

Prediction of the Effect of Gash Rake Angle on Thrust Force and Drilling Moment by Fuzzy Logic

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Abstract— During drilling of AISI 4140 tempering steel with different gash rake angle, the effects of the gash rake angle on the thrust force and drilling moment, which are called cutting loads, were predicted by fuzzy logic. The data from monolithic solid carbide drill were used that has +10°, 0°, -10° gash angle and diameter with 6,8 mm in the experiments, which published previously. According to the experimental study, the gash rake angle and the feed amount are the most effective parameters on the thrust force and the drilling moment. A limited number of experimental studies were conducted to determine the relationship between drilling parameters and cutting loads. However, obtaining the mathematical model that gives the thrust force and the drilling moment values with respect to the gash rake angle and the feed amount is difficult to define with high accuracy. Proposed fuzzy model consists of two input variables and two output variables. The fuzzy model was constituted with the gash rake angle and the feed amount as independent parameters for the thrust force and the drilling moment. The results showed that the proposed fuzzy model represented experimental results with high confidence.

Keywords— Drilling, Gash Rake Angle, Thrust Force, Drilling Moment, Fuzzy Logic

I. INTRODUCTION

Drilling is an important part of machining process. Its accounts for about one-third of machining operations[1-3]. The cutting tool in manufacturing by machining process is critical for material removal, breaking on ideal cutting force and removing the cutting chip from the cutting zone. Because the cutting tool geometry is a complex structure that determines the cutting conditions, cutting forces, tool life and machining quality, and determines the efficiency of the process.

Among the cutting tools, conventional two-edged drills are the most widely used and they have most complex geometry. Both the tip geometry and the amount of feed and all other cutting parameters differ from the point of view of different types of materials [4,5]. High feed amount causes good chip control, lower cutting time, as well as the positive aspects of the bad hole quality, while the low feed amount, abrasion on

the rake face, built up on the cutting edge and lead to poor chip control.

Drill geometry is one of the most important parameters affecting the cutting forces in the machining process [6]. In drilling with the drill, the chisel edge penetrates the workpiece and occurs the largest part of the thrust force when making the first cut, while the main cutting edge causes the formation of drilling moment when removing chips. In order to avoid such problems and to shorten the length of the chisel edge, an auxiliary surface called the gash surface is opened. The gash surface allows the chisel edge to be shortened, positioning the drill to the workpiece (coaxial of the drill axis and the drill) and making the first plunge more convenient. In addition, one of the important parameters affecting the thrust force is the point angle. In drilling, the main cutting lips performs the cutting process, while the helical flute guide the removal of the resulting chips [7,8].

It is expected that gashing rake angle (Fig. 1), which is the angle that the gash surface in the drill geometry makes with the axis of the drill (Figure 1), has significant effects on the cutting forces and the drilling torque.

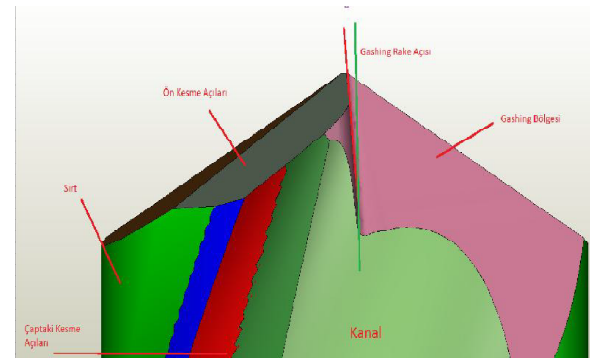


Fig. 1 Gashing rake angle on drill

Cost of cutting tools have large amount of total cost of machining processes. In this reason, it is important that choosing correct cutting tools, which have suitable geometry and material, according to machining types, and materials.

Mathematical models established using Finite Element Analysis (FEA) and experimental data, where cutting is performed in virtual environments, are widely used in the machining industry in recent years to produce products of the desired quality, to select suitable cutting tool geometry and to eliminate wastage of cutting tools, and raw materials ([9], [10]).

Fuzzy logic is a system, which uses experience of experts and experimental data, to predict the results using by non integer algorithms and some rule based functions [11].

Vinayagamorthy and Rajeswari used the fuzzy rule model to estimate thrust and torque based on cutting speed, feed rate and depth of cut in drilling of natural jute reinforced composite material [12]. They used Fuzzy Logic to predict tool wear, surface roughness, and specific cutting pressure in turning of titanium alloys [13]. Singh and Gill used Fuzzy Logic to estimate the material removal rate in ultrasonic drilling of porcelain ceramics with hollow stainless steel tools [14]. Yumak and Ertunç have used Fuzzy Logic for predicting the wear situation in the drill due to the cutting forces generated during drilling [15]. Pendokhare and Quazi have developed a Fuzzy Logic model for the determination of material hardness and cutting speed [16]. Latha and Senthilkumar used Fuzzy Logic to estimate the amount of delamination that occurs when drilling glass fiber reinforced composites with solid carbide drills [17]. Ahamed et al. Developed a Fuzzy Logic control design for the determination of cutting parameters based on tool and material hardness in drilling operations [18].

