Investigate the Surface Roughness and Bushing Shape in Friction Drilling Of A7075-T651 and St 37 Steel

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Abstract* – Due to the beneficial of the bushing form, the connection length and clamping strength is increased in friction drilling of thin-walled cast materials. In this experimental study 2400, 3600, and 4800 rpm spindle speeds, 50, 75, and 100 mm/min feed rates, 24^0, 36^0, and 48^0 tool conical angles were selected. 2, 4, and 6 mm thicknesses of A7075-T651 aluminium alloys and St 37 steel materials were drilled with using 10 mm diameter HSS (High Speed Steel) and WC (Tungsten Carbide) rotating conical tools which have 16 mm cylindrical region length. I was analysed the surface roughness, bushing height and bushing sheet thickness according to the spindle speed, feed rate, tool conical angle, workpiece material thickness, both workpiece and tool material types parameters. Consequently it was discovered that in friction drilling of 2 mm thickness A7075-T651 aluminium alloy, the bushing was formed as petal shape, which limited providing connection length and clamping strength owing to the brittleness of the material. In friction drilling of brittle materials, there were a lot of cracks generated on the bushing shape. The minimum surface roughness values were obtained at 3600 rpm spindle speed and 75 mm/min feed rate conditions friction drilling of St 37 steel material. The surface roughness values of A7075-T651 aluminium alloys were higher than St 37 steel materials. In conditions decreasing the spindle speeds, tool conical angles, and increasing feed rates, the bushing height was increased and bushing wall thickness was decreased.

***Keywords* – Friction Drilling, Surface Roughness, Bushing Height, Bushing Sheet Thickness**

1. Introduction

Friction drilling is a non-traditional hole drilling method that owing to a beneficial of the heat which generated as a result of friction between a rotating conical tool and the workpiece material. Generally friction drilling is applied to thin-walled materials owing to increasing connection length and clamping strength. The generated frictional heat cause to softening workpiece material, increase its ductility and providing it to flow, which extruded on to both the front and back sides of the holes. The process is clean and chipless, which called flow drilling, form drilling and friction stir drilling [1-3].

The most important goal of the bushing is increased the thickness for threading and available clamp load. Friction drilling is suitable apply to ductile materials. The petals and cracks formations are generated at the bushing which obtained at the end of friction drilling of brittle cast metals. Petal formation generates a bushing with limited load capability for thread fastening. The difference in brittle and ductile workpiece can be seen as the brittle work-material does not form a bushing with desired shape and ductile work-material has a smooth cylindrical bushing with sufficient length. The ratio of workpiece thickness, t, to diameter, d, is important parameter for bushing shape and bushing height in friction drilling. A high t/d ratio is provided larger portion of material to contribute the bushing form [4,5].

The bushing shape, the cylindricality, petal formation, bushing wall thickness, and surface roughness are made to judge the friction drilled hole quality. The ductility of workpiece material, which is extruded onto both the front and back sides of the material drilled, increases due to the frictional heat. The length the threaded section of the hole can increases about three to four times because of the added height of the bushing shape [6, 7]. The bushing shape is to increase thickness to threading and available clamp load. The bushing height, which generated as a result of friction drilling processes, is approximately two to three times of material thickness [8]. At high spindle speeds the shape of bushing is destroyed, nonetheless increasing spindle speed does not affect bushing generation [9].

Slow feed rates are caused to material melting temperature, which have different cooling speeds. The upper material layer is cool down faster than the lower material layer. Thus the drill tool adhere the metal chip, and obtain a bad hole surface quality [8]. The surface roughness values decrease with increasing spindle speed, nevertheless it increases with increasing feed rates. At higher feed rates and lower tool conical angles owing to the barely adequate temperature, which represents into the contact area between conical tool and workpiece material, the flow material is plastered to the hole surface and it causes to increase surface roughness values [10, 11].

The aim of this experimental study is investigated the friction drilling of both A7075-T651 aluminium alloy and St 37steel materials using HSS and WC rotating conical tools of which cylindrical diameter is 10 mm. It was analysed of bushing shape, bushing sheet thickness and surface roughness of drilled holes. Both bushing height and bushing sheet thickness were quite limited studied issues, despite the fact that these parameters represented the most important goal of friction drilling method. It found out the effect of spindle speed, feed rate, and tool conical angle, workpiece material thickness, and type, tool material type over the hole surface roughness, bushing height and bushing sheet thickness.

2. Nomenclature

d: Hole diameter (mm)

$ØD_1$: Tool shoulder diameter (mm)

ØD: Tool shank diameter (mm)

t: Material thickness (mm)

h_a: Bushing height (mm)

n: Spindle speed (rpm)

f: Feed rate (mm/min)

L: Tool handle region (mm)

T: Tool shoulder region (mm)

h_l: The length of the tool cylindrical region (mm)

h_n: The length of the tool conical region (mm)

h_c: The length of the tool tip region (mm)

β: Tool conical angle (^{o})

α: Tool tip angle (^{o})

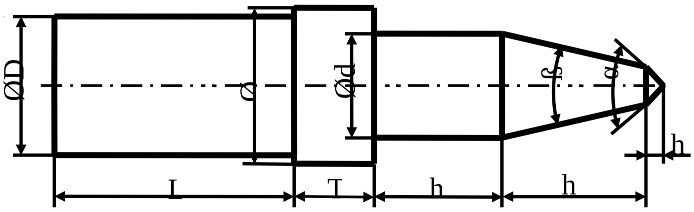
HSS: High Speed Steel

WC: Tungsten Carbide

3. Experimental setup and procedure

A HESSAP True – Trace C – 360/3D 1095 Model copy milling machine was used for friction drilling experiments of A7075 – T651aluminium alloy and St 37 steel materials. Overview of the setup in HESSAP True – Trace C – 360/3D 1095 Model copy milling machine was shown in Fig. 1. The tool was held by a standard tool holder. The diameter of the was 10 mm which used in this study, tool cylindrical height was 16 mm, the tool tip angle was 90^0, tool conical angles were 24^0, 36^0, and 48^0. The tool materials were HSS and WC shown in Fig. 2.b and c. The selected spindle speeds were 2400, 3600, and 4800 rpm, feed rates 50, 75, and 100 mm/min respectively. 2, 4, and 6mm thicknesses A7075-T651 aluminium alloys and St 37 steel materials were selected. Surface roughness values were measured by using Hobson Surtronik 3+ Surface Roughness apparatus at 0.25cm dimension.

