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An Experimental Study on The Effect of Diameter and Rotational Speed on Mechanical Behavior of Aa6063-T6 Friction Welded Joints

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Abstract— Friction welding is a solid state welding process that generates heat through mechanical friction between wok pieces in a relative motion to one another with the addition of lateral force called "upset" to plastically displace and fuse the materials. The purpose of this work is to join and assess the development of solid state joints of similar AA6063T6 grade aluminum alloy materials and studying the effect of rotational speed and size effects on the mechanical behaviour of welded joints. Apart from being a very efficient heat source friction provides an effective cleaning action. Various foreign inclusions, surface oxides and absorbed films that oppose formation of bonds are destroyed & removed by abrasion produced by friction. Hence the bonding or welding is stronger. Finally it is concluded that the rotational speed and size of the material strongly influencing the mechanical properties of the welded joints.

Key words: Rotational Speed, Aa6063-T6 Friction Welded Joints

I. INTRODUCTION

"Friction Welding" (FW) is a group of solid-state welding processes using heat generated through mechanical friction between a moving work piece, with the addition of an upsetting force to plastically displace material. Frictional heat is developed at the interface until the material becomes plastic, at which time the rotation is stopped and the load is increased to consolidate the joint. A strong welded joint is formed by metallic bonds that arise between the contacting surfaces. The surface films and inclusions are broken up by friction and removed from the weld area, in radial direction, such that they don't interfere in the formation of bonds so that a marked plastic deformation takes place on the surface. Mechanical energy is directly converted into heat which is liberated on the rubbing surfaces and rapidly arise the metal to a temperature necessary to produce a welded joint. Briefly the friction-welding process consists in bringing into contact two elements to be welded while one of the two is static and the other is rotated rapidly on its axis. As the soon as the heat generated by attrition at the interface is sufficient for solid state welding without melting, the rotation is stopped and the elements are forced together under pressure producing local forging which concludes the intimate joining and also expels at the joint all surface contamination and some of the upset material called flash. In friction welding one component is rotated and one component is held stationary. The part that is rotated is brought into contact with the stationary component and when enough heat has been generated to bring the components to a plastic state and the desired burn-off has been achieved, rotation is stopped. More axial force is then applied between the two components resulting in a solid state bond at the interface forming a friction welded joint.

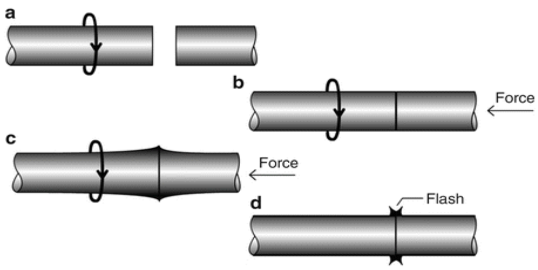

Fig. 1: Principle of Friction Welding

Friction welding can be applied by using one of the two methods depending on the source of mechanical energy[1-4]. With current advances, a combined welding method including both of the methods aforementioned has been developed. These are continuous driven friction welding, flywheel driven friction welding and a combination of the two.

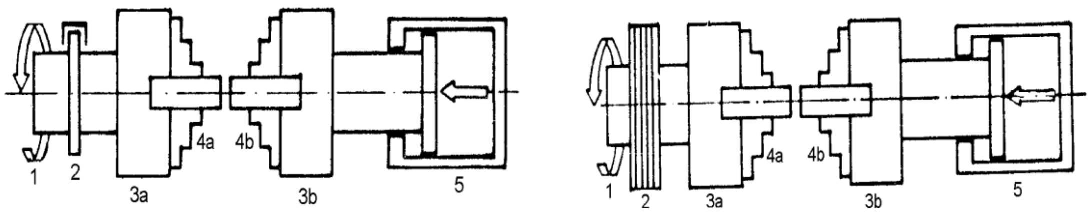

Fig. 2: Types of Friction Welding

Hybrid friction welding is a combination of aforementioned the two methods of friction welding. It has advantages in joining parts with high capacity. This method is also sometimes termed as flywheel induced friction welding. The essential welding parameters are rpm, friction force on the surface, the length of friction time, and forging time on the surface, forging time and time of brake. There are 5 important parameters which are useful in friction welding process they are forge pressure, forge time, friction time, friction pressure and upset time.

We are considering two conditions for friction welding of similar friction welding joints. One is single diameter at different diameters and second condition is single diameter at different rpms.

