JOINING OF ALUMINUM ALLOYS WITH FRICITION STIR WELDING METHOD

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Abstract

Friction stir welding is a solid phase welding method which takes place in non-traditional welding techniques and the industrial applications of this method intensify in recent years. In this method, parts in various geometries can be joined in solid state and not using extra metal. Friction stir welding that has limited and very little usage in our country at industrial meaning are heavily used in aerospace, automotive and marine industry and supplies advantage for same and different material joining with low distortion after welding process according to the other special welding methods. In this study, Al – Mg based AA 5083 aluminum alloys, which are widely used in industry, were joined with friction stir welding method and then mechanical properties of the joints were obtained. Obtained results in the tests were compared with the other researches.

Keywords: Friction Stir Welding, AA 5083 – H111 Aluminum Alloy, Mechanical Properties

1. INTRODUCTION

Friction stir welding is a solid phase welding method which takes place in non-traditional welding techniques and the industrial applications of this method intensify in recent years. In this method, parts in various geometries can be joined in solid state and not using extra metal. Friction Welding (FW), which is older, forms the basis of this method. This joining method was appeared with the aim of joining non-ferrous metals which are difficult and expensive especially with traditional methods and brings material and energy saving together. \(^1\) Friction stir welding that has limited and very little usage in our country at industrial meaning are heavily used in aerospace, automotive and marine industry and supplies advantage for same and different material joining with low distortion after welding process according to the other special welding methods. \(^2\)

Friction Stir Welding (FSW) was invented and experimentally proven at The Welding Institute (TWI) in December 1991 and TWI holds a number of patents on the process. \(^3\) FSW uses a rotating and traversing non consumable tool to generate frictional heat and cause mechanical deformation at the joint. A constantly rotated cylindrical-shouldered tool with a profiled nib is traversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The process has numerous advantages over other joining technologies and can be used to weld numerous materials including, but not limited to aluminum, bronze, copper, titanium, steel, magnesium, and plastic. Frictional heat is generated between the wear-resistant welding components and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward a special profile on its leading face forces plasticized material to the rear where clamping force assists in a forged consolidation the weld. This process of the tool traversing along the weld line in a plasticized tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.

2. MATERIALS AND METHODS

FSW is a solid-state process, which means that the base materials to be joined do not melt during the joining process. Alloys from 2xxx and 7xxx series, which have traditionally been non-weldable can now be joined with FSW with speed and quality. The rotation action and the specific geometry of the FSW tool generates
Friction and mechanical working of the material which in turn generate the heat and the mixing necessary to transport material from one side of the joint line to the other. In FSW, a cylindrical shouldered tool with a profiled pin is rotated and plunged into the joining area between two pieces of sheet or plate material. The parts have to be securely clamped in a manner that prevents the joint faces from being forced apart. Principle of FSW is given in Fig. 1.

![Fig. 1 Principle of FSW (detailed view)](image)

Frictional heat between the wear resistant welding tool and the work pieces causes the latter to soften without reaching the melting point and allows traversing of the tool along the weld line. The plasticized material is transferred to the trailing edge of the tool pin and is forged by the intimate contact of the tool shoulder and the pin profile. On cooling down, it leaves a solid phase bond between the two pieces. The process advantages and limitations of FSW are given in Table 1. [1]

