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Experimental Investigation and Analysis of Thrust, Torque and Surface Roughness during Drilling of EN31 using Fuzzy Logic

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Abstract : *This paper focuses to find the effect of machining parameters on thrust, torque and surface roughness during drilling of EN31.The machining parameters considered for experiments were drill diameter, feed and speed. Experimental data were optimized using Fuzzy logic with the help of MATLAB. The optimized combination of parametric values for minimum thrust, torque and surface roughness, found are effective.*

Keywords: *Thrust, Torque, Surface Roughness, Drilling, Optimization, Fuzzy Logic, EN31*

INTRODUCTION

In the present scenario when controlled and precise manufacturing is highly concerned aspect of manufacturing industry, then various optimization techniques used to find out combination of optimum parameters. C. Tsao and H. Hocheng et al (2008) presents the prediction and evaluation of thrust force and surface roughness in drilling of composite material using candle stick drill. The approach is based on Taguchi method and the artificial neural network. The experimental results indicate that the feed rate and the drill diameter are the most significant factors affecting the thrust force, while the feed rate and spindle speed contribute the most to the surface roughness. In this study, the objective was to establish a correlation between the feed rate, spindle speed and drill diameter with the induced thrust force and surface roughness in drilling composite laminate. The correlations were obtained by multi-variable regression analysis and radial basis function network (RBFN) and compared with the experimental results. The results indicate the RBFN is more effective than multi-variable regression analysis. It used Kistler 9257 piezoelectric dynamometer to measure the forces [15]. Ranganath M S et al (2014) conducted a series of experiments on aluminum material to find out the optimization process on them these experiments are basically classified in taguchi or the RSM process so as to decide which is better out of two. The process is done by the set of experiments and the RSM technique was found to be better than the taguchi and predicted better results and good surface finish [11].

J. L. Lin et al (2005) has presented the use of the grey-fuzzy logics for the optimization of the electrical discharge machining process with the multiple process responses. Grey relational coefficient analyzes the relational degree of electrode wear ratio, material removal rate and surface roughness. Fuzzy logic is used to perform a fuzzy reasoning of the multiple performance characteristics. These approaches can significantly improve the process responses such as the electrode wear ratio, material removal rate and surface roughness in the electrical discharge machining process [2]. J. L. Lin et al (2000) has presented the use of fuzzy logics to the Taguchi method for the optimization of the electrical discharge machining process with multiple responses. A fuzzy reasoning of the responses has been performed by the fuzzy logic unit. In the result the responses such as EWR and MRR improved. An experiment was conducted to confirm this approach thus, the optimization methodology developed for improving multiple performance characteristics in the electrical discharge machining operation. [3].

Liu Dong et al (2010) studied thrust force and torque in Drilling Carbon Fiber Reinforced Plastics (CFRP) Using Twist Drill Brazed Diamond. The composites are difficult machining materials which widely used in aerospace industry due to their excellent mechanical properties. Tool wear and delamination are considered the major concern in manufacture the parts and assembly. The thrust force and torque affect the tool life and delamination mostly. This paper investigated the drilling force and torque of carbon fibred composite with carbide drilling tools brazed diamond. The experiments were carried out under air cooling cutting conditions and the regulation of the drilling force influenced by the feed rate and cutting speed was obtained. The exponential formula of drilling force and torque were obtained through regression analysis method and results show that the model of drilling force fitted the experimental data well and the relations of drilling force and drilling parameters approximately satisfies exponential function [16]. Ranganath M S et al (2014) collected various papers published on the RSM technique to find out the best optimization technique for the analysis of various cutting parameters like cutting speed, feed, and depth of cut on the surface roughness. Surface roughness has become the most significant technical requirement and it is an index of product quality. In order to develop a surface roughness model and optimize, it is essential to understand the current status and optimization through that variable that is surface roughness [10]. The situations where the results may be partially true and partially false simultaneously may be termed as conditions of Fuzziness. The real world is not precise and the notions of vagueness, looseness, uncertainty, imprecision, concepts and perceptions are central to the way human beings solve problem. In academia, most of the early fuzzy set theory research focused exclusively on scientific applications. Another separate issue is the valuation that each individual granted such a fuzzy character (the glass half full or half empty), which depend on subjective psychological issues and difficult to evaluate. Over the past four decades, fuzzy set theory has gained in popularity, and there are now more than thousands of commercially available products that make use of it, ranging from washing machines to high-speed trains. Nearly every application is potentially able to realize some of the benefits of fuzzy set theory, including better performance, higher productivity, better efficiency, and lower cost. Lotfi Zadeh in 1960s created fuzzy set theory to mathematically represent the uncertainty. Zadeh wanted to create a set theory

which reflects human reasoning in its use of approximate information and uncertainty to generate decisions. It follows that there was need a radical rethink of our classical concepts of truth and falsehood, replacing the concept of fuzziness (fuzziness or vagueness) as a result of which the truth or falsity are only extreme cases. It has further been used to develop formalized tools to deal with the imprecision intrinsic to a wide variety of problems. It was not until the late 1980s that this state-of-the-art technique was used to develop a wide variety of business applications and that; as a result, an increase in amount of published research began to appear [14, 17]. Du and Wolfe (1997) studied the utilization of fuzzy logic and ANN, especially in the areas of scheduling and planning, quality control, inventory control, group technology, and forecasting, and suggested four types of integration between the two to-stimulate future research [18].

