ENGINEERING RESEARCH JOURNAL (ERJ)

Vol. 1, No. 49 Jul. 2021, pp 36-41

Journal Homepage: http://erj.bu.edu.eg

THE QUALITY OF HOLES MANUFACTURED USING FRICTION STIR DRILLING TECHNIQUE

Abdullah T. A. M. Abdulkareem M. A. Khedr A.M. Gaafer

Mechanical Engineering Department, Shoubra Faculty of Engineering, Benha University, Cairo, Egypt.

ABSTRACT In the present investigation, the effect of the tool rotational speed as well as the conical angle on the quality of friction stir drilled holes in AA7075 aluminum alloy sheets was studied. The diameters of the developed holes, the bushing height and the bushing wall-thickness were measured to evaluate the effect of the aforementioned parameters on the dimensional accuracy of the holes and bushing. The holes were friction stir drilled using CNC machine at several tool rotational speeds of 3250, 3550 and 3900 rpm as well as using drill tools having different conical angles of 38^o, 42^o and 58^o. The analysis of variance (ANOVA) was used to determine the level of significance of the investigated friction stir drilling process parameters on the aforementioned hole characteristics. The regression analysis models were developed to predict the hole diameters and bushing dimensions. The results revealed that the maximum hole diameter (15.35 mm), bushing height (7.92 mm) and wall-thickness (1.62 mm) were noticed for holes friction stir drilled using tool rotational speed and conical angle of 3250 rpm and 58^o, respectively. The conical angle has higher significant effect on hole diameter and the bushing wall-thickness than the spindle speed. While, for bushing height, the tool spindle speed exhibited higher significant effect than the tool conical angle.

KEYWORDS: Friction stir drilling, Aluminum Alloys, ANOVA.

1. INTRODUCTION

The friction stir drilling process, also known as thermal drilling, flow drilling or form drilling, is a hole nontraditional forming process in the sheet metals using the heat generated by means of friction [1,2]. The main advantages of the friction stir drilling process over the conventional drilling machining process are that the holes formed using this process does not need any backing arrangements such as weld nuts, rivet nuts …etc. [3-5]. Because the extruded bush itself acts as a supporting structure for the fasteners. This eliminates the need for the access to the backside of the work material for fastening operations. The major factors contributing the friction stir drilling operation are the spindle speed and the thrust force required for forming a hole [6-8].

In the present investigation, 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.

2. EXPERIMENTAL PROCEDURES

The work-material used is the high strength AA7075 aluminum alloy in the form of rolled sheets. The sheets have 3.4 mm thickness. Table 1 lists the chemical compositions of the AA7075 alloy. The material of the tool used to drill the holes is made from H13 tool steel. The H13 steel was made by Bohler-Uddeholm UDDEHOLM ORVAR (Germany).

Table 1. The chemical compositions of the 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.

Figures 1 shows the drilling tools with hexagonal conical regions and different conical angles, β, typically 38°, 42° and 58°, respectively. The tip angles, α, of the tools were kept constant at 70°. The shank lengths and diameters of the tools were kept constant at 40 mm and 15 mm, respectively. The diameter and length of the cylindrical regions of the tool were also kept constant at 15 mm and 20 mm, respectively. The shoulder regions have 30 mm diameter and 10 mm thickness.

The friction stir drilling process of the AA7075 sheets was performed using CNC vertical machining center. Before friction stir drilling, the AA7075 sheets were placed and clamped. The friction stir drilling was performed using different spindle rotational speeds, typically, 3250 rpm, 3550 rpm and 3900 rpm. The plunging rate was kept constant at 30 mm/min. The measured parameters were hole diameter (d), bushing height (h) and bushing wall-thickness (t). These measurements were carried out after cutting the friction stir drilled samples using the wire-cutting machine into two-half. The measurements were performed with the aid of image analysis techniques.

