

Effect of Pre-hole Diameter on Bushing Dimensions for Friction Drilling Process of A6063-T6 Aluminum Alloy

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Abstract: *Friction drilling is a non-conventional method for hole making in thin sheet metals. It depends on many parameters regarding the tool conical angle, process conditions and material parameters. In this work, the effect of process conditions and pre-drill diameter on temperature, drilling force, bushing height and bushing thickness of A6063-T6 aluminum alloy were studied. It was found that adding a pre-hole to the plate helps in obtaining uniform bushing thickness and reduces the heat and force required to perform the process.*

Keywords: *Friction drilling, bushing thickness, bushing height, pre-hole*

1. Introduction

Friction drilling is a non-conventional method for hole making in thin sheet metals. In this process, the frictional heat is generated when a rotating tool touches the surface of the sheet as shown in figure 1 (phase I). At (phase II), the heat softens the sheet material and the tool indents the sheet. During tool indentation, some soften material moves in the opposite direction of tool feeding direction and forms burr at the upper surface of the sheet (phase III). As the tool continues indentation, a bushing is formed at the lower surface of the sheet (phase IV) [1].

Friction drilling is a fast and clean process which provides strong and high quality joints in less production steps. No special machines or additional components are needed [2] so that it is cost effective and small investment process. Friction drilling is more suitable for ductile materials, but it can be used with composites [3], ST12 steel [4] and aluminum alloys. The friction drill consists of different regions as shown in figure 2. The center region (tool tip) is used to provide the material frictional heat and generally it is a (90°) angle. The conical region has sharper angle $(30^\circ-40^\circ)$ and generates more heat, it helps the tool to penetrate by progressively pushing the material sideward [5]. The cylindrical region is used to determine the final size of the bushing. The shoulder is used to trim the upwardly extruded material and the shank is used to hold the tool at the machine holder. The tool conical angle affects the bushing characteristics; decreasing tool conical angle increases the bushing height and decreases bushing wall thickness [6] while adding a flat surface to the tool tip reduces the torque and thrust force [7].

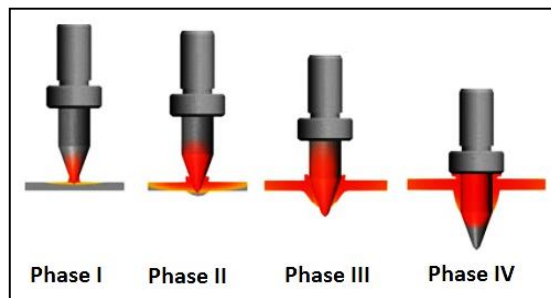


Figure 1: Different stages of friction drilling process

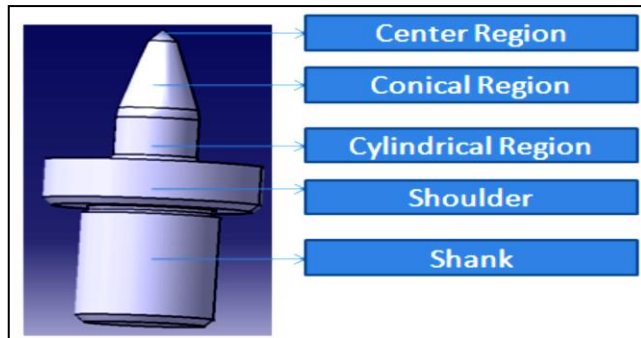


Figure 2: Geometry of Friction Drilling Tool

Friction drill can be made of HSS or other materials like sintered carbide [8], tungsten carbide with and without AlCrN and TiAlN coating [9] or sintered carbide coated with a thin TiN layer [10]. Tool wear in friction drilling is a concern because it affects the characteristics and tolerances that are achievable. It is promoted by the high temperature and forces generated in the process [11].

