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Effect of Conical angle and Spindle speed on the Characteristics of Holes Machined using Friction Drilling Process

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Abstract. In the present investigation, holes in AA7075 aluminum sheets were drilled using friction drilling method. The effect of the tool rotational speed (spindle speed) and the tool conical angle on the hole dimensions were investigated. The friction drilling process was performed using tool rotational speeds of 3100 rpm, 3400 rpm and 3700 rpm. The tool conical region has hexagonal shape with conical angles of 25^o, 30^o and 35^o. To evaluate the quality of the manufactured holes, the hole diameter, bushing height and wall thickness dimensions were measured. The analysis of variance (ANOVA) statistical method was used to evaluate the influence of the spindle speed and the conical angle. Moreover, models were developed using regression analysis technique to predict the hole dimensions. The results revealed that the maximum average busing height was about 7.945 mm exhibited by holes friction drilled using rotational speed and conical angle of 3700 rpm and 30^o, respectively. While the maximum average busing wall thickness was about 1.325 mm exhibited by holes friction drilled using rotational speed and conical angle of 3700 rpm and 25^o, respectively. The maximum hole diameter was ≈15.17 mm for a hole drilled using spindle speed and conical angle of 3100 rpm and 30^o, respectively. Furthermore, the minimum hole diameter was about 15 mm for a hole friction drilled using tool spindle speed and conical angle of 3400 rpm and 30^o, respectively.

Keywords: Friction drilling, Aluminum Alloys, Regression Analysis.

1. INTRODUCTION

Friction drilling is a non-conventional drilling process used for making holes in metallic sheets [1]. The friction drilling can be called also thermal drilling, flow drilling, form drilling or friction stir drilling. In friction drilling process, a rotating tool with a pointed tip is forced through a sheet metal workpiece. The heat developed due to friction, between at the interface between the rotating tool and stationary workpiece, enables the softening, deformation, and displacement of workpiece material. This creates a bushing, surrounding the hole, without generating chip or waste material. The bushing can be threaded and/or offers a structural support for assembly devices connected to the sheet metal [2]. The friction drilling process can be used to manufacture parts for heat exchangers, luggage rack in a bicycle frame …etc [3].

Friction drilling is usually applied to thin-walled workpieces such as plates, tubes and box-shaped profiles. However, not all materials are suitable for friction drilling process. The friction drilling can be applied to steels (UTS < 700 MPa), aluminum, stainless steel, copper and brass alloys. There are several investigations were reported on the friction drilling of different Al alloys such as AA1100, AA6061, AA1050, AA5083, AA6351, AA2024 and AA7075 [1-8].

In this work, hole on AA7075 aluminum sheets were machined using friction drilling. The effect of the spindle speed and the tool profile on the hole quality was studied. The diameters of the developed holes, the bushing height and the bushing thickness were measured to evaluate the effect of the aforementioned parameters on the dimensional accuracy of the holes and bushing. The regression analysis models were developed to predict the hole diameters and bushing dimensions.

2. EXPERIMENTAL PROCEDURES

The workpiece to be drilled using friction drilling was in the form of sheet with 3.4 mm thickness and is made from AA7075 aluminum alloy. The chemical composition of the alloy is shown in Table 1. The tool used for drilling the AA7075 Al sheets is made from H13 tool steel manufactured by by Bohler-Uddeholm UDDEHOLM ORVAR (Germany).

Table 1. The chemical composition of the investigated AA7075 aluminum alloy (wt. -%).

Elements	Cu	Fe	Mn	Mg	Si	Zn	Cr	Ti	Pb	Al
Weight %	1.33	0.258	0.052	2.29	0.112	5.94	0.166	0.023	0.005	Bal.

A typical drill tool used in the present work is shown in Fig. 1. The conical region of the tool has a hexagonal shape with different conical angles, β, typically 25°, 30° and 35°. The tools have constant tip angle, α, of 70°. The tools have constant shank lengths and diameters of 40 mm and 15 mm, respectively. The cylindrical region of the tools has also constant dimensions of the diameter and length of 15 mm and 20 mm, respectively. The shoulder regions have 10 mm thickness and 30 mm diameter.

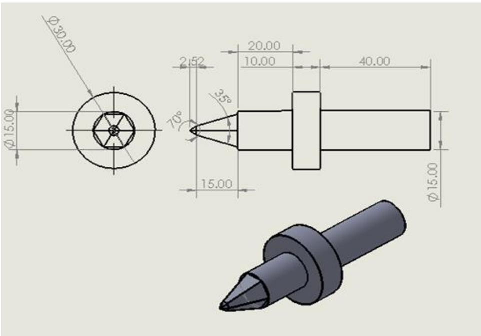

Fig 1. A tool with a conical angle (β) of 35°.

