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EXPERIMENTAL INVESTIGATION ON TURNING PARAMETERS DURING TURNING OF ALUMINIUM ALLOY FOR SURFACE ROUGHNESS AND CUTTING FORCES USING DESIGN OF EXPERIMENT (DOE)

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Abstract: Nowadays, surface finish has become an important indicator of quality and precision in manufacturing processes and it is considered one of the most important parameter in industry. In this present study, the influence of different machining parameters on cutting forces and surface roughness has been analysed through experiments. For this experiment the material used is Aluminium alloy 6082-T6. Aluminium alloy is one of the highly used material in automobile and manufacturing industries due to its excellent mechanical properties (such as tensile strength, low weight and corrosion resistance) and as well as technological properties (such as excellent cast ability and very good surface finish) most of the metal parts are manufactured by machining resulting in one of the most important characteristics of all metal parts which is the surface roughness of the machined surfaces. Moreover, DOE techniques have been used to predict the surface quality and to select the optimal turning conditions.

Keywords: Turning, Aluminium Alloy, Surface roughness, Cutting forces, DOE

I. INTRODUCTION

Turning is a form of machining, a material removal process, which is to create rotational parts by cutting away unwanted materials. Experiment is based on Turning on Aluminium Alloy which will be conducted on conventional Lathe Machine as this will be very much economical to the users. Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical tool path by moving more or less linearly while the work piece rotates the tool's axes of movement maybe literally a straight line, or they may be along some set of curves or angles, but they are essentially linear. Usually the term "Turning" is reserved for the generation of external surfaces by this cutting action. Thus the phrase "Turning" categorized the larger family of processes. Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by operator. In metal turning process, all cutting tools remove a certain layer of material and impart the required shape, size and surface quality to the workpiece. There is always a scope of research in fabrication of new materials, in the present scenario there is so much need in development of lightweight materials with the high strength, stiffness, hardness, wear resistance. So we are going to perform experiments on Aluminium alloy because it is mostly used in Automobile and Manufacturing industries due to its good mechanical properties as well as technological properties. Further its different properties can be improved by adding reinforcements. Moreover, we are using Taguchi method to get the optimal result by performing minimum Experiments.

Fig No.1 Rough Specimen

Fig No. 2 Turning Operation

Taguchi method is a statistical method developed by Taguchi and Konishi. Initially it was developed for improving the quality of goods manufactured (manufacturing process development), later its application was expanded to many other fields in Engineering, such as Biotechnology etc. Professional statisticians have acknowledged Taguchi's efforts especially in the development of designs for studying variation. Success in achieving the desired results involves a careful selection of process parameters and bifurcating them into control and noise factors. Taguchi Method involves identification of proper control factors to obtain the optimum results of the process. Orthogonal Arrays (OA) are used to conduct a set of experiments. Results of these experiments are used to analyse the data and predict the quality of components produced.

II. LITERATURE SURVEY

1) D. Sai Chaitanya Kishore (2014).[1] et al experimented on cutting force, surface roughness, flank wear in turning of In-situ Al6061 bar Tic metal matrix composites. Turning experiments were performed on 0, 2wt% and 4wt% of Tic reinforcement. The effect of process parameters such as cutting speed, feed rate and depth of cut on response cutting force, surface roughness and flank wear were studied during turning process. L25 taguchi design was used for designing the experiments, from the analysis of means of the responses at all the levels it was found that addition of Tic reinforcements raises surface roughness and flank wear and reduces cutting force.

2) Dr. C. J. Rao (2013).[2] et al carried out influence of cutting parameters on cutting force and surface finish on turning operation. Working with two made of ceramic with anAl_2O_3+ Tic matrix and the work material of AISI 1050 steel. Experiments were conducted using JohnfordTC35 industrial type of CNC lathe. Taguchi method (L27 design with 3 levels and 3 factors) and Analysis of Variance was adopted. Depth of cut has a significant influence on cutting force, but has an insignificant influence on surface roughness. The interaction of feed and depth of cut and the interaction of all the three cutting parameters have significant influence on cutting force, whereas, none of the interaction effects are having significant influence on the surface roughness produced.

3) B. Durgaprasad (2014).[3] et al experimented on hard turning of AISI D2 steel using coated carbide insert and revealed that the machining of AISI D2 steel workpiece having 66HRC hardness is carried out using coated carbide insert. The microstructure shows rolled grains of the steel along the direction of the material. The microstructure shows the fine grains of cementite with the grain boundary chromium and other alloys and the presence of carbide, which increases strength and wear resistant. It shows the importance of hard turning of AISI D2 steel. Investigations were carried out on conventional lathe using the prefixed cutting condition.