II. EXPERIMENTAL WORK

A. Materials

AA 6063 is an aluminum alloy, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminum Association. It has generally good mechanical properties and is heat treatable and weld able. It is similar to the British aluminum alloy is mostly used in extruded shapes for architecture, particularly window frames, door frames, roofs, and sign frames. It is typically produced with very smooth surfaces fit for anodizing.

1) Specimen Preparation

Preparing the specimen size from initial to required size is called specimen preparation. Material Al 6063T6 into long rods with the diameter of 24mm was cut into small pieces (90mm length) using hand axe by clamping the material into a bench vice. Small pieces were made into required diameters by using turning process on lathe machine. In specimen preparation turning, facing and step turning operations were used to prepare a specimen.

B. Friction Welding

Experimental studies included production of friction welded joints from Aluminum Alloy rods with various interface geometries. The basic frame work of the friction welding setup is a medium duty lathe. The present study utilized a continuous drive friction welding machine. In continuous drive friction welding one work piece is rotated at nominal constant speed in action alignment with the second part under an applied pressure. The rotation and pressure are maintained for the specific period to ensure adequate thermal and mechanical conditioning of the interface region. Thereafter, the rotation is stopped often with forced braking and at the same time pressure is increased to upset parts together [5-7].

Fig. 4: Facing and Turning Operations

The application of an axial force maintains intimate contact between the parts and causes plastic deformation of the material near the weld interface. Experiments performed with three different rpms and also joints were made on different diameter cylindrical rods.

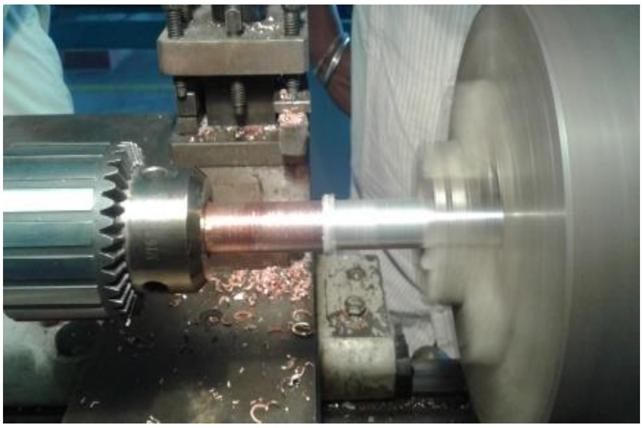

Fig. 5: Friction Welded Joint

III. RESULTS AND DISCUSSIONS

A. Micro Structure

Conducted the experiments on first condition i.e. single diameter (18mm diameter) at different rpms (1000, 646, and 270 rpms) to similar friction welded joints. We observed about grain size and microstructure of similar weld joints at 10X.At first condition Al-Al with 18mm diameter at 1000 rpm. there is a gap between the joints due to improper weld. Sample has grain size according to ASTM E112 the number is 5. The Fig 7 shows the the microstructure of Al-Al with 18mm diameter at 270 rpm, sample has grain size according to ASTM E112 the number is 5.5. From the microstructure there is no gap between the joints due to proper weld condition.

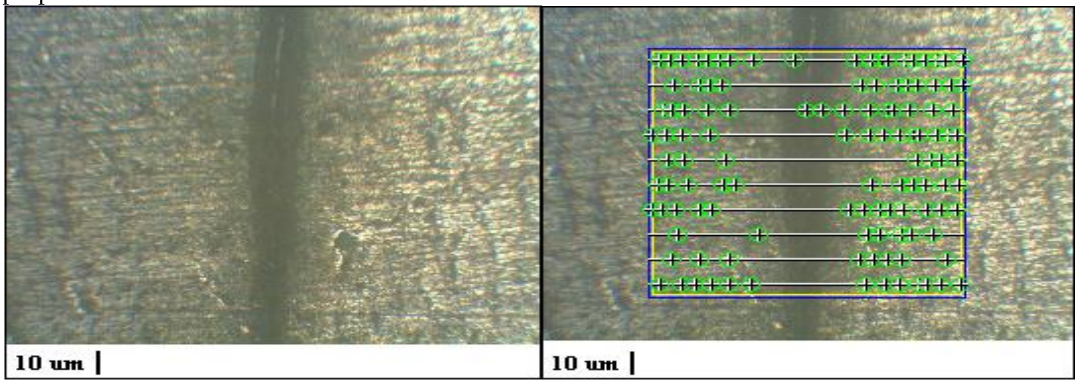

Fig. 6: Microstructure of Al to Al friction welded joint at 1000rpm with 18mm diameter.

