Friction Welding of Aluminium 6061 and Aluminium 6082 Rods by using Conventional Lathe

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Abstract— Friction welding (FW) is fairly a recent technique that utilizes friction between two surfaces to generate frictional heat and plastic deformation at the welding location, thereby producing a joint while the material is in solid state. The principal advantages of frictional welding are low distortion, absence of melt-related defects and high joint strength, even in those alloys that are considered non-weldable by conventional welding techniques. Friction welding is used to weld a variety of similar and dissimilar alloys as well as for welding metal matrix composites. Since friction welding machine is a costlier one, for small scale applications it is not economical. So we tried conventional lathe setup to perform friction welding. In this work friction welding of Aluminium 6061 & Aluminium 6082 metal rods are performed in conventional lathe for studying mechanical & micro structural characteristics of welded joints.

Keywords— Friction welding, Aluminium 6061, Aluminium 6082, mechanical characteristics

I. INTRODUCTION

Traditionally, friction welding is carried out by moving one component relative to the other along a common interface, while applying a compressive force across the joint. The friction heat generated at the interface softens both components, and when they become plasticised the interface material is extruded out of the edges of the joint so that clean material from each component is left along the original interface. The relative motion is then stopped, and a higher final compressive force may be applied before the joint is allowed to cool. Many dissimilar metal combinations can be joined through this process. Different types of friction welding methods are Linear Friction Welding, Spin Welding, Rotary Friction Welding, Inertia Friction Welding, Friction Surfacing, Friction Stud Welding and Friction Stir Welding.

The principle of this process is the changing of mechanical energy into heat energy. Our objective was to study the different mechanical and microstructure characteristics of friction welded joint and arrive at a conclusion whether the joint can be used for any applications.

II. EXPERIMENTAL DETAILS

In this experiment of friction welding, one rod is fixed with the help of chuck and the other rod is fixed to dead centre of the tail stock. Then the rod attached to the chuck is rotated and the other rod is pushed towards it by applying pressure manually.
2.1 FRICTION WELDING EXPERIMENTAL PROCEDURE

Stages involved in the experiment is given below,

1. Preparation of components to be welded

2. Component setting

3. Operational steps in friction welding process

2.2 PROPERTIES OF ALUMINIUM 6061

Aluminium 6061 alloy is a precipitation hardening aluminium alloy containing magnesium and silicon as its major alloying elements. Originally called “Alloy 61S” it was developed in 1935. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminium for general purpose use. It is commonly available in pre-tempered grades such as 6061-O (annealed) and tempered grades such as 6061-T6 (solutionized and artificially aged) and 6061-T651 (solutionized, stress-relieved stretched and artificially aged).

2.2.1. Physical Properties:

- Density: 2.7 g/cm³
- Melting Point: Approx 580°C
- Modulus of Elasticity: 70-80 GPa
- Poissons Ratio: 0.33
- Electrical Resistivity: 3.7 – 4.0 x10⁻⁶ Ω.cm
- Thermal Conductivity: 173 W/m.K
2.2.2. Chemical composition:

Table 1 Chemical composition of 6061

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount wt.(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>Balance</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.8-1.2</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.4 – 0.8</td>
</tr>
<tr>
<td>Iron</td>
<td>Max. 0.7</td>
</tr>
<tr>
<td>Copper</td>
<td>0.15-0.40</td>
</tr>
<tr>
<td>Zinc</td>
<td>Max. 0.25</td>
</tr>
<tr>
<td>Titanium</td>
<td>Max. 0.15</td>
</tr>
<tr>
<td>Manganese</td>
<td>Max. 0.15</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.04-0.35</td>
</tr>
<tr>
<td>Others</td>
<td>0.05</td>
</tr>
</tbody>
</table>

2.3. PROPERTIES OF ALUMINIUM 6082

Aluminium 6082 alloy is an alloy in the wrought aluminium-magnesium-silicon family (6000 or 6xxx series). It is one of the more popular alloys in its series, although it is not strongly featured in ASTM (North American) standards. It is typically formed by extrusion and rolling, but as a wrought alloy it is not used in casting. It can also be forged and clad, but that is not common practice with this alloy. It cannot be work hardened, but is commonly heat treated to produce tempers with a higher strength but lower ductility.