4) B.de Augustina (2013).[4] et al experimented on cutting forces obtained in dry turning process of UNS A97075 Aluminium alloys and found that the magnitude of cutting forces are strongly related to the amount of heat in cutting area, tool wear, quality of machined surface and accuracy of the workpiece. Design of experiments (DOE) 2^4 was used to analyse the influence of the cutting parameters and type of tool (nose radius on the cutting forces). It can be affirmed the cutting components of the forces is more sensible to the variation of the cutting condition that the rest of the components analysed. Tool with nose radius of 0.4 and of 0.8 mm have similar behaviour from the point of view of the forces generated during the machining at low feed rates.

5) P. Jayaraman (2014) .[5] et al led by multi-response optimization of machining parameters of turning AA6063 T6 aluminium alloy using grey relational analysis in taguchi method. The responses are based on orthogonal array and experiments are conducted on AA6063 T6 aluminium alloy. Optimum levels of parameters have been identified based on the values of grey relational grade and then the significant contribution of parameters is determined by ANOVA.

III. EXPERIMENTAL PROCEDURE

3.1 Design of Experiments

The Design of Experiments is considered as one of the most comprehensive approach in product/process developments. It is a statistical approach that attempts to provide a predictive knowledge of a complex, multi-variable process with few trials. Out of the numbers of methods we have selected the Taguchi method for the stated experiments.

3.2 Taguchi Method

The other methods require a large number of experiments to be carried out. It becomes laborious and complex, if the number of factors increase. To overcome this problem Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. Taguchi thus, recommends the use of the special function to measure the performance characteristics that are deviating from the desired target value. The value of this function is further transformed into selected responses.

Taguchi method is based on given steps of planning, conducting and evaluating results of matrix experiments to determine the best levels of control parameters. Those steps are given as follows.

- Identify the performance characteristics (responses) to study and process parameters to control (test).
- Determine the number of levels for each of the tested parameters.
- Select an appropriate orthogonal array, and assign each tested parameters into the array.
- Conduct an experiment randomly based on the arrangement of the orthogonal array.
- Calculate the Thrust and Torque for each combination of the tested parameters.
- Analyse the experimental result and selection appropriate results.
- Graphical representation and observe the behaviour of the each plot.

3.3 Experimental Setup

The Conventional Lathe machine having 8 speed with range from 35-1600 rpm. The Lathe Machine is attached to the Lathe Tool Dynamometer. And finally, the dynamometer is connected to the computerized system having installed Lathe tool force indicator.