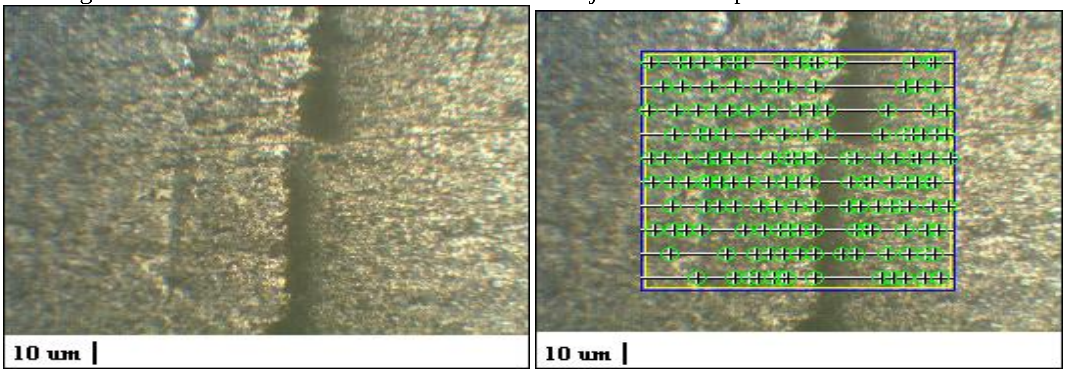

Fig. 7: Microstructure of Al-Al with 18mm dia at 646 rpm

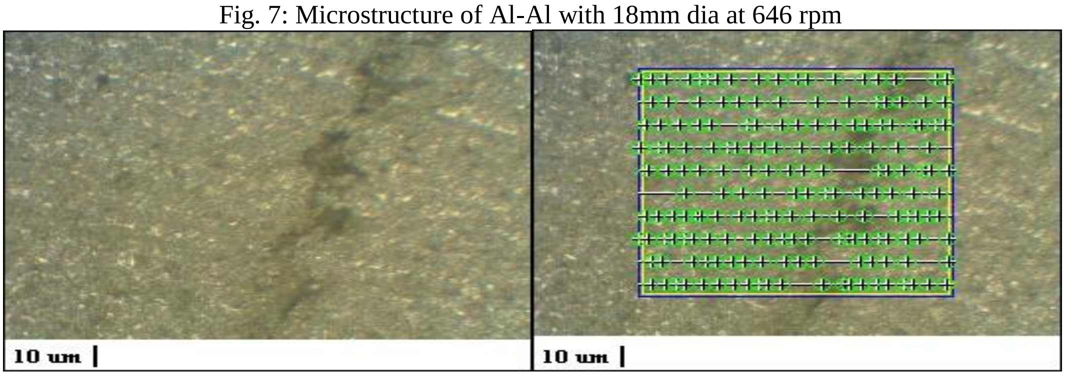

Fig. 8: Microstructure of Al to Al at 270 rpm

B. Hardness:

Macro hardness measurement of the specimens was done along the weld and at the cross section of base metal. Hardness was taken at a constant distance of 0.10mm from the interface in all samples. Total of 3 readings were taken on intersection for all samples, Higher Hardness values are observed next to interface but they dramatically decreased with increase distances. As rpm is increases hardness is also increases. But hardness is decreases with increases the upset time. Macro hardness value in the weld zone was much higher then the parents' material. Hardness increase with decreasing particle size. Hardness is decreasing with increase in diameter of the cylindrical rod.