Friction drilling is affected by the process parameters, increasing the feed rate and material thickness increases the drilling force while increasing the tool speed decreases the force [12]. Increasing feed increases bushing dimensional errors and surface roughness [5]. Surface roughness decreases with increasing spindle speed and decreasing tool conical angle [13]. Zülküf Demir & Cebeli Özek [14] studied the effect of pre-drilling on the friction drilling of A7075-T651 aluminum alloy. They found that with increasing pre-drilling diameter the temperature and surface roughness were decreases, the bushing shape and cylindricity were improved; cracks and petal formation were removed

There are few researches regarding the effect of pre-drilling on the friction drilling and the resulting bushing characteristics. The aim of this work is to study the effect of drilling regimes and pre-drill diameter on temperature, drilling force, bushing height and bushing thickness of A6063-T6 aluminum alloy.

2. Experimental work

The experimental work was performed on (A6063-T6 alloy) sheets of 1.44 mm thickness using a TX 32 CNC machine and a HSS tool whose dimensions are shown in figure 3. Three different conical angles were used ($\beta= 24^{\circ}$, 36° and 48°) which results in three conical region lengths ($h_n= 5.41$, 3.55 and 2.58 mm) respectively.

The other working parameters were: three different spindle speeds (750, 1250, and 1800 rpm), three different feed rates (30, 50, 80 mm/min) and five pre-hole diameters of (without pre-hole (0), 1, 1.5, 2, and 2.5 mm).

An infrared thermometer type (OmegetteOS542) was used to measure the tool surface temperature at a point which is located 5 mm above the surface of the specimen as shown in figure 4. The axial force was measured using a SEWHA load cell (1000kg capacity).

The wall thickness and height of formed bushing are measured with a dial caliper shown in figure 5.

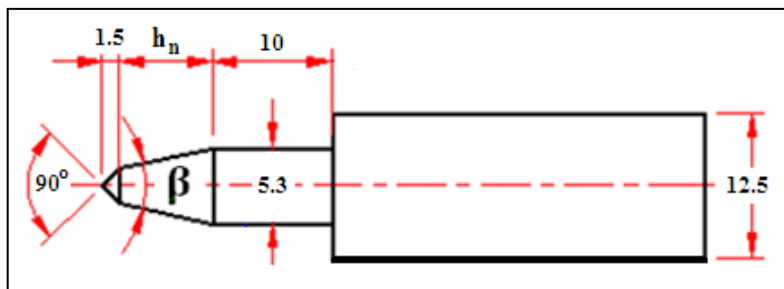
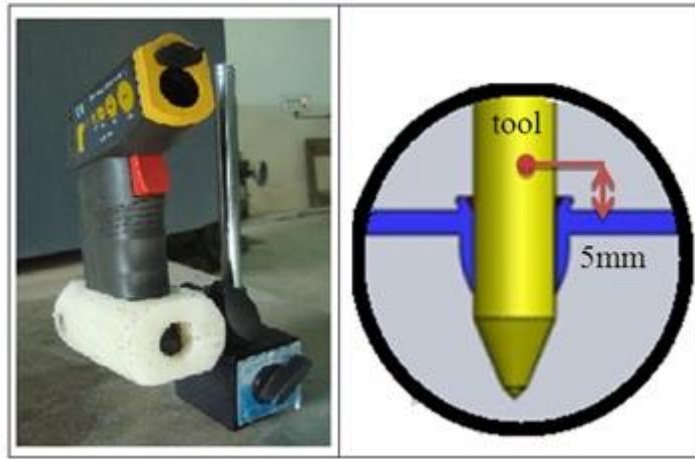


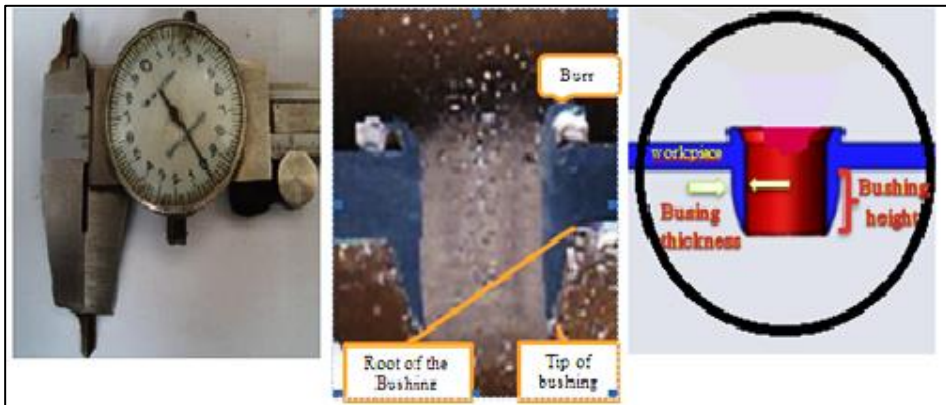
Figure 3: Tool with main dimensions



(a)