When the studies in the literature are examined, it is seen that there are many studies with fuzzy logic about drilling. However, there are no studies that predict the effect of gashing rake angle on thrust force and drilling moment. In most of the studies with fuzzy logic, the data obtained from the prediction process were found to coincide with the experimental data [12-18].

In this paper, a fuzzy model was proposed to estimate the thrust force and the drilling moment by using gashing rake angle and feed amount during drilling of AISI 4140 steel. Since the manufacturing of drills is an expensive and time consuming process, a fuzzy logic model has been established to predict the performance of the drills based on experimental data before the tool manufacturing.

II. METHODS

In the experimental section of the study, three cutting parameters were examined by Taguchi's L9 orthogonal design table [19]. According to the experimental study, gashing rake angle and feed amount are the most effective parameters on thrust force and drilling moment during drilling of AISI 4140 samples. In Table 1, the input parameters and their levels of the model were given. A limited number of experimental studies were conducted to determine the relationship between drilling parameters and cutting loads. However, obtaining the mathematical model that gives the thrust force and the drilling moment values with respect to the gash rake angle and the feed amount is difficult to define with high accuracy.

In this study, a fuzzy model was proposed to estimate the thrust force and the drilling moment. Proposed fuzzy model consists of two input variables and two output variables. The fuzzy model was constituted with the gash rake angle and the feed amount as input variables and the thrust force and the drilling moment as output variables. Block diagram of the fuzzy model is shown in Figure 2.

TABLE I
INPUT PARAMETERS AND LEVELS

Factors	Levels		
Gashing rake angle (°)	-10	0	+10
Feed amount (mm/rev) x10 ⁻²	15	25	30

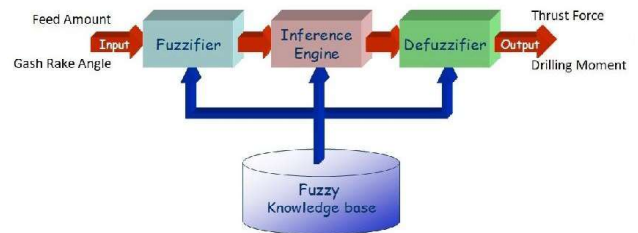


Fig. 2 Block diagram of proposed fuzzy model

It has chosen three linguistic levels for gash rake angle, three linguistic levels for feed amount and 9 linguistic levels for both thrust force and the drilling moment. The membership functions of the fuzzy input variables are shown in Figure 3. Rule bases of the fuzzy model are shown in Table 2.

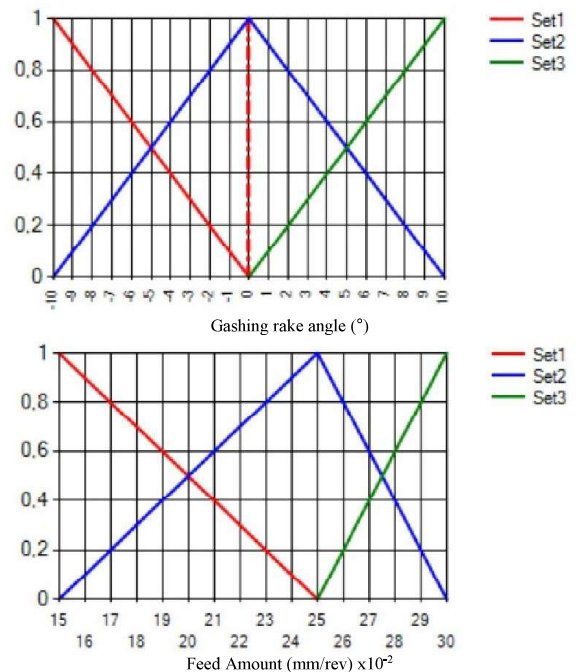


Fig. 3 Membership functions of the input variables including gashing rake angle and feed amount

TABLE II
A) FUZZY RULE BASE FOR THE THRUST FORCE, (B) FUZZY RULE BASE FOR THE DRILLING MOMENT

	Feed Amount – Gashing Rake Angle	Set1	Set2	Set3
a	Set1	OSet9	OSet1	OSet2
	Set2	OSet7	OSet3	OSet4
	Set3	OSet8	OSet5	OSet6
b	Set1	OSet9	OSet2	OSet1
	Set2	OSet5	OSet3	OSet4
	Set3	OSet8	OSet6	OSet7

MAX-MIN composition method was selected for the inference mechanism and Centroid method was selected for defuzzification.

