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EFFECT OF BURN OFF LENGTH AND ROTATIONAL SPEED ON MECHANICAL PROPERTIES OF BUTT WELDED ALUMINIUM RODS USING FRICTION WELDING TECHNIQUE

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Abstract:

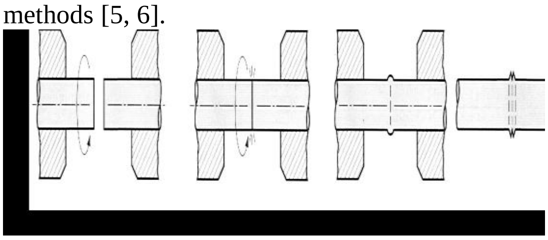
Friction welding is an emerging trend in the field of welding technology. It is a type of solid state welding in which the heat energy required is generated by application of frictional force between two components one being in motion and another kept stationary. It is required to apply a lateral force known as "upset", in order to displace the material plastically and fuse them together. The friction can be generated either by rubbing the two joining materials (RFW & LFW) or by using a special purpose tool (FSW) on the weld surface. The phenomena of direct heat input at the weld interface and with a very less joining time this process is almost melt free which eliminates the unwanted change in grain structure of the joining materials, improving its overall physical and mechanical properties as well as the ergonomics of the process in terms of safety. Aluminum is a very soft material, but it finds its application almost everywhere these days because of its light weight and high strength. It has huge application in the field of automobile and aerospace engineering. But it is very difficult to weld two aluminum parts by conventional fusion welding process. The weld time and temp plays a vital role in the above process. If the time and temperature is very high then the whole material will melt down instead of joining. So in friction welding process the above problem is eliminated as it is carried out below the melting point of the component. It forms a high strength and uniform bond without using any filler material reducing the overall weight of the component. When it comes to productivity, friction welding process trims down the production time drastically. In order to get a successful weld we need to look after certain parameters like upsetting force, spindle speed, axial force, weld time, burn off length and the temperature generated. In this paper we have joined aluminum with aluminum using the rotational friction welding technique (RFW) effectively using a lathe machine. We have analyzed the effects of the rotational speed and burn off length on the ultimate tensile strength and hardness of the welded component. The welded components has been tested using Universal testing machine, Brinell hardness tester, to determine the strength and hardness. It has also been thoroughly examined under microscope to study the metallurgical properties.

Key Words: Friction Welding, Lathe M/C, Universal Testing Machine, Brinell Hardness Tester, Burn off Length & Spindle Speed

1. Introduction:

Friction welding is an emerging trend in the field of welding technology. It is a type of solid state welding in which the heat energy required is generated by application of frictional force between two components one being in motion and another kept stationary [1]. It is required to apply a lateral force known as "upset", in order to displace the material plastically and fuse them together. The friction can be generated either by rubbing the two joining materials (RFW & LFW) or by using a special purpose tool (FSW) on the weld surface [2]. It has the advantage of joining soft materials like aluminum which is having a low melting point. As the crave for light weight, more strength, corrosion and wear resistant and economical components is getting high day by day in the industries like locomotive, aerospace, shipyards and automobiles, the demand of friction welding processes is also increasing rapidly.

Another major reason of the exponential growth in application of these metal joining techniques is in the form of technical and economic advantages, including high efficiency and stability of the process and enhanced safety and less production time compared to conventional welding methods [5, 6].



(a) (b) (c) (d)

The main principle is to convert the mechanical energy into heat energy by friction. The friction can be generated either by rubbing the two joining materials (RFW & LFW) with each other or by using a special purpose tool (FSW) on the weld surface [4, 5]. In RFW process one of the two joining parts is gripped in a chuck and rotated about its own axis and the other part is gripped and only moved in the axial direction without any rotation. When both the components comes into contact with each other a lot of heat energy is generated because of the friction between them. At a certain point of time the temperature of the components reaches fusion temperature (below melting point), where the rotation is stopped and the forging pressure is applied axially [3, 16]. This creates a uniform welded joint without actually melting the metal. This eliminates the unwanted change in grain structure of the joining materials, improving its overall physical and mechanical properties as well as the ergonomics of the process in terms of safety. In LFW the rotational motion is replaced by a linear oscillatory motion.