(b)

Figure 4: Temperature measurement (a) Thermometer fixing, (b) fixing positions



(a)

(b)

(c)

Figure 5: Bushing height and thickness measuring style, (a) 0-150 mm dial caliper, (b) bushing shape, (c) sketch of bushing.

3. Results and discussion

The effect of pre-hole diameter on temperature, thrust force, bushing thickness and bushing height at different tool conical angle are shown in figures (5 to 8) while figures (9 to 13) shows the

resulting bushing shapes at different working conditions and different pre-hole diameters.

3.1 Without pre-hole

Increasing the conical angle decreases the temperature due to the decrease in the tool side surfaces length and less contact surface area between tool and work-piece. More generated heat causes more softening of the sheet metal and in turn, a lower force is needed to perform the work.

At speed (1800 rpm) and feed rate (30mm/min), the bushing thickness is (0.46 to 0.55 mm) and the bushing height is (1.56 to 1.66 mm). Cracks and burr are formed on the bushing; this indicates for a waste of the available material in the form of burr and cracks. Increasing the feed rate to (50 mm/min) results in increasing both of temperature and axial force and this in turn results in forcing more soften metal to form the bushing. The bushing thickness is (0.58 to 0.62 mm) and the bushing height is (2.2 to 2.1 mm). Shorter cracks and burr are formed on the bushing which indicates an improvement in the usage of the available material volume. Increasing the feed rate to (80 mm/min) increases the temperature more and this result in forming long cracks on the bushing as shown in figure 6. The bushing thickness is (0.45 to 0.6 mm) and the bushing height is (1.36 to 1.86 mm), this indicates a shortage in the usage of the available material volume.

For lower spindle speed, insufficient frictional heat is generated and less softening of material, so that lower bushing height is obtained. At feed rate (50mm/min) and speed (1250 rpm), the bushing thickness is (0.55 to 0.6 mm), the bushing height is (2.1 to 2.3 mm). Decreasing the speed to (750 rpm) results again in loss in the available material volume, the bushing thickness is (0.55 to 0.6 mm), the bushing height is (1.4 to 1.6 mm).

It can be concluded that the working conditions of (conical angle 48° , speed 1800 rpm and feed rate 50 mm/min) gives the best result where the bushing thickness (0.61 mm), bushing height (2.1 mm).

3.2. With pre-hole

The same behavior as (without pre-hole) is obtained; increasing the conical angle decreases the temperature and increases the axial force. Increasing the spindle speed increases temperature. Both of temperature and force increase because of increasing the plastic deformation that results from increasing the feed rate. But in general the generated heat is less than (without pre-hole) case.

For (1mm) pre-hole diameter: at low feed rate (30mm/min), the soften metal has enough time to flow so that we can obtain long bushing (2 to 2.4 mm) and thickness of (0.55 to 0.58 mm). Increasing the feed rate to 50mm/min increases the thrust force which pushes more soften metal into the pre-hole and improves the resulting bushing thickness (0.6 to 0.63 mm). Increasing the feed rate to 80 mm/min increases the length of the cracks. Decreasing the rotational speed decreases the temperature and increases the thrust force and this in turn increases the crack length. The best result was obtained at spindle speed 1800rpm, feed rate 50mm/min and conical angle 48° where the bushing thickness (0.63 mm), bushing height (2.2 mm).

For (1.5 mm) pre-hole diameter, it can be noted that a uniform bushing thickness (0.6 mm) and almost uniform bushing height (2.36 to 2.4 mm) are obtained. The uniform bushing dimensions indicates a steady flow of the soften metal through the pre-hole and this results in less crack formation. The best result was obtained again at spindle speed 1800rpm, feed rate 50mm/min and conical angle 48° where the bushing thickness, bushing height are (0.6 mm, 2.4 mm) respectively.