For proposed fuzzy model, a Graphical User Interface (GUI) was prepared by using C# programming language. Prepared GUI is shown in Figure 4.

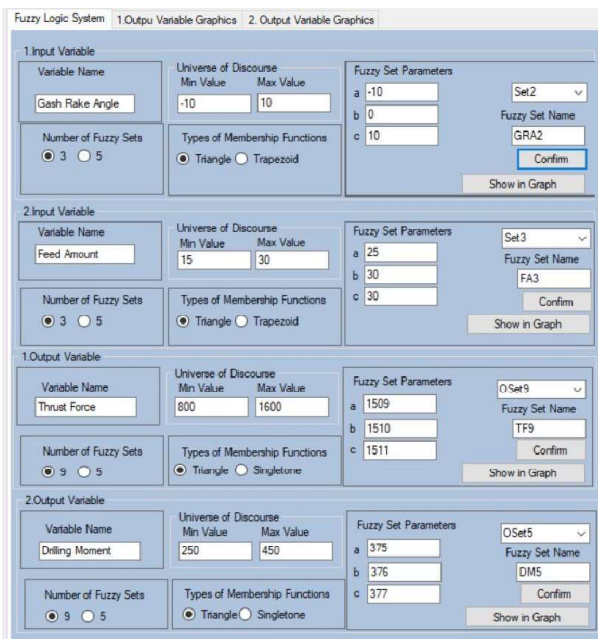


Fig. 4 Screenshot of a part of the Developed Graphical User Interface

III. RESULTS

To explore the effectiveness of the proposed modelling, comparison of the results obtained from fuzzy based modelling and experimental data has been made. Figure 5 shows a sum of experimental results that describing the effects of gashing rake angle and feed amount on thrust force and drilling moment [19]. Predicted amounts of both thrust force and drilling moment by the fuzzy logic model depending on gashing rake angle and feed amount are given in Figure 6 and 7 respectively.

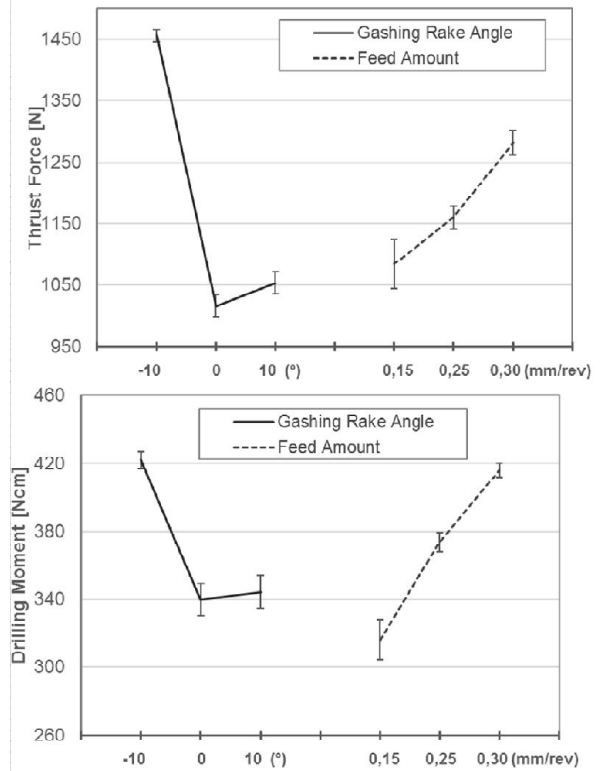


Fig. 5 Experimental main effect plots of thrust force and drilling moment [19].

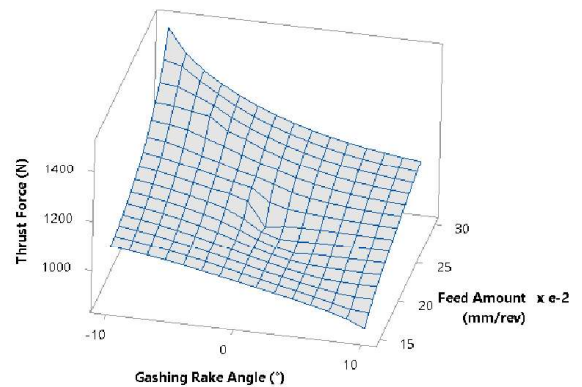


Fig. 6 Predicted amounts of thrust force by the fuzzy logic model in relation to gashing rake angle and feed amount

When Figure 6 is examined the lowest thrust force generated at positive gashing rake angle (+10°) and at low level feed amount (0.15 mm/rev). In addition, the highest value of thrust force occurred at negative gashing rake angle (-10°) and high level of feed amount (0,30 mm/rev). Similar results with thrust force obtained in Figure 7 for drilling moment.