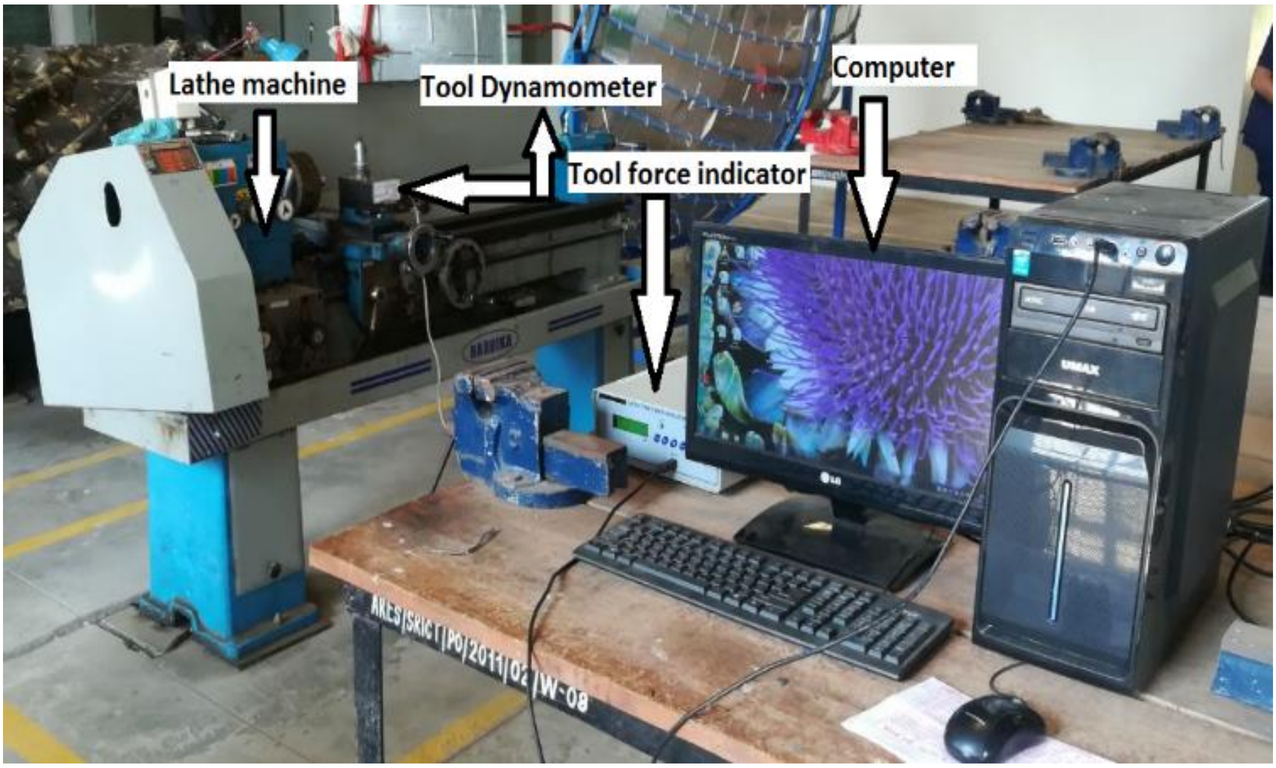

Fig No. 3 Experimental Setup

IV. APPROACH TO THE EXPERIMENTAL DESIGN

In accordance with the steps that are involved in Taguchi's Method, a series of experiments are to be conducted. Here, turning operation on Aluminium alloy 6082-T6 on a Lathe machine has been carried out as a case study.

4.1 Control Factors

Factor	**Control parameters**	**Levels**			**Units**
		1	2	3	
1	Speed (V)	140	230	310	rpm
2	Depth of Cut (d)	0.5	1	1.5	mm
3	Feed Rate (f)	1.25	2.5	3.75	mm/rev
	Back Rake Angle ((Degree)	6°	8°	10°	degree

Table 4.1: Control parameters and their levels

The selected control parameters Speed (V), Depth of cut (d) Feed Rate (f) and Back Rake Angle and their levels are as shown in table 4.1. The generated Feed force, tangential force, radial force are measured by the set up mentioned above. Experimentation has been carried out using their levels on an Aluminium alloy 6082-T6 specimen.

4.2 Selection of an orthogonal array

The most suitable orthogonal array for experimentation is L18 as it will give accurate result as shown in Table 4.2. Therefore, a total 18 experiments are to be carried out.

Run	**Columns**			
	A	**B**	**C**	**D**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	1	2
5	2	2	2	3
6	2	3	3	1
7	3	1	2	1
8	3	2	3	2
9	3	3	1	3
10	1	1	3	3
11	1	2	1	1
12	1	3	2	2
13	2	1	2	3
14	2	2	3	1
15	2	3	1	2
16	3	1	3	2
17	3	2	1	3
18	3	3	2	1

Table 2: Table of Taguchi designs (Orthogonal array L_{18})

4.3 Conducting the Matrix Experiment

In accordance with the above OA, experiments were conducted with their factors and their levels as mentioned in table 4.3. The experimental layout with the selected values of the factors is shown in table 4.3. Each of the above 18 experiments were conducted.

Experiment Number	Control parameter levels			
	A	B	C	D
	Back Rake Angle (°)	Depth of cut (d)	Feed Rate (f)	Speed (V)
1	6	0.5	1.25	140
2	6	1	2.5	230
3	6	1.5	3.75	310
4	8	0.5	1.25	230
5	8	1	2.5	310
6	8	1.5	3.75	140
7	10	1	1.25	140
8	10	1.5	2.5	230
9	10	0.5	3.75	310
10	6	1.5	1.25	310
11	6	0.5	2.5	140
12	6	1	3.75	230
13	8	1	1.25	310
14	8	1.5	2.5	140
15	8	0.5	3.75	230
16	10	1.5	1.25	230
17	10	0.5	2.5	310
18	10	1	3.75	140

Table 4.3: Experimental layout based on an Orthogonal array L_{18}

4.4 Experimental Data for Dry Turning

The experiment has been performed using above three factors with their levels and conducted the experiments for each of the factors. The Feed force, tangential force and radial force were measured for them. We got the accurate values for all the control parameters. By performing 18 runs of experiment we got less errors.