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The sequence is portrayed in the figure1 for the typical application of this operation, welding of two cylindrical parts. Figure 1 Illustration of rotational friction welding technique. (a) No contact, (b) parts brought into contact to generate friction heat, (c) rotation stops and axial pressure applied, (d) final product showing the flash.

In this research paper we have concentrated in joining of two aluminum cylindrical bars by Rotational Friction Welding technique (RFW) using a lathe machine. Our major focus was to study and analyze the effects of the rotational speed and burn off length of the joining parts on the mechanical properties like ultimate tensile strength and hardness of the welded component. We have used Universal Testing Machine for getting the tensile strength and a Brinell hardness tester for the hardness of the component.

2. Materials and Methods:

2.1 Materials: The material used in this experiment is aluminum. Each specimen is taken in cylindrical form, having dimensions of 12 mm in diameter and 110 mm in length, (Shown in fig:2).

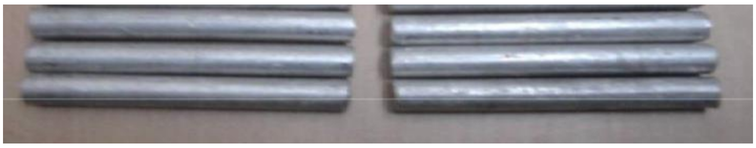

Figure 2: Aluminum cylindrical rods for welding.

2.2 Experimental Setup: Here we have used a lathe machine to weld the two aluminum cylindrical pieces. One cylindrical rod is fixed to the chuck attached to the spindle. The other part is fixed to the tool post by the help of screws. The axis of the two rods are made to coincide with each other, when both came to contact. The setup is illustrated in the figure3 and figure4

Figure 3: Two aluminum rods fixed to the lathe machine. One to spindle and another to tool post

Figure 4: Axis of both the components are aligned and brought close to each other

After the setup the lathe machine is started and one component is made to rotate at different rpm. Here we have taken three different speeds i.e. (1500, 975, 675 rpm) for a particular burn off length. Then the stationary component is brought closer to the rotating part and allowed to touch the surface creating a lot of heat because of the frictional force. This heat energy makes the material to fuse. At that point the rotation is stopped suddenly and an axial force is applied i.e. (upsetting force) in order to join the two components together. The figure5 showing the process is given below.

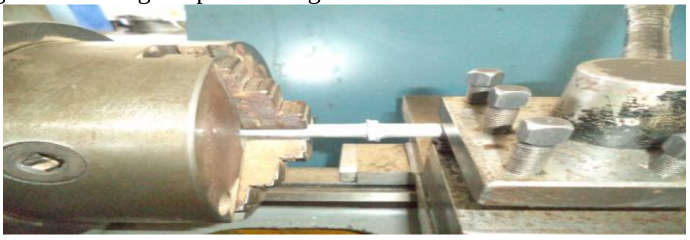

Figure 5: Both the components joined together post welding. Post processing can be done if required

2.3 Tests Conducted: The welded specimens are tested for tensile strength in a Universal Testing Machine. After the joining process the specimens are post processed using belt grinders, belt polishers and disc polishers to remove any unwanted materials. This prepares the components to be examined under the microscope to check the microstructure of the welded region.

3. Results and Discussion:

After completion of the experiment we have analyzed all the parameters as shown in the below mentioned tables.

Area of aluminum rod $A = \pi\,(6)^2 = 113.09\ \text{mm}^2$

Observations taken from the UTM

Table 1: Variation of speed, strength and time for 3mm burn off length of welded joint

Speed (rpm)	Burn off length (mm)	Load (KN)	Strength (N/mm^2)	Time (sec)
1500	3	10	88.4642	13
975	3	8	70.771	20
675	3	7	61.924	46

From the table1 it is clearly visible that when the speed increases the strength of the welded component also increases. The breaking load obtained by the UTM is also more when the rotation speed is more. Whereas the time required fusing the materials together reduces with increase in speed.

