Understanding of Optimization of Axial Force in Drilling Using Taguchi Method: An Overview

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ABSTRACT

This research outlines the Taguchi's Parameter Design Approach, which is applied to optimize cutting parameters in drilling. Analysis of variance (ANOVA) is used to study the effect of process parameters on machining process. This procedure eliminates the need for repeated experiments, saves time and conserves the material as opposed by the conventional procedure. The drilling parameters investigated are cutting speed and feed rate. An orthogonal array has been used to conduct the experiments and raw data and signal-to-noise ratio are employed to analyze the influence of these parameters on axial force during drilling. The methodology could be useful in predicting thrust and torque parameters as a function of cutting parameters and specimen parameters. The main objective is to find the important factors and combination of factors influencing the machining process to achieve low axial force.

Keywords: Annova, Design of Experiments, Drilling Operation, Orthogonal Array, S/N Ratio, Taguchi Method.

1. INTRODUCTION

The drilling machine is one of the most important machine tools in a workshop. As regards its importance it is second only to lathe. Although it was primarily designed to originate a hole, it can perform a number of similar operations. In a drilling machine holes may be drilled quickly and at a low cost the hole is generated by the rotating edge of a cutting tool known as the drill which exerts large force on the work clamed on the table .As the machine tool exerts vertical pressure to originate a hole it is loosely called a "drill press". Holes were drilled by the Egyptians in 12000 B.C. about 3000 years ago by bow drills. The bow drill is the mother of present day metal cutting drilling machine. (Source- Elements of workshop technology Volume two Machine [1].

2. WORKING PRINCIPLE AND OPERATION OF A DRIILING MACHINE

Drilling machine is used to produce holes in the workpiece. The end cutting tool used for drilling holes in the workpiece is called a drill. The drill is placed in the chuck and when the machine is 'ON', the drill rotates. The linear motion is given to the drill towards the workpiece, which is called feed in order to remove the chips from the hole, drill is taken out from the hole so the combination of rotary and linear motion produces the hole in the work piece. Figure 1. shows the drilling operation on to the work piece [2]. the work piece.

Fig. 2.1 Drilling operation on

3. MECHANICS OF DRILLING OPERATION:

The most common hole making operation is drilling and it is usually performed with the help of a twist drill. Unlike shaping and turning, this involves two principal cutting edges. Fig. 3.1 shows a drilling operation[8]. If the total advancement of the drill per revolution (the feed rate) is f, then the share of each cutting edge is f/2 because each lip is getting the uncut layer the top surface of which has been finished by the other lip 180^0 ahead (during 180^0 rotation, the vertical displacement of the drill is f/2). The uncut thickness t1 and the width of cut w are given as

$$T1 = (f/2) \sin \beta$$
$$W = (D/2) \sin \beta$$

Where β is the half point angle (Fig. 3.1.b)

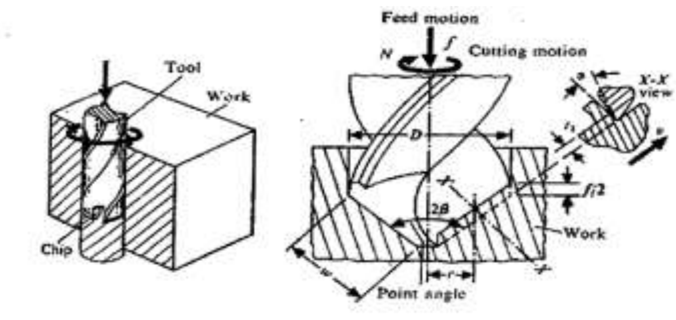

Fig. 3.1 (a) Basic scheme (b) Details of drilling geometry

4. FACTORS AFFECTING CUTTING FORCE

In order to identify the process parameters affecting the quality features of drilled parts, an Ishikawa cause-effect diagram has been constructed and is shown in Fig. 4.1.

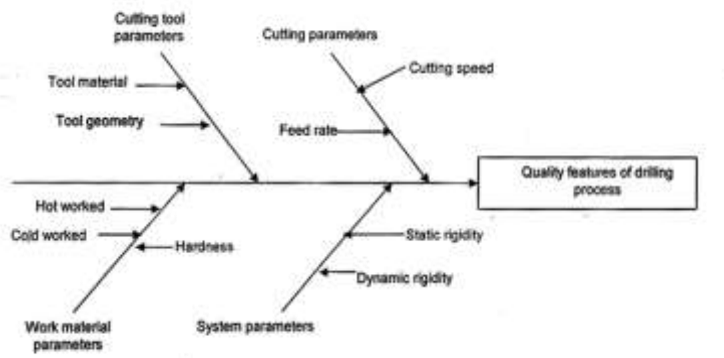

Figure 4.1 Ishikawa cause - effect diagram of a drilling process [10]

5. OBJECTIVE OF THE PAPER

The paper was carried out to investigate the effect of the operating conditions, which are cutting speed and feed rate expected.

