The Effect of Copper and Brass on Friction Stir Welded Dissimilar Aluminium Alloy When Used as in Thin Sheet Form

G. Gopala Krishna1, P.Ram Reddy2, M.Manzoor Hussain3
1Department of Mechanical Engineering, J.B.Institute of Engineering and Technology (Autonomous), Yenkappally, Moinabad Mandal, Hyderabad – 500 075, Telangana, India,
2Department of Mechanical Engineering and Former Registrar, JNTU, Hyderabad, Telangana, India
3JNTUH College of Engineering, Suthanpur, Medak District, Telangana, India.
*Corresponding author E-mail: krishkans@gmail.com,

Abstract: In recent year’s aluminium and aluminium alloys are most widely used in many applications because of light weight, good formability and malleability, corrosion resistance, moderate strength and low cost. Friction Stir Welding (FSW) process is efficient and cost effective method for welding aluminium and aluminium alloys. FSW is a solid state welding process that means the material is not melted during the process. Complete welding process accomplishes below the melting point of materials so it overcomes many welding defects that usually happens with conventional fusion welding technique which were initially used for low melting materials. Though this process is initially developed for low melting materials but now process is widely used for a variety of other materials including titanium, steel and also for composites. The present butt jointed FSW experimental work has been done in two ways. Initially a comparison of tensile properties of friction stir (FS) welded similar aluminium alloy (AA6351 with AA6351) and dissimilar aluminium alloy (AA6351 with AA5083) combinations. Later the effect of impurities (copper and brass) in sheet form (0.1 mm thick) when used as insert in between two dissimilar aluminium alloy (AA6351 with AA5083) plates during FSW. Tensile tests were performed for these combinations and results were compared for with and without using strip material (copper and brass).

Keywords: Friction Stir Welding, Tensile behaviour, Aluminium alloys AA6351 and AA5083, Copper and Brass.

INTRODUCTION

Friction Stir Welding (FSW) is a new solid state welding process (means material is not melted during the welding process) which is developed and patented by The Welding Institute (TWI) in 1991. This process found world wide acceptance throughout the joining and welding community since its inception and emerged as a novel welding technique to be used for high strength alloys that were difficult to join with conventional fusion welding techniques1. Though this process initially developed for aluminium alloys2-10, but latter FSW has been found suitable for joining of a variety of other materials like magnesium11, 12, steel13, 14, titanium15, copper16, 17 and also for composites18.

The basic principle of FSW process is simple. Instead of a conventional welding torch, friction stir welding uses a non consumable rotating tool (harder than material to be welded) with a specially designed shoulder and pin is inserted into the abutting edges of the two parts to be welded and traversed along the line of the joint as shown in Fig.1. The heating is localised and generated by friction between the rotating tool and workpiece, with additional adiabatic heating from metal deformation. The shoulder and pin of the tool can be modified in number of ways to influence material flow and microstructural formation.

Mechanical properties can improve by various techniques in FSW process such as post weld heat treatment19, 20, pre heating the weld during the process21, different types of peening processes22 and overlapping weld passes23. Though FSW process requires no additional material during the process but addition of alloying elements influences microstructure and improves mechanical properties in aluminium alloys24. So, an effort has been made to improve the mechanical properties by adding copper and brass (an alloy of copper and zinc) separately to dissimilar aluminium alloy combination, in thin sheet form during FSW.

EXPERIMENTAL PROCEDURE
Aluminium AA6351 (standard and experimental chemical composition shown in Table 1) and AA5083 (standard and experimental chemical composition shown in Table 2) alloys of 5 mm thickness plates were friction stir (FS) welded in butt joint configuration. Both alloys were FS welded with different combination. Initially similar aluminium combination, AA6351 alloy with AA6351 alloy and dissimilar aluminum combination, AA6351 with AA5083 alloy were FS welded as shown in Fig.2. Later dissimilar aluminium alloy combination were FS welded separately with copper (99.95 % of copper) and brass (65 % of copper and 35 % of zinc) sheets of thickness 0.1 mm used as inserts in between two dissimilar aluminium alloy (AA6351 with AA5083) plates separately as shown in Fig.3.

Table 1. Standard chemical composition and chemical composition of base material (Aluminium alloy AA6351) used for experiments

<table>
<thead>
<tr>
<th>Element</th>
<th>Standard</th>
<th>Base material used for experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Fe</td>
<td>0.5</td>
<td>0.357</td>
</tr>
<tr>
<td>Cu</td>
<td>0.1</td>
<td>0.037</td>
</tr>
<tr>
<td>Mn</td>
<td>0.4</td>
<td>0.35</td>
</tr>
<tr>
<td>Mg</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Zn</td>
<td>0.2 max</td>
<td>0.004</td>
</tr>
<tr>
<td>Ti</td>
<td>0.2 max</td>
<td>0.024</td>
</tr>
<tr>
<td>Al</td>
<td>Balance</td>
<td>Balance</td>
</tr>
</tbody>
</table>

Table 2. Standard chemical composition and chemical composition of base material (Aluminium alloy AA5083) used for experiments

<table>
<thead>
<tr>
<th>Element</th>
<th>Standard</th>
<th>Base material used for experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>0.2</td>
<td>0.134</td>
</tr>
<tr>
<td>Fe</td>
<td>0.35</td>
<td>0.284</td>
</tr>
<tr>
<td>Cu</td>
<td>0.15</td>
<td>0.028</td>
</tr>
<tr>
<td>Mn</td>
<td>0.15</td>
<td>0.58</td>
</tr>
<tr>
<td>Mg</td>
<td>5</td>
<td>4.466</td>
</tr>
<tr>
<td>Zn</td>
<td>0.25</td>
<td>0.006</td>
</tr>
<tr>
<td>Ti</td>
<td>0.1</td>
<td>0.021</td>
</tr>
<tr>
<td>Al</td>
<td>Balance</td>
<td>Balance</td>
</tr>
</tbody>
</table>

The tool material used in this work was high speed steel (HSS) with conical shape probe without threads. Then the tool was subjected to heat treatment to improve hardness, the hardness tool after the heat treatment process is 54 HRC.