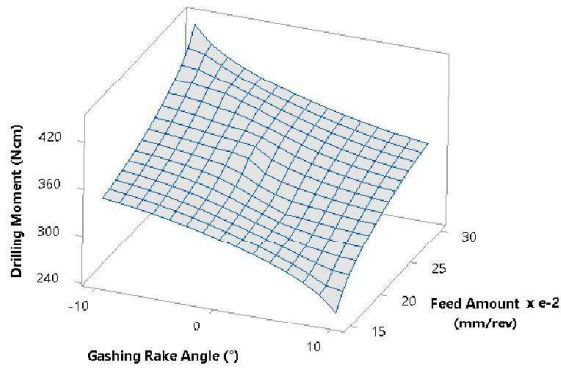


Fig. 7 Predicted amounts of drilling moment by the fuzzy logic model in relation to gashing rake angle and feed amount

Figure 8 and 9 show the effects of gashing rake angles and feed amounts on thrust force and drilling moment. The graphs make clear that the drills, which have neutral and positive gashing rake angles, are more suitable for drilling AISI 4140 steels because of the lowest values of thrust force, and drilling moment. According to results the best combination of the parameters is neutral or positive gashing rake angle and low level feed amount.

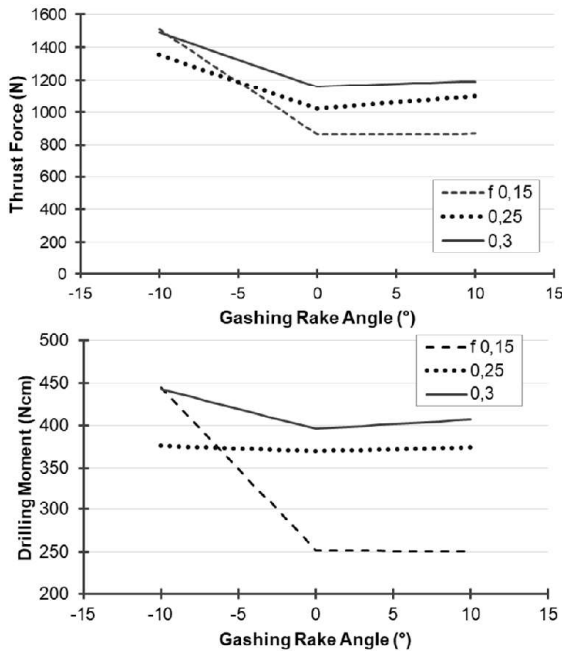


Fig. 8 Effect of gashing rake angles on thrust force and drilling moment according to feed amount

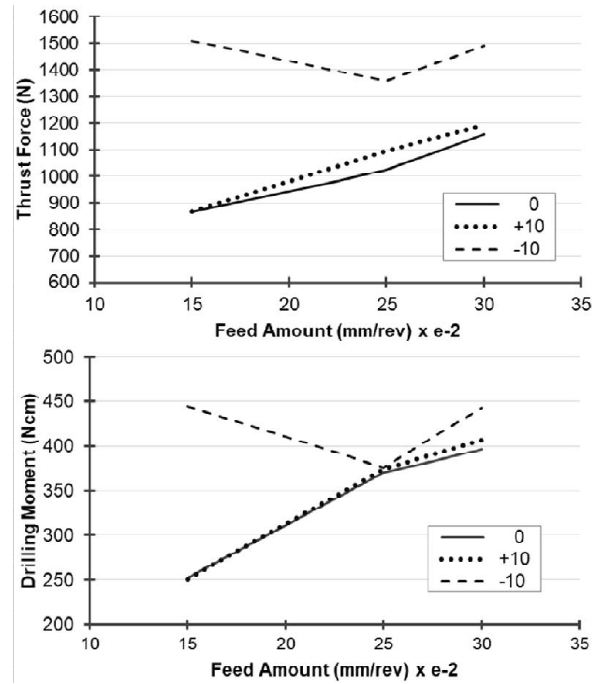


Fig. 9 Effect of feed amount on thrust force and drilling moment according to gashing rake angle

IV. CONCLUSIONS

In this study, the effects of gashing rake angle and feed amount on the thrust force and the drilling moment were modelled by fuzzy logic. The drills have neutral or positive gashing rake angles and low-level feed amount were found more suitable for drilling AISI 4140 steels. The predicted results proved that the proposed fuzzy model could be used to find better combination of the cutting parameters.

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