Experiment Number	Control Parameter levels						
	Back Rake Angle (°)	Depth of cut (d)	Feed Rate (f)	Cutting Speed (V)	X (Feed Force) (N)	Y (Tangential Force) (N)	Z (Radial Force) (N)
1	6	0.5	1.25	11.17	58.8	39.2	7.84
2	6	1	2.5	18.35	117.6	68.4	13.6
3	6	1.5	3.75	24.73	274.4	156.8	29.8
4	8	0.5	1.25	18.35	29.4	12.8	2.3
5	8	1	2.5	24.73	127.4	63.6	13.4
6	8	1.5	3.75	11.17	303.8	156.8	29.7
7	10	1	1.25	11.17	78.4	36.2	5.7
8	10	1.5	2.5	18.35	225.4	116.4	26.7
9	10	0.5	3.75	24.73	78.4	38.4	6.9
10	6	1.5	1.25	24.73	117.6	61.2	12.3
11	6	0.5	2.5	11.17	49	22.9	3.6
12	6	1	3.75	18.35	205.8	107.8	20.4
13	8	1	1.25	24.73	78.4	43.4	7.3
14	8	1.5	2.5	11.17	254.8	133.5	30.7
15	8	0.5	3.75	18.35	78.4	34.7	5.5
16	10	1.5	1.25	18.35	117.6	68.8	13.7
17	10	0.5	2.5	24.73	49	23.8	3.6
18	10	1	3.75	11.17	147.15	68.6	11.6

Table 4.4: Experimental Results for Dry Turning

Fig No. 4 Final Specimen

4.5 Graphical Observation

The plot of the control parameters cutting speed, depth of cut, feed rate and back rake angle versus cutting forces with their different levels are described below. The observation has been made on the basis of their behaviour on the plots. The nature of their performance are observed and used to predict their nature for the future work. The given observation is taken for the L_{18} orthogonal array on Aluminium alloy 6082-T6.

4.5.1 Effect on Cutting Force for Dry Condition

Cutting Force→ Cutting Speed:
At the initial stage of turning, the maximum cutting force is produced. As the turning speed is increased the cutting force generated is gradually decreasing. The same nature is observed for all three level in fig no.1 for the given array for specimen.

Cutting Force→ Feed Rate:
At the initial stage of turning, the minimum cutting force is produced. As the feed rate is increased the cutting force generated is gradually increasing. The same nature is observed for all three level in fig no.2 for the given array for specimen.

Cutting Force→ Depth of Cut:
At the initial stage of turning, the minimum cutting force is produced. As the depth of cut is increased the cutting force generated is gradually increasing. The same nature is observed for all three level in fig no.3 for the given array for specimen.

Cutting Force→ Back Rake Angle:
At the initial stage of turning, the maximum cutting force is produced. As the back rake angle is increased the cutting force generated is gradually decreasing. The same nature is observed for all three level in fig no.4 for the given array for specimen.

