Experiment study of Process Parameters of Drilling Operation of an bearing material (AISI 52100) Using Design of Experiments (DOE)

Samir D. Jariwala
Assistant Professor, Department of Mechanical Engineering, Shroff S. R Rotary Institute of Chemical Technology, Bharuch

***Abstract*— Drilling operation is the most commonly used machining operation that uses multipoint cutting tool called drill or drill bit to remove unwanted material for producing or enlarging desire hole. The present study is concerned on the examination of the process parameters of the drilling process on a bearing material. A statistical approach is used to analyse the experiment data and it is called as design of experiments (DOE). The technique minimizes the number of test required and maximizes the amount of reliable information. A low alloy steel bearing material (AISI 52100) is used for the testing. There are three variation of drill bits and plate thickness are taken to examine the characteristics of thrust and torque at different speed. Such techniques for investigating variation in parameter, can be used in improving manufactured quality and performance.**

Index Terms: **Process parameters; Drilling, Design of Experiment (DOE), alloy steel.**

1.INTRODUCTION

Drilling operation is the most commonly used machining operation that uses multipoint cutting tool called drill or drill bit to remove unwanted material for producing or enlarging desire hole. The main focused of modern machining industries on achievement of high quality, in term of work piece drilled accuracy and surface finish. The geometry of cutting tool, work materials, and parameters like cutting speed and feed directly affects drill performance. These parameters should be selected to optimize the drilling operation. So it can be achieved by function of drilling conditions using design of experiments (DOE).

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.

2. LITERATURE REVIEW

KompanChomsamutr et al [1] researched on optimization parameters of tool life model using the Taguchi Approach and Response Surface Methodology. They used RSM and Taguchi method to compare the cutting parameters of turning. It is found that by using both the methods and derived the mathematical model to cause the longest tool's life. Also they followed the procedure of Taguchi method and identify the performance characteristics (responses) to optimize and process parameters to control (test).

Md. Anayet u. Patwari et al [2] experimented on prediction and optimization of surface Roughness by coupled statistical and desirability analysis in drilling of mild steel. They adopted the Desirability function approach in order to find out the overall improvement in surface finish & MRR through use of abrasives in comparison to the plain coolant is very promising

which will lead to huge savings in the cost and improvement in quality.

Mr. N.S Kurzekar et al. [3] carried out the optimization of drilling process parameters of AISI 304 austenite stainless steel by using response surface methodology. They researched on surface roughness as geometry of cutting tool, work materials, and parameters like cutting speed and feed directly affects drill performance. They also suggested that there are many research done on optimization techniques for process parameter for material removal rate and surface roughness. But they found that there is very little research done on drilling process parameter for AISI alloy steel.

C. O. Izelu at el. [4] experimented on response surface methodology in the study of induced machining vibration and work surface roughness in the turning of 41cr4 alloy steel. The examined induced vibrations and surface roughness of a tool-work-piece system in a turning process. From this study it is shown that induced vibration has significant effect on surface roughness of work-piece. This effect interacts with other independent variables such as depth of cut, cutting speed and tool nose radius.

Ashutosh Kumar pandey et al. [5] experimented on optimization of the process parameters in micro-electric discharge machining using response surface methodology and genetic algorithm. These mathematical models using Response Surface Methodology (RSM) is used to correlate the response and the parameters. They found that the qualities required during micro hole drilling is to decrease the tool wear rate while drilling a micro-hole. Also the concluded that the tool wear rate can be considered as a measure of machining efficiency.

Parminderjeet Singh et al. [6] experimented on Optimization of Process Parameters of AISI D3 Steel with Abrasive Assisted Drilling. The experiment conducted with abrasive slurry then the observations were made using Taguchi method. They observed the variation in MRR and surface roughness and then the optimized response variables were calculated. Also they found the drill diameter, material thickness and the drill point angle leading to desired output or responses with acceptable variations that will ensure a low cost of manufacturing through optimization. Also spindle speed, feed rate affects the material removal rate and the surface roughness is mostly affected by spindle speed, feed rate, type of drill & drill diameter.

Amarnath R. Mundhekar et al. [7] had given the review on Optimization of Drilling Process Parameters. It states thatto determine the region of critical process control factors such as probability of the minimum surface roughness within the range predicted by response surface method. They focused on the surface roughness and also they found that the cutting parameters like spindle speed and feed has significant effect on surface roughness.

Woo TzeKeong et al. [8] states that while understanding and controlling the thrust force and drilling generated temperature, the RSM integrated models were validated and it resulted in a low percentage error delaminating factor estimation equation from drilling parameters. It is observed that Feed rate and thickness contributes significantly to the increase of thrust force, while feed rate significantly affects the drilling generated heat followed by thickness and spindle speed.