For (2 mm) pre-hole diameter, the bushing thickness is uniform but the height is less and this is due to the less amount of available material to form the bushing. Finally, for (2.5 mm) pre-hole diameter, again the bushing thickness remains uniform but the bushing height decreases more because of less available material to form the bushing.

4. Conclusions

From the results, it can be concluded that:

- Increasing the conical angle decreases the temperature.
- Decreasing the spindle speed decreases the bushing height.
- Conical angle 48o, speed 1800 rpm, feed rate 50 mm/min and pre-hole diameter 1.5 mm gives the best result for bushing height and thickness.
- The generated heat in with pre-hole case is less than (without pre-hole) case.
- Uniform bushing thickness can be obtained when adding a pre-hole to the plate.



Figure 6: Bushing shape with crack

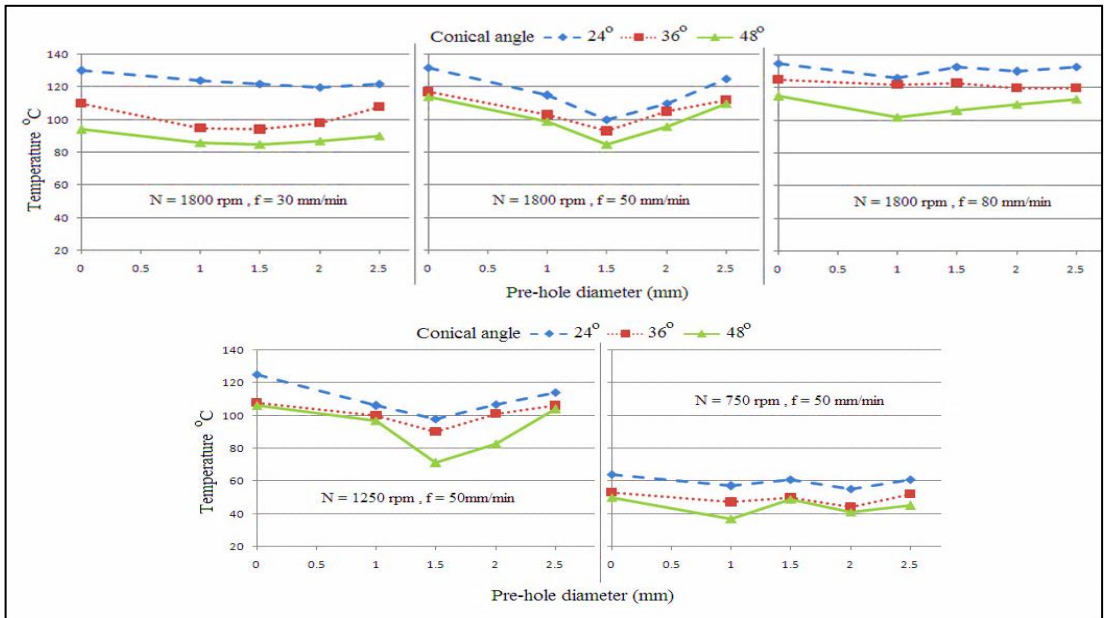


Figure 7: Effect of pre-hole diameter on temperature at different tool conical angle