Figure 1: Experimental setup with tool, and workpiece.



(a)

(b)

(c)

Figure 2: Friction drilling tool key dimensions (a), HSS tool image (b), and WC tool image (c)

The mechanical and thermal properties of the aluminium spaces which were used in this experimental study were denoted on Table 1.

Workpiece Material Mechanical Properties	Material Type and Thickness (mm)				
	A7075 –T6 (2mm)	A7075 –T6 (4mm)	A7075–T651 (6mm)	St 37 (2mm)	St 37 (4 ve 6mm)
Yield Strenght (N/mm^2)	567	580	605	235	
Tensile Strenght (N/mm^2)	490	505	550	340	
Shear Strenght (N/mm^2)	331			370	
Hardness	150 HB, 53.50 HRA, 175 HV, Mikro Sertliği 191			320 HB	
Elongation (%)	13.4	11.7	10.5	21	26
Modulus of Elasticity (kN/mm^2)	71.7			210	
Poisson Rate	0.33			0.3	0.3
Thermal Conductivity (W/m-K)	130			76	
Melting Temperature (^{0}C)	635			1530	
Density (kg/cm^3)	2.81			7,85	

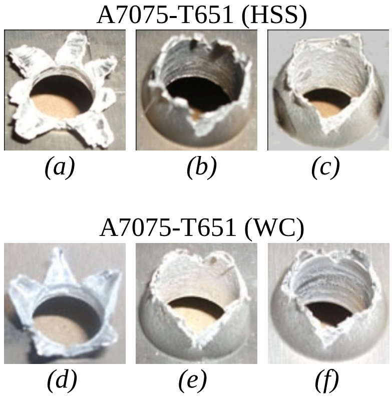
Table 1: The properties of experimental materials

4. Results and discussion

4.1. Bushing Shape

The bushing shapes, which were generated at the result of drilled aluminium alloys and St 37 steel materials were demonstrated in Fig. 3. The bushings, which symbolized a-l were generated in friction drilling A7075-T651aluminium alloys at 2400rpm spindle speed and 75mm/min feed rate. In friction drilling of a-c bushings HSS tool, and for friction drilling of d-f bushings WC tool were used. The bushings, which symbolized g-ı were generated in friction drilling St 37 steel material by WC tool. The bushing heights were measured with a depth micrometer at four different positions, which was shown in Fig. 3.ı. as h_a, and take into considers the greater values. On Fig. 3. j, k, l, the bushing sheet thickness measure type was shown. j was drilled to A7075-T651 material using HSS tool, k was drilled to A7075-T651 material with WC tool, and l was drilled to St 37 material with WC tool. All of bushings on Fig. J, k, and l were drilled to 4 mm thicknesses of A7075-T651 and St 37 steel materials. Owing to the HSS tool working temperature is under 600^{0}C, the St 37 steel material could not frictional drilled with HSS tools.

A7075-T651 (HSS)



St 37 (WC)

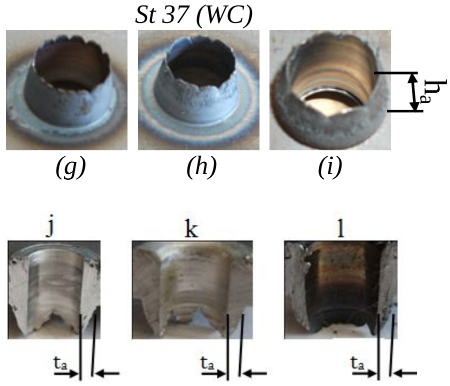


Figure 3: Bushing shapes pictures, (A7075-T651 a-f), (St37 g-ı), drilling tools, (a-c) HSS, (d-ı) WC, materials thicknesses (a, d, g: 2 mm), (b, e, h: 4 mm), (c, f, ı: 6 mm), Bushing sheet thickness (j: A7075-T651 material, HSS, t:4 mm), (k: A7075-T651 material, WC, t:4 mm), (l: St 37 material, WC, t:4 mm)

Owing to the lower t/d ratio there was barely adequate flow material, which providing bushing shape, in friction drilling 2 mm A7075-T651 aluminium alloy bushings were generated as petal (Fig. 3. a, d). With increasing the t/d ratio the bushings were shaped cylindrical, which include less cracks (Fig. 3. b, c, e, f). Because of the higher elongation percentage of St 37 steel material, the bushings were formed more cylindrically and greater bushings heights were obtained than A7075-T651 aluminium alloy in friction drilling. Nonetheless the bushing sheet thicknesses of St 37 were smaller than the A7075-T651 aluminium alloy. Bushing sheet thickness, due to the provided the threading strength, it was an important result in friction drilling. According to the tools, which were used in this experimental study, diameter (10 mm) it was threaded with M12. M12 threading teeth height is 1.07 mm. The more bushing sheet thickness was greater than 1.07 mm, the more threading strength was gained.

4.2. Surface Roughness

The friction heat was coming up with increasing spindle speed, decreasing feed rate and tool conical angle. At the lower feed rates the frictional heat stepping up owing to the high tool cycling at unit feed rate. The tool surface and workpiece material temperature was going up, with rising spindle speed, dropping of feed rate and tool conical angle, which is the most important parameters to effect the surface roughness.

