EFFECT OF BURN-OFF LENGTH AND ROTATIONAL SPEED ON TENSILE STRENGTH OF ROTARY FRICTION WELDED AL 6061 AND AL 7075

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Abstract :Joining of dissimilar materials is one of the most essential needs of industries. There are various welding methods that have been developed to obtain suitable joints in various applications. However, friction welding is a solid-state joining technique which utilizes the heat generated by rubbing of two faying surfaces for the coalescence of material. In the present study, an experimental set-up was designed in order to achieve friction welding of plastically deformed Al 7075 and Al 6061. Samples were welded under different burn-off lengths and different rotational speeds. The tensile strengthof the welded joints was determined and evaluated and on the basis of the results obtained from the experimentation, the graphs were plotted. The experimental results indicate that burn-off length and rotational speed has a significant effect on the tensile strength of the joint and it is possible to increase the quality of the welded joint by selecting the optimum burn-off lengths and rotational speeds.

***IndexTerms*–Rotary friction welding, Burn-off length, Aluminium,Tensile test.**

I. INTRODUCTION

Friction welding is a solid-state welding process. [1] Optimized that the frictional heat, generated at the rubbing surfaces to raise the temperature of the interface which is higher enough to cause the two surfaces to be forged together under higher pressure. [2] Mentioned that the metals of group IV, V and VI of the periodic table, especially titanium, vanadium, zirconium, niobium, molybdenum and also tantalum and tungsten can be joined by friction welding.

1.1 Principle of Friction Welding

In continuous drive friction welding, one of the work pieces is attached to a motor driven unit while the other is restrained from rotation. The motor driven work piece is rotated at a predetermined constant speed. The work pieces to be welded are forced together and then a friction force is applied. Heat is generated as the weld interfaces which rub together, this continues for a predetermined time or until a pre-set amount of upset takes place. The rotational driving force is discontinued and the rotating work piece is stopped by the application of braking force. The friction force is maintained or increased for a predetermined time after rotation ceases.

Figure 1 explains the variation of welding speed, friction force and forging force with time. The stages of welding such as starting, axial shortening and weld completion are also described in same figure.

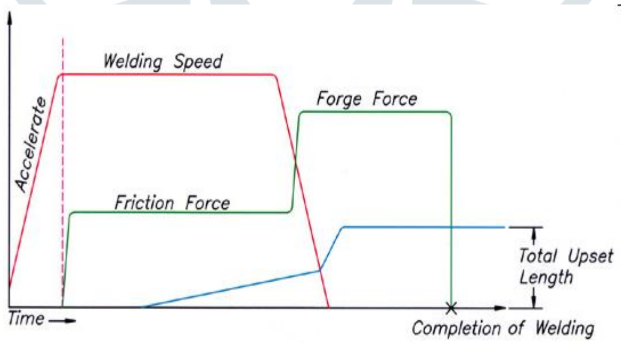


Fig. 1: Parameters on Continuous-drive friction welding [3]

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. The temperature at the surface depends on the applied pressure, rotational speed, and thermal conductivity and also on the coefficient of friction. [4] observed that heat dissipation is an automatic process since friction and adhesion occur in places where micro welds cause an increase in the rate of heat dissipation, which contributes to an increase in micro welds and bond of two surfaces. In general heat is conducted away from the interfaces and a plastic zone develops. [5] Investigated that plasticized layer is formed on the interfaces and the local stress system with the assistance of rotary movement extrudes material from the interface into the flash.

II. EXPERIMENTALPROCEDURE

2.1Materials. The material selected for this proposed work is Al 7075 and Al 6061 as it is widely used in the number of industrial applications due to its outstanding machining characteristics, weight to strength ratio and its corrosion resistant properties. The chemical composition of both the Al alloys has been presented in Table 1

Table1 Chemical composition of the materials

Metals	Si %	Fe%	Cu%	Mn%	Mg%	Cr%	Zn%	Ti%	Al
Al 7075	0.09	0.2	1.4	0.07	2.3	0.20	5.6-5.7	0.03	Balanced
Al 6061	0.6	0.7	0.3	0.15	1.0	0.2	0.25	0.15	Balanced

2.2Sample Preparation. The bars were cleanedmechanicallyand chemically in order to make them free from oil, dirt,grease, and so forth.These bars were then cut to the suitablelength of 100mm each for friction welding and subsequentlyfacing operation of all the samples was done on the lathemachine. These specimens were then fitted on the frictionwelding setup.