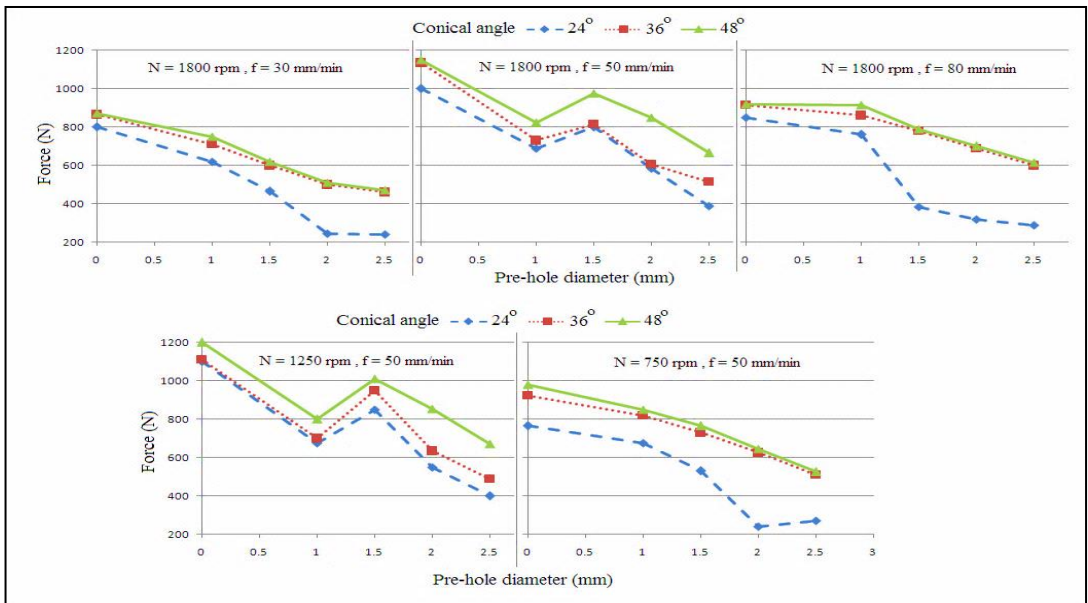


Figure 8: Effect of pre-hole diameter on thrust force at different tool conical angle

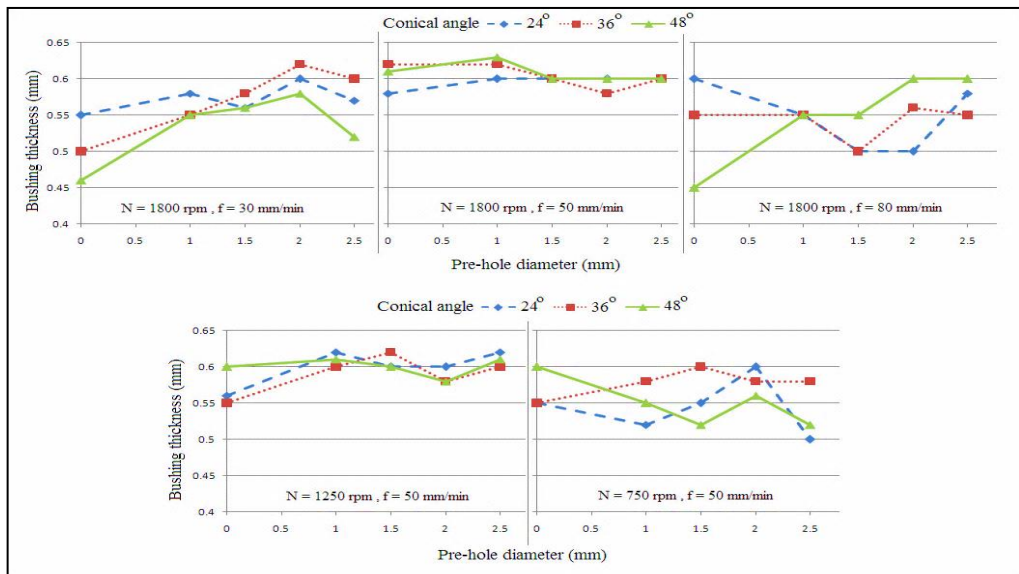


Figure 9: Effect of pre-hole diameter on bushing thickness at different tool conical angle

