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INFLUENCE OF DRILLING PARAMETERS FOR THRUST FORCE AND TORQUE IN FRICTION DRILLING PROCESS

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***Abstract* - Friction drilling is a novel machining process that utilizes the heat generated from the friction between the rotating conical tool and the work piece to form the hole. This process does not produce chip, but shortens the time required for hole-making and incurs less tool wear, thus lengthening the service life of the drill. In this study, high speed steel drill was employed to make holes in Aluminium 6061- T6 alloy at different spindle speeds and feed rates. In this study Taguchi technique and regression analysis is used to optimize the drilling parameters.**
Key words: friction drilling, chipless machining, Aluminium 6061- T6 alloy, high speed steel, Taguchi technique and regression analysis

I INTRODUCTION

The Friction drilling is a thermal drilling and bush forming tool that attaches to the chuck of any high-powered drill press rotating the form drill at high speed under high axial load (the drill bit is strongly pushed towards the workpiece) and generates frictional heat. Unlike a convetional drill, the strengh of workpiece is not compromised by the removal of material.Instead, the heated material flows away from its original position to form a 360 degree bush around the periphery of the hole. During initial stages of the form drill process, the heated material rises aganist the tool's leading taper but once the surface is complety penetrated, the bulk of the displaced material forms on the underside of the hole. This underside bush usually project downwards of the material. Figure 1. Shows a schematic illustration of the five steps in friction drilling. The tip of the conical tool approaches and contacts the work piece, as shown in Fig. 1. (a). The tool tip, like the web center in twist drill, indents into the work piece and supports the drill in both the radial and axial directions. Friction on the contact surface, created from axial force and relative angular velocity between tool and work piece, produces heat and softens the work piece material. As the tool is fed into the work piece, as shown in Fig. 1. (b), it initially pushes the softened work-material sideward and upward. With the work piece material heated and softened the tool is able to pierce through the work piece, as shown in Fig. 1.(c). Once the tool penetrates the work piece, as shown in Fig. 1.(d), the tool moves further forward to push aside more work piece material and form the bushing using the cylindrical part of the tool. As the process is completed, the shoulder of the tool may contact the work piece to collar the back extruded burr on the bushing. Finally, the tool retracts and leaves a hole with a bushing on the work piece Fig. 1. (e).

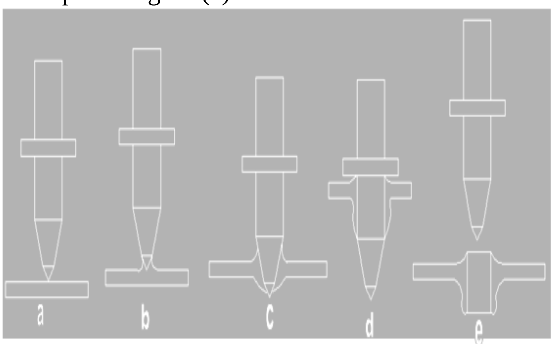

Fig. 1. Illustration of stages in friction drilling process

Miller et.al [1,2] applied friction drilling to machining low carbon steel as well as aluminium and magnesium alloys, and explored experimentally the relationship between axial thrust force and torque under different spindle and feed rates.

Shin Min Lee, et al (2008) studied, tungsten carbide drills with and without coating to make holes in AISI 304 stainless steel,. TiAlN and AlCrN were coated onto the drill surface by physical vapor deposition (PVD). Performances of coated and uncoated cutting tools were examined for drilling made under different spindle speeds and feed rate.

Han-Ming Chow, et al (2007) studied tungsten carbide drills to makes holes in AISI 304 stainless steel, The Taguchi method was applied to explore how the different parameters such as drill shape and friction angle, friction contact area ratio, feed rate, and drilling speed would affect the response parameter. However high speed steel used in friction drilling have not been studied. In this study conducted main objective is The main objective of the present work is to study the influence of cutting parameters such as cutting velocity and feed rate on friction drilling of Al 6061-T6 and to assess and optimize the chosen factors to obtain minimum thrust force and torque by using analysis of variance (ANOVA) technique.