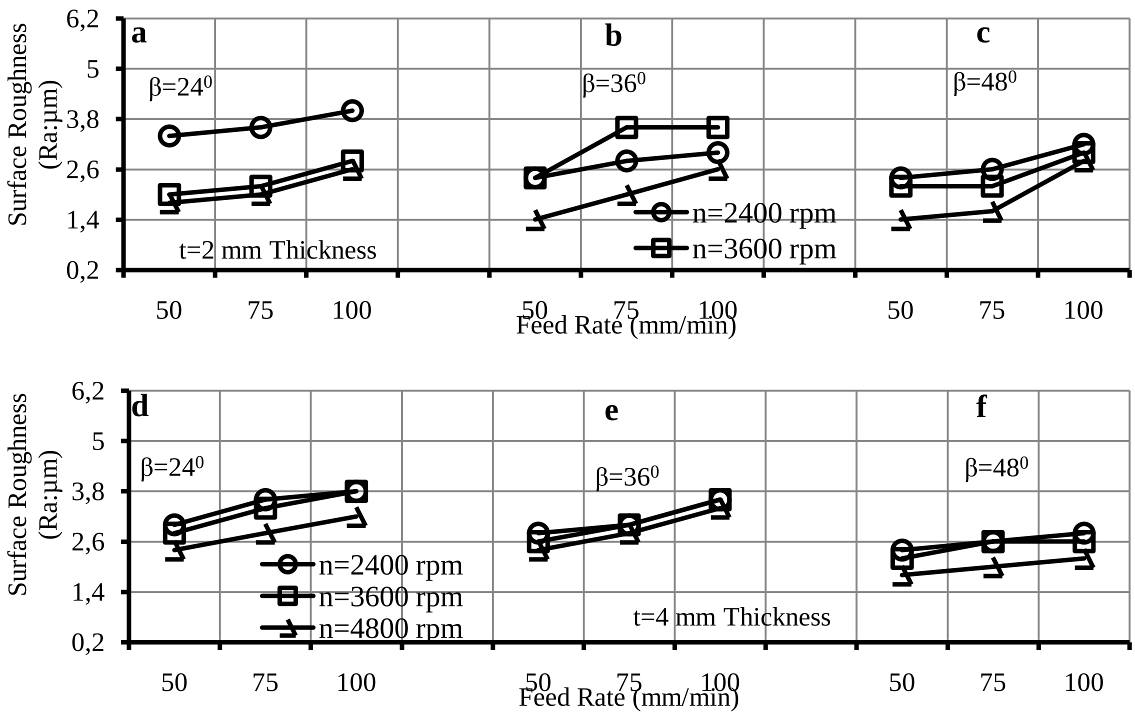
The impression of spindle speed, feed rate, tool conical angle, and workpiece material thickness on the surface roughness were demonstrated in Fig. 4 – 6.

In friction drilling of A7075-T651 aluminium alloy, in case using HSS tools, the surface roughness values were rising at elevated feed rates, owing to the barely adequate frictional heat which provided melting and softening workpiece material. In condition elevated spindle speed, because of enough frictional heat originated between tool surface and workpiece material contact area, therefore workpiece material sufficiently melting, softening and flowing, finally surface roughness values were dropped off and surface quality was developed.

The optimum surface roughness values were obtained as 0.6 µm in friction drilling conditions that selected at 50 mm/min feed rate, 4800 rpm spindle speed, 6 mm workpiece thickness, and 48^0 tool conical angle.

In friction drilling of A7075-T651 aluminium alloy with WC tools the optimum surface roughness values were achieved at 2400 rpm for 50 mm/min and 24^0, 3600 rpm for 75 mm/min and 36^0, 4800 rpm spindle speed for 100 mm/min feed rate and 48^0 tool conical angle.

The materials, which observe the lower elongation percentage properties, are more appropriate for friction drilling operations. Owing to elongation percentage of St 37steel material is lower thatn A7075-T651 aluminium alloy the surface roughness values of St 37 steel material were more nominal than A7075-T651 aluminium alloy. The lower measured surface roughness values were gained as 0.2 µm at 3600 rpm spindle speed, 75 mm/min feed rate and 36^0 tool conical angle conditions, in friction drilling of St 37 steel material with WC tool.



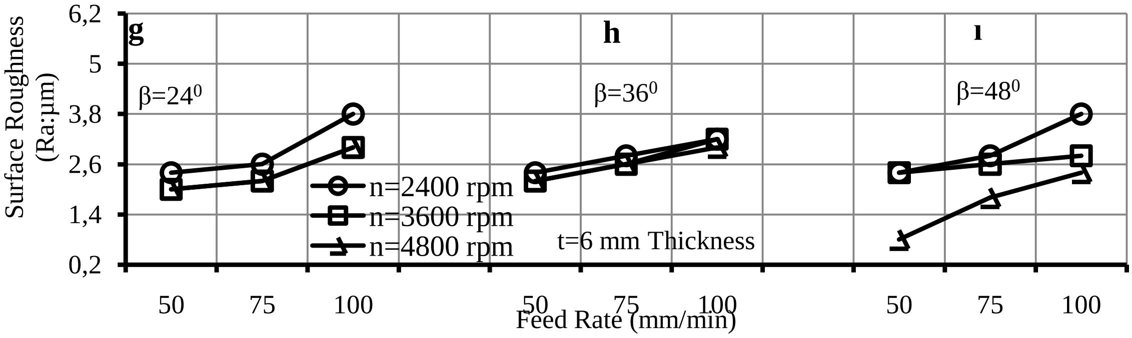


Figure 4. Investigate the surface roughness in friction drilling of A7075-T651 with HSS tool