Srinivas Athreya, Dr. Y. D venkatesh[9] experimented on the lathe to improve the surface roughness using taguchi method. They concluded that the Taguchi's method of parameter design can be performed with lesser number of lesser number of experimentations as compared to any other method of DOE. Also Taguchi provides a simple, systematic and efficient methodology for optimizing the process parameters.

P.marimuthu, TTM kannan at el [10] experimented on Micro drilling process parameters of Austenitic Stainless Steel (AISI 316) using DOE concepts. They found that the speed and feed are the most influent parameters of micro drilling. Point angle of drill is not significant for such kind of material like AISI 316. Also tool wear rate is minimum on the micro drilling process.

3. EXPERIMENT METHODOLOGY

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[9].

3.2 TAGUCHI METHOD

The other methods require a large number of experiments to be carried out. It becomes 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 TEST SPECIMEN

Fig.1 experimental setup

The Radial drilling machine having capacity of 25mm with speed range 73-1800 rpm. The bench wise is attached to the Drill Tool Dynamometer. And finally, the dynamometer is connected to the computerized system having installed Drill tool force indicator.

4. 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, drilling operation on Alloy steel (AISI 52100) components on a radial drilling machine has been carried out as a case study.

4.1 CONTROL FACTORS

The selected control parameters Speed (V), Drill diameter (d) and Plate thickness (t) and their levels are as shown in table 1. The generated Thrust and Torque are measured by the set up mentioned above. Hence, the experimentation has been carried out using their levels on an alloy steel AISI 52100.

Table 1: Control parameters and their levels

Factor	Control parameters	Levels			Units
		1	2	3	
1	Speed (V)	103	310	720	rpm
2	Drill diameter (d)	5	10	15	mm
3	Plate thickness (t)	6	10	25	mm

4.2 SELECTION OF AN ORTHOGONAL ARRAY

To select an appropriate orthogonal array for conducting the experiments, the degrees of freedom are to be computed. The same is given below:

Degrees of Freedom: 1 for Mean Value, and 8= (2x4), two each for the remaining. The total Degrees of Freedom = 9.

The most suitable orthogonal array for experimentation is L9 array as shown in Table 2. Therefore, a total nine experiments are to be carried out.

Table 2: Taguchi designs (Orthogonal array L_9)

Experiment Number	Control parameters levels		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

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 3. The experimental layout with the selected values of the factors is shown in. Each of the above 9 experiments were conducted two times to get the error less results.

Table 3: Experimental layout based on an Orthogonal array L_9

Experiment Number	Control parameters levels		
	A	B	C
	Speed (V)	Drill diameter (d)	Plate thickness (t)
1	103	5	6
2	103	10	10
3	103	15	25
4	310	5	25
5	310	10	6
6	310	15	10
7	720	5	10
8	720	10	25
9	720	15	6

5. RESULT AND DISCUSSION

The following are the experimental results of the work carried out.

5.1 EXPERIMENTAL DATA

The experiment has been performed using above three factors with their levels and conducted the two separate experiments for each of the factors. The holes generated was throughout the thickness.

The Torque and Thrust were measured for them. Since, we want the accurate value; we have taken average of both experiment and calculated the average Torque and average Thrust. So that we get the values can be converging to the accurate readings.

Table 4: Experimental Results (Average Torque and Thrust)

Experiment Number	Average Torque (Nm)	Average Thrust (N)
1	2.45	539.36
2	2.94	956.15
3	4.9	1804.42
4	0.98	598.2
5	1.96	760.02
6	1.96	1544.55
7	0.5	318.71
8	1.96	603.1
9	1.96	1093.45

5.2 GRAPHICAL OBSERVATION

The plot of the control parameters speed, drill diameter and plate thickness versus their generated Torque and Thrust 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_9 orthogonal array on AISI 52100.

5.2.1 EFFECT ON THRUST

Thrust→ Speed:At the initial stage of drilling, the maximum thrust force is produced. As the drilling speed is increased the thrust force generated is gradually decreased. The same nature is observed for all three level for the given array for AISI 52100.

Thrust→ Drill Diameter:As the drill diameter is increased the thrust force also generated simultaneously. So in case of drill diameter the friction between the surfaces increased and hence the thrust generated is increased.

