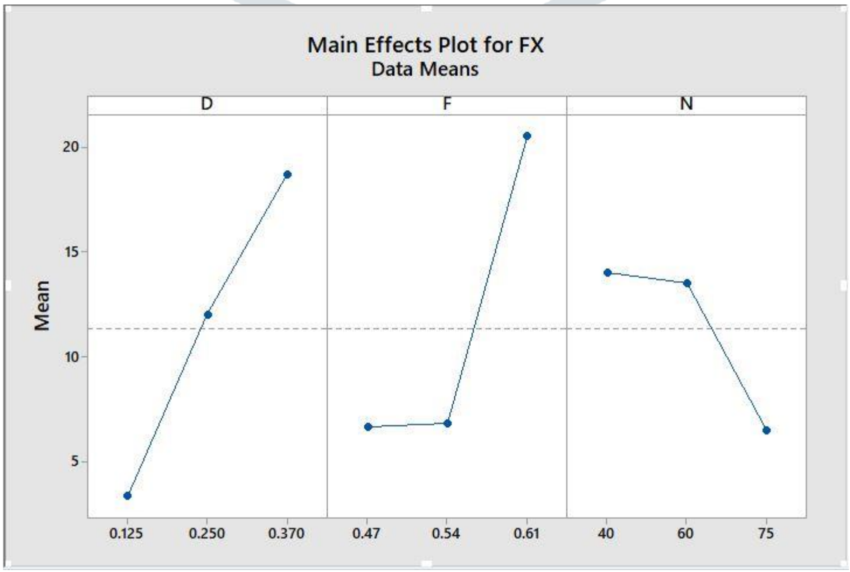

Figure 3 Main effects plot for Fx for coated tool

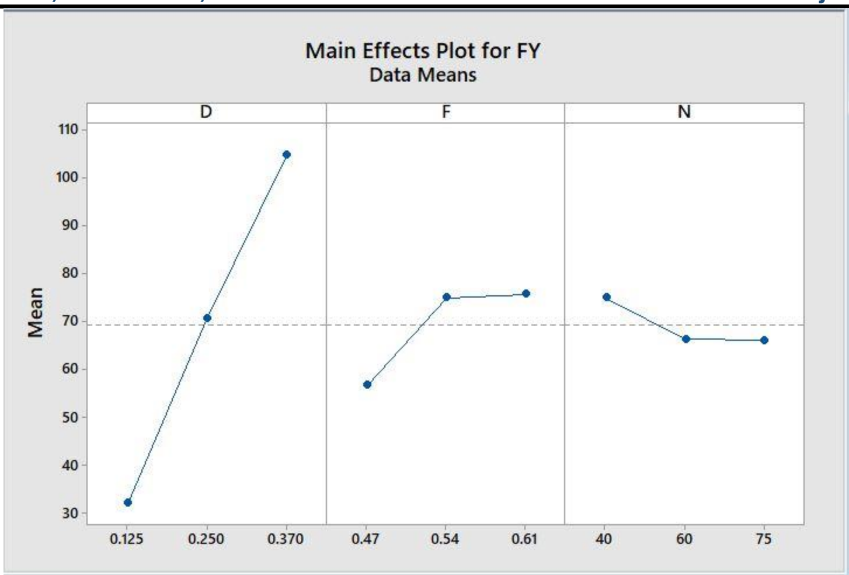

Figure 4 Main effects plot for Fy for coated tool

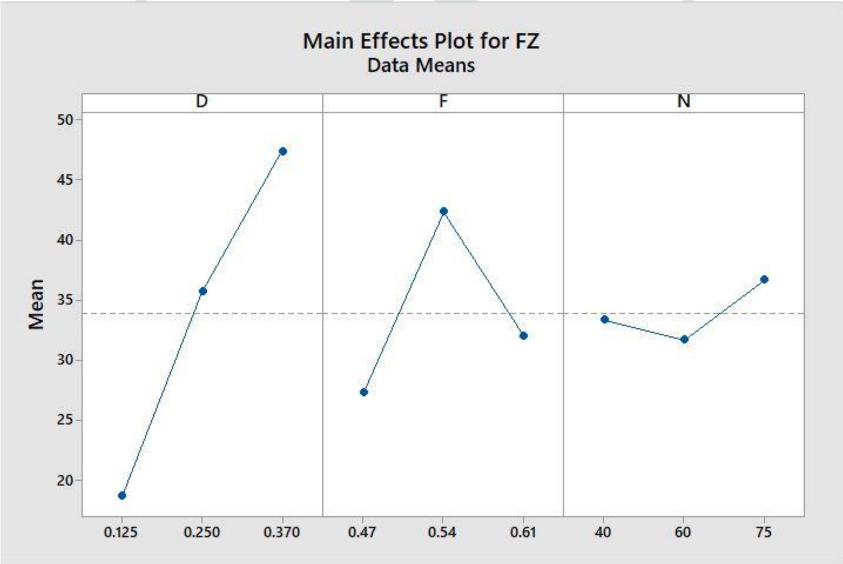

Figure 5 Main effects plot for Fz for coated tool

The given figure represents the main effect plot for uncoated tool in X, Y and Z direction