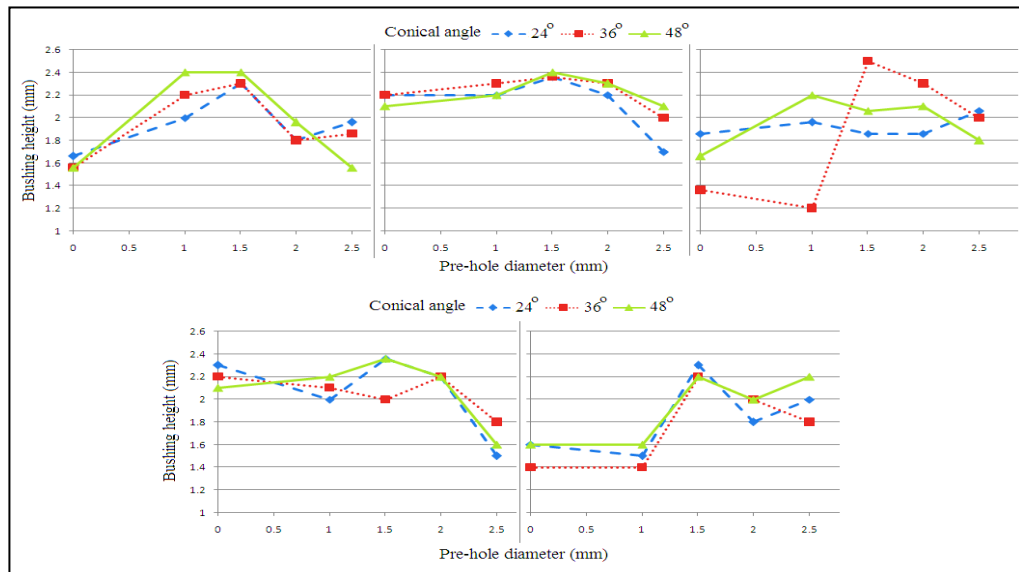


Figure 10: Effect of pre-hole diameter on bushing height at different tool conical angle

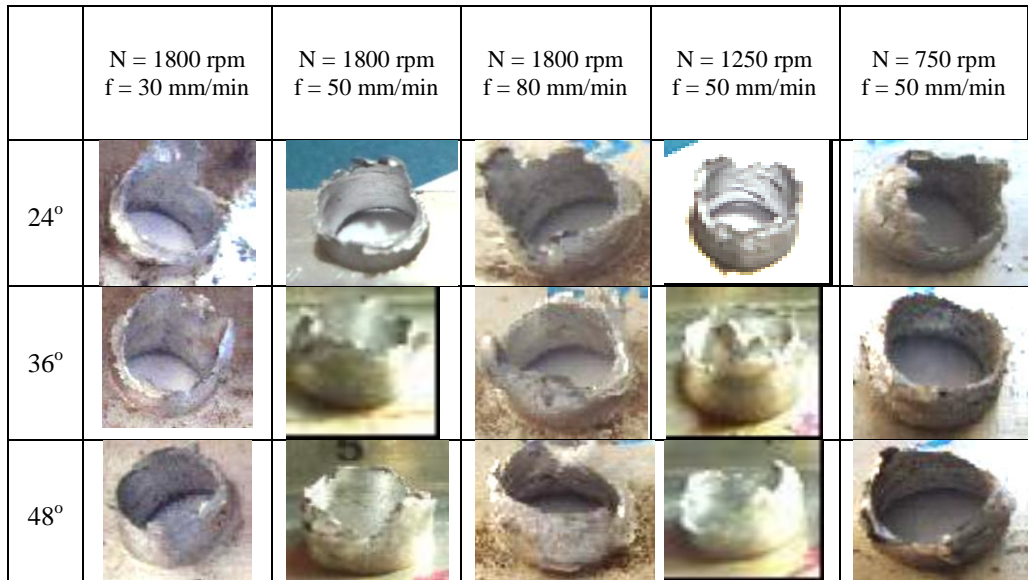


Figure 11: Bushing shapes at different working conditions (without pre-hole).