2.3 Experimental Setup. The lathe machine of make "Lotey [Lotus High Cut]," with a speed range of 90-1228 rpm, was modified to fulfil the requirement of this experimentation work. The modification was done by fitting a stationary chuck on tailstock side; a foot operated servo brake mechanism was fitted for immediate ceasing of the rotating element. The required rotational speed was attained with the help of a gear box already fitted in the machine. Within a fraction of seconds, the constant speed was achieved. The axial alignment of specimen was checked, and subsequently the axial pressure was applied for achieving the predetermined burn-off length. The specimens were prepared at different rpm starting from 518 rpm to 1228 rpm. The welding joint so formed was allowed to cool down for 3-5 minutes. The welded specimens at different burn-off lengths have been presented in Figure 2.

Fig. 2: Friction Welded Specimen depicts various burn-off lengths

III. MECHANICAL TESTING

3.1Tensile Test: - Tensile test carried for the current investigation was performed on the Universal Testing machine make "FIE"having the capacity of 100 T. The specimens were prepared for this test and for that ASTM standards were followed for producing the specimen. The gauge length of the specimens was maintained according to the ASTM A370-12 standard keeping the weld interface at the centre of the gauge length. The sample was then fitted between the jaws of the machine and load was applied gradually. The value of stress at gradual intervals has been calculated. This test was carried out on the friction welded samples of Al 7075 with Al 6061 materials to measure their strength in tension. The specimen was subjected to axial tensile load till its failure occurs.

IV. RESULTS AND DISCUSSION

4.1 Tensile Testing: - Tensile test was performed on Universal Testing Machine made by FIE having a capacity of 100 T. In this test the specimens were subjected to axial tensile load till its fracture occurs. On the basis of the result obtained from the test, stress versus strain graphs has been plotted. The graphs were plotted at different rpm starting from 518 rpm to 1228 rpm at three different burn-off lengths.

At a rotational speed of 518 rpm, it has been observed that the tensile strength obtained from the specimens varied from 68.8 MPa to 156 MPa. Figure 3(a) shows the variation between stress and strain; from the figure it has been observed that with increase of burn-off length the value of stress goes on increasing. It reaches the maximum value which is known as ultimate stress value, thereby starts decreasing. A similar phenomenon between all the curves i.e. 7 mm, 9 mm and 12 mm were observed. Minimum stresses as well as strain values were noticed at 7 mm burn-off lengths, indicating fewer adherences between the interfacing surfaces. However, stress values were noticed at 12 mm burn-off length along with maximum strain values which were found to be 22%. The experimental value obtained during testing of welding produced at 518 rpm has been presented in Table 2. Similar results have been noticed by [6].

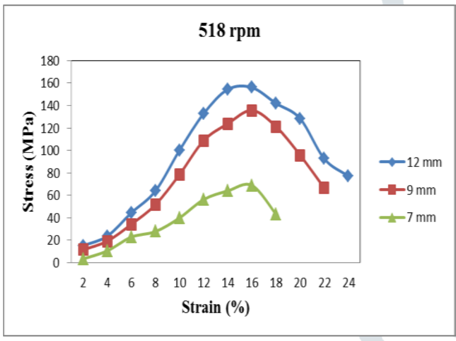
At a rotational speed of 692 rpm, maximum value of stress was 171.9 MPa at 12 mm of burn-off length and minimum value of stress was 83.53 at 7 mm of burn-off length. As shown in Figure 3 (b), it indicates that on increasing the burn-off length there was increase in the tensile strength. At 12 mm of burn-off length more mass was transferred between surfaces, which lead to increase the bond strength. After reaching at maximum stress value there was decline in the stress and increase in strain value. However, if we compare the results of 692 rpm with the results of 518 rpm, better value of stress was noticed.