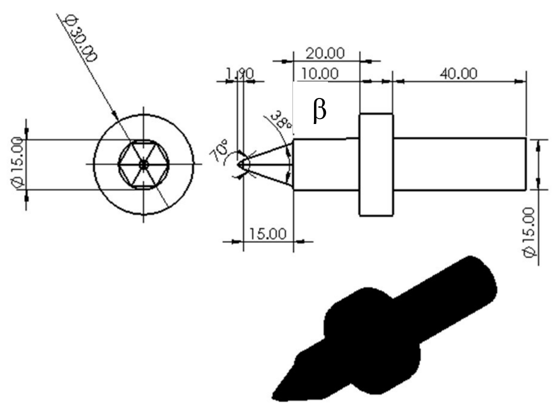


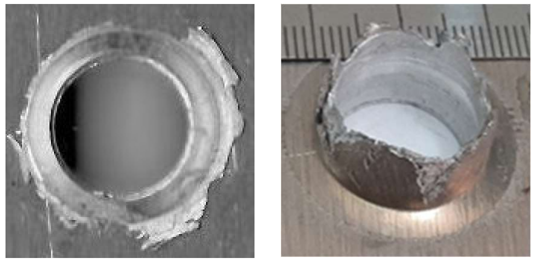
Figure 1. (a) The dimensions of the tool with hexagonal shape and conical angles (β). The conical angle has values of 38°, 42° and 58°.

The analysis of variance (ANOVA) statistical approach was used to determine the level of significance of the investigated friction stir drilling process parameters on the hole characteristics, typically, the hole diameter and the bushing height and bushing wall thickness.

3. RESULTS AND DISCUSSION

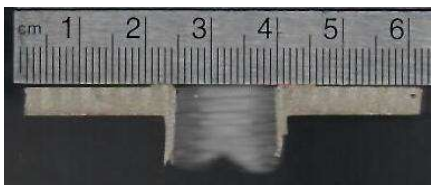
3.1. Hole Diameter

Typical photographs of the friction stir drilled holes are shown in Figure 2. Figure 3 shows photographs of typical cross-sections of a drilled hole. The results indicate that the maximum hole diameter of 15.35 mm was noticed for sample friction stir drilled using a tool rotational speed and a tool conical angle of 3250 rpm and 58°, respectively. While the minimum hole diameter of 15 mm was noticed for sample friction stir drilled using a tool rotational speed and a tool conical angle of 3250 rpm and 38°, respectively. Figure 4 shows the main effects plot for the mean of the hole diameters manufactured friction stir drilling. The results revealed that increasing the conical angle increases the hole diameter. Also, increasing the tool rotational speed reduces the hole diameter.

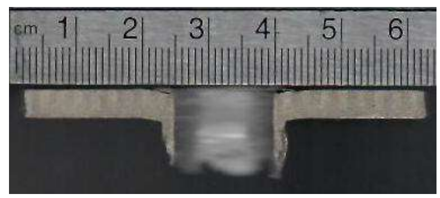


(a) (b)

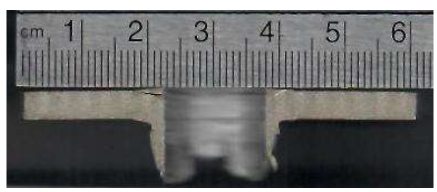
Figure 2. Photograph of a typical hole fabricated using friction stir drilling
(a) top view and (b) bottom view.



(a)



(b)



(c)

Figure 3. Cross-sections of friction stir drilled holes and bushing fabricated using constant tool rotational speed of 3250 rpm and different conical angles of (a) 38°, (b) 42° and (c) 58°.

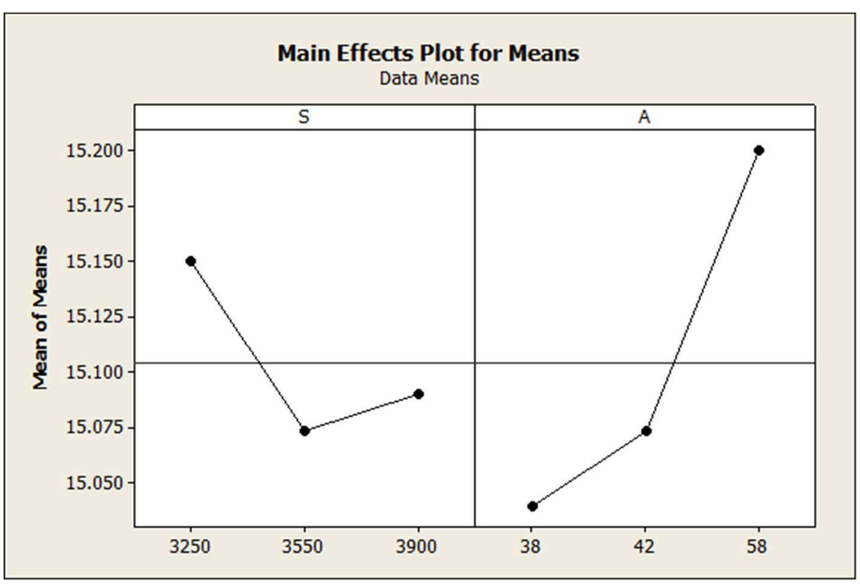


Figure 4. Main effects plot for means of the hole diameter.