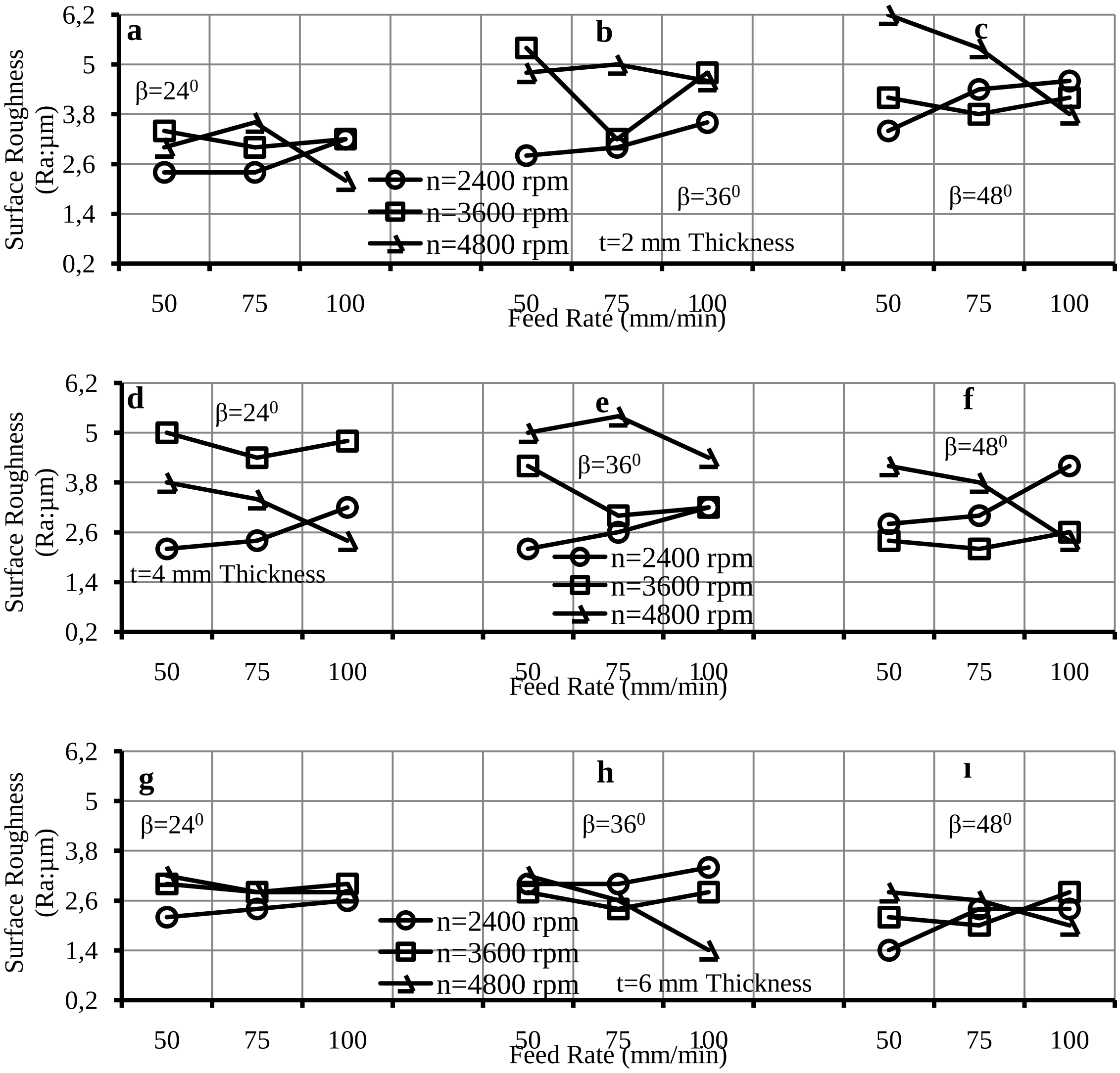


Figure 5. Investigate the surface roughness in friction drilling of A7075-T651 with WC tool