At a rotational speed of 832 rpm, it hasbeen observed that the tensile strength obtained from the specimens varied from 65.19 MPa to 167.07 MPa; also, it has been depicted from the values obtained experimentally that with the increase in the burn-off length the tensile strength goes on increasing as shown in Figure 3 (c). This may be attributed to the fact that with the increase in burn-off length more mass is thought to be transferred at the weld interface. After maximum value of stress there was decline in the stress and increase in the value of strain. There is marginal difference between the burn-off length of 12 mm and 9 mm as compared with the burn-off length of 7 mm.

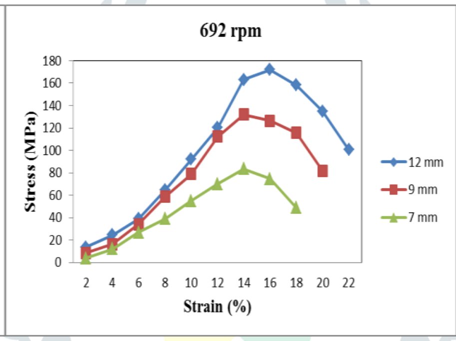
At a rotational speed of 1228 rpm, maximum value of stress was observed as compare to other rotational speeds. Table 2 shows the experimentation value of specimen, in which tensile strength varied from 79.54 MPa to 240.4 MPa. From Figure 3 (d), it has been observed that at reaching maximum value of stress at 12 mm of burn-off length there was decrease in the stress. Also, it has been found from the figure the value of strain at 12 mm and 9 mm of burn-off length remains same. At 7 mm of burn-off length the value of stress and strain was found to be minimum due to less formation of frictional heat.

Table 2 Values observed during friction welding produced at 518, 692, 832 and 1228 rpm

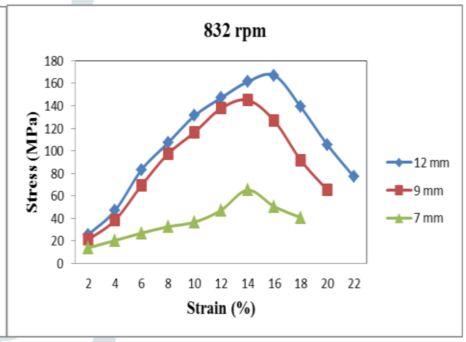
Burn off length	Peak load (KN)	Peak displacement (mm)	Peak stress (MPa)	Peak strain (%)
At 518 RPM				
7 mm	8.45	9	68.86	0.18
9 mm	16.65	11	135.69	0.22
12 mm	19.15	12	156.07	0.24
At 692 RPM				
7 mm	10.25	9	83.53	0.18
9 mm	16.20	10	132.03	0.20
12 mm	21.10	11	171.96	0.22
At 832 RPM				
7 mm	8.00	10	65.19	0.20
9 mm	17.80	11	145.06	0.22
12 mm	20.50	12	167.07	0.24
At 1228 RPM				
7 mm	9.76	10	79.54	0.20
9 mm	21.40	12	174.40	0.24
12 mm	29.50	12	240.42	0.24



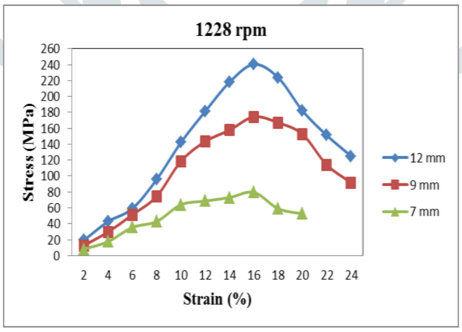
(a)



(b)



(c)



(d)

Fig.3: Stress vs. strain at 518, 692, 832 and 1228 rpm

V. CONCLUSION

In the present study, Al 6061 and Al 7075 aluminum alloys successfully friction welded. The welding using aforesaid processes were investigated by tensile testingwith the following results:

1.The laboratory-built friction welding set-up was found to be successful for the production of friction welds.

2.The burn-off length and rotational speed of the welding has been found to be an influential parameter for the friction welding process, which has been optimized for the process based on the results of present study.

3.The maximum tensile strength for welded bars was achieved at a rotational speed of 1228 rpmand at 12 mm burn-off length. which was found to be 240.4 MPa.

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