The friction drilling process of the AA7075 sheets was carried out using Sino computer numerical controlled (CNC) vertical machining center of model VMC 1060B, China. Before drilling the AA7075 sheet were clamped with a die using a clamp. The friction drilling was carried out using different rotational speeds, typically, 3100 rpm, 3400 rpm and 3700 rpm. The plunging rate was kept constant at 30 mm/min. In the present investigation, the (3^2) full factorial design of experiment technique (DoE) was used. Figure 2 shows a schematic illustration of the hole and bushing dimensions. The measured parameters were hole diameter (d), bushing height (h) and bushing thickness (t). Each sample was cut using the wire cut machine into two half and the measurements were carried out using image analysis techniques.

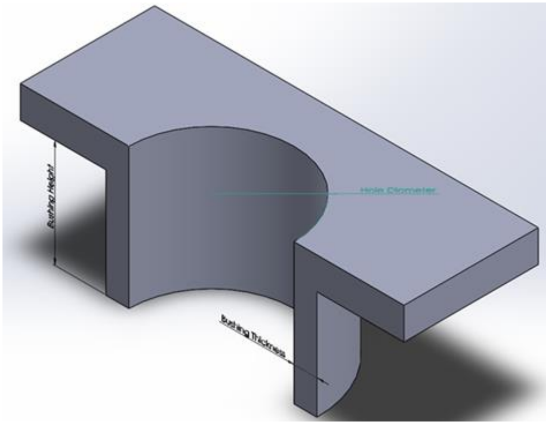

Fig 2. The hole and bushing measurements.

3.RESULTS AND DISCUSSION

3.1. The Hole Diameter Measurements

Figure 3 show typical photographs of the top views of friction drilled hole. The holes are without bossing. This is because the tool during the drilling operation plunges until the shoulder of the tool touches the surface of the AA7075 sheet. In some cases, a burr is formed and clearly seen on the surface of the hole. The maximum hole diameter was about 15.17 mm for a hole friction drilled using tool spindle speed and conical angle of 3100 rpm and 30°, respectively. While the minimum hole diameter was about 15 mm for a hole friction drilled using tool spindle speed and conical angle of 3400 rpm and 30º, respectively.

Figure 4 shows the variation of the hole diameter with the conical angles for holes formed at different spindle speeds. At spindle speed of 3100 rpm, increasing the conical angle from 25º to 30º increases the hole diameter. Further increase in the conical angle up to 35º reduces significantly the hole diameter. While at both spindle speeds of 3400 and 3700 rpm, increasing the conical angle from 25º to 30º reduced the hole diameter while additional increase in the conical angle increases the hole diameter.

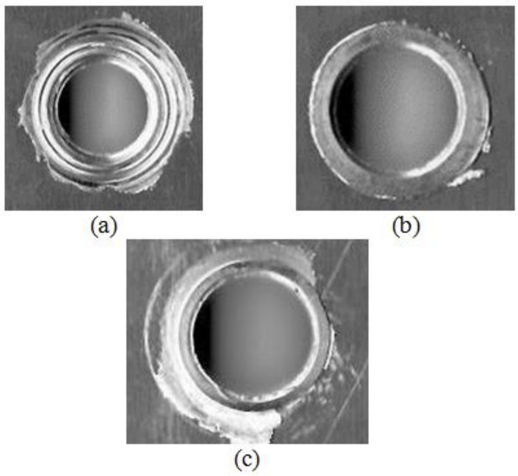

Fig 3. Photographs of typical friction drilled holes using constant rotational speed of 3400 rpm and several conical angles of (a) 25º, (b) 30º and (c)35º.

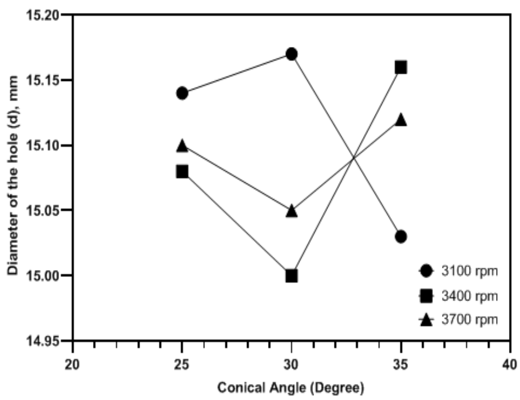

Fig 4. Variation of the hole diameter with the conical angle at several rotational speeds.