2.3.1. Physical Properties:

- Density: 2.71 g/cm$^3$, or 169 lb/ft$^3$.
- Melting point: Approx 550°C
- Modulus of elasticity: 70GPa
- Electrical Resistivity: $0.038 \times 10^{-6}$ ohm.m
- Thermal Conductivity: 180 W/m.K

2.3.2. Chemical composition:
Table 2. Chemical combinations of 6082

<table>
<thead>
<tr>
<th>Element</th>
<th>Amount wt.(% )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon</td>
<td>0.7-1.3</td>
</tr>
<tr>
<td>Iron</td>
<td>0.0-0.5</td>
</tr>
<tr>
<td>Copper</td>
<td>0.0-0.1</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.4-1.0</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.6-1.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.0-0.2</td>
</tr>
<tr>
<td>Titanium</td>
<td>0.0-0.1</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.0-0.25</td>
</tr>
<tr>
<td>Aluminium</td>
<td>Balance</td>
</tr>
</tbody>
</table>

2.4. PROCESS PARAMETERS

The important process parameters during fractioning stage are 1) Rotational speed 2) Friction pressure 3) Friction time. During forging stage the important process parameters are 1) forging pressure 2) forging time. There are many other parameters like feed rate, upset delay time, brake delay time which also are required for precise control of the process.

III. RESULTS AND DISCUSSION

The friction welding parameters which can be controlled in our machine set are speed of rotation = 1400 rpm, friction time = 3 min, upset time = 10 seconds. And the forging force and frictional force are held as constants during the welding operation. Subsequently, tensile tests, shear test and metallurgical examinations were applied to the welded specimens according to ISO15620:2000(E) and different weldability tests such as micro-hardness tests, impact tests are conducted.

3.1. Tensile Tests

For finding the tensile strength of the friction welded specimen 12 mm diameter and 260mm length specimens are made and a gauge length of 16mm is used for the testing, they are tested according to the procedure In the UTM. During the testing the following results were obtained.

After the tension test of welded specimen in the UTM, we have obtained the Ultimate load as 23.25KN, and the Breaking load of the specimen was 22.25KN. According to that the Tensile strength is calculated as 205.58 N/2. This value indicates that the obtained weld possess a good weld strength.
3.2. Shear Test

Maximum shear stress of the friction welded joint is found out using shear test shear test is conducted in a 16mm diameter specimen in the UTM for more accuracy. Maximum shear stress is found out using formula \((W/2)^2\). Where \(W\) - breaking load in N and \(r\) - radius of specimen in mm. After the single shear test we have obtained breaking load as 17KN. And the maximum shear strength is calculated as 42.275 N/2. This value indicates that the obtained weld possess a good weld strength.

3.3 Izod Impact Test

To study the toughness property of the friction welded joint Izod Impact test is being conducted.

Toughness depends fundamentally upon the strength and ductility. The property of the material relating to the work required to cause rupture has been termed as toughness.

The following observations are obtained during the test:

Energy absorbed by the specimen in Izod test=Izod impact value=32J

The Izod impact value is 32J. This value indicates that the obtained weld possess a good toughness as compared to base metal.

3.4. Vicker’s Hardness Test

To determine the Vicker’s hardness number of the friction welded joint we conduct Vicker’s hardness test. The term hardness means resistance to penetration. Vicker’s hardness test is conducted on the specimen, Load applied is 10kgf for the time 15seconds and the following observations are obtained.

![Figure 2. Vickers hardness no vs distance from joint](image)

After conducting Vickers hardness test we have obtained a relatively less value at the weld position and surroundings to that than the base metals. This may be due to the presence of heat effected zone (HAZ). The three lines indicates the Vickers hardness value at three different points.
3.5. MICROSTRUCTURE EVALUATION

We used optical microscope to do the microstructural evaluation. Modern optical microscopes with resolution limit of 200 nm and magnification up to 2000 x are used to observe details like grain shape and size, morphology of inclusions and precipitates, micro-segregation, micro-cracks, surface coating thickness and structure, weld defects etc. in metals.

**WELD ZONE**

![Weld Zone Image](image)

*Figure 3. Microstructure of welded region*

The weld joints are seen to be continuous and the deformation zone being very different. However, there is a distinction between the microstructures developed near the interface in the two parts joined. The weld region is seen as a thin line and so we can assume that there will be a small heat affected zone.

IV. CONCLUSION

We observed that friction welding is possible by using conventional lathe and we got a perfect weld for aluminium 6061 and aluminium 6082 by using conventional method.

We also done mechanical and microstructure analysis of friction welded joint and we got a very small weld region in the microstructure analysis.

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