3.2. Bushing Height

The results revealed that the maximum bushing height of 7.92 mm was observed for specimen friction stir drilled using tool rotational speed and conical angle of 3250 rpm and 58°, respectively. Figure 5 shows the main effects plot for means of the bushing height of the friction stir drilled holes. Increasing of the tool spindle steed from 3250 rpm to 3550 rpm and/or conical angle from 38° to 42° reduce(s) the bushing height. Further increase of the tool spindle steed from 3550 rpm to 3900 rpm and/or conical angle from 42° to 58° increase(s) the bushing height.

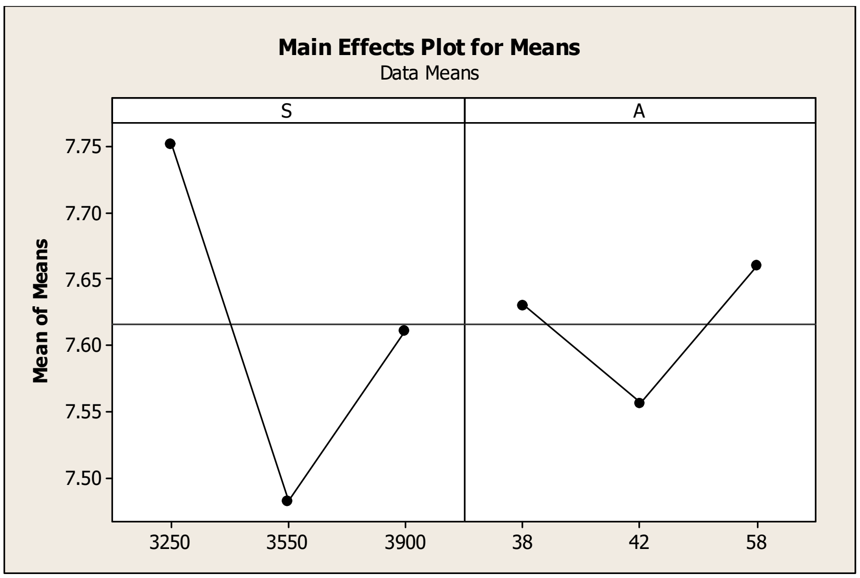


Figure 5. Main effects plot for means of the bushing height.

3.3. Bushing Wall-Thickness

The maximum wall-thickness was about 1.62 mm and obtained from holes friction stir drilled using tool rotational speed and conical angle of 3250 rpm and 58°, respectively. While the minimum wall-thickness was about 1.105 mm and obtained from holes friction stir drilled using tool rotational speed and conical angle of 3550 rpm and 58°, respectively. Figure 6 shows the main effects plot for the bushing wall-thickness. Increasing the conical angle from 38° to 58° increases the bushing wall thickness. Increasing the tool rotational speed from 3250 rpm to 3550 rpm reduces the bushing wall-thickness. Further increase in the tool rotational speed from 3550 rpm to 3900 rpm increases the bushing wall-thickness.

3.4. ANOVA Results

Tables 2, 3 and 4 show the response tables for means of the hole diameter, bushing height and bushing wall-thickness respectively. The ANOVA results revealed that the conical angle (ranked #1) has higher significant influence on hole diameter and the bushing wall-thickness than the spindle speed (ranked #2). While, in case of bushing height, the tool spindle speed (ranked #1) has higher significant influence than the tool conical angle (ranked #2).

