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SOME INVESTIGATIONS IN FRICTION DRILLING AA6351 USING HIGH SPEED STEEL TOOLS

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ABSTRACT

Friction drilling is a non traditional hole making process in which a conical rotating tool is applied to penetrate into workpiece and create the hole in a single step, without generating chips. The process relies on the heat generated due to the frictional force between tool and workpiece, to soften, penetrate and deform the work material into a bushing shape. The mechanical aspects of friction drilling are investigated in this paper. Aluminum (AA6351) is taken as work material and friction drilling is carried out by high speed steel conical tool. Mathematical models are developed in this work for axial thrust and torque. Proper experimental layout is designed and Taguchi Method is applied to evaluate the performance of high speed steel friction drill on AA6351 workpiece of thickness 1mm.

Keywords: drilling, friction, cutting speed, feed, cone angle, torque, thrust force, Taguchi's methods.

1. INTRODUCTION

The mechanics of hole formation in friction drilling is due to thermal softening followed by the penetration of tool into work. Drilling is traditionally a hole making process. The mechanics of material removal is due to combination of extrusion and negative rake cutting. However all traditional drilling methods suffer from various disadvantages they inherit from the machining processes. Poor dimensional accuracy and quality of surface finish is a matter of concern for high end applications such as air crafts, missiles, space vehicles etc. A new method of hole generation viz. friction drilling is making its way into the literature and into the shop floor, promising to solve the aforementioned problems. Friction drilling in the present work is performed by a sharp cone of circular shanked high speed steel. The tool is rotated at high speed to develop sufficient temperature and thrust is applied to form a hole with out chips, hence some investigators prefer to call this method as form drilling, however at least half a dozen patents are granted for the title friction drilling. The formation of shoulder is a bonus in this method, which can be used as a natural bush in sheet metal or it can be used for tightening screws after tapping. The bush thickness is observed to be two times thickness of sheet metal further no cutting fluid is required for friction drilling. The friction drilling process is a potential area and it calls for investigations on various shapes of tools. The best shape of tool is yet to be identified. Figure-1 depicts the sequence in friction drilling process, a rotating conical tool contacts the workpiece and heat is generated due to friction between mating surfaces, owing to this the work softening occurs and on further advancement of tool into the workpiece, the softened material is pushed sideward and forms the bushing. The shoulder of tool contacts the workpiece and does the trimming.

France [1] studied the strength characteristics of friction drilled holes in metal tubes. Thermal studies in friction drilling were carried out by Bak [2] however the process is described as integral bushing. The effect of coatings on tool is investigated by Kerkhofs [3] to evaluate the mechanical characteristics in form drilling. Several investigators started working on the friction drilling process only after the lead work carried out by Miller [4]. Torque and thrust force was first modeled for AISI1020 steel using tungsten carbide friction drill, thermal aspects of the process are also highlighted by Miller. The lucid explanation by Ross [5] on Taguchi method formed a fundamental back bone for current investigations. The literature survey revealed that the work on this process is scarce and calls for the attention of both machining specialists and metal forming specialists.

2. EXPERIMENTATION

A sharp point is avoided and a small flat surface is provided on the cone head to initiate friction heat, as the cone penetrates into work the metal gives way due to plastic deformation and the diameter gradually increases. The work material used in the current investigations is AA6351, it has a composition C 0.37-0.44, Mn 0.60-0.90, P 0.40 (max), S 0.50 (max). Aluminum of this series has wide variety of applications and is most commonly used in industry we hope these studies will be useful for the industries. A pillar drilling machine of Batli-Boi make is retrofitted with special pulleys in order to get the working speed range of 3000-4000 rpm. As the temperature generated is estimated to be in the range 400-500^{O}C the tool made of High Speed steel is selected for experimentation. The tool has conical portion at the bottom and a shoulder in the cylindrical region. For the purpose of experimentation two tools are chosen, one is with an included angle of 45^{O} and the other is of 90^{O}, these tools are shown in Figure-2. The work piece is a 1 mm thick aluminum cold rolled sheet and is mounted on top of Spranktronics model drilling dynamometer, for measuring thrust force and torque during friction drilling process (Figure-3). The friction drilled work pieces are shown in Figure-4.