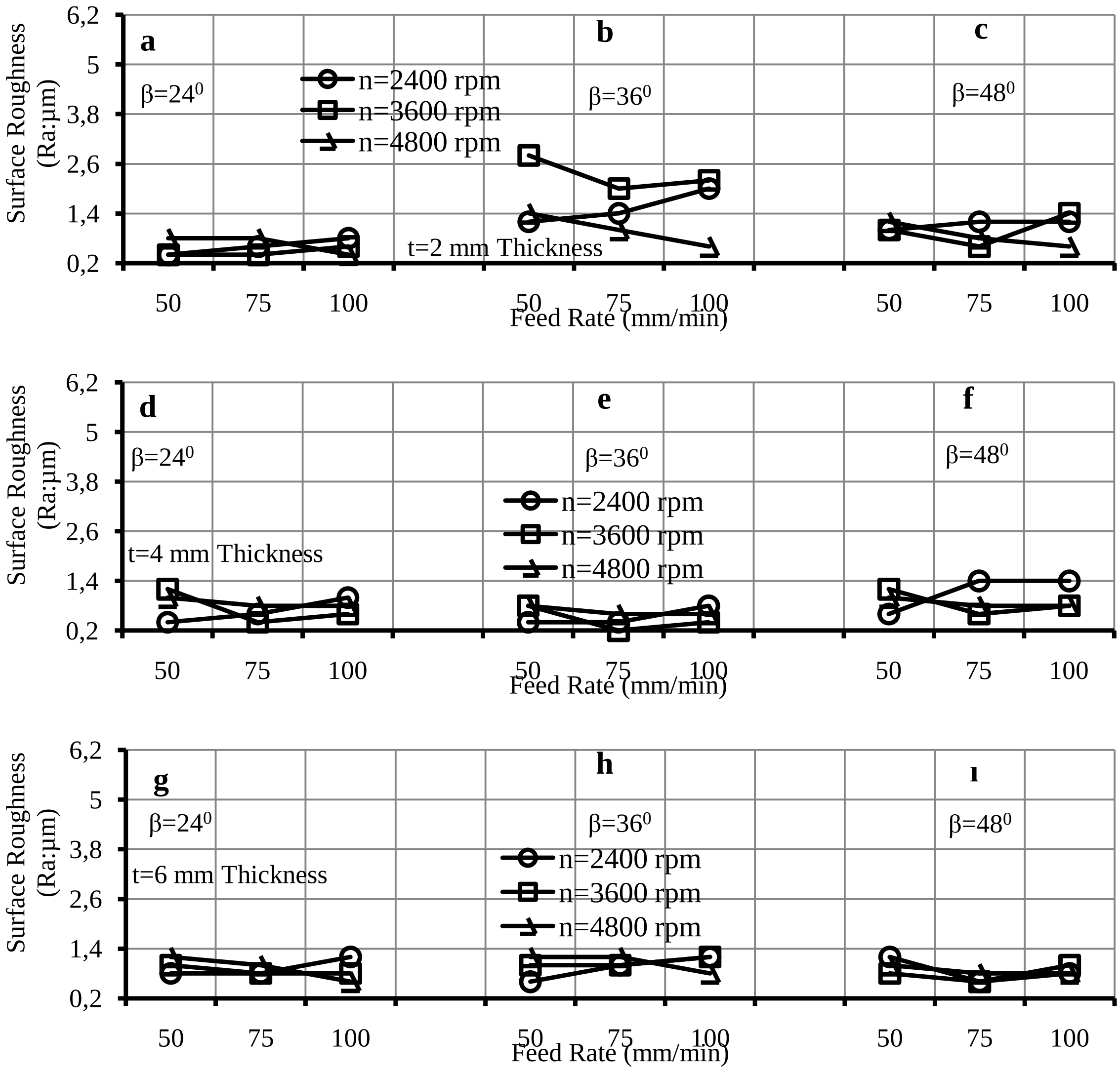


Figure 6. Investigate the surface roughness in friction drilling of St 37 with WC tool

4.3. Bushing Height

In friction drilling conditions that at higher feed rates and tool conical angles, because of gaining barely adequate frictional heat, insufficient ductility and softening resulting in inappropriate bushing formation. With stepping up spindle speeds, owing to the higher momentum impression, bushing height was dropped off. The materials, which have lower elongation percentage, were observed the high fracture and petal formation. Bushing height was increased orderly with stepping up feed rate, owing to softened material was pushed in direction of the tool motion.

The effect of the spindle speed, feed rate, tool conical angle, and workpiece thickness were shown in Fig. 7-9. In friction drilling of A7075-T651 aluminium alloy with HSS tools, it was seen that the greater bushing height was gained at 2400 rpm spindle speed, 50 mm/min feed rate and 24^0 tool conical angle. It was higher at 3600 rpm spindle speed, 75 mm/min feed rate and 36^0 tool conical angle. In friction drilling of St 37 steel material, the bigger bushing height values were obtained at 75 and 100 mm/min feed rates, 3600 and 4800 rpm spindle speeds. The bushing height values, which were gained in friction drilling of St 37 steel material, were greater than A7075-T651 aluminium alloy, due to the lower elongation percentage of St 37 steel material.

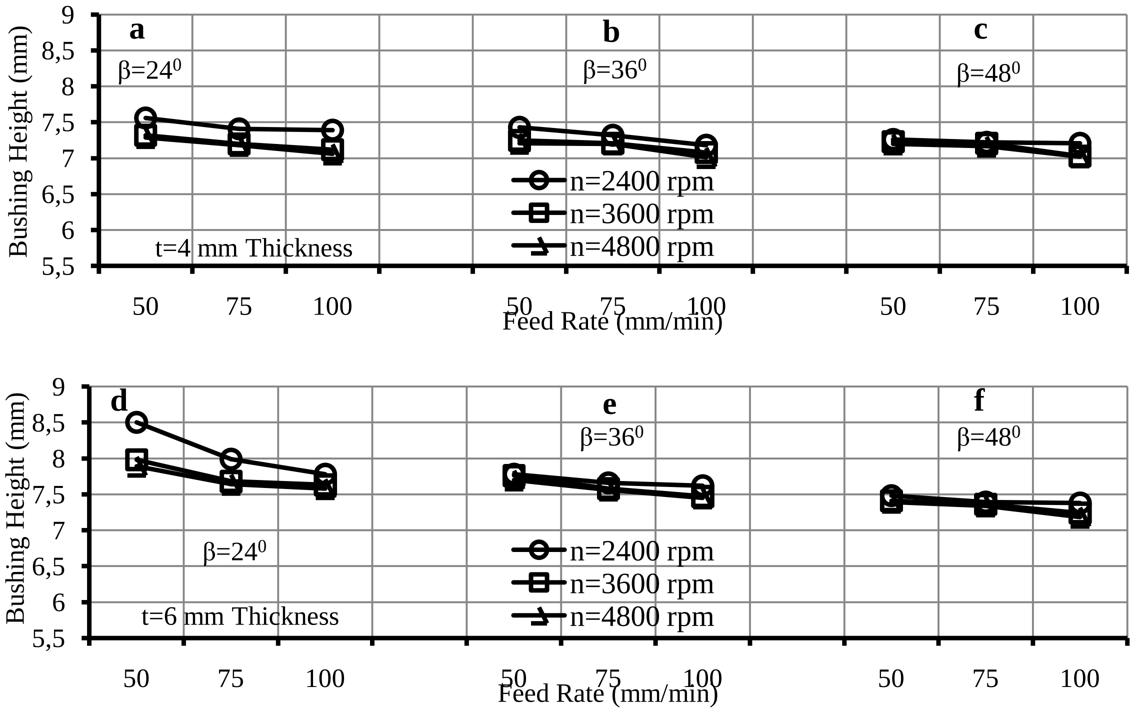


Figure 7. Investigate the bushing height in friction drilling of A7075-T651 with HSS tool

