A Fuzzy Logic Model to Evaluate the Surface Roughness in the Drilling of Oil Hardened Non - Shrinking Die Steel

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Abstract- **Machining is an important material removal process in which materials are removed from the work piece in the form of chips. There are lots of machining operations like milling, grinding, drilling and turning is used in the manufacturing industries to develop the finished component with high quality and accuracy. Drilling is the one of the most important hole making process used in the manufacturing and assembly sectors. During the drilling process, heat is generated at the contact of drill bit and test specimen to produce hole at the required position. The selection of process parameters in drilling operation plays vital role in the quality of the drilled specimen. Recently Oil Hardened Non Shrinking die steel materials are used in the automobile, chemical, nuclear and marine industries. The experiments were conducted by the proper selection of drilling process parameters to obtain better mechanical strength by using the L_{27} orthogonal array. In this experimental investigation, Oil Hardened Non Shrinking die steel has been drilled by using the Bhagwan Udyog Milling machine with soluble oil as a coolant for wet conditions. The optimum level of drilling process parameters plays great impact in the manufacturing environment. The basic drilling parameters such as spindle speed, feed rate and drill size were selected and examined at three different levels, to study the effect of drilling process parameters on the surface roughness. The present experimental work is focused on the optimization of drilling process parameters using Taguchi design of experiments and the optimum level of parameters by using the Fuzzy Logic technique to be recommended for process planner.**

Keywords: Drilling, Process Parameters, Fuzzy Logic, Surface Roughness.

I. INTRODUCTION

In today's world, the primary objective of all the manufacturing industries is to achieve the economical machining condition to increase the profit with desired quality. Many researchers have developed the mathematical models to predict the optimum level of input process parameters to increase the quality of the component. Machining is an important material removal process in which materials are removed from the work piece in the form of chips. Various machining operations like milling, grinding, drilling and turning are used in the manufacturing industries to develop the finished component. Drilling is a form of machining, a material removal process, which utilizes drill bit to cut a hole of circular cross-section in solid materials. Tool life is heavily affected in drilling operation due to higher thrust force and wear rate of the drill bit. These increase the production cost of modern manufacturing industries. During the drilling process, heat is generated at the interface of the drill bit and the test specimen. The basic drilling parameters such as cutting speed, feed rate, depth of cut and drill size are selected and examined to study the effect of drilling parameters on the roundness , surface roughness , metal removal rate. The present research work is focused on the development of a fuzzy logic model to predict the Surface Roughness for any combination of the cutting speed, feed rate and drill diameter within the experimental range.

II. LITERATURE SURVEY

Zhanghua Lian et al. (2015) established a theoretical model of drill string dynamics to study the motion state of drill string. It was found that the change of WOB is a typical sine curve and the frequency of WOB increases linearly with the rotary speed. B. Lundberg et al. (2015) conducted a study to maximize the efficiency of conversion of wave energy into work in percussive drilling with detachable drill. It was found that short incident waves, there is a weak influence of the bit mass on the optimal wave shape, which is nearly rectangular. Craig Pitcher et al. (2015) conducted a study to determine the relationship between final depth, total drill radius and cone shape for dual-reciprocating drilling (DRD) technique. It was found that the cone half-apex angle, which defined the shape of cone, has a small negative linear relationship with depth. Agata Guzek et al. (2015) conducted an experiment to investigate the influence of the non-Newtonian mud rheology on the vertical drill bit vibrations. They found that as the shear-thinning behavior is desirable in drilling muds, for a typical fluid used the generated damping will decrease with increasing vibrations and its influence on the vibration reduction will not be significant. Y. Karpat et al. (2015) compared the influence of drill geometry on process outputs such as drilling forces, torques and tool wear. It was found that higher feeds with lower cutting speed decrease the total power during drilling and would improve tool life without affecting the productivity.

Sukru Merey (2016) experimented the various drilling operations in gas hydrate reservoirs. Recent drilling expeditions in marine environment and permafrost show that gas hydrate does not dissociate immediately and most of the drilling problems faced were similar to those observed in conventional drilling operations. Zhenyuan Jia et al. (2016) developed a novel drill structure to change the cutting conditions at the drill exit and effectively reduce damages in drilling CFRP. Analyses of the cutting model indicate that cutting from the drill exit to the machined side of CFRP which is defined as the upward cutting in the reverse direction of feeding in the drilling process, alters the machined side as back supports for drill exit materials. Arne Feldmann et al. (2016) conducted an extensive experimental study at reducing temperature elevation of bone drilling. They found that due to the low thermal conductivity of bone, drilling in intervals is in general beneficial for limiting the accumulation of heat and allowing the bone to cool down in between intervals while improving chip evacuation as well as flute cleaning when the drill bit is extracted. J.Chen et al. (2016) applied drilling process monitoring (DPM) methodology to determine the weak zone characterization through full drilling analysis of rotary drilling. It was found that weak zone with infilling collapse during drilling action can be characterized by net drilling analysis. Babaei Khorzoughi Mohammad et al. (2016) conducted an experiment to find the optimum parameters for mining operation. They used different techniques to determine rate of penetration (ROP) and based on these an approach for the calculation of a true ROP was developed to be used in specific energy calculation and rock mass characterization.