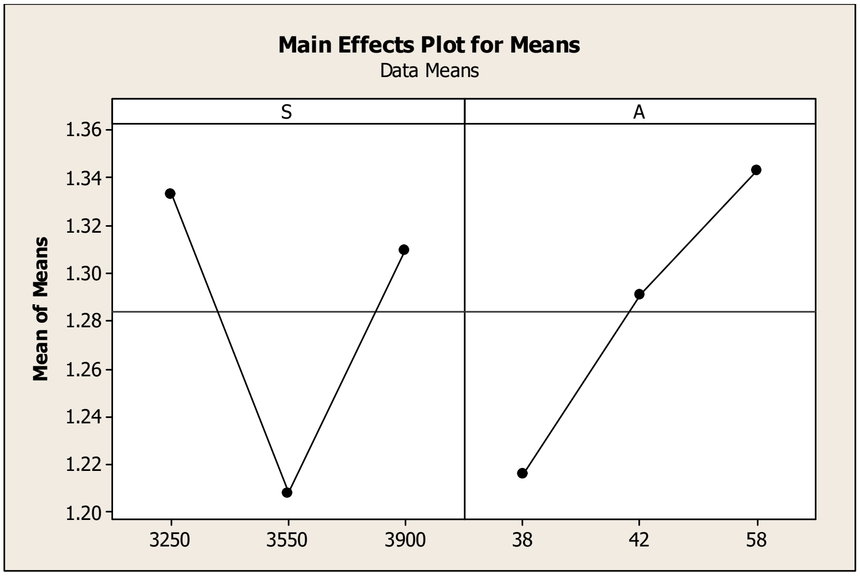


Figure 6. Main effects plot for means of the bushing wall-thickness.

Table 2. Response table for means for hole diameter.

Level	S	A
1	15.15	15.04
2	15.07	15.07
3	15.09	15.20
Delta	0.08	0.16
Rank	2	1

Table 3. Response table for means for bushing height.

Level	S	A
1	7.752	7.630
2	7.483	7.557
3	7.612	7.660
Delta	0.268	0.103
Rank	1	2

Table 4. Response table for means for bushing wall-thickness.

Level	S	A
1	1.333	1.217
2	1.208	1.292
3	1.310	1.343
Delta	0.125	0.127
Rank	2	1

4. CONCLUSIONS

Based on the results obtained in present investigation, the following conclusions can be drawn: -

1. The maximum bushing height of 7.92 mm, hole diameter of 15.35 mm and wall-thickness was about 1.62 mm were observed for holes friction stir drilled using tool rotational speed and conical angle of 3250 rpm and 58^o, respectively.
2. Increasing the conical angle increases the hole diameter. While, increasing the tool rotational speed reduces the hole diameter.

3. The conical angle has higher significant influence on hole diameter and the bushing wall-thickness than the spindle speed. While, in case of bushing height, the tool spindle speed has higher significant influence than the conical angle of the tool.

ACKNOWLEDGMENTS
The authors are thankful to Faculty of Engineering at Shoubra - Benha University for providing the facilities for carrying out the experimental work.

REFERENCES

[1] B.Padma Raju and M.Kumara Swamy, "Finite Element Simulation of a Friction Drilling process using Deform-3D", International Journal of Engineering Research and Applications (IJERA), 2(6), 2012, pp.716-721.

[2] P. Vijayabaskar and N. Rajesh Jesudoss Hynes, "Simulation of friction stir drilling process", AIP Conference Proceedings, 1953(1), 2018.

[3] Scott F. Miller, Rui Li, Hsin Wang and Albert J. Shih., "Experimental and Numerical Analysis of the Friction Drilling Process", Journal of Manufacturing Science and Engineering, 128(3), 2006, pp. 802-810.

[4] Scott F. Miller, Peter J. Blau and Albert J. Shih., "Tool wear in friction drilling", International Journal of Machine Tools & Manufacture, 47, 2007, pp. 1636–1645.

[5] S. Dehghan, M. I. S. Ismail, M. K. A. Ariffin, B. T. H. T. Baharudin, S. Sulaiman, "Numerical simulation on friction drilling of aluminum alloy", Mat.-wiss. u. Werkstofftech. 2017, 48, pp. 241–248.

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

[7] L.M. Alves, E.J. Dias, P.A.F. Martins, "Joining sheet panels to thin-walled tubular profiles by tube end forming", J. Clean. Prod., 19, 2011, pp. 712-719.

[8] O. Waldmann, "The Thermdrill® Method Solves an Old Problem", http:// thermdrill.com/threaded-bushing-flowing-drill-instead-of-rivet-nut/. (Accessed Dec. 2019).