# Burnishing Effects on Friction Stir Welding of Al-Alloy 7075 T6

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## Abstract

Burnishing process is widely used to produce excellent surface finish, hardness and compressive residual stresses by plastically deforming the workpiece surface for the various types of materials such as steel, copper, brones, aluminum and thier alloys. Many works have studied the effect of burnishing on surface characteristics of different materials. In this work the optimum parameters of burnishing process on Friction Stir Welded joints of Aluminum 7075 T6 alloy are investigated by testing the effect of different burnishing parameters i.e. table speed, burnishing force, and transverse feed rate on Friction Stir Welded joints and study the mechanical behavior before and after burnishing process. It has been found that good surface finish is achieved at low burnishing speed and transverse stroke with burnishing force around 200 N, high micro-hardness and high bending strength can be obtained at low burnishing speeds and low transverse stroke, with high burnishing force where as a high tensile strength is obtained at high burnishing speeds due to directional deformation of grains and the orientation of residual stresses.

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***Index terms***— material properties, friction stir welding, burnishing of aluminum alloys, mechanical properties, burnishing parameters.

## 1 Introduction

riction Stir Welding (FSW) is a solid-state joining process used for applications where the original metal characteristics must remain unchanged as far as possible. This process is primarily used on aluminum and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics [1]. One of the key elements in the FSW process is the heat generated at interface between the tool and the work piece which is the driving force to make the FSW process successful. The heat flux must keep maximum temperature in the work piece high enough so that the material is sufficiently soften for the pin to stir but low enough so that the material dose not melts. The maximum temperature created by FSW process ranges from 80% to 90% of the melting temperature of the welding material as measured by Tang et al [2]. Welding of dissimilar metals leads to excessive wear of the rotating pin in a short duration.

The rotational speed has great effect on FSW, if the rotational speed is lower than the optimum value the pin wore out in a short time due to insufficient heat generation and insufficient plasticization of the laying surface, consequently a quarter of the weld interface may be welded, but if the rotational speed is faster than the optimum value pin rotation, oxidation may occur during the welding process; consequently the weld will be poor [3]. K. Kimapong and T. Watanabe, studied the FSW of Aluminum Alloy to Steel [4], they obtained the variation of the friction torque with both welding time and welding distance.

Burnishing is economically desirable, because it is simple and cheap process, requiring less time and skill to obtain a high-quality surface finish. There is an optimum burnishing speed, feed and burnishing force at which the best surface finish could be obtained, hardness, mechanical properties, fatigue life, and wear resistance [5]. At the begging of the plastic deformation zone the yield point is exceeded and cold flow takes place, after the material has been subjected to maximum compressive strain under the bottom of the ball it begins to elastically relive through the elastic recovery zone, finally exiting the area beneath the ball with a smooth surface and a significant value of compressive stresses [8]. In this study the Aluminum 7075 T6 alloy has been selected for the study because of its important use in several industries such as aircraft industry, the optimum parameters of burnishing process on FSW joints of Aluminum 7075 T6 alloy will be investigated by testing the effect of different burnishing parameters i.e. table speed, burnishing force, and feed rate on FSW joints and the mechanical behavior before and after burnishing process will be investigated.

# 2 II.

# 3 Method: Tools and Experiments

In order to study the effect of ball burnishing process on FSW joints, an experiment of 5 steps had been established.

? First weld 2 plates of aluminum using FSW.

? Then Mill the surface of the welded joint to improve the surface quality.

? After that the welded joint will be burnished.

? Test the surface roughness, hardness, tensile and bending tests before and after burnishing process and compare.

? Establish the optimum parameters of the burnishing process on friction stir welded joints.

AL 7075-T6 has been selected for this study because of its wide use in industry especially in aircrafts. Alloy 7075_sheet and plate have application throughout aircraft and aerospace structures where a combination of high strength with moderate toughness and corrosion resistance are required. Aircraft fittings, gears and shafts, fuse parts, meter shafts and gears missile parts, regulating valve parts, worm gears, keys, defense applications bike frames, all-terrain vehicle (ATV) sprockets [7].

To perform the tests, 40 specimens were prepared by cutting a sheet of 107 cm length, 112 cm width and 4 mm thickness to plates of 200 mm length and 100 mm width. The dimensions were selected to make it possible to carry put tensile and bending tests afterwards. The material chosen for the welding tool is alloy steel D2 due to its high hardness, wear resistance, and its excellent abrasion resistance, due to a large volume of carbides in the microstructure. The welding tool was cut from 25 mm diameter bar (D2) for length 45 mm then the tool was machined on lathe machine to the dimensions shown in figure 1. The diameter and length of pin was chosen closely to the thickness of plate. The shoulder diameter is taken around three times of the pin diameter. The hardness of tool material was 27 HRC as received. For welding process the hardness was increased to 50 HRC by heat treatment. The heat treatment conditions were austenite temperature of 1030°'C, holding time 37 min, and quenching media was oil, tempering temperature 500°C and tempering time 120 min. The hardness 50 HRC was necessary to resist the friction between the pin and shoulder with butted surface.