Hemant S. Patne et al. (2017) developed a finite element model for evaluating temperature distribution in the process. They found that increase in cutting speed and feed rate results in significant increase in temperature. Long Sun et al. (2017) established a mathematical model of a sonic drill with a flexible drill string on rock. They found that the peak value of the impact increases with increasing rock stiffness and resonant order of the drill string. Vitazoslav Krupa et al. (2017) investigated the penetration depth of rocks. The model quantified the decreasing drill bit ability to achieve maximum penetration depending on progressing bit wear. Area of efficient rock chipping in the drilling process was visualized as moving to higher thrust force with total drilled length due to progressing bit wear. Mahadi Hasan et al. (2017) reviewed and compared the features of different micro drilling techniques and found that due to the advantage of high speed, laser micro drilling has always shown to be a good choice in industrial application. Zhiqiang Huang et al. (2017) analyzed and studied the erosion wear law of drill pipe by theoretical derivation and laboratory experiment. They found that the gas injection volume has more impact on drill pipe erosion compared with ROP, and high ROP will suppress the erosion wear of drill pipe.

M. Ramesh et al. (2014) conducted an experiment to analyse the machining characteristics of a hybrid composite. They examined the drilling induced damage with the help of a profile projector by using a scanning electron microscope SEM and concluded that the parameters such as cutting speed , feed , depth of cut alters the result of the drilling operation. V. Durga Prasada Rao et al. (2014) conducted an experiment to determine the optimum machining parameters so that the production rate can be increased. It is understood that irrespective of number of passes, the drilling cost for pilot hole influences the total cost of the operation. Ravinder Singh Joshi et al. (2014) carried out a study to evaluate the effect of conventional and modulation assisted drilling on surface quality of the hole. It is found that the factors such as surface roughness, mode of drilling, feed and rotational speed plays a vital role in quality of the drilled hole. Dirk Biermann et al. (2013) carried out a study to determine the heat flow into the machined part. It is conclude that the thermal load experienced by the machined part significantly depends upon the machining time of the component. Xin Wang et al. (2013) investigated the wear experienced by certain coated drills when drilling carbon fibre reinforced composites (CFPR). It is conclude that due to brittle nature of CFRP, the stagnation zone in front of the cutting edge does not occur, and this leads to rapid dulling of the cutting edge.

III. EXPERIMENTAL PROCEDURE

The experiments are conducted on the Bhagwan Udyog vertical milling machine with is shown in Figure 1. The test specimen used in this research work is Oil Hardened Non-Shrinking Die Steel. The specimen was prepared from the raw materials having the dimensions of 200 mm x 110 mm x 12 mm is shown in Figure 2 by using the power hacksaw machine. The Drilling operations were carried out by using the HSS drill bits of diameters 10 mm, 12 mm and 14 mm. The experimental investigations is carried out based on the L_{27} orthogonal array by using the Design of Experiments approach and the factors which are considered into account in this experiments are feed rate, spindle speed, drill diameter and depth of cut with their levels are presented in Table 1. The combinations of all input factors with different levels during all trials are conducted and Surface Roughness (SR) value is measured by using the surface tester is shown in Figure 3. The weight of the test specimen for before and after drilling operation is measured by using the weighing machine and the time taken for drilling operation is observed by using the stopwatch. After completing the drilling operation on the OHNS material is shown in Figure 4.


Figure 1. Vertical Milling Machine

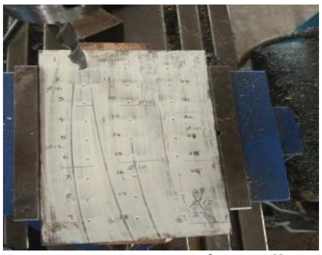
Figure 2. Specimen Before Drilling

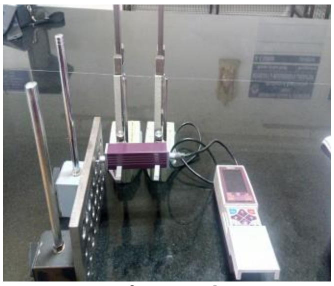
Figure 3. Surface Roughness Tester

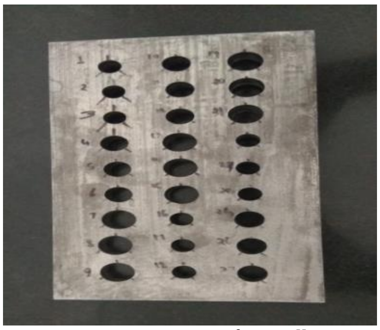
Figure 4. Specimen After Drilling

Table 1. Input Factors and Levels

Drilling Parameters	**Levels**		
	1	**2**	**3**
Spindle speed(rpm)	357	520	727
Feed (mm/min)	0.015	0.018	0.028
Drill diameter(mm)	10	12	14
Depth of cut (mm)	12	12	12

IV. FUZZY LOGIC BASED MODELING

Fuzzy logic is a methodology from artificial intelligence and is an effective tool to deal with complex nonlinear systems. Fuzzy logic modelling is based on mathematical theory, combining multi-valued logic, Probability theory and Artificial Intelligence methods and can be used to tackle complex problems. In this work, the concept of fuzzy logic rule is applied using Matlab software to evaluate the Surface Roughness along with other output parameters such as Material Removal Rate, Burr Height and Ovalty while drilling OHNS. The structure of a fuzzy logic system consists of three conceptual components: a fuzzy rule base, a data base, and a reasoning mechanism. The fuzzy reasoning for three-input-one output fuzzy logic unit is described as follows. The fuzzy rule base consists of a group of IF- ELSE statements with different input and output combination with three input x_1, x_2 and x_3 and output y.

