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

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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 an 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 was initially used for low melting materials. Though this process is initially developed for low melting materials but now the 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 an insert in between two dissimilar aluminium (AA6351 with AA5083) alloy 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.

1. Introduction

Friction Stir Welding (FSW) is a new solid state welding process (means the material is not melted during the welding process) which is developed and patented by The Welding Institute (TWI) in 1991. This process found worldwide 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 techniques [1]. Though this process initially developed for aluminium alloys [2-10], but later FSW has been found suitable for joining of a variety of other materials like magnesium [11,12], steel [13,14], titanium [15], copper [16,17] and also for composites [18].

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 the pin is inserted into the abutting edged 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 a number of ways to influence the material flow and microstructural formation.

Mechanical properties can improve by various techniques in FSW process such as post weld heat treatment [19, 20], preheating the weld during the process [21], different types of peening processes [22] and overlapping weld passes [23]. Though FSW process requires no additional material during the process but the addition of alloying elements influences microstructure and improves mechanical properties in aluminium alloys [24]. 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.

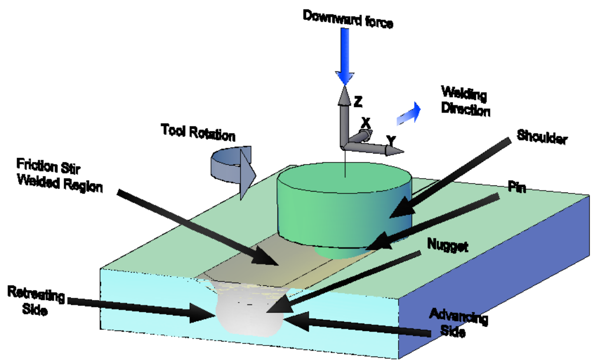

Fig.1. Friction Stir Welding (FSW) Process.

2. 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 a different combination. Initially, similar aluminium combination, AA6351 alloy with AA6351 alloy and dissimilar aluminium combination, AA6351 with AA5083 alloy were FS welded as shown in Fig.2. Later dissimilar aluminium alloy combination was FS welded with copper (99.95 % of copper) and brass (65 % of copper and 35 % of zinc) placed separately in between two plates as shown in Fig.3.

Table1. Standard chemical composition and chemical composition of base material (Aluminium alloy AA6351) used for experiments

Element	Standard	Base material used for experiments
Si	0.8	0.7
Fe	0.5	0.357
Cu	0.1	0.037
Mn	0.4	0.35
Mg	0.4	0.3
Zn	0.2 max	0.004
Ti	0.2 max	0.024
Al	Balance	Balance

Table2. Standard chemical composition and chemical composition of base material (Aluminium alloy AA5083) used for experiments

Element	Standard	Base material used for experiments
Si	0.2	0.134
Fe	0.35	0.284
Cu	0.15	0.028
Mn	0.15	0.58
Mg	5	4.466
Zn	0.25	0.006
Ti	0.1	0.021
Al	Balance	Balance

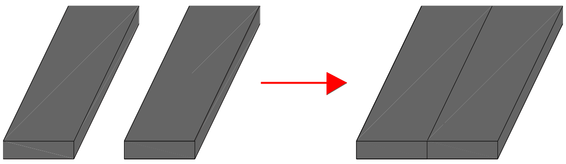

Fig.2. Process FSW of AA6351 with AA6351 and AA6351 with AA5083.

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. The tool is plunged into the joint in the downward direction. Higher tool rotation generates temperature because of higher frictional heating and resulted in the more intense stirring of mixing material.

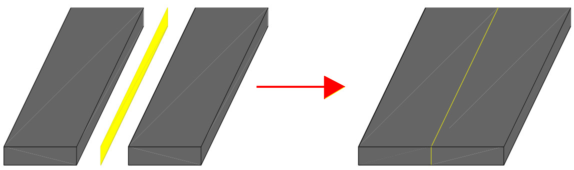

Fig.3. Process FSW of AA6351 with AA5083 with copper/brass thin sheet.

3. 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 aluminium 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 a maximum at 1300 rpm. After reaching an 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 lower the heat input during FSW which results in lower tensile properties because of wavy zigzag pattern formation on weldment cross section [27] and crack or pinhole defect [25]. Higher rotational speed of the tool results higher temperature at weld joint [28] which results in large size defect like tunnel [25]

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 joint [29]

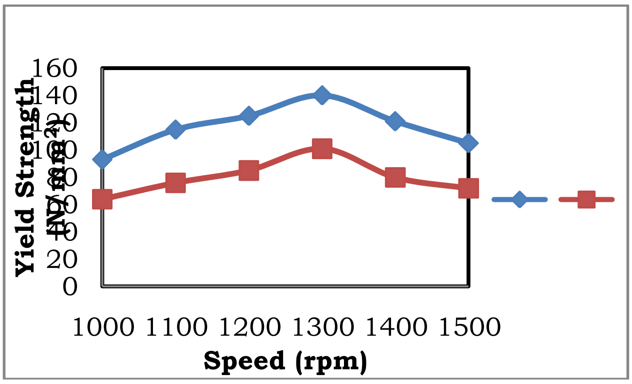

Fig.4. Effect of the rotational speed of tool on yield strength for both similar and dissimilar aluminium alloy combination.

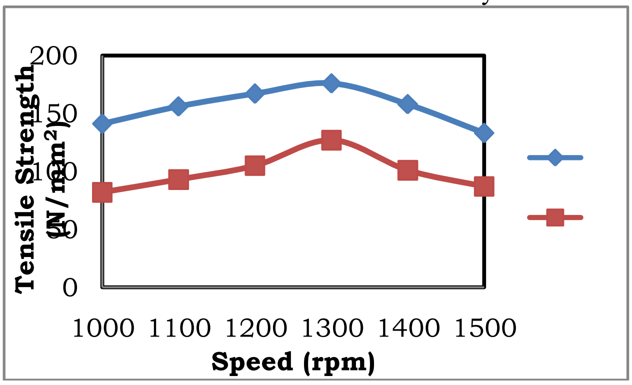

Fig.5. Effect of the rotational speed of tool on tensile strength for both similar and dissimilar aluminium alloy combination.

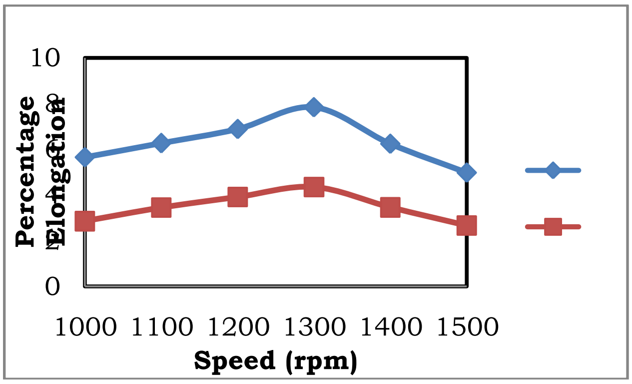

Fig.6. Effect of the rotational speed of tool on percentage elongation for both similar and dissimilar aluminium alloy combination.

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 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 a maximum at 1300 rpm. After reaching an 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 the 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 for lower values for copper and brass addition are the complete melting of copper and brass material was not taking place at bottom sides of the welded plates as the sheet thickness of copper and brass is too small (0.1mm).