Proud love et al. (1998) carried out a review of the use of various artificial intelligence (AI) techniques as solutions to eight areas of POM, although fuzzy logic was briefly discussed in only two of these application areas, namely, product design and scheduling [19]. Kobbacy et al. (2007) studied and examined four AI techniques, namely, genetic algorithms, knowledge-based systems, case-based reasoning, fuzzy logic, and hybrid systems. They then discussed the application of each technique in four areas of operations management, including design, scheduling, and process planning and control and quality, maintenance, and fault diagnosis [20]. Our study has objective is to find those such condition for drilling which is optimum where the parameter studied were drill diameter, feed and speed of rotation correspondingly the values were obtained for the thrust, torque and surface roughness in drilling process. The torque, thrust and surface roughness are responses and they are controlled by parameters. Use of Fuzzy logics is taken to analyze the data.

EXPERIMENTAL SET-UP AND PROCEDURE

The experimental set up was made by connecting the dynamometer to the machine and then the results were obtained while performing the experiments.

Fig1: Drilling machine used

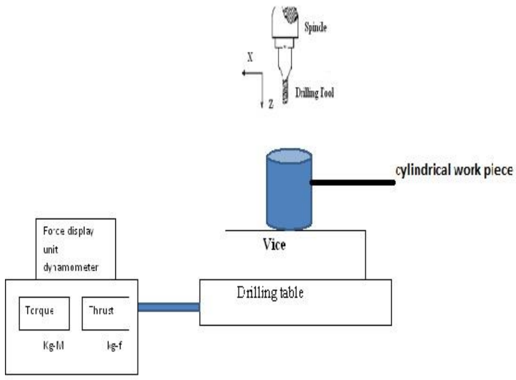

Fig2: Schematic diagram of experimental setup consist of drilling machine combined with a drill tool and dynamometer.

Procedure

Considering the basic aim of analysis of drilling the material was chosen in the process. The material thus selected was EN – 31 which is a relatively new material than any other material used as metal for domestic as well as military purposes. The material was then brought in the desired shape so that the force and the torque could be measured during the drilling process. The dimensions required were:- Length - 70mm, Diameter – 40mm . The specimen thus obtained was then drilled and the recorded accordingly on the desired feed speed and the drill diameter after the drilling process the surface roughness was measured by the tylrsurf surtonic 3+. This gave the measurements of the surface roughness and thereby the roughness was measured. After, this process results were used in the Minitab and thus the graphs and the plots were obtained. A dynamometer is a device used to find the torque and thrust in the machine either in drilling or any other machining process. Dynamometer is an electrical device which is used to measure the value of the force and torque exactly in the process. A dynamometer is first balanced with respect to a known force and then the pointer is moved with respect to the new force coming into action at that point or in that process.

Surface roughness is an important parameter required for the measurement of the quality of the product. Surface measurement is nothing but the comparison of the previously fixed value with the new value obtained. The taylsurf instrument used in this experiment is a taylor hobson unit with surtonic3+ as its product name. Surtronic 3+ is combination of advanced technology along with high precision and accuracy to give effective measurement of surface finish in the experiment, inspection room or laboratory.

Fig3: Dynamometer used in the process

Fig4: Roughness Tester

EN-31 is a type of steel which has high quality and high hardness with respect to other type of steels also this is abrasion resistant steel which is superior to the commonly available steels in the market. The compressive strength is also of high degree and better then the available steels bars. EN with a capital 'N' designates "Europäische" Norm which converts to European Standard. En with a lowercase 'n' implies Emergency Number and was used as a representation for various steel grades in BS 970 until a uniform system was set up after the world war 2. Table 2, Shows the different observed values of thrust, torque and surface roughness obtained by changing the control factors drill diameter, feed rate and speed.

Compositions:

Table 1 : compositions of EN-31

Alloying Elements	**Percentage**
Carbon	0.90-1.20%
Chromium	1.00-1.60%
Silicon	0.10-0.35%
Manganese	0.30-0.75%
Sulphur	0.050%at max
Phosphorous	0.050% at max

OBSERVATIONS

Table 2: The observed thrust, torque and Ra values by changing the control factors.