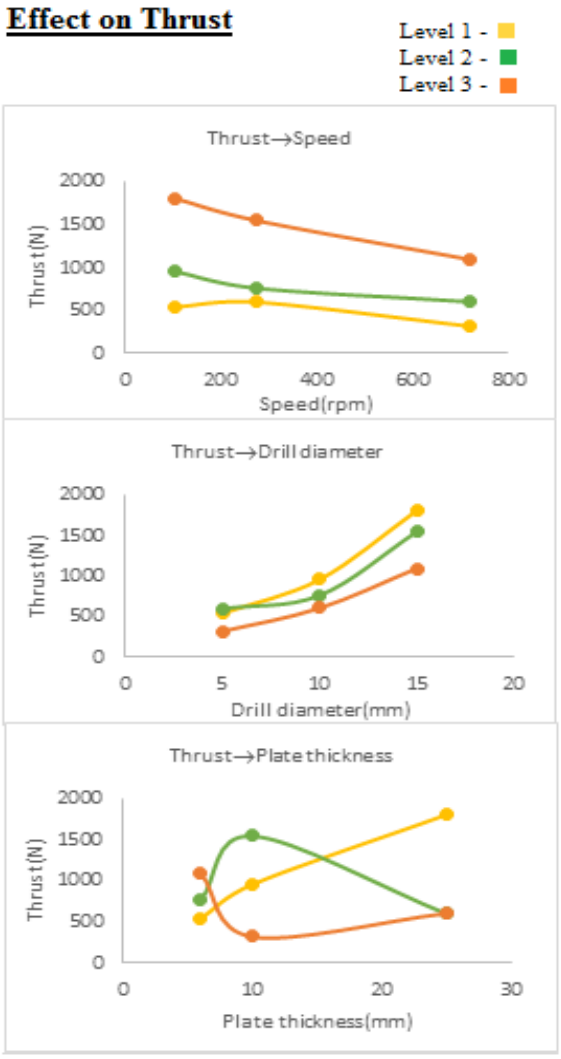

Fig. 2 Effect on Thrust

Thrust→ Plate Thickness:The behaviour on varying plate thickness is uncertain. (a)For the lower speed, as plate thickness increases the thrust generated increases. (b)For moderate speed, it is increasing up to some range afterward the thrust force decreases because the plastic medium generated after that range. (c)For the high speed, on increasing the plate thickness the thrust generated increases up to some range. Afterward it increases slowly as shown in the graph because there is more distance between the moderate plate thickness (10mm) and high plate thickness (25mm).

5.2.1 EFFECT ON TORQUE

Torque→ Speed:At the initial stage of drilling, as speed increases the torque decreases drastically. After some speed range, torque is remains constant or may decreases for lower speed on AISI 52100.

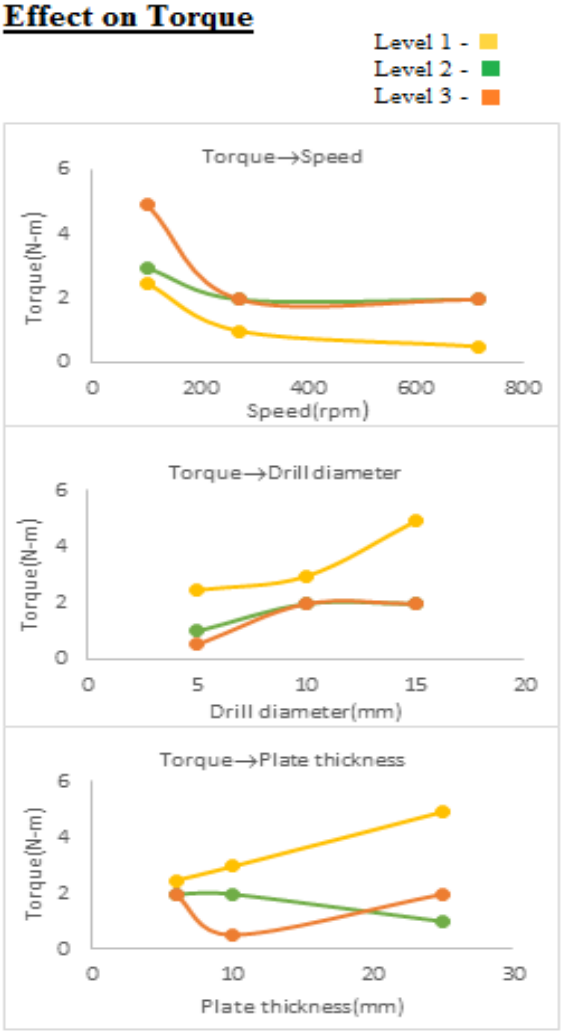

Fig. 3 Effect on Torque

Torque→ Drill Diameter:As shown in the graph, In case of drill diameter; as it increases the torque increase. But after moderate level, it remains constant or may increases.

Torque→ Plate Thickness:Similarly in case of the plate thickness, the behaviour of the torque is uncertain. (a)For low speed, the torque generated increasing with the plate thickness. Because if the thickness increases, the friction between the drill bit and work piece also increases. (b)For moderate the behaviour was observed opposite than for lower speed up to some range. Afterward the Torque decreases for moderate speed while increasing plate thickness. (c)For higher speed, if the plate thickness increases the torque generated also increases.

6. CONCLUSION

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

- Taguchi's method of parameter design can be performed with the lesser number of experiments as compared to other methods.
- For low drilling speed, if the plate thickness and drill diameter are higher than the maximum torque and thrust are generated.
- For higher drilling speed, if the plate thickness and drill diameter are lower than the minimum torque and thrust are generated.
- Uncertain behaviour of the thrust and torque is observed while changing the plate thickness.

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