II. EXPERIMENTAL SETUP AND PROCEDURES

The friction drilling was carried out in ARIX 100 CNC vertical machining center. The work piece material chosen was Aluminium 6061-T6 Alloys. The dimension of the work piece is 81x70x2 mm. The drilling parameters chosen for the friction drilling are cutting velocity and feed with 5mm diameter drill tool. The combination of the drilling variables are 0.654,0.523,0.392 m/sec and feed rate 100,75,50 mm/min respectively The axial thrust force and torque from the drilling experiment was measured through a 3 point Kistler model 9257 B piezoelectric dynamometer. The work piece was clamped over the dynamometer. Care was taken to avoid the heat dissipation to the dynamometer. The experimental set up is shown in Fig. 2. With the work piece mounted on the dynamometer and drilling process taking place.

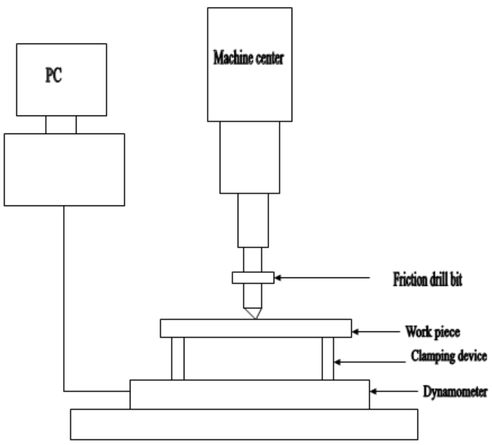

Fig. 2. Experimental setup of friction drilling.

The friction drilling is a special type of tool which is not available commercially. Hence in the present work the tool was manufactured as per the given geometry in fig.3. pin of diameter (d) 5mm was machined according to the tool geometry. α =90˚, β =36˚, center region 1mm, cylindrical region 10mm ,conical region 6mm respectively.

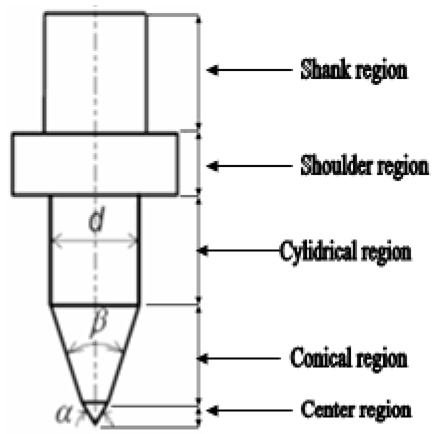

Fig 3. Nomenclature of friction drilling

Experimental Result

Table1 experimental value in different cutting velocity and feed rate

Experiment al no	Cutting velocity (m/sec)	Feed rate (mm/ min)	Thrust force (N)	Torque (Nm)
1	0.654	100	614	1.234
2	0.523	100	552	1.11
3	0.392	100	480.4	1.024
4	0.654	75	564	1.290
5	0.523	75	517	1.211
6	0.392	75	474.4	1.03
7	0.654	50	531.7 4	1.16
8	0.523	50	410	1.05
9	0.392	50	380	0.97

Analysis of variance (ANOVA)

Table1 shows the experimental value in different cutting velocity and feed rate. The experiments were conducted as per the standard orthogonal array. In the present investigation an L9 orthogonal array was chosen.

Table2 ANOVA table for thrust force obtained by high speed steel drill bit

Source	D.O.F	Sum of square	Mean square	Calculated frequency	Percentage of contribution
velocity	2	23846.1	11923	23.54	53.5
Feed	2	18698	9349	18.46	41.95
Error	4	2026.3	506		
Total	8	44570.4			

The thrust force was analyzed by using analysis of variance ANOVA technique was under taken for level of significance of 5% that is, for level of confidence of 95%. Table2 shows Cutting velocity is greater influencing factor on thrust force over feed rate. The percentage contribution of feed rate is 41.95% followed by cutting velocity 53.5% for friction drilling of Al 6061-T6 alloy with H.S.S drill bit. The statistical table value of frequency for degree of freedom (2, 4). Table value is 6.94 here the statistical table value is less than calculated values so there is statistical significance.