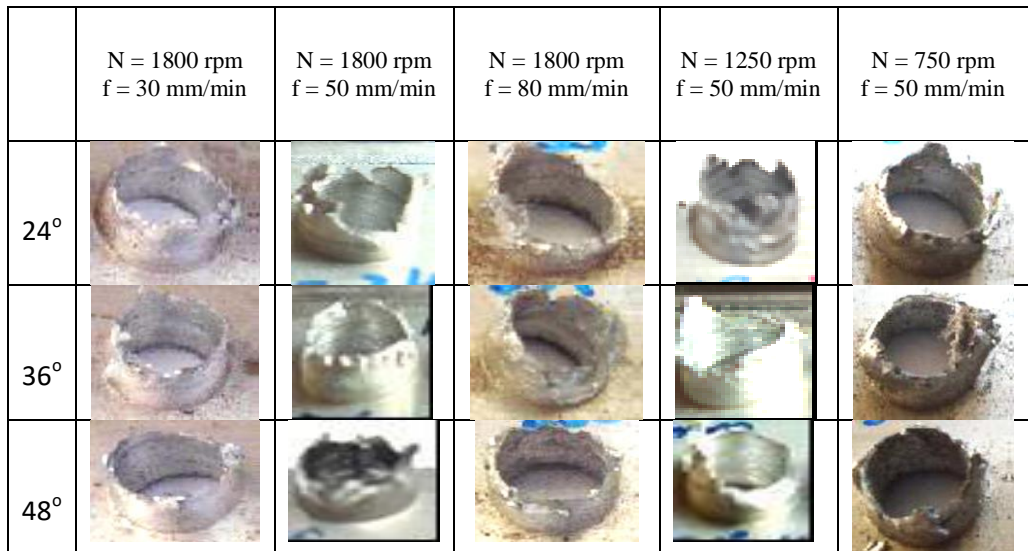


Figure 12: Bushing shapes at different working conditions (with 1mm diameter pre-hole).

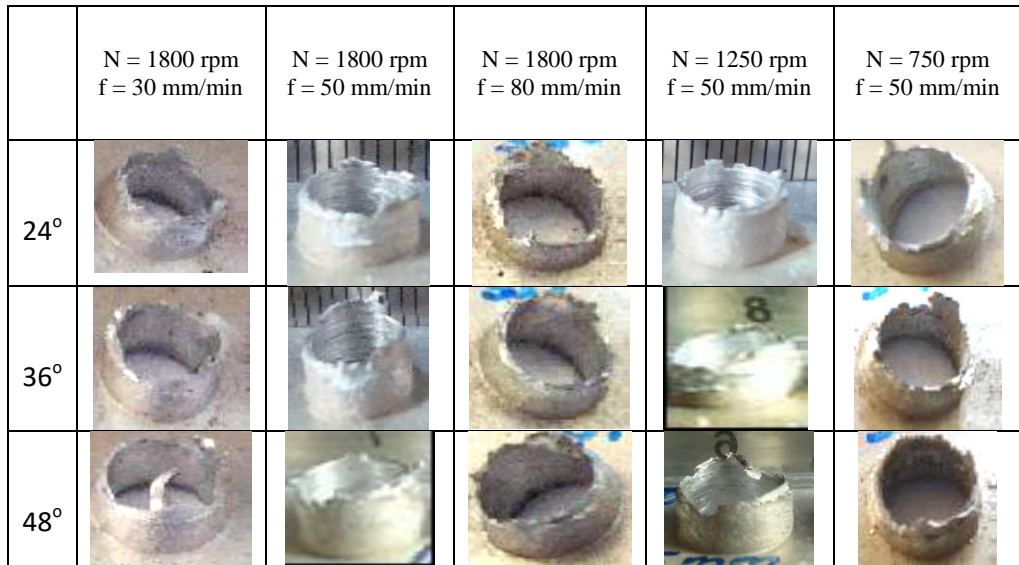


Figure 13: Bushing shapes at different working conditions (1.5mm diameter pre-hole).