The specially designed simple burnishing tool is shown in Figure 2. the tool is composed of several elements, each has a particular function. The burnishing action is carried out with a steel bearing ball having an outside diameter of 18 mm which is fitted to the tool shank with the help of the holder. Two bolts are used for locating and positioning the holder. The holder and the ball are moved into the desired position by compressive spring. The spring constant (K =28016.86 N/m) [8]. The burnishing force used in this study are 150, 200, 250 N.

A Lagun FU1 100 vertical milling machine Figure 3. was used for friction stir welding, surface milling, and burnishing processes. In this machine the main motion is provided to the tool (CW rotary motion), while the feed motion is provided to the table (liner motion). Rotational speed range is (35-800 rpm), and the feed range is (10-660 mm/min).

# 4 Results and Discussions

The forty specimens were welded by FSW process resulting in 20 welded specimens, two of which were kept for comparison, and the other 18 specimens were subjected to burnishing under different conditions.

Friction stirs welding Process Parameters, tool rotation speed 700 rpm; and table speed is 40 mm\min. the burnishing process parameters are Burnishing Force N, Table Speed mm/min, and Transverse Feed, mm/stock. a) Roughness Test Surface roughness values (Ra) were measured before and after burnishing process, the Ra value of the unburnished surface was measured to be 1.55 ?m. Figure **??**. shows the effect of burnishing force on the surface roughness for low and high table speeds. It is clear from the figure that the surface roughness is much better under low table speeds and transverse strokes, both increasing the transverse stroke and table speed badly affect the surface roughness of the welded specimens. The optimum surface roughness was obtained around 200 N burnishing force, which should be related to the welding material properties.

# 5 b) Hardness Test

To observe the effect of the burnishing force, table speed and transverse stroke distance on the welding zone hardness, the hardness values before and after burnishing were measured. The microhardness values for the specimens before burnishing were almost the same and the mean value was calculated to be (77 HV) which is used as initial microhardness value. The hardness of the burnished specimens were measured under different conditions and the results are shown in figure 5. Figure 5. shows that the microhardness of the specimens increases with increasing the burnishing force due to the plastic deformation and strain hardening of the welding material, on the other hand the transverse stroke distance does not show any significant effect on the specimens which is expected as the burnishing force is constant and the table speed is fixed.

# 6 c) Bending Test

During the bending test the bending load (kN) against bending deflection (mm) was recorded on a chart, from which the yield bending load and deflection were determined. The same procedure was done for each test. This yield value was equivalent to 0.2% of total deflection. Figure 6. summarizes the results of bending stresses with respect to other burnishing parameters. The Figure **??** shows the effect of burnishing force on the bending stress, as expected the bending stresses increases as the burnishing force increases, this obviously improves the welding bending property. The table speed and the transverse stroke distance did not affect the bending stress in a clear way, more investigations are required to be able to judge about the effect of the table speed and transverse stroke distance. For tensile testing of the specimens, the specimens were prepared with the suitable dimensions, and subjected to the tensile force, during the tensile test tensile load and deformation were recorded, from these data the yield tensile corresponding elongation were determined. Figure 7. shows the effect of the burnishing force on the tensile stress. Once more figure 7. (a and b) show that the increase in burnishing force leads to an increase in the tensile stress.

IV.

# 7 Conclusions

The experimental results presented in this work generally reveal that the surface roughness, microhardness, bending and tensile stresses of aluminum alloy 7075-T6 joints were affected by the variation of the burnishing parameters i.e. transverse stroke, machine table speed, and the burnishing force. The surface roughness improved by reducing the peak to valley height. As the ball rolls on the surface of the FSW joint, the metal plastically deformed the surface hardness of the FSW joint is also increased by increasing burnishing force. Both tensile and bending strengths are increased as a result of the formation of residual compressive stresses due to the ball pressure applied to the work piece surface.

From the results obtained the optimum surface roughness was achieved at low burnishing speed (40 mm/min), medium burnishing force (200N) and low transverse stroke (0.25 mm/stroke). The high micro hardness, bending strength were achieved at low burnishing speed (40 mm/min), high burnishing force (250N) and low transverse stroke (0.25 mm/stroke). The high tensile strength was achieved at high burnishing speed (120 mm/min) and high burnishing force (250N), where the burnishing transverse stroke did show a significant affect on the tensile strength. [1] [2]

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Figure 1: Figure 1 :