At constant conical angle of 25º, increasing the tool rotational speed from 3100 to 3400 rpm reduced the hole diameter from 15.14 mm to 15.00 mm. Further increase in the tool rotational speed up to 3700 rpm slightly increases the hole diameter to 15.10 mm. The same observation was noticed for holes drilled using constant angle of 30º. Moreover, at constant conical angle of 35º, increasing the tool rotational speed from 3100 to 3400 rpm increased slightly the hole diameter from 15.03 mm to 15.16 mm. Further increase in the tool rotational speed up to 3700 rpm slightly reduced the hole diameter to 15.12 mm.

3.2. The Formation of Petals

Figure 5 shows typical photographs of the formed bushes for hole friction drilled using spindle speeds of 3100 rpm and conical angles of 25º, 30º and 35º, respectively. Cracking and petal formation in bushing were observed. The petals and cracks are undesired features, this because that cracking and petals destroy the useful surface area and limit the load carrying capability of the threaded holes. It has been reported that for aluminum alloys, the deformation of material and petal formation, i.e., fracture in the bushing or lip, is like that in the plate perforation or hole flanging using a conical tool [9,10].

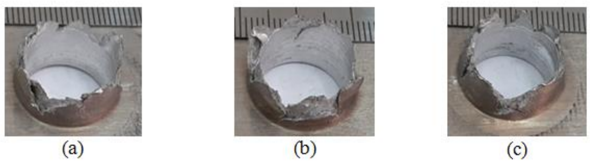

Fig 5. The formed bushing developed using friction drilling of AA7075 Al alloy at constant rotational speed of 3100 rpm and several conical angles of (a) 25º, (b) 30º and (c)35º.

3.3. **The Bushing Height**

Figure 6 shows photographs of the cross-sections of bushes formed during friction drilling the sheets of AA7075 alloy using rotational speed of 3700 rpm and conical angles. The maximum average busing height was observed for a hole (≈ 7.945 mm) friction drilled at rotational speed and conical angle of 3700 rpm and 30º, respectively. While the minimum average busing height was observed for a hole (≈ 6.9 mm) friction drilled at rotational speed and conical angle of 3400 rpm and 35º, respectively.

Figure 7 shows the variation of the height of the bushing (h) with the conical angle at several rotational speeds. The results revealed that at spindle speed of 3100 rpm, increasing the conical angle from 25º to 30º reduced slightly the hole diameter from 7.785 mm to 7.135 mm. Further increase in the conical angle up to 35º increases slightly the hole diameter to 7.725 mm. While at both spindle speeds of 3400 and 3700 rpm, increasing the conical angle from 25º to 30º increased slightly the hole diameter while additional increase in the conical angle reduced the hole diameter. For example, at constant rotational speed of 3700 rpm, increases the conical angle from 25º to 30º increased slightly the hole diameter from 7.36 mm to 7.945 mm. Further increase in the conical angle up to 35º reduces the hole diameter slightly to 7.015 mm.

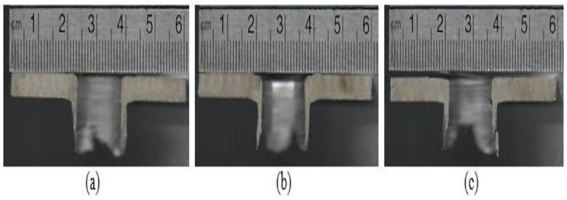

Fig 6. The cross section of friction drilled specimens showing the bushing developed using constant spindle speed of 3700 rpm and several conical angles of (a) 25º, (b) 30º and (c)35º.

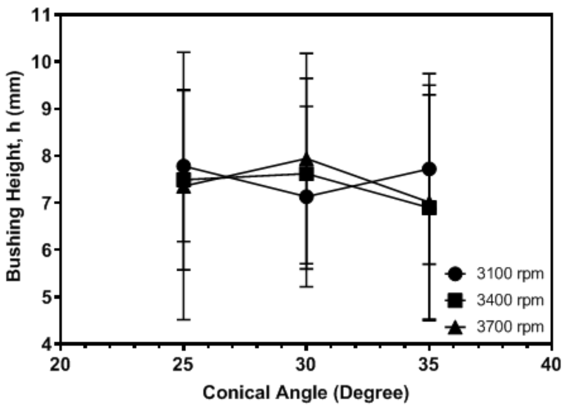

Fig 7. Variation of the height of the bushing (h) with the conical angle at several rotational speeds.