A vertical Compter Numerically Controlled (CNC) milling machine was used to carry out welding process. The two plates are partitioned in the fixture which is prepared for fabricating FSW joint by using mechanical clamps so that the plates will not separate during the welding process. Two aluminium alloys were perfectly clamped in CNC milling machine bed on a back plate. Tool is plunged into the joint in the downward direction. Higher tool rotation generates temperature because of higher frictional heating and resulted more intense stirring of mixing material.

The Effect of Copper and Brass on Friction Stir Welded Dissimilar Aluminium Alloy

Figure 2. Process FSW of AA6351 with AA6351 and AA6351 with AA5083.

Figure 3. Process FSW of AA6351 with AA5083 with copper/brass thin sheet.
RESULTS AND DISCUSSIONS
Tensile tests were performed to determine the tensile properties (yield strength, tensile strength and percentage elongation) for all FS welded all combination samples. Tensile properties were lower at lower rotational speeds of the tool and increases with increase in rotational speeds and after reaching optimum value reverse trend has been observed i.e., tensile properties decrease with increase in rotational speed of the tool. This type of trend observed for all the combinations of alloys i.e., similar alloy, dissimilar alloy and dissimilar alloy using strip material combinations.

Figures 4, 5 and 6 shows the effect of rotational speed of the tool on yield strength, tensile strength and percentage elongation of similar aluminium alloy combination, AA6351 alloy with AA6351 alloy and dissimilar aluminum alloy combination, AA6351 alloy with AA5083 alloy respectively. It is clear from these figures that at lower rotational speed (1000 rpm), tensile properties of both similar and dissimilar alloy combination were lower and reaches maximum at 1300 rpm. After reaching optimum value at 1300 rpm rotational speed, tensile properties decreases with increase in rotational speed of the tool. This type of trend coincided with authors 25 26.

Lower rotational speeds of the tool, lowers the heat input during FSW which results lower tensile properties because of wavy zigzag pattern formation on weldment cross section27 and crack or pinhole defect25. Higher rotational speed of the tool results higher temperature at weld joint28 which results large size defect like tunnel25.

Similar aluminium alloy combination AA6351 with AA6351 shows higher tensile properties compared to dissimilar alloy combination AA6351 with AA5083 because weaker alloy (AA5083) dictates the performance of the weld joint29.

Figure 4. Effect of rotational speed of tool on yield strength for both similar and dissimilar aluminium alloy combination.

Figure 5. Effect of rotational speed of tool on tensile strength for both similar and dissimilar aluminium alloy combination.

Figure 6. Effect of rotational speed of tool on percentage elongation for both similar and dissimilar aluminium alloy combination.

Figures 7, 8 and 9 shows the effect of rotational speed of the tool on yield strength, tensile strength and percentage elongation of dissimilar aluminium alloy combination AA6351 with AA5083 alloy, dissimilar AA6351, AA5083 with copper and brass strip material respectively. It is clear from these figures that at lower rotational speed (1000 rpm), tensile properties of all the combination were lower and reaches maximum at 1300 rpm. After reaching optimum value at 1300 rpm rotational speed, tensile properties decreases with increase in rotational speed of the tool. Tensile values of dissimilar alloy combination with copper addition values are lower than pure dissimilar combination. Tensile values of dissimilar alloy combination with brass addition values lower than both pure dissimilar combination and also copper addition combination. The main reason of lower values for copper and brass addition are complete melting of copper and brass material was not taking place at bottom sides of the welded plates though sheet thickness of copper and brass is too small (0.1mm).
CONCLUSIONS
The following conclusions are arrived from the present work.

- Tensile values (yield strength, tensile strength and percentage elongation) are lower at lower rotational speed of the tool, increases with increase in rotational speeds and reaches optimum at a particular value of speed (1300 rpm) and thereafter, values came down with increase in rotational speed of the tool. This trend is common for all types of combinations.
- Tensile values of similar aluminium alloy combination of AA6351 with AA6351 are greater than the dissimilar aluminium alloy combination of AA6351 with AA5083.
- Tensile values of copper addition with dissimilar aluminium alloy combination of AA6351 with AA5083 are lower than pure dissimilar aluminium alloy combination of AA6351 with AA5083 but better than that of brass addition with dissimilar aluminium alloy combination of AA6351 with AA5083.

REFERENCES
11. Dr. Richard Johnson, Dr. Philip Threadall, Friction stir welding of magnesium alloys, Magnesium technology 2003, Edited by Howard I. Kaplan TMS (The minerals, metals & material society), (2003), pp.147-152.
17. Ratnesh K.Shukla, Dr. Pravin K. Shah, Experimental investigations of copper joining by friction stir welding, proceedings of the international conference on emerging research and advances in mechanical engineering (ERA 2009), Velammal engineering college, Chennai-600 066, Taminadu, India. Pp.657-660