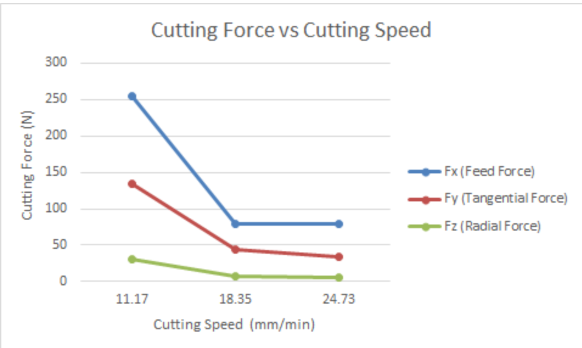

Fig No. 1 Cutting Force→ Cutting Speed

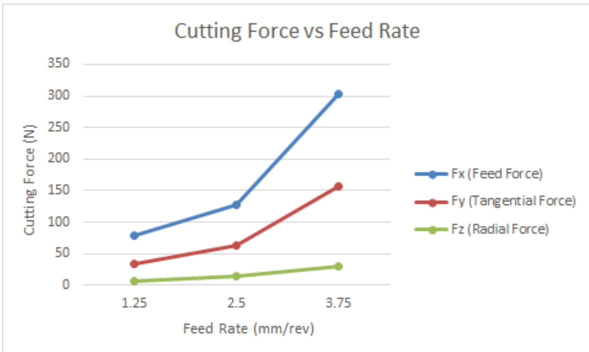

Fig No. 2 Cutting Force→ Feed Rate

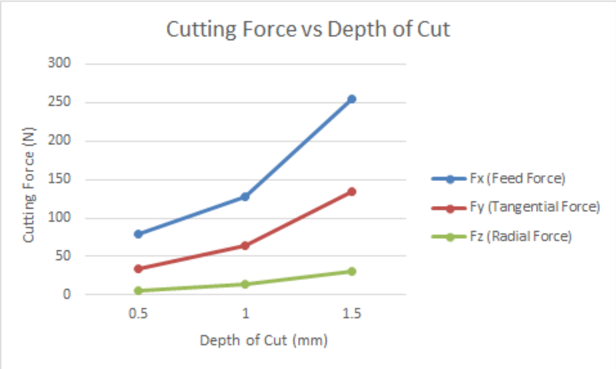

Fig No. 3 Cutting Force→ Depth of Cut

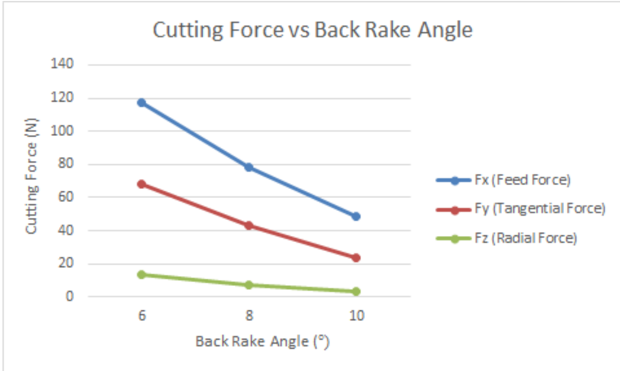

Fig No. 4 Cutting Force→ Back Rake Angle

4.6 Experimental Data for Wet Turning

The experiment has been performed using above three factors with their levels and conducted the experiments for each of the factors. The Feed force, tangential force and radial force were measured for them. We got the accurate values for all the control parameters. By performing 18 runs of experiment we got less errors.

Experiment Number	Control Parameter levels						
	Back Rake Angle (°)	Depth of cut (d)	Feed Rate (f)	Cutting Speed (V)	X (Feed Force) (N)	Y (Tangential Force) (N)	Z (Radial Force) (N)
1	6	0.5	1.25	11.17	29.4	14.6	3.1
2	6	1	2.5	18.35	105.2	51.5	9.7
3	6	1.5	3.75	24.73	184.6	95.4	20.1
4	8	0.5	1.25	18.35	24.8	10.4	1.8
5	8	1	2.5	24.73	118.7	60.5	13.3
6	8	1.5	3.75	11.17	294.7	153.2	36.4
7	10	1	1.25	11.17	69.2	31.8	5.7
8	10	1.5	2.5	18.35	211.6	107.6	22.6
9	10	0.5	3.75	24.73	49	23.5	4.23
10	6	1.5	1.25	24.73	106.9	51.3	10.8
11	6	0.5	2.5	11.17	34.8	16.1	3.3
12	6	1	3.75	18.35	196.7	102.3	19.4
13	8	1	1.25	24.73	69.2	33.4	5.9
14	8	1.5	2.5	11.17	225.4	117.2	28.2
15	8	0.5	3.75	18.35	57.4	26.8	4.5
16	10	1.5	1.25	18.35	105.2	51.6	10.6
17	10	0.5	2.5	24.73	34.8	16.1	3.1
18	10	1	3.75	11.17	88.2	43.1	7.8

Table 4.6: Experimental Results for Wet Turning

4.6.1 Effect on Cutting Force for Wet Condition

Cutting Force→ Cutting Speed:
At the initial stage of turning, the maximum cutting force is produced. As the turning speed is increased the cutting force generated is gradually decreasing. The same nature is observed for all three level in fig no.5 for the given array for specimen.

Cutting Force→ Feed Rate:
At the initial stage of turning, the minimum cutting force is produced. As the feed rate is increased the cutting force generated is gradually increasing. The same nature is observed for all three level in fig no.6 for the given array for specimen.

Cutting Force→ Depth of Cut:
At the initial stage of turning, the minimum cutting force is produced. As the depth of cut is increased the cutting force generated is gradually increasing. The same nature is observed for all three level in fig no.7 for the given array for specimen.

Cutting Force→ Back Rake Angle:
At the initial stage of turning, the maximum cutting force is produced. As the back rake angle is increased the cutting force generated is gradually decreasing. The same nature is observed for all three level in fig no.8 for the given array for specimen.