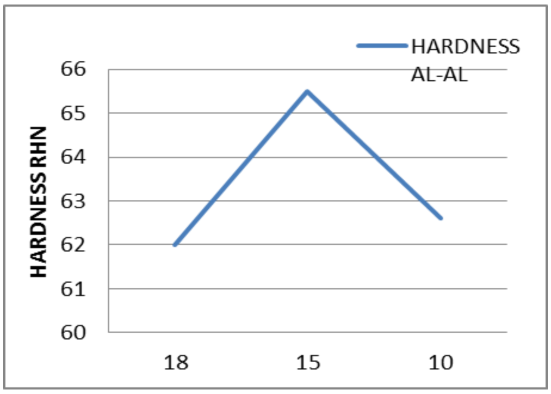

Fig. 9(a): Hardness versus speed and rpm

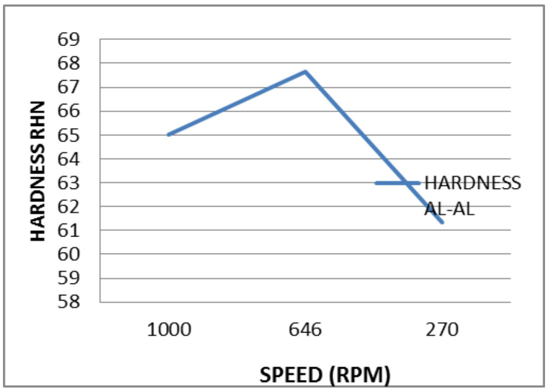

Fig. 9(b): Hardness versus speed and rpm

C. Tensile Strength:

Tensile testing, also known as tension testing is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area.

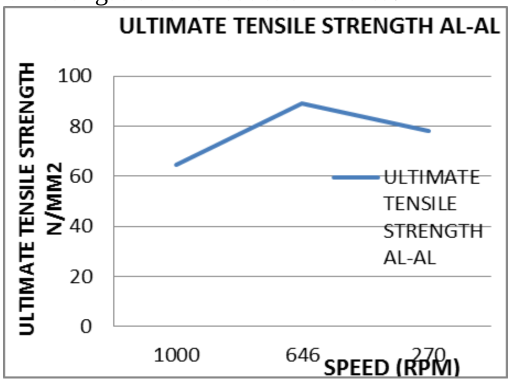

Fig. 10(a): Ultimate tensile strength versus diameter and speed

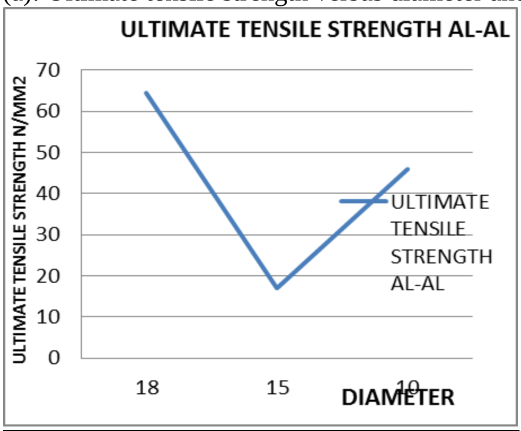

Fig. 10(b): Ultimate tensile strength versus diameter and speed

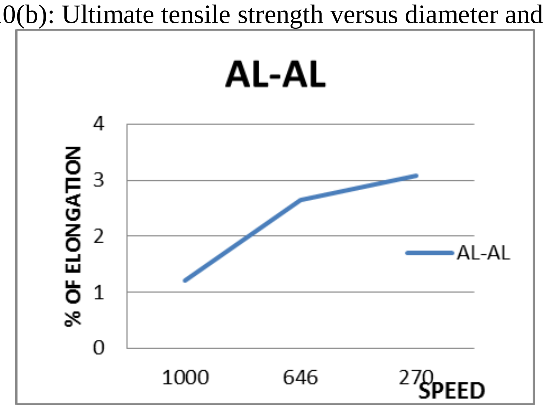

Fig. 11(a): % of elongation versus speed

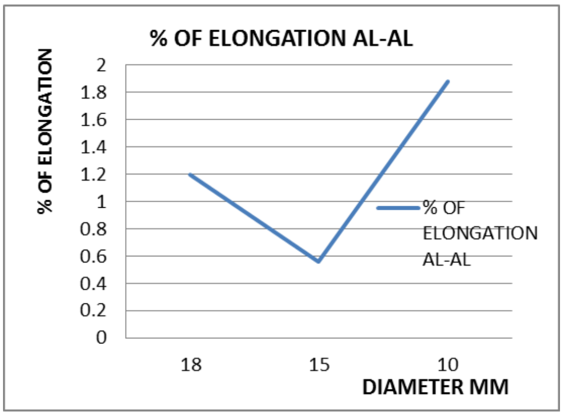

Fig. 11(b): % of elongation versus diameter

By seeing first and second graphs in speed versus ultimate tensile test graph at medium speed i.e. 646 rpm there is no effect to the ultimate tensile strength but remain speeds are effecting the ultimate tensile strength. By seeing second graph there is no size effect to the ultimate tensile strength at 18mm reaming two diameters are effecting the sizes to ultimate tensile strength.