Rule 1: if x_1 is A_1, x_2 is B_1 and x_3 is C_1, then y is E_1 else
Rule 2: if x_1 is A_2, x_2 is B_2 and x_3 is C_2, then y is E_2 else……..
Rule 3: if x_1 is A_n, x_2 is B_n and x_3 is C_n, then y is E_2 else

A_i, B_i, C_i, D_i and E_i are fuzzy subsets defined by the corresponding membership functions. Let x_1= Feed rate, x_2= Spindle speed, x_3= Drill diameter and y= output parameters are the three input values and one output value of the fuzzy logic unit as shown in Figure 5,

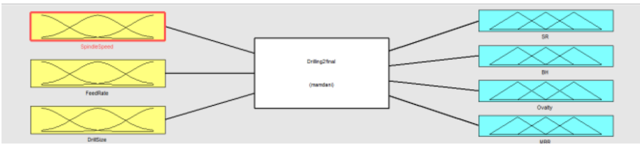

Figure 5. Defining input and output in Fuzzy inference system

The membership functions can be of different forms like triangular, trapezoidal, Gaussian, sigmoid, etc. In this study, triangular membership function was considered as the error which is occurring is low in triangular membership function.

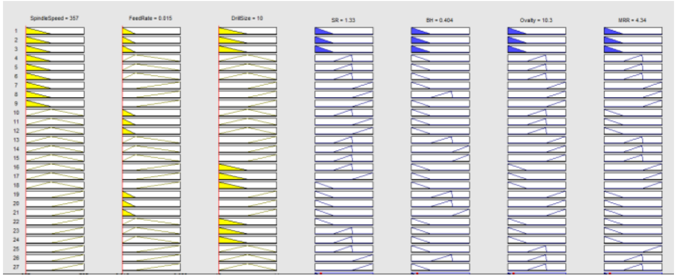

Figure 6. Fuzzy Rule Viewer

Fig 5 shows the inputs given in fuzzy logic tool box and the output response. All the 27 experimental results are given as fuzzy rules in the form of If-Else statement. Fig 6 shows the pictorial representation of the 27 rules got in the rule viewer of fuzzy logic tool box. Based on the 27 rules, using fuzzy logic, modelling is automatically done in the software. The main purpose of this fuzzy logic model is to predict the Surface Roughness for any combination of the cutting speed, feed rate and drill diameter within the experimental range.

V. RESULTS AND DISCUSSIONS

The material removal rate for Oil Hardened Non-Shrinking Die Steel has been investigated according to the L_{27} orthogonal array experiment. Fuzzy rule based model has been developed for predicting the Surface Roughness in drilling of OHNS. The experimental results with combinations of input factors and levels are shown in Table 2.

Table 2. Experimental Results

Exp No.	**Spindle Speed**	**Feed Rate**	**Drill size**	**Depth of Cut**	**SR**	**SR obtained in Fuzzy Model**
	rpm	**mm/rev**	**mm**	**mm**	**µm**	**µm**
1	357	0.015	10	12	1.972	1.33
2	357	0.015	10	12	0.959	
3	357	0.015	10	12	1.749	
4	357	0.018	12	12	2.268	2.88
5	357	0.018	12	12	3.139	
6	357	0.018	12	12	3.472	
7	357	0.028	14	12	4.38	4.11
8	357	0.028	14	12	4.521	
9	357	0.028	14	12	3.883	
10	520	0.015	12	12	3.26	3.53
11	520	0.015	12	12	3.379	
12	520	0.015	12	12	3.805	
13	520	0.018	14	12	3.071	2.88
14	520	0.018	14	12	2.728	
15	520	0.018	14	12	3.093	
16	520	0.028	10	12	2.231	2.81
17	520	0.028	10	12	3.769	
18	520	0.028	10	12	1.596	
19	727	0.015	14	12	1.836	1.33
20	727	0.015	14	12	1.722	
21	727	0.015	14	12	1.01	
22	727	0.018	10	12	1.135	2.08
23	727	0.018	10	12	2.924	
24	727	0.018	10	12	2.926	
25	727	0.028	12	12	2.549	3.54
26	727	0.028	12	12	3.904	
27	727	0.028	12	12	3.637	

VI. CONCLUSION

Based on the experimental investigation on the OHNS material, the authors highlight the following points.

- Feed rate and Cutting Speed are found to be the crucial factors for Surface Roughness.
- Fuzzy Modeling helps to accurately predict the responses for any values of input parameters within the experimental range.

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