The objectives of this paper are:

- To investigate the effect of the operating condition, which are cutting speed and feed rate.
- The main objective is to find the important factors and combination of factors influencing the machining process to achieve low axial force[6].

6. EXPERIMENTAL SET UP

Two main equipments used in the present case study are:

1. Radial drilling Machine
2. Drilling Dynamometer.

Radial drilling Machine

The redial drilling machine used in this case study in available at IIT, Delhi Workshop. It is the largest and most versatile of the drilling machines and is very well suited for drilling large number of holes. It is a single spindle intended for handling large and heavy work or work which is beyond the capacity of the small drilling machines. It consists of vertical column with a radial arm that can be driven for vertical movement, is an independently driven drilling head equipped with a power feed. The drill a hole the arm is raised or lowered as needed. The drill head is then positioned and locked on the arm. The arm next is locked in that position, the spindle speed and feed are adjusted, and the depth is set. The drills will then feed down and return when the proper depth has been reached.

Drilling dynamometer:
It is force-measuring equipment, which undergoes some deflection when measuring the cutting force. The main requirements of any dynamometer are that it should be sensitive and at the same time rigid also. Frequently, the dominating stiffness criterion is the natural frequency of the dynamometer [3]. All machine tools operate with some vibrations executing certain cutting operations like milling, drilling etc. For any cutting process it is desirable to measure three components of the force in a set of rectangular co-ordinates. While measuring these three forces, the dynamometer should be so designed that force in x-direction should not give any reading in y and z directions and so should be case in y and z directions.

The drilling dynamometer used in the present work is shown fig. 6.2(b).

Figure 6.1 Experimental Set Up(Tool Machine)

Figure 6.2 (a) HSS Tool **Figure 6.2 (b) Drilling Dynamometer**

7. TAGUCHI TECHNIQUE

The Taguchi Technique for quality engineering is intended as a guide and reference source for industrial practitioners (managers, engineers & scientists) involved in product or process experimentation and development. Dr. Genichi Taguchi, a Japanese engineer was born on 15 Jan 1924. He was active in the improvement of Japan's industrial products and processes since the late 1940s. After the Second World War, the allied forces found that the quality of Japanese telephone system was extremely poor and totally unsuitable for long distance communication purpose. To improve the system the allied command recommended that Japan should establish research facilities similar to the Bell Laboratories in the United States in order to develop state-of-the-art communication systems. The Japanese founded the "Electrical Communications Laboratories" (ELC) with Dr. Genichi Taguchi in charge of improving R&D productivity and enhancing product quality. He observed that a great deal of money and time was expended in engineering experimentation and testing. Dr. Taguchi started to develop new methods to optimize the process of engineering experimentations. He developed techniques, which are now known as "Taguchi techniques"[4,7].

7.1 Designing, Conducting and Analyzing An Experiment Methodology

Selection of OA
Assignment of parameters and interactions to OA
Selection of outer array
Experimentation and data collection
Data analysis
Determination of confidence intervals
Confirmation experiment

Figure 7.1 Flowchart of the Taguchi Method.

Selection of factors and/or interactions to be evaluated

The determination of which parameters to investigate hinges upon the product or process performance characteristics or responses of interest. Taguchi suggests several methods for determining which parameters to include in the experiment. There are:

Selection of number of Levels for the Factors

One can select two or three levels of the factors under study. Three levels of factors are considered more appropriate since and non-linear relationship between the process variables and the performance characteristics can only be revealed if more than two levels of the process parameters are taken. In the present case study, three levels of the process variables have thus been selected.

Selection of the Orthogonal Array (OA)

The selection of which orthogonal array [5] to use depends on these items.
1. The number of factors and interactions of interest
2. The number of levels for the factors of interest
These two items determine the total degrees of freedom required for the entire experiment. The degree of freedom for each factor is the number of levels minus one.

$$f_A = k_A - 1$$

The degree of freedom for an interaction is the product of the interacting factors' degrees of freedom.

$$f_{AxB} = (f_A)(F_B)$$

The total required degree of freedom in the experiment is the sum of all the factors and interactions degrees of freedom.
The basic kinds of OA's developed by Taguchi are either two level arrays or three level arrays. The standard two level and three level arrays are:

(a) Two way Array L_4, L_8, L_{16}, L_{32}

(b) Three way Array L_9, L_{18}, L_{27}

When a particular OA is selected for an experiment the following inequality must be satisfied.

$F_{LN} \geq$ Total DOF required for parameters and interactions[9]

Where,
$F_{LN} \geq$ Total Degree of Freedom of an OA
(Department on the number of levels of the parameters and total DOF required for the experiment, a suitable OA is selected)

Assigning of Parameters and Interactions to the orthogonal Array[5]:

The OA's have several columns available for assignment of parameters and some columns subsequently can estimate the effect of interactions of these parameters. Taguchi has provided two tools to aid in the assignment of parameters and interactions to arrays.