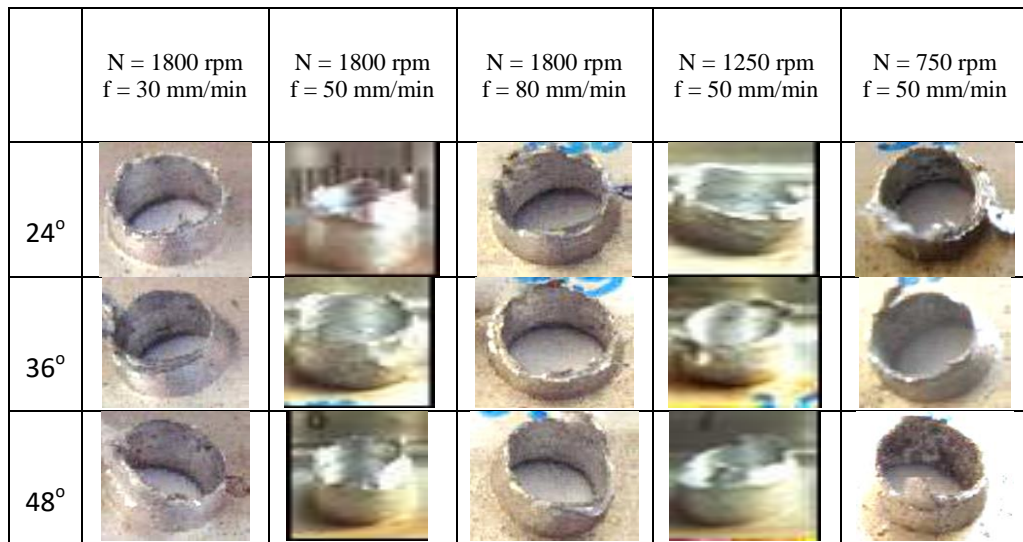
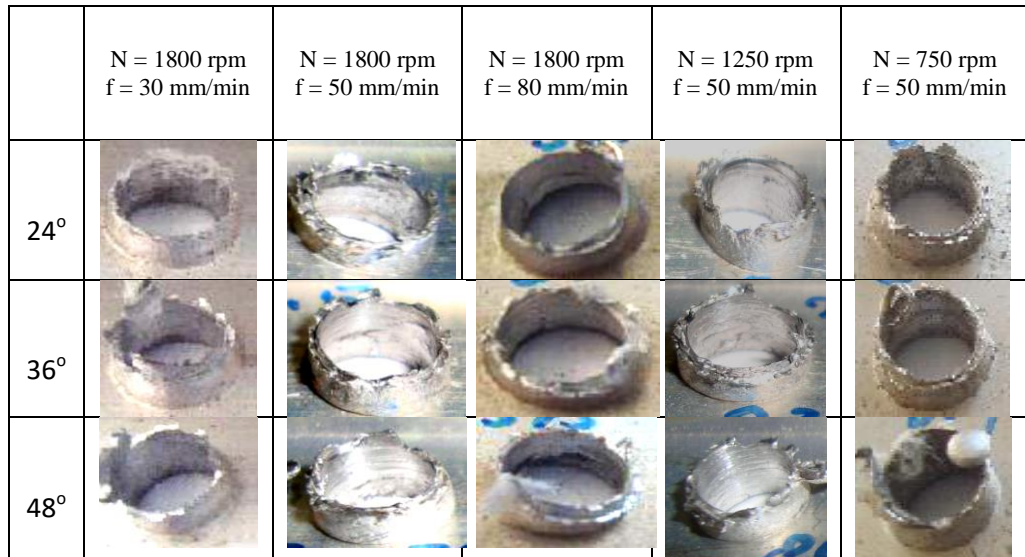


Figure 14: Bushing shapes at different working conditions (with 2mm diameter pre-hole).



**Figure 15: bushing shapes at different working conditions
(2.5mm diameter pre-hole).**

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تأثير قطر الثقب الاولي على ابعاد الجلبة في عملية التنقيب بالاحتكاك لسبيكة المنيوم A6063-T6

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المستخلص:

التنقيب بالاحتكاك طريقة غير تقليدية تستخدم لتشغيل الثقوب في الصفائح المعدنية الرقيقة. تعتمد هذه الطريقة على العديد من العوامل المتمثلة بزواوية المخروط للأداة، ظروف العملية ومواصفات المعدن. تم في هذا البحث دراسة تأثير ظروف العمل وقطر الثقب الاولي على درجة الحرارة، قوة التنقيب، ارتفاع وسمك الجلبة الناتجة عند تشغيل صفيحة المنيوم A6063-T6. وجد من نتائج الدراسة ان اضافة ثقب اولي للصفحة يساهم في الحصول على سمك جلبة متجانس مع تقليل كمية الحرارة الناتجة والقوة اللازمة لانجاز العملية.

الكلمات الرئيسية: تنقيب بالاحتكاك، سمك الجلبة، ارتفاع الجلبة، ثقب اولي.