<table>
<thead>
<tr>
<th>Process Advantages</th>
<th>Main Limitations</th>
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<tbody>
<tr>
<td>* Energy efficient</td>
<td>* Work pieces must be rigidly clamped</td>
</tr>
<tr>
<td>* Environmentally friendly</td>
<td>* Backing bar required (except where self-reacting tool or directly opposed tools are used)</td>
</tr>
<tr>
<td>* Low distortion</td>
<td>* Keyhole at the end of each weld</td>
</tr>
<tr>
<td>* Low shrinkage</td>
<td>* Can not make joints which required metal deposition (e.g. fillet welds)</td>
</tr>
<tr>
<td>* Applicable to technical automation</td>
<td></td>
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<tr>
<td>* Welding of dissimilar alloys</td>
<td></td>
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<tr>
<td>* Can operate in all positions</td>
<td></td>
</tr>
<tr>
<td>* Excellent mechanical properties</td>
<td></td>
</tr>
<tr>
<td>* No arc, fume or porosity</td>
<td></td>
</tr>
<tr>
<td>* Non – consumable welding tool</td>
<td></td>
</tr>
<tr>
<td>* No filler wire and gas shielding for welding aluminum</td>
<td></td>
</tr>
<tr>
<td>* No welder certification required</td>
<td></td>
</tr>
<tr>
<td>* No grinding, brushing or pickling required in mass production</td>
<td></td>
</tr>
<tr>
<td>* Can successfully join materials that are “unweldable” by fusion welding methods</td>
<td></td>
</tr>
<tr>
<td>* Can join aluminium and copper of &gt;50 mm thickness in one pass</td>
<td></td>
</tr>
</tbody>
</table>
In this study, joining of 5083 aluminum alloys, obtaining optimum parameters, determining of mechanical properties of joined parts were experimentally investigated. The chemical composition of AA 5083 alloy used in FSW experiments is given in Table 2.

### Table 2 Chemical composition of AA 5083 alloy used in FSW experiments

<table>
<thead>
<tr>
<th>Material</th>
<th>AA 5083</th>
</tr>
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<tbody>
<tr>
<td>% Al</td>
<td>94.5</td>
</tr>
<tr>
<td>% Si</td>
<td>0.1</td>
</tr>
<tr>
<td>% Fe</td>
<td>0.3</td>
</tr>
<tr>
<td>% Cu</td>
<td>0.03</td>
</tr>
<tr>
<td>% Mn</td>
<td>0.6</td>
</tr>
<tr>
<td>% Mg</td>
<td>4.31</td>
</tr>
<tr>
<td>% Cr</td>
<td>0.06</td>
</tr>
<tr>
<td>% Zn</td>
<td>0.01</td>
</tr>
<tr>
<td>% Ti</td>
<td>0.05</td>
</tr>
</tbody>
</table>

A milling machine, given in Fig. 3, was designed as FSW experimental set-up for this study. In FSW method a non-consumable rotating tool, moves along a joint line between two components to produce high quality butt or lap welds, is used. For butt welding, the length of the pin is similar to the thickness of the work piece, so that the tool penetrates almost completely through the joint line. The FSW tool consists of a profiled pin, which is contained in a shoulder of larger diameter than that of the pin. The pin for FSW experiments was given in Fig. 4. Subsequently, the pin depth, rotating speed and forward speed for pin which are the parameters for FSW were designed and FSW experiments were made. The optimum parameters were designed according to literature studies and FSW pre-experiments. Some of the joined parts were given in Fig. 5.
After joining of specimens with FSW method, the specimens for fatigue strength tests were prepared as in the following figures.

Table 3 Optimum parameters for FSW experiments

<table>
<thead>
<tr>
<th>#</th>
<th># of specimens joined</th>
<th># of rotation (rpm)</th>
<th>Forward Speed (mm / min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>550</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>550</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>700</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>700</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>800</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>800</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>1400</td>
<td>40</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>1400</td>
<td>80</td>
</tr>
</tbody>
</table>
3. RESULTS AND DISCUSSION

Fatigue strength test results graphics obtained for constant rotation speeds (550 rpm, 700 rpm, 800 rpm and 1400 rpm) is given in Fig. 8. All the values for rotation and forward speeds are given together in graphics.
As it was seen from the fatigue strength experiments of friction stir welded parts, the specimens joined with lower rotation speeds were fractured before the other parts. It can be said that, the sufficient stirring for bond formation could not be achieved by these lower rotation speed specimens. The maximum # of cycle values was obtained with 1400 rpm and 80 mm/min welding speed. These results were consistent with prior studies.

4. CONCLUSION

In this study, the application of FSW methods to 5083 aluminum alloys, which are widely used in industry, were investigated. By these experimental values, it can be said that the maximum fatigue strengths for FSW of AA 5083 alloys can be achieved by using 800 rpm and 1400 rpm with these optimum parameters and the strength of FSW can be changed by # of rotation and welding speed enhancement. After these experimental studies, the metallurgical studies were started with these alloys and also the other aluminum alloys and different material welding will be studied in future studies.

LITERATURE