Table 2: Variation of speed, strength and time for 5mm burn off length of welded joint

Speed (rpm)	Burn off length (mm)	Load (KN)	Strength (N/mm^2)	Time (sec)
1500	5	10.4	92.004	25
975	5	9	79.617	37
675	5	8	70.724	57

From the table 2 it is again clear that with the increase in speed the strength and breaking load of the component increases, while decreasing the overall weld time. But in the above table the burn off length has been increased from 3mm to 5mm. This 2mm change in burn off length increases the strength of the component within the range 5-10 N/mm2 when compared to the component with 3 mm burn off length. Whereas the time required to complete the weld also increased in the range of 10-17 seconds, for the corresponding speed value.

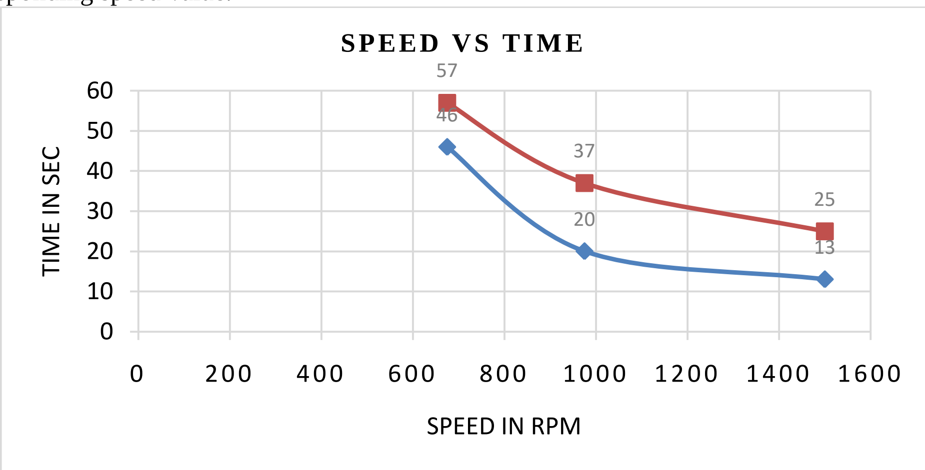

Figure 6: Speed VS Time

The Figure 6. has been plotted between the speed of rotation and the weld time. The red line shows for the 5mm burn off length whereas the blue line is for 3mm burn off length. It can be concluded that the time required to weld the components decreases with increase in rotational speed.