By seeing the graph 3.6 speed versus % of elongation is saying that there is no effect of the speed to % of elongation while decreasing in speed and graph diameter versus % of elongation there is no size effect to the small diameter to the % of elongation. But remaining diameters are affecting the % of elongation.

D. Yield Stress

The yield point determines the limits of performance for mechanical components, since it represents the upper limit to forces that can be applied without permanent deformation. In structural engineering, this is a soft failure mode which does not normally cause catastrophic failure or ultimate failure unless it accelerates buckling.Yield strength is the critical material property exploited by many fundamental techniques of material-working: to reshape material with pressure (such as forging, rolling, pressing, or hydroforming), to separate material by cutting (such as machining) or shearing, and to join components rigidly with fasteners.

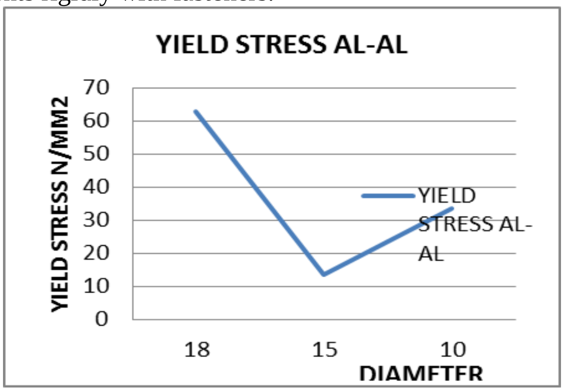

Fig. 12(a): Yield stress versus diameter

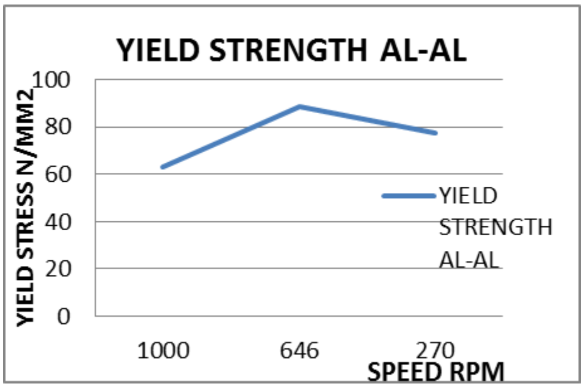

Fig. 12 (b): Yield stresses versus speed

By seeing 3.7yield stress graphs with respective to speed versus yield stress graph at medium speed i.e. 646 rpm there is no effect to the yield stress but reaming speeds are effecting the yield stress. By seeing diameter versus yield stress graph there is no size effect to the yield stress at 18mm reaming two diameters are effecting the sizes to yield stress.

IV. CONCLUSIONS

1) At medium diameter i.e.15mm diameter and 646 rpm are not effecting the hardness but reaming two diameters and two rpms are effecting the diameters and rpms because one is large diameter and high speed, low speed and small diameters. Rpm and diameter varies the hardness at diameter and speed at 15mm diameter and 646 rpm is good.
2) From the tensile tests graphs in speed versus ultimate tensile test graph at medium speed i.e. 646 rpm there is no effect to the ultimate tensile strength but remaing speeds are effecting the ultimate tensile strength. there is no size effect to the ultimate tensile strength at 18mm reaming two diameters are effecting the sizes to ultimate tensile strength.
3) Speed versus % of elongation graph shows that there is no effect of the speed to % of elongation while decreasing in speed and graph diameter versus % of elongation there is no size effect to the small diameter to the % of elongation. But remaining diameters are effecting the % of elongation.
4) Yield stress graphs with respective to speed versus yield stress graph at medium speed i.e. 646 rpm there is no effect to the yield stress but reaming speeds are effecting the yield stress. By seeing diameter versus yield stress graph there is no size effect to the yield stress at 18mm reaming two diameters are effecting the sizes to yield stress

5) In this condition the similar friction welded joint i.e. Al-Al was tested with 18mm diameter to 1000 rpm and 646 rpm at 10x and we observed the micro structure and grain size. From the microstructure there is a gap between the joints due to improper weld.
6) In this condition the dissimilar friction welded joint i.e. Al-Al with 270 rpm was tested at 10x and we observed the micro structure and grain size. From the microstructure there is no gap between the joints due to proper weld condition.

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