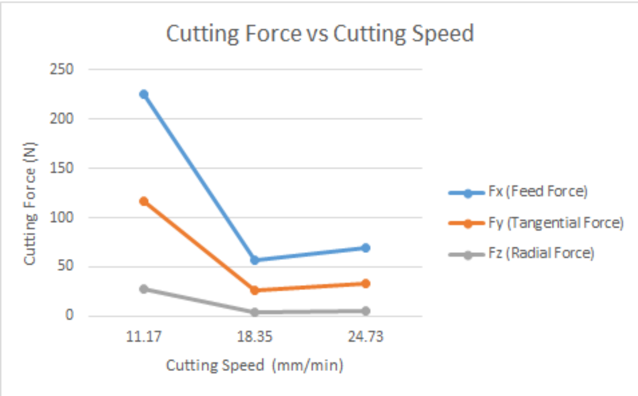

Fig No. 5 Cutting Force→ Cutting Speed

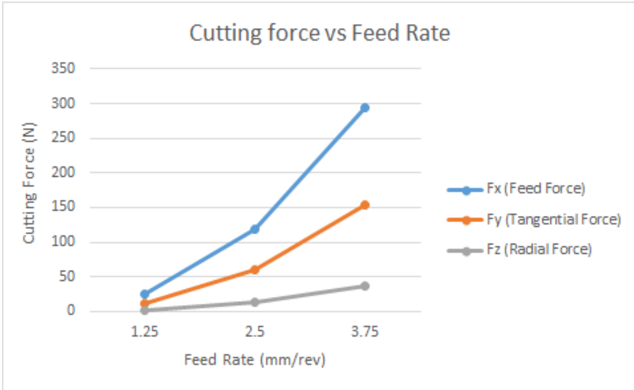

Fig No. 6 Cutting Force→ Feed Rate

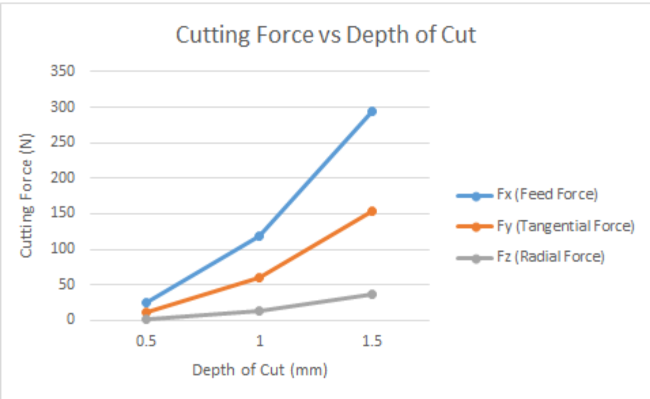

Fig No. 7 Cutting Force→ Depth of Cut

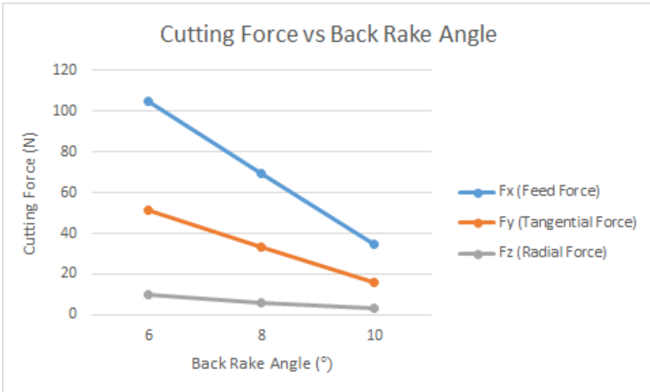

Fig No. 8 Cutting Force→ Back Rake Angle

V. RESULT AND CONCLUSION

The paper illustrates the application of the parameter design (Taguchi method) to examine the effects of the process parameters of turning operation. The following conclusions can be drawn based on above experiment results of this study:

Results:

- ➢ After analysis of experiments the results we got:
1. If cutting speed increases than there is reduction in cutting forces.
2. When depth of cut increases, cutting force also increases.
3. When Feed rate increases, cutting force also increases.
4. If back rake angle increases than there is reduction in cutting forces due to its positive angle.

Conclusion:

- ➢ After analysis of each of the parameter which affects the cutting force generated during machining operation, we came to conclusion that “Depth of Cut” has highest effect and that can be controlled to reduce the cutting force.

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