1) Linear Graphs
2) Triangular Tables

Linear Graphs (Three-Level OAs)

An L9 OA linear graph is shown in Fig. 7.2 the dots represent columns available for a three-level factor, which is allocated 2 degree of freedom. The line represents the two columns, which together evaluate the interaction of the dot columns. The interaction will require 4 degree of freedom; hence two columns are necessary to assign the interaction.

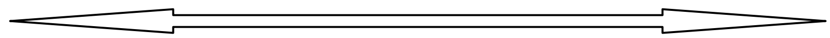

Figure 7.2 L9 Linear Graph

Selection of the Outer Array

Taguchi separates factors (parameters) into two main groups:

- Controllable Factors
- Uncontrollable Factors

7.2 EXPERIMENT & DATA COLLECTION

The experiment is conducted against each of the trial conditions of the inner array. Each experiment at trial condition is repeated simply or conducted according to the outer array used. Factors are assigned to columns, trial test conditions, however, are dictated by the rows. The interaction conditions cannot be controlled when conducting a test because they are dependent upon the main factor levels. Only the analysis is concerned with the interaction columns. Therefore, it is recommended that test sheets be made up which show only the main factor levels required for each trial. This will minimize mistakes in conducting the experiment, which may inadvertently destroy the orthogonality.

Data Analysis

There are a number of methods suggested for analyzing the experimental data like Observation Method, Ranking Method, Column Effect Method, and Interaction Graphs etc. However, in the present investigation the following methods have been used:

1) Plot of average response curves
2) ANOVA for the Raw Data
3) ANOVA for S/N Data

Parameter Design Strategy

Parameter classification and selection of the optimum levels:
When the ANOVA on the raw data (identifies control parameters which affect average values) and S/N data (identifies control parameters which affect variations) are completed, the control parameters are classified into four classes:
Class 1: Parameters that affect both average value and variation (significant in both i.e. raw data ANOVA and S/N ANOVA)
Class 2: Parameters which affect variation only (significant in S/N ANOVA only)
Class 3: Parameters that affect average value only (significant in raw data ANOVA only)
Class 4: Parameters which affect nothing (Not significant in both i.e. raw data ANOVA and S/N ANOVA).
The parameter design strategy is to select the proper levels of Class 1 and Class 2 parameters to reduce variations and Class 3 parameters to adjust the average to the target value. Parameters may be set at the most economical levels since nothing is affected.

Prediction of the Mean: (μ)

After determination of the optimum condition, the mean of the response (μ) at the optimum condition is predicted. This mean is estimated only for the significant parameters. The ANOVA identifies the significant parameters. Suppose, parameters A and B are significant and A_1, B_2 is the optimum treatment condition. Then the mean at the optimum condition is estimated as:

$\mu_A \quad + \mu_B \quad \overline{U} + \left(\overline{A_1} - \overline{U}\right) + \left(\overline{B_2} - \overline{U}\right)$

$= \quad \overline{A_1} + \overline{B_2} - \overline{U}$

Whereas,

$\overline{U}$ = Overall mean of the response

$\overline{A_1}, \overline{B_2}$ Represent average values of the response at the first level of parameter A and second level of parameter B.

Determination of the Confidence Level

The estimate of the mean (µ) is only a point estimate based on the average of the results obtained from the experiment. Statistically this provides a 50% chance of the true average being greater than µ and 50% chance of the true average being less than µ. It is, therefore, customary to represent the values of statistical parameters as a range within which it is likely to fall for a given level of confidence. This range is termed as Confidence Interval. In other words, the confidence interval is a maximum and minimum value between which the true average should fall at some stated percentage of confidence.

Confirmation Experiment

The confirmation experiment is the final step in verifying the conclusion from the previous round of experimentation. The optimum condition is set for the significant parameters and selected number of tests is run under constant specified conditions. The average of the confirmation experiment results is compared with the anticipated average on the parameters and levels tested. The confirmation experiment is a crucial step and is highly recommended to verify the experimental conclusion.

CONCLUSIONS

The expected results may be after experimental work which is given below:

(1) After analyzing S/N response graphs and the average plots for the raw data the optimal cutting conditions for the selected quality Characteristic, axial force.

(2**)**The following are the percentage contributions of the parameters to the variations of axial force in drilling of **Mild Steel** part using **HSS drill**. The percentage contribution of the parameters reveal that the influence of the feed rate in controlling both mean and variation of axial force is significantly larger than that of cutting speed.

(3) The interaction between cutting speed end feed rate (A x B) is significant confidence level in ANOVA for raw data.

(4) The predicted optimal range of axial force.

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