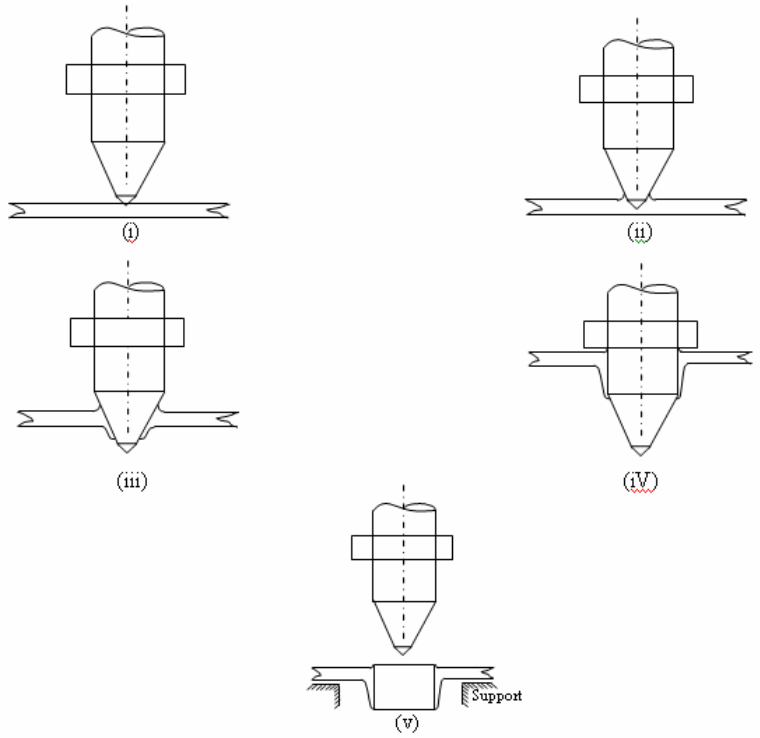

Figure-1. Steps in friction drilling process.

Figure-2. Typical tools.

Figure-3. Drill dynamometer.

Figure-4. Workpieces after machining.

2.1 Design of experiments

Variation of torque and thrust force in the friction drilling process are investigated in the present work. The significant process parameters envisaged are speed of tool, feed rate given to tool and included angle in the cone portion of tool. After having through trials, which induces defect free holes, the range of the process parameters is identified. The upper and lower limits of the parameters are depicted in Table-1.

A full factorial (2^3) experiments are envisaged and are conducted at random to eliminate error [6]. Each experiment is repeated twice for the sake of consistency. As the design matrix is equivalent to L_8 orthogonal array of Taguchi method, the data was analyzed for contributions and for identification of optimal parameters. Multiplicative regression models are considered for the responses namely torque and thrust force. The regression equation is in the form $y = K. N^a. S^b. \beta^c$ where y is the selected response, N is speed, S is feed, β is the cone angle and K, a, b and c are constants. There is sharp variation in thrust force and torque during the process, however only peak values are considered. At times the work got welded to the tool during the withdrawal. Hence proper clamping is provided during experimentation.

3. RESULTS AND DISCUSSIONS

The experiments are conducted at random and the results are compiled in Table-2. After applying logarithms to the regression model the constants are evaluated. The final equations of the responses are given in Table-3.

The data have been analysed and the analysis of variance (ANOVA) is computed using Yate's algorithm [6]. The contribution of each parameter is also evaluated and is presented in Tables 4 and 5.

It is found that the influence of cone angle is high on thrust force and torque as evident from large contributions. The variation of torque and thrust force are in the same trend with the variation of speed and feed while they demonstrate inverse relationship with cone angle (Figure-5). High thrust force is not desirable since it deforms sheet metal and shortens the life of tool. The bent sheets indicate high thrust force and hence low speed is desired for effective drilling. The work piece is penetrated by the tool tip centre and is responsible for the thrust force also the change in color of the hole manifested that the heat generation was different for various speeds of the tool.