Exp. No.	Control Factors			Data		
	Drill dia (mm)	feed rate(mm)	Speed(rpm)	Thrust(kg-f)	Torque(kg-m)	Ra (µm)
1	10	0.2	220	427	1.2	5.48
2	10	0.2	220	420	1.2	5.92
3	8	0.3	150	348	1.1	5.16
4	10	0.2	150	331	1.4	4.76
5	8	0.3	440	377	1.6	6.82
6	10	0.2	220	332	1.4	5.18
7	10	0.12	220	246	0.8	4.82
8	8	0.2	220	203	0.8	6.32
9	10	0.2	220	312	1.3	5.94
10	10	0.2	220	315	1.4	6.72
11	10	0.2	440	440	1.2	9.32
12	10	0.2	220	335	1.3	7.48
13	12	0.2	220	429	1.7	6.52
14	10	0.3	220	452	1.6	9
15	12	0.12	150	299	1.4	6.74
16	12	0.3	150	634	2.6	5.32
17	12	0.12	440	268	1.4	5.28
18	8	0.12	150	170	0.5	6.48
19	8	0.12	440	163	0.7	4.3
20	12	0.3	440	819	2.4	9.14

CALCULATIONS

Table3: The observed thrust, torque and Ra values by changing the control factors

Exp. No.	Grey Relational Coefficients			MPCIs	S/N Ratios
	Thrust	Torque	Ra		
1	0.55405	0.60000	0.68022	0.579	-4.74643
2	0.56068	0.60000	0.60775	0.548	-5.22439
3	0.63938	0.63636	0.74481	0.625	-4.08240
4	0.66129	0.53846	0.84512	0.668	-3.50447
5	0.60517	0.48837	0.49901	0.529	-5.53089
6	0.65996	0.53846	0.74041	0.616	-4.20839
7	0.79805	0.77778	0.82838	0.688	-3.24823
8	0.89130	0.77778	0.55408	0.703	-3.06089
9	0.68763	0.56757	0.60482	0.585	-4.65688
10	0.68333	0.53846	0.50913	0.569	-4.89775
11	0.54215	0.60000	0.33333	0.474	-6.48443
12	0.65600	0.56757	0.44112	0.539	-5.36822
13	0.55219	0.46667	0.53066	0.506	-5.91699
14	0.53160	0.48837	0.34813	0.457	-6.80168
15	0.70690	0.53846	0.50707	0.58	-4.73144
16	0.41051	0.33333	0.71105	0.515	-5.76386
17	0.75751	0.53846	0.71920	0.638	-3.90359
18	0.97910	1.00000	0.53518	0.796	-1.98174
19	1.00000	0.84000	1.00000	0.821	-1.71314
20	0.33333	0.35593	0.34150	0.411	-7.72316

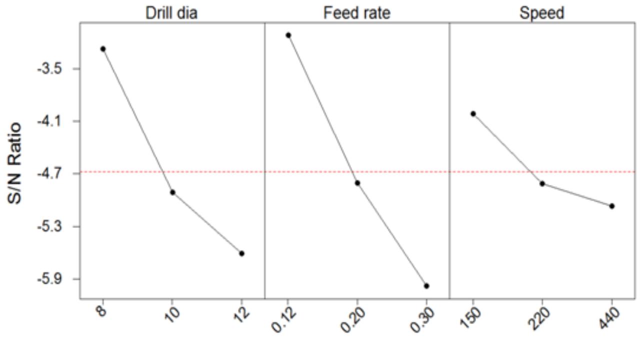

Fig5: Main effects plot of S/N Ratio vs. control parameters

The grey relational coefficients of thrust, torque and surface roughness were calculated based on the lower the better criteria. These coefficients were then inputted into the fuzzy inference system and the corresponding Multi Performance Characteristic Indices (MPCIs) were recorded in the table. Corresponding S/N Ratios were calculated based on the nominal the best criteria.

Based on the values of S/N Ratios an optimal solution was obtained when drill diameter is equal to 8 mm, feed rate equal to 0.12mm/min and speed equal to 440 rpm. Figure 5 shows the main effects plot of the S/N ratios calculated in table 2 and the corresponding control parameters. It can be clearly seen that the optimal solution according to the plot corresponds to drill diameter of 8 mm, feed rate of 0.12 mm/min and speed of 150 rpm.

CONCLUSIONS

The parameter studied were drill diameter, feed and speed of rotation correspondingly the values were obtained for the thrust, torque and surface roughness in drilling process.
The torque, thrust and surface roughness are responses and they are controlled by parameters.
The drilling process is studied and fuzzy logic is applied on the data obtained from the experiment.
With help of the Fuzzy, optimized values were obtained satisfactorily.
Based on the S/N Ratio values, an optimal solution of drill diameter equal to 8 mm, feed rate equal to 0.12mm/min and speed equal to 440 rpm is obtained which gives thrust equal to 163kgf, torque of 0.7kg.m and surface roughness of 4.3µm.
The optimal solution according to the main effects plot corresponds to drill diameter of 8 mm, feed rate of 0.12 mm/min and speed of 150 rpm which gives thrust equal to 170kgf, torque equal to 0.5kg.m and surface roughness equal to 6.48µm have been obtained

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