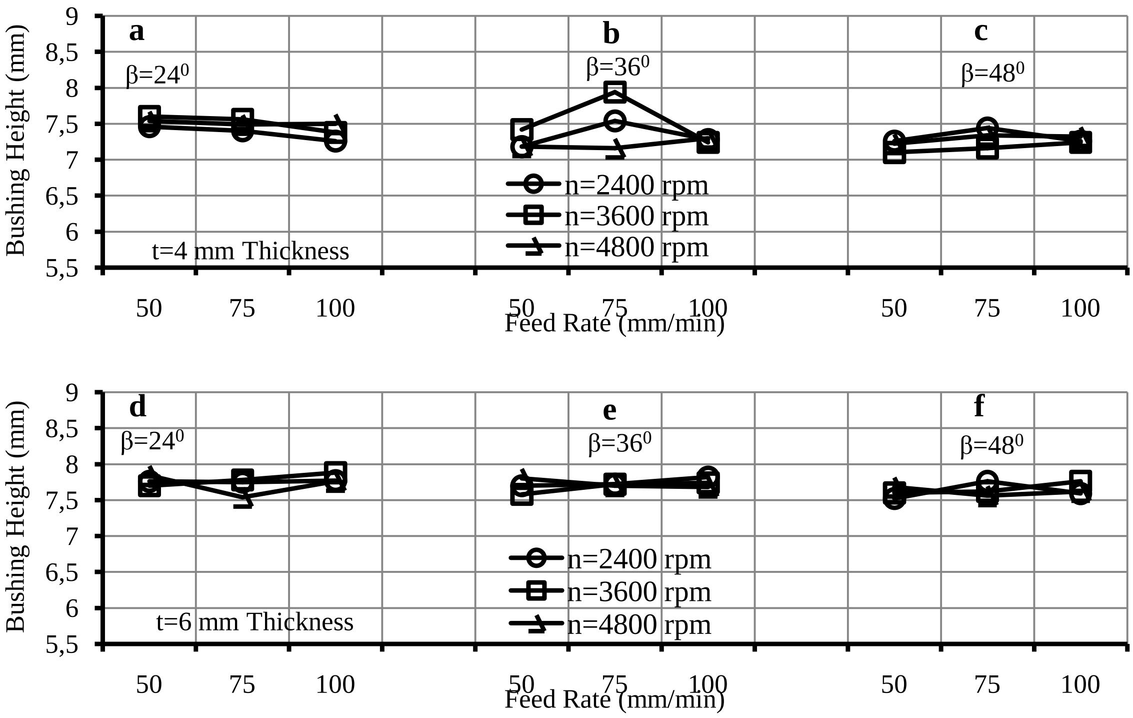


Figure 8. Investigate the bushing height in friction drilling of A7075-T651 with WC tool

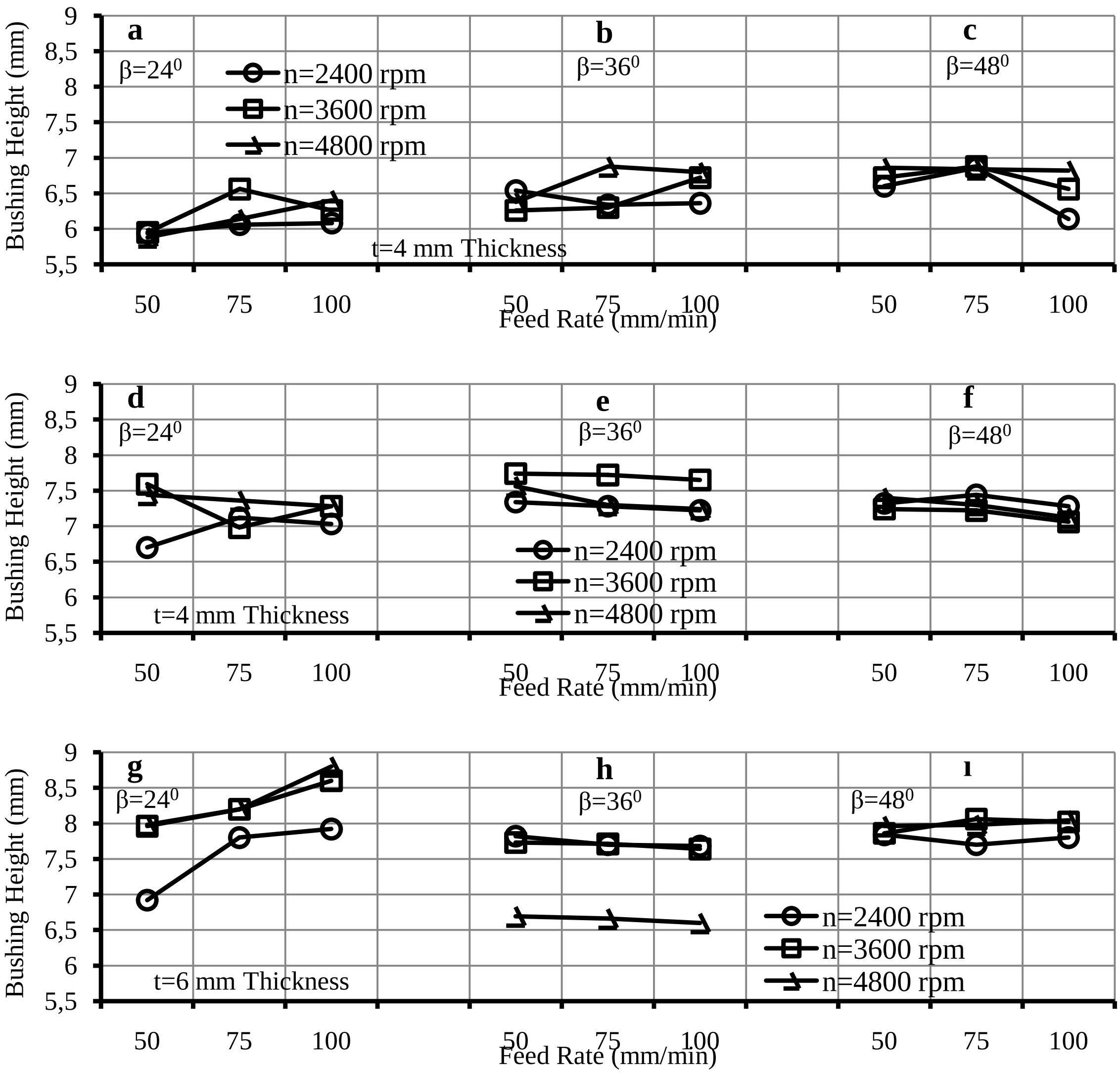
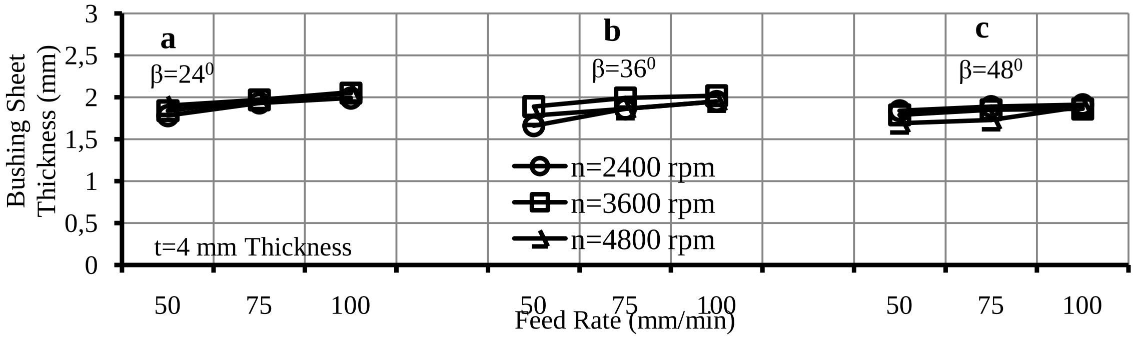