3.4. The Bushing Thickness

The results revealed that the maximum average busing thickness was about 1.325 mm and observed for a hole friction drilled at rotational speed and conical angle of 3700 rpm and 25º, respectively. While the minimum average busing thickness was about 1.025 mm observed for a hole friction drilled at rotational speed and conical angle of 3400 rpm and 25º, respectively. Figure 8 illustrates the variation of the bushing wall thickness (t) with the conical angle at several rotational speeds. The results revealed that at spindle speeds of 3100 and 3400 rpm, increasing the conical angle from 25º to 30º increased slightly the bushing wall thickness. Further increase in the conical angle up to 35o reduces slightly the bushing wall thickness. In contrast, at constant spindle speed of 3700 rpm (i.e. the maximum rotational speed), increasing the conical angle from 25º to 30º reduced the bushing wall thickness while additional increase in the conical angle (i.e. up to 35º) reduced the bushing wall thickness.

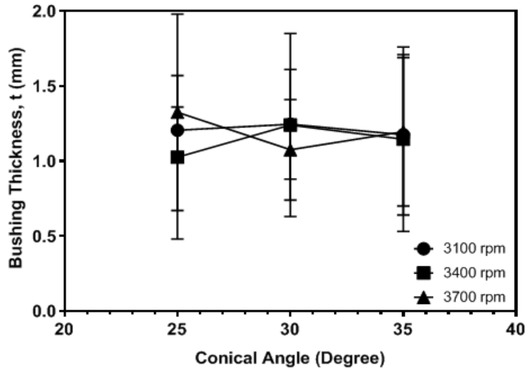

Fig 8. Variation of the bushing wall thickness with the angle at different spindle speeds.

4.CONCLUSIONS

The conclusions of significance are drawn as follows :-

1. The maximum hole diameter was ≈15.17 mm for a hole drilled using spindle speed and conical angle of 3100 rpm and 30º, respectively. Furthermore, the minimum hole diameter was about 15 mm for a hole friction drilled using tool spindle speed and conical angle of 3400 rpm and 30º, respectively.
2. The maximum average busing height, ≈ 7.945 mm, for hole drilled using rotational speed and conical angle of 3700 rpm and 30º, respectively. Moreover, the minimum average busing height was observed for a hole (≈ 6.9 mm) drilled using rotational speed and conical angle of 3400 rpm and 35º, respectively.

3. The maximum average busing wall thickness was about 1.325 mm for a hole drilled using rotational speed and conical angle of 3700 rpm and 25^o, respectively. Moreover, the minimum average busing wall thickness was about 1.025 mm observed for a hole friction drilled at rotational speed and conical angle of 3400 rpm and 25^o, respectively.

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REFERENCES

[1] M. Boopathi, S. Shankar, S. Manikandakumar, R. Ramesh, “Experimental Investigation of Friction Drilling on Brass, Aluminium and Stainless Steel,” International Conference on Design and Manufacturing, IConDM 2013, Procedia Engineering, 64, 2013, pp. 1219-1226.

[2] S. A. El-Bahloul, H. E. El-Shourbagy, M. Y. Al-Makky and T. T. ElMidany, “Thermal Friction Drilling: (A Review)”, 15th International Conference on Aerospace Sciences & Aviation Technology, ASAT-15, May 28-30, 2013.

[3] R. Kumar, N. Rajesh Jesudoss Hynes, “Thermal drilling processing on sheet metals: A review”, International Journal of Lightweight Materials and Manufacture, 2, 2019, pp. 193-205.

[4] P.V.G. Krishna, K. Kishore, V.V. Satyanarayana, “Some investigations in friction drilling AA6351 using high speed steel tools”, ARPN J. Eng. Appl. Sci., 5, 2010, pp. 11-15.

[5] C. Ozek, Z. Demir, “Investigate the friction drilling of aluminium alloys according to the thermal conductivity”, TEM J., 2(1), 2013, pp. 93-101.

[6] A.A. Eliseev, S.V. Fortuna, E.A. Kolubaev, “Microstructure modification of 2024 aluminum alloy produced by friction drilling”, Mater. Sci. Eng. A, 691, 2017, pp. 121-125.

[7] R.V. Diwakar, G. Krishnaiah, C. Gopi, “Analysis in Form Drilling AA1100 Using HSS Tools”, International Conference on Trends in Mechanical and Industrial Engineering (ICTMIE'2011), 2011. Bangkok, Thailand.

[8] T. Prabhu, A. Arulmurugu, “Experimental and Analysis of Friction Drilling on Aluminium and copper”, International Journal of Mechanical Engineering and Technology (1.1MET), 5(5), 2014, pp. 123-132.

[9] W.J. Johnson, N.R. Chitkara, A.H. Ibrahim, A.K. Dasgupta, “Hole flanging and bushing of circular plates with conically headed cylindrical punches”, Journal of strain analysis, 8, 1973, pp. 228-241.

[10] N.M. Wang, M.L. Wenner, “An analytical and experimental study of stretch flanging”, International journal of mechanical science, 16, 1974, pp. 135-143.