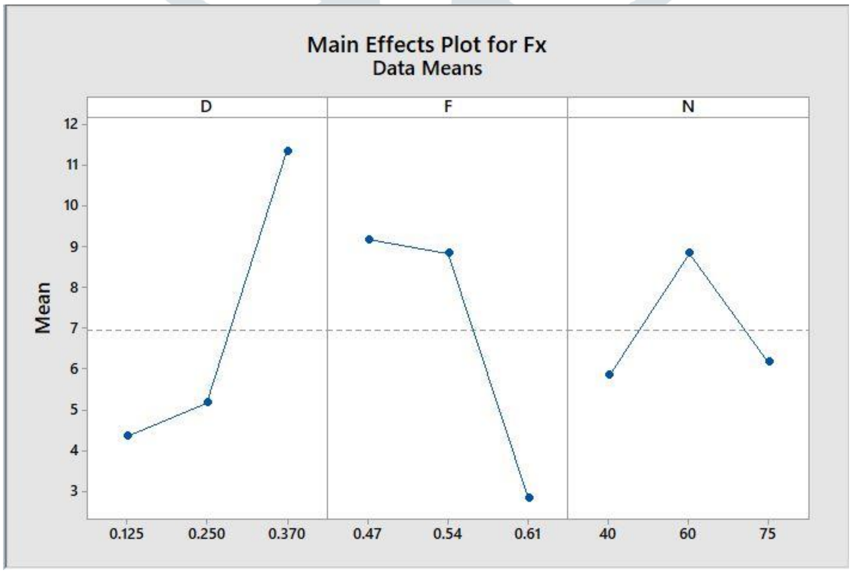

Figure 6 Main effects plot for Fx for Uncoated tool

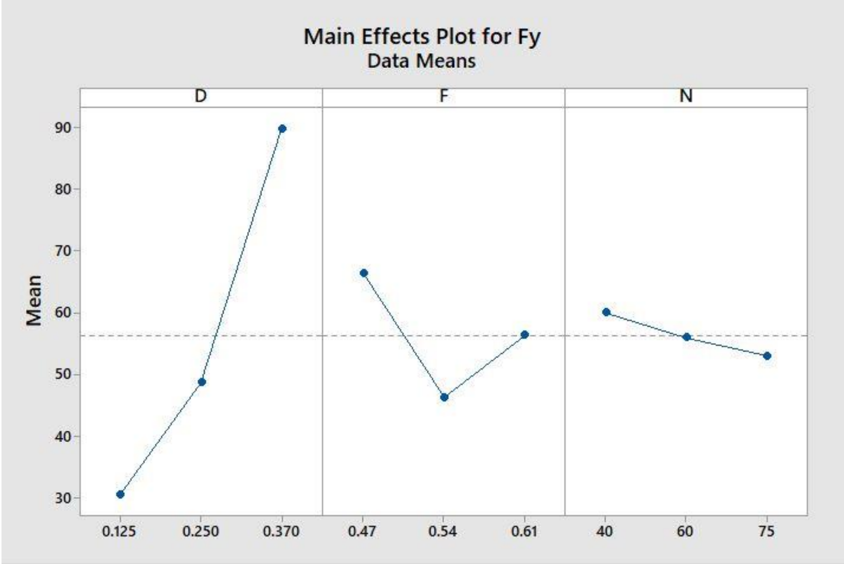

Figure 7 Main effects plot for Fy for Uncoated tool

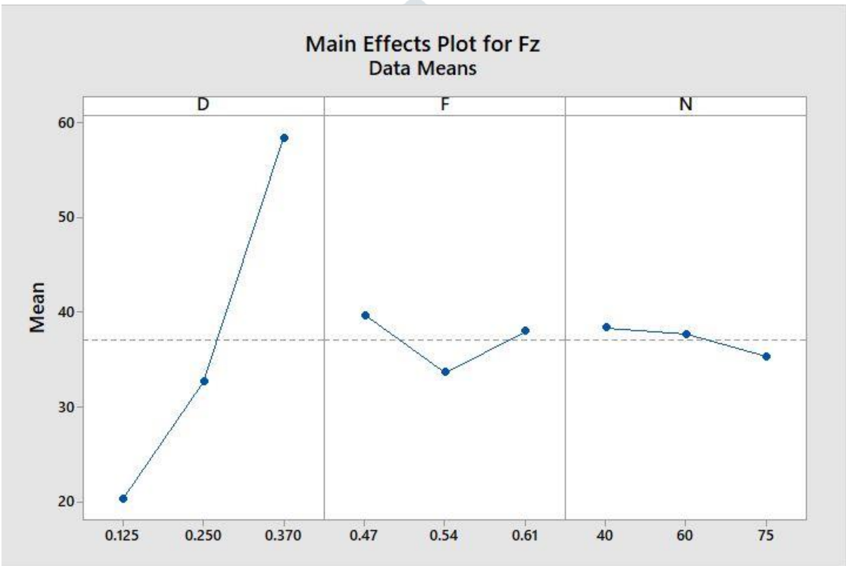

Figure 8 Main effects plot for Fz for Uncoated tool

Analysis of variance (ANOVA) is a Statistical tool used to detect differences between experimental groups resource. In ANOVA terminology, the independent variable is called the factor, and within the group Each factor is referred to as levels. In the analysis of variance, many quantities such as degrees of freedom, sums of squares, mean square, and so on, are computed and organized in a standard tabular format. Anova was used for determine the significance of input parameters. The Minitab 18 statistical software is used to investigation of significance of Thread turning parameters namely, depth of cut, feed rate and spindle speed.

Sum of Squares:

The sum of squares is a measure of the deviation of the experimental data from the mean value of the data. Summing each squared deviation emphasizes the total deviation.

$$\text{TSS} = \sum_{i=1}^{n} (y_i - \bar{y})^2$$

Mean squares:

Each mean square value is computed by dividing a sum-of-squares value by the corresponding degrees of freedom.

Table 7: Results of ANOVA for Fx For Coated Tool

Parameters	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
D	2	354.67	354.67	177.33	7.07	0.124	39.92%
F	2	378.17	378.17	189.08	7.54	0.117	42.56%
N	2	105.50	105.50	52.75	2.10	0.322	11.87%
Error	2	50.17	50.17	25.08			5.65%
Total	8	888.50					100.00%

As shown in table 7 it is found that depth of cut and feed rate are the most significant affecting parameter while spindle speed is less significant factor affecting the feed Force.

Table 8: Results of ANOVA for Fy For Coated Tool

Parameters	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
D	2	7931.6	7931.6	3965.78	73.74	0.013	89.19%
F	2	697.6	697.6	348.78	6.49	0.134	7.84%
N	2	156.2	156.2	78.11	1.45	0.408	1.76%
Error	2	107.6	107.6	53.78			1.21%
Total	8	8892.9					100%

As shown in table 8 it is found that depth of cut is the most significant factor while feed rate and spindle speed are less significant factors in affecting the cutting force.

Table 9: Results of ANOVA for Fz For Coated Tool

Parameters	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