Figure 9. Investigate the bushing height in friction drilling of St 37 with WC tool

4.4. Bushing Sheet Thickness

The bushing sheet thickness was dropped off with raising the spindle speed, because of coming into existence the higher momentum impression. It was also stepped up at lower feed rates and higher tool conical angles, owing to insufficient frictional heat.

The effects of spindle speed, feed rate, tool conical angle and workpiece thickness on the bushing sheet thickness were seen in Fig. 10-12. In friction drilling of A7075-T651 aluminium alloy the bigger bushing sheet thicknesses were obtained at 4800 rpm spindle speed, 50 mm/min feed rate, and 48^0 tool conical angle.



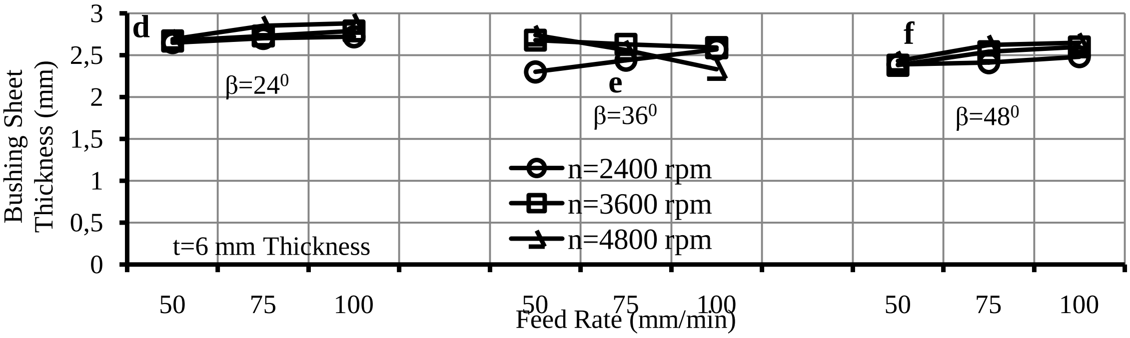
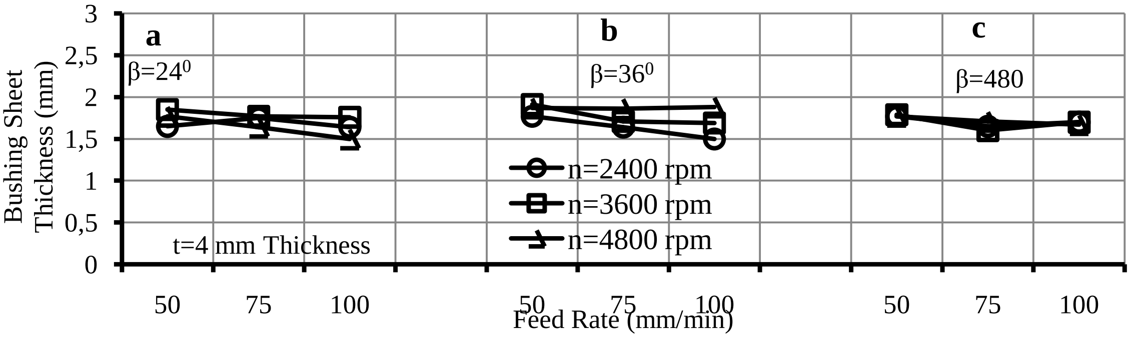


Figure 10. Investigate the bushing height in friction drilling of A7075-T651 with HSS tool