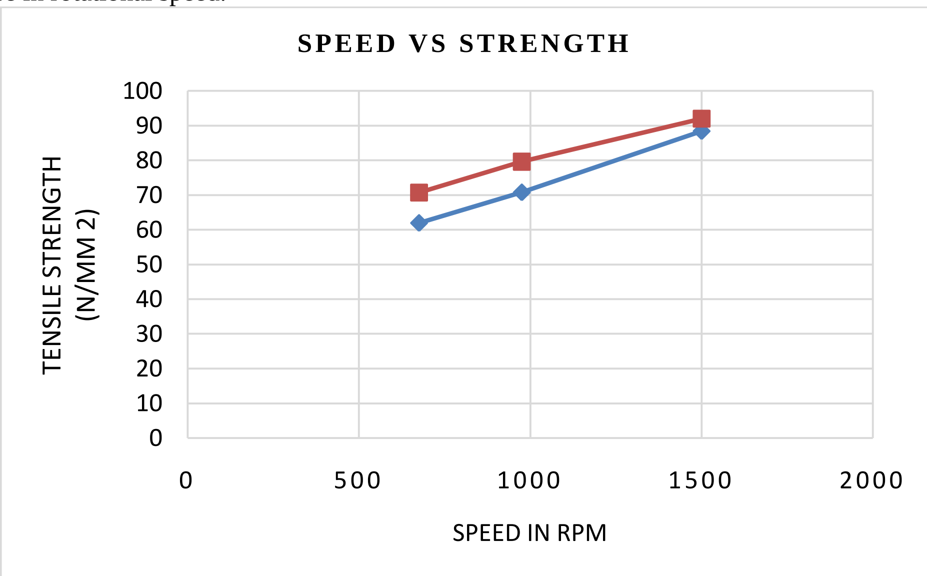

Figure 7: Speed vs Strength

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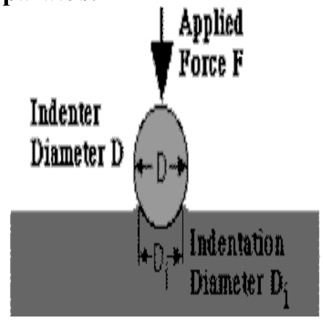
In the Figure 7, speed of rotation has been plotted with respect to tensile strength. The red line shows the strength when the burn off length is 5mm whereas the blue line belongs to strength when burn off length is 3mm. It is clear that with the increase in burn off length the strength also increases. When the speed increases the tensile strength also increases.

Hardness Test using Brinell's Apparatus:



$$BHN = \frac{F}{\frac{\pi}{2} D \left(D - \sqrt{D^2 - D_i^2}\right)}$$

Where

F=applied load, in kg
D=Diameter of ball, in mm
Di=Diameter of indentation, in mm

Table 3: Comparison of hardness in welded and non-welded region

Parameters	Ball Dia (mm) i.e. D	Indentation Dia (mm) i.e. D	Hardness (BHN)
Welded portion	10	4	38.127
Non welded portion	10	4.5	29.757

From the data (Table: 3) taken from the hardness test it is clear that the indentation diameter (Di) is less at the welded region compared to non-welded portion. This shows that it is hard to penetrate the welded region as the hardness value is around 9 units more compared to the non-welded region.

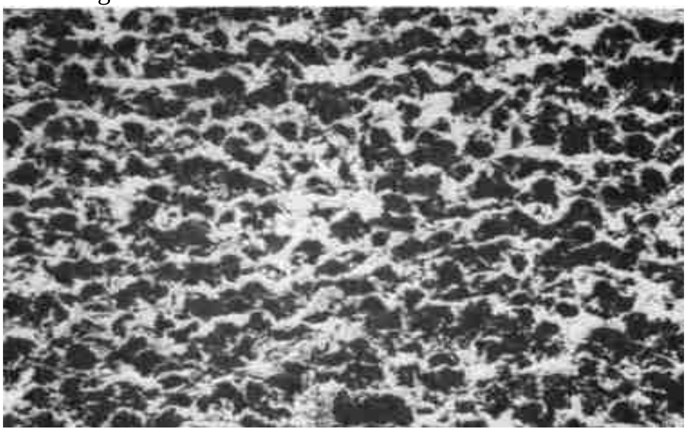


Figure 8: Microstructure of the welded region

The figure 8 taken from the microscope we can clearly see that the grains are perfect and there are no visible defects in it.

4. Conclusion:

In the present study aluminum has been successfully welded to another aluminum by means of friction welding technique. The main objective of the paper was to analyze the various parameters in friction welding of aluminum which was properly concluded with the following conclusions. The welded components have been investigated under Universal Testing Machine for tensile strength, and Brinell hardness tester for hardness of the welded region. As a result:

- ✓ Strength of the welded component emerged more when it is compared to its base material. The joint strength increased with increase in rotational speed.
- ✓ The weld time has decreased with the increase of rotational speed.
- ✓ While increasing the burn off length increased the strength as well as the weld time.
- ✓ Sufficient heat energy could not be obtained in less rotational speed. So we need to increase the speed to get a perfectly welded joint.
- ✓ The hardness of the aluminum material is found out to be more in the welded region when compared to non-welded region or base metal.
- ✓ When examined under microscope the welded portion was found out to be free from any defects and abnormalities.

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