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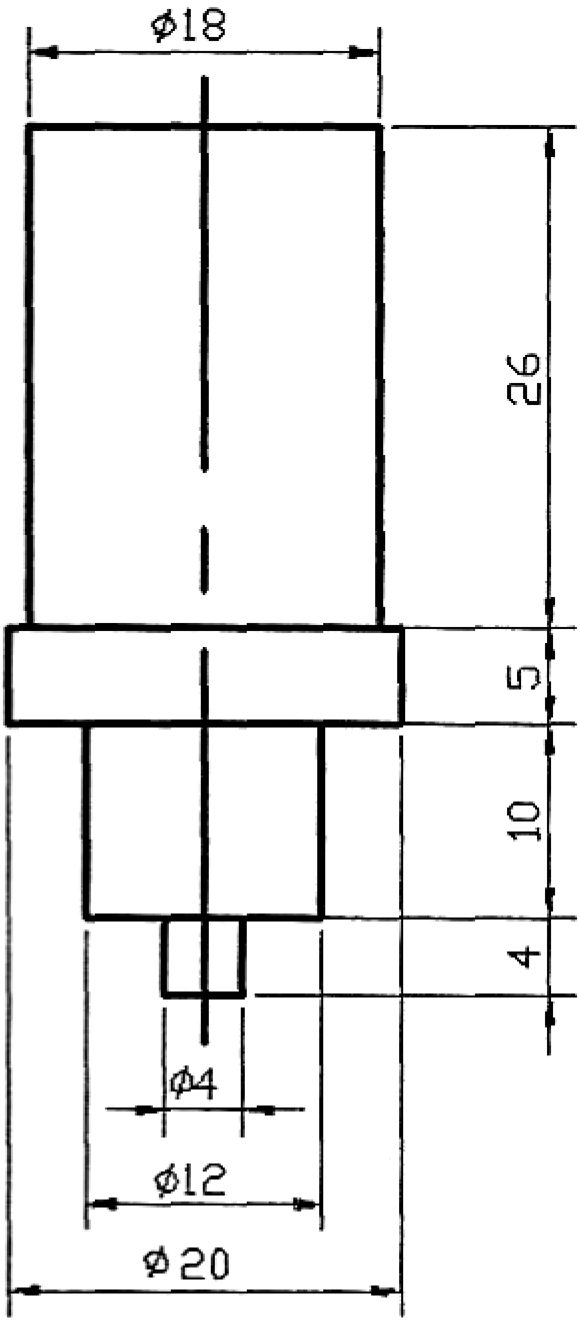


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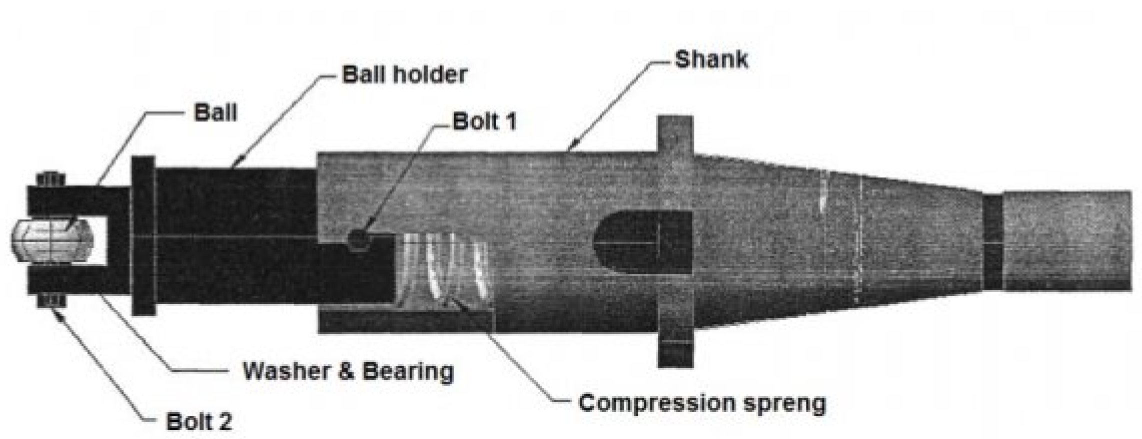
Figure 2: Figure 2 :




**3**

Figure 3: Figure 3 :


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Figure 4: Figure 4 :Figure 4 :

**1**

| | |
|---|---|
| Al 7075-T6 [7] | |
| Density | 2.81 g/cm 3 |
| Ultimate tensile strength | 572 MPa |
| Tensile yield strength | 503 MPa |
| Elongation at break | 11% at 1.6 mm thickness |
| Modulus of elasticity | 71.7 GPa |
| Shear modulus | 26.9 GPa |
| Poisson's ratio | 0.33 |
| Fatigue strength | 159 MPa |
| Machinability | 70% 0-100 scale of aluminum alloys |
| Shear strength | 331 MPa |
| Thermal conductivity | 130 W/m-K |
| Melting toint | 477-635 °C |

Figure 5: Table 1 :

**2**

| Comp. | C | Cr | Mg | P | S | V | Si | Mo |
|---|---|---|---|---|---|---|---|---|
| Wt% | 1.5% | 11.0-13.0% | 0.45% | 0.030% Max | 0.030% | 1.0% | 0.30% | 0.7° |

Figure 6: Table 2 :

**3**

| | | composition | | |
|---|---|---|---|---|
| component | C | Mn | Si | Cr |
| Wt% | 1.00% | 0.35% | 0.25% | 1.50% |

Figure 7: Table 3 :

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