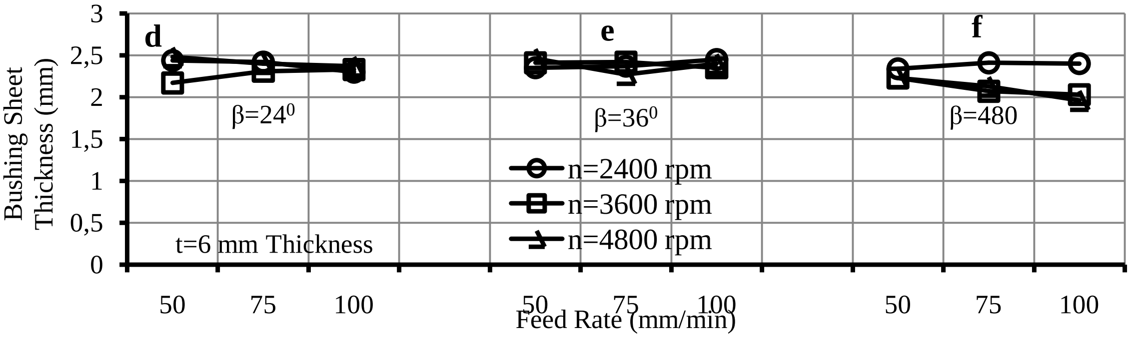
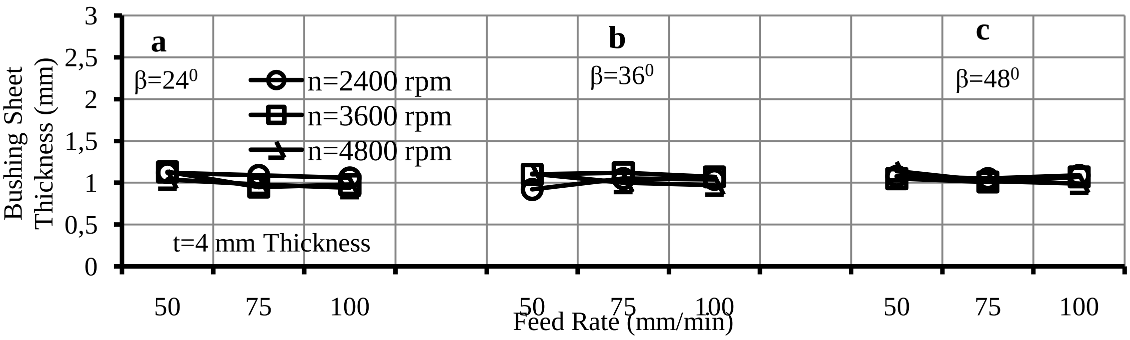


Figure 11. Investigate the bushing height in friction drilling of A7075-T651 with WC tool



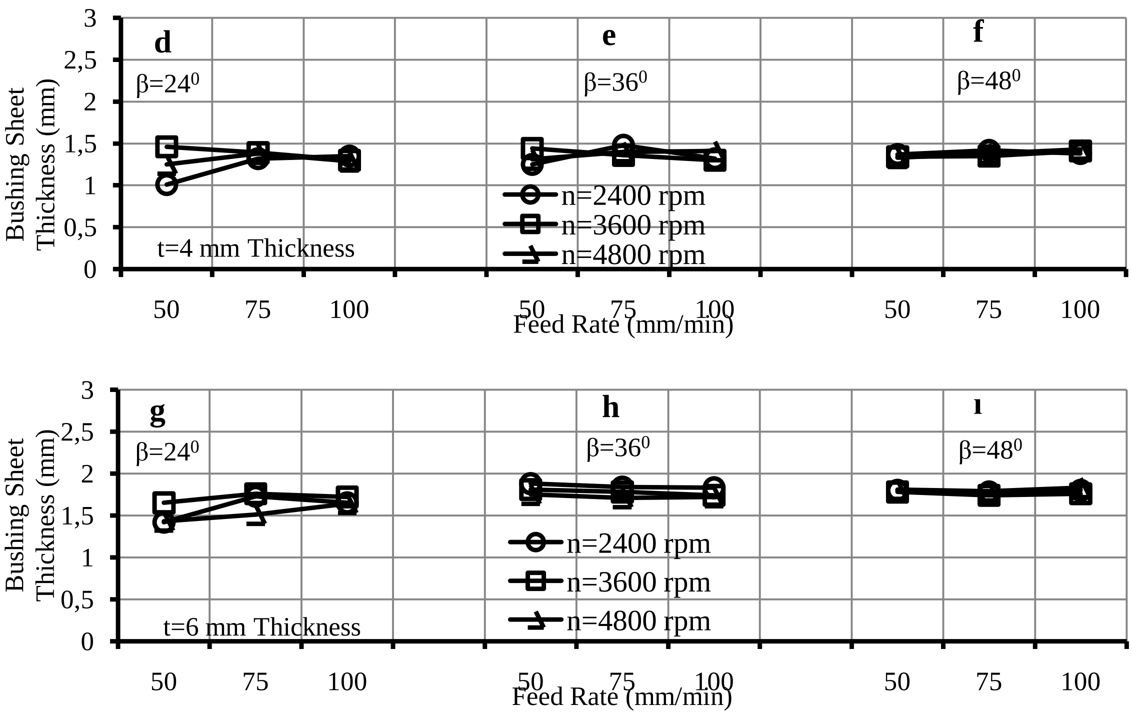


Figure 12. Investigate the bushing height in friction drilling of St 37 with WC tool

5. Conclusions

Surface roughness was dropped off with increasing spindle speed, decreasing both feed rate and tool conical angle.

At higher spindle speeds, the bushing height was decreased and bushing sheet thickness was increased, owing to the ascending momentum impression.

The bushing height was dropped off and the bushing sheet thickness was raised with increasing feed rate and tool conical angle.

Owing to the lower elongation percentage of St 37 steel material, the lower surface roughness values and bushing sheet thicknesses and greater bushing heights were gained. In friction drilling of St 37 steel material than A7075-T651 aluminium alloy.

The St 37 steel material could not friction drilled with using HSS tools, because of its thermal working temperature is lower than 600^0C.

Due to the lessen the rate of workpiece material, t, to the hole diameter, d, (t/d), in friction drilling of 2 mm thickness of A7075-T651 aluminium alloy, the bushings were formed as petal, which has cracks and fractures.

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