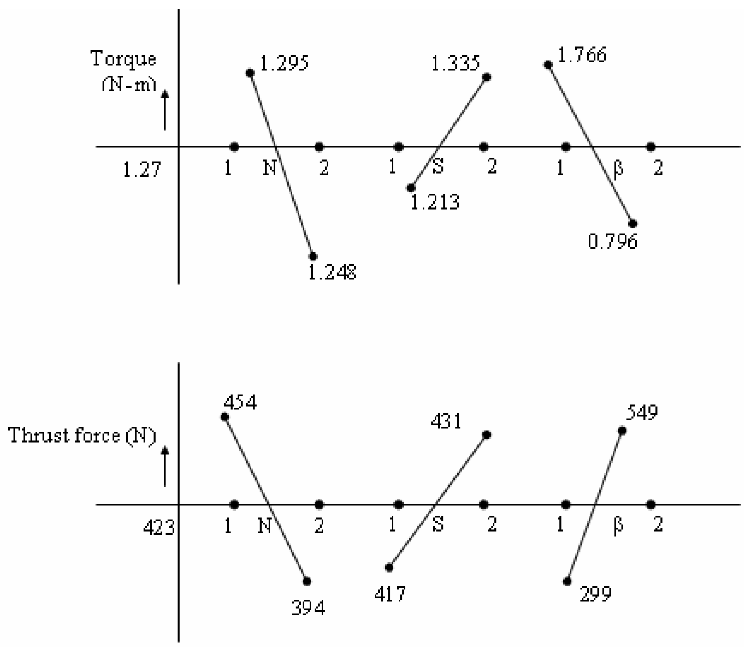

Figure-5. (a) Variation of torque, (b) variation of thrust force.

Table-1. Selection of levels for process parameters.

S. No.	Process parameters	Units	Levels	
			1	2
1	Speed (N)	rpm	2000	3000
2	Feed (S)	mm/rev	0.1	0.3
3	Cone angle (β)	Angle in degrees	45^O	90^O

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Table-2. Experimental matrix.

Expt. No.	**Speed** (N)	**Feed** Rate (S)	**Cone angle** (β)	**Torque** (N-m)		**Thrust force** (N)	
				Trail 1	**Trail 2**	**Trail 1**	**Trail 2**
1	2	2	2	1.1	1.05	532	535
2	2	2	1	1.5	1.45	275	280
3	2	1	2	0.85	0.87	506	510
4	2	1	1	1.62	1.65	253	260
5	1	2	2	0.71	0.73	608	615
6	1	2	1	2.1	2.15	304	302
7	1	1	2	0.51	0.55	551	540
8	1	1	1	1.82	1.85	356	360

Table-3. Development of regression equation.

Response	**Regression equation**
Thrust force (y_1)	$y_1 = 423N^{-31.6} S^{53.0} \beta^{1009}$
Torque (y_2)	$y_2 = {}^{2.9} N^{-0.07} S^{0.61} \beta^{-3.9}$

Table-4. ANOVA for thrust force.

Parameter	**SS**	**Dof**	**Variance**	**F Ratio**	**Contribution** (%)
Speed (N)	15977	1	15977	0.102	1.86
Feed (S)	44944	1	44944	0.284	5.25
Cone angle (β)	16300	1	16300	1.03	19.05
Error	631474	4	157868		
Total	**855395**	**7**			

Table-5. ANOVA for torque.

Parameter	**SS**	**Dof**	**Variance**	**F Ratio**	**Contribution** (%)
Speed (N)	0.0784	1	0.0784	0.001	0.028
Feed (S)	5.95	1	5.95	0.9	2.16
Cone angle (β)	243.4	1	243.4	38.6	88.3
Error	25.2	4	6.3		
Total	**275.2**	**7**			

4. CONCLUSIONS

a) From the contribution values it is concluded that the cone angle of the tool is a critical parameter and is influencing both torque and trust force;
b) This process can be used as an alternate for two step drilling and counter sinking;
c) A highly burnished surface is obtained for AA6351 in friction drilling at low and medium speed, discolorations is observed at high speed;
d) The surface finish on the conical surface can be considered for tribological investigations in friction drilling; and
e) Stray bending was observed on work piece.

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REFERENCES

[1] France J.E., Davidson J.B. and Kirby P.A. 1999. Strength and rotational stiffness of simple connections to tubular columns using flow drill connectors. J. Constr. Steel Res. 50: 15-34.

[2] Bak D. 1987. Friction, Heat from Integral Bushings. Des. News. 43(11): 124.

[3] Kerkhofs M., Steppen M.V., D Olieslaeger M., Quaeyhaegons C. and Stals L.M. 1994. The performance of (Ti.Al.) N-Coated Flow drills. Surf. Coat Technology. 68/69: 741-746.

[4] Scot F. Miller. 2006. Experimental and numerical analysis of Friction drilling process. Transactions of ASME, Manuf. Science. 128: 802-810.

[5] Phillip J. Ross. Taguchi Techniques for Quality Engineering. McGraw-Hill.

[6] Kempthore. 1986. Design and analysis of experiments. John Wiley and Sons, New York.

[7] Taguchi G. 1987. Systems of Experimental design. John Wiley and Sons, New York.

[8] Strenkowski J.S., Hsieh C.C. and Shih A. J. 2004. An analytical finite Element Technique for predicting Thrust Force and Torque in Drilling. Int. J. Mach. Tools Manuf. 44: 1413-1421.