Table3 ANOVA table for torque obtained by high speed steel drill bit

Source	D.O.F	Sum of square	Mean square	Calculated frequency	Percentage of contribution
Feed	2	0.02056	0.01028	12.24	21.28
Velocity	2	0.07266	0.03633	43.25	75.22
Error	4	0.0033	0.00084		
Total	8	0.09659			

The torque was also analyzed by using analysis of variance (ANOVA) technique for level of significance of 5% that is, for level of confidence of 95%.Table3 shows Cutting velocity is greater influencing factor on torque over the feed rate. The contribution of cutting velocity is 75.22% followed by feed rate 21.28% for friction drilling of Al 6061-T6 alloy with H.S.S drill bit. The statistical table value of frequency for degree of freedom (2, 4). Table value is 6.94 here the statistical table value is less than calculated values so there is statistical significant.

III. REGRESSION ANALYSIS

The treatment of the experimental results is based on the regression analysis. It is a mathematical process of using observations to find the line of best fit through the data in order to make estimates and predictions about the behavior of the variables.Cutting velocity(X_1), feed rate(X_2) are the two independent variables and thrust force, torque on tool (Y) is the dependent variable. The equation describing the relationship among three variables is

$$Y=a+b_1X_1+b_2X_2$$

a and b's are the true coefficients to be used to weight the observed X's and they are obtained by solving the three normal equations.

$$\Sigma Y = na+b_1\Sigma X_1+b_2\Sigma X_2$$
$$\Sigma X_1Y = a\Sigma X_1+b_1\Sigma (X_1)^2+b_2\Sigma X_1X_2$$
$$\Sigma X_2Y = a\Sigma X_2+b_1\Sigma X_1X_2+b_2\Sigma (X_2)^2$$

Thrust force

a=-1061.70, b1=1848.93, b2=7.56

Torque

a=0.583, b1=0.844, b2=0.00125

Validation of the predicted values with the experimental values for the friction drilling of high speed steel drill bit

Figure 4 shows the predicted values along with the experimental values for the thrust force of the holes drilled using high speed friction drill bit. It is observed from the figure 4 that the predicted values of the thrust force obtained from the regression equation traces the same path as that of the experimental values of the thrust force for the holes drilled using high speed steel drill bit. The error associated with predicted value and experimental value is ten percentages for the thrust force with high speed steel friction drill bit.

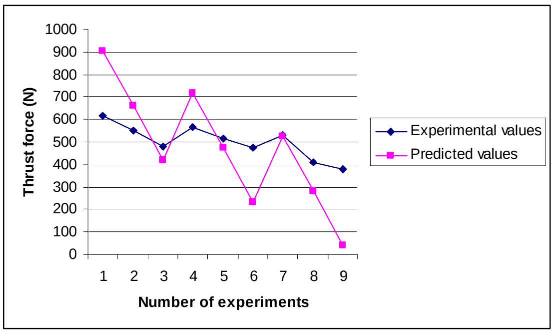

Figure 4 Predicted values and experimental values for thrust force for friction drilling of high speed steel drill bit.

Figure5 shows the predicted values along with the experimental values for the torque of the holes drilled using high speed steel friction drill bit. It is observed from the figure 5 that the predicted values of the torque obtained from the regression equation traces the same path as that of the experimental values of the thrust force for the holes drilled using high speed steel drill bit. The error associated with predicted value and experimental value is one percentage for the thrust force with high speed steel friction drill bit

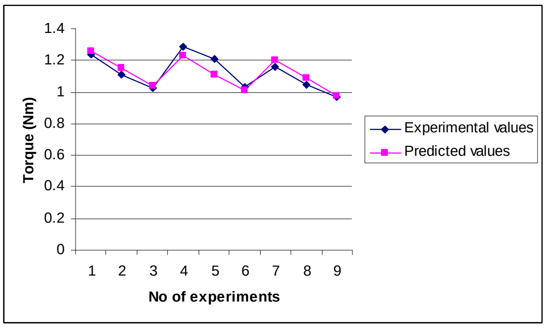

Figure 5 Predicted values and experimental values for torque for friction drilling of high speed steel drill bit.

Variation of the predicted values of thrust force and torque for high speed steel for friction drill bit.

With the help of regression equations the variation of thrust force and torque for friction drill bit is developed in a three dimensional view. Figure6 and 7 shows the variation of the thrust force for the holes drilled using friction drill tool. It is observed that the thrust force and torque for the holes drilled using the high speed steel drill tool increases with increase in feed rate. And increase with increase in cutting velocity.

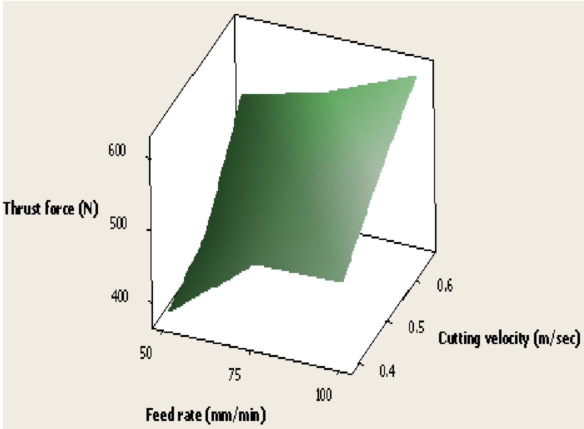

Figure 6 Variation of the predicted values of thrust force for high speed steel for friction drill bit.

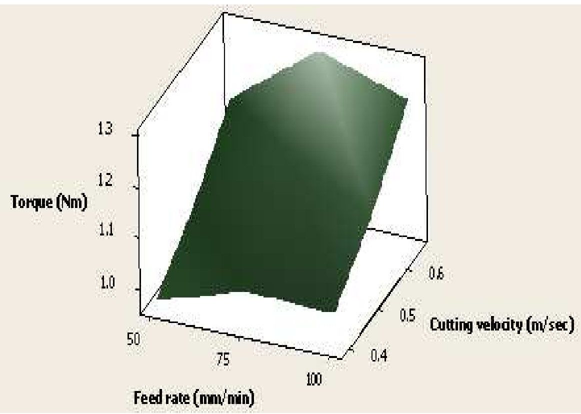

Figure 7 Variation of the predicted values of torque for high speed steel for friction drill bit.

IV RESULT AND DISCUSSION

Fig .8. Displays the variation in measured axial thrust with respect to distance from contact in friction drilling. The variations in axial thrust force fall into four different regions. Region A shows an abrupt increase in axial thrust force. It is the time when the drill makes initial contact with the work piece and drilling begins. Under constant high speed drilling between the cutting tool and work piece, friction heat is generated and the temperature rises above the recrystallization temperature of the work piece. High temperature softens and eventually melts the work piece, allowing easy penetration of the cutting tool, as evidenced by the marked decrease in axial thrust force in region B. Further drilling in region C pushes up the metal Melted in region B and breaks into the work piece, thus making a hole, during which the increase in axial thrust force is gradual. Finally, in region D, with hole made, drilling stops as evidenced by the abrupt drop in axial thrust force

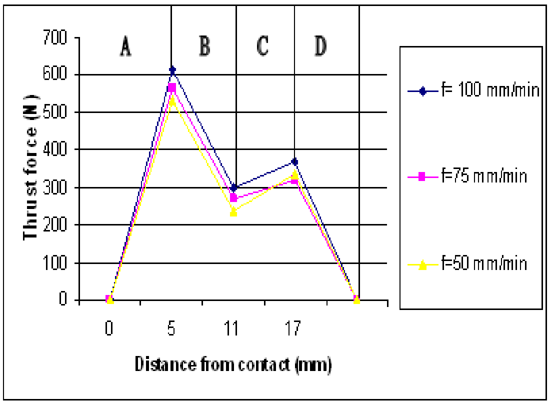

Fig.8. Thrust force at friction drilling of Al 6061-T6 alloys at different cutting velocity and feed rate.

The Fig. 9. Shows the variation in torque during friction drilling. The variations in torque with respect distance from contact fall into two different regions. When the drill comes into contact with the work piece resulting in enhanced friction between the two, thus causing the torque to increase. On the other hand, when the conical part of the drill has fully penetrated into the work piece and reached the depth to be machined, further drilling has little impact on the interaction between the cylindrical part of the drill and the work piece, and the torque thus decreases.

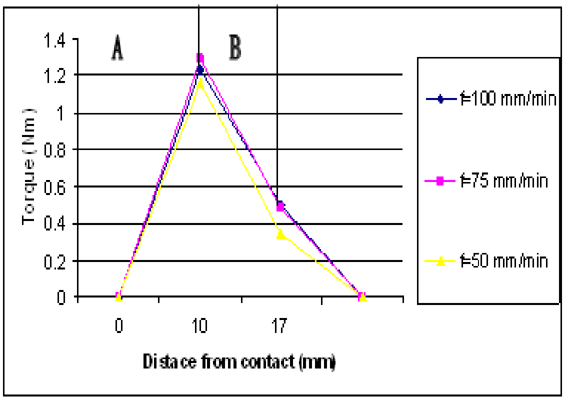

Fig.9. Thrust force at friction drilling of Al 6061-T6 alloy at different cutting velocity and feed rate.

Thrust force and torque for various cutting velocity and feed rate for high speed steel friction drill bit.

Figure 10 shows the variation of the thrust force with varying cutting velocity and feed rate in drilling holes using high speed steel friction drill bit. The thrust force is plotted along the y-axis and the cutting velocity along x-axis. It is observed that the thrust force for the holes drilled using high speed steel drill bit increases with increase in feed rate and increase with increase in cutting velocity.

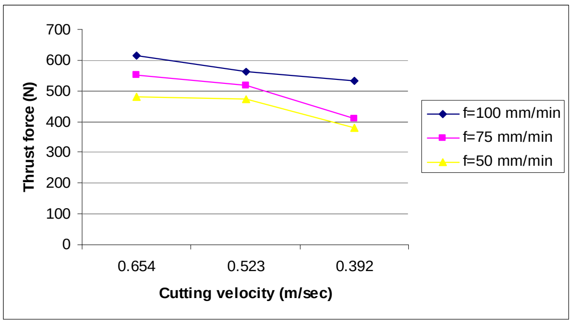

Figure 10 Thrust force Vs cutting velocity at different feed rate and cutting velocity

Figure 11 shows the variation of the torque with varying cutting velocity and feed rate in drilling holes using high speed steel friction drill bit. The torque is plotted along the y-axis and the cutting velocity along x-axis. It is observed that the torque for the holes drilled using high speed steel drill bit increases with increase in feed rate and increase with increase in cutting velocity.

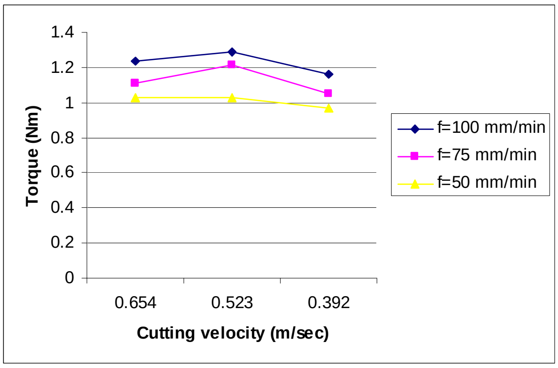

Figure11 Torque Vs cutting velocity at different feed rate and cutting velocity

V CONCLUSION

In this study friction drill toll was manufactured with HSS tool material. The torque and thrust force was measured at different cutting speed and feed rate with Kistler model 9257B piezoelectric dynamometer. The effect of the drilled holes was analysed using the ANOVA and the regression techniques, both the independent variables, cutting velocity and feed rate has a more significance on the dependent variables, thrust force and torque.

The percentage contribution of the cutting velocity is greater than that of the feed rate, so cutting velocity is the dominating parameter than the feed rate.

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