D	2	1246.89	1246.89	623.444	130.49	0.008	75.62%
F	2	353.56	353.56	176.778	37.00	0.026	21.44%
N	2	38.89	38.89	19.444	4.07	0.197	2.36%
Error	2	9.56	9.56	4.778			0.58%
Total	8	1648.89					100.00%

As shown in table 9 the depth of cut play an important factor in affecting the radial force and feed rate and spindle speed are less important in affecting force.

Table 10: Results of ANOVA for Fx For Uncoated Tool

Parameters	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
D	2	87.72	87.72	43.861	2.61	0.277	41.04%
F	2	76.22	76.22	38.111	2.27	0.306	35.66%
N	2	16.22	16.22	8.111	0.48	0.674	7.59%
Error	2	33.56	33.56	16.778			15.70%
Total	8	213.72					100.00%

As shown in above table 10 the depth of cut and feed rate are significantly affecting the feed force.

Table 11: Results of ANOVA for Fy For Uncoated Tool

Parameters	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
D	2	5486.00	5486.00	2743.00	44.97	0.022	87.33%
F	2	600.00	600.00	300.00	4.92	0.169	9.55%
N	2	74.00	74.00	37.00	0.61	0.622	1.18%
Error	2	122.00	122.00	61.00			1.94%
Total	8	6282.00					100.00%

As shown in table no 11 the depth of cut has significant effect on cutting force.

Table 12: Results of ANOVA for Fz For Uncoated Tool

Parameters	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
D	2	2254.89	2254.89	1127.44	76.29	0.013	95.67%
F	2	57.56	57.56	28.78	1.95	0.339	2.44%
N	2	14.89	14.89	7.44	0.50	0.665	0.63%
Error	2	29.56	29.56	14.78			1.25%
Total	8	2356.89					100.00%

As shown in table no 12 the depth of cut have significant effect on radial force while feed rate and spindle speed are less significant.

LITERATURE REVIEW CONCLUSIONS

The significance and contribution of each parameter were analyzed and evaluated by ANOVA. Following are the conclusions given below:

- From analysis of variance it is found that depth of cut is the most significant factor in affecting the thread forces.
- As the depth of cut is reduced the chip will generating in continues form while increasing it chip will in discontinuous form.
- The optimal set of lathe parameters for coated tool are depth of cut as 0.125mm, feed rate as 0.47mm and spindle speed as 75rpm.
- The optimal set of lathe parameters for uncoated tool are depth of cut as 0.125mm, feed rate as 0.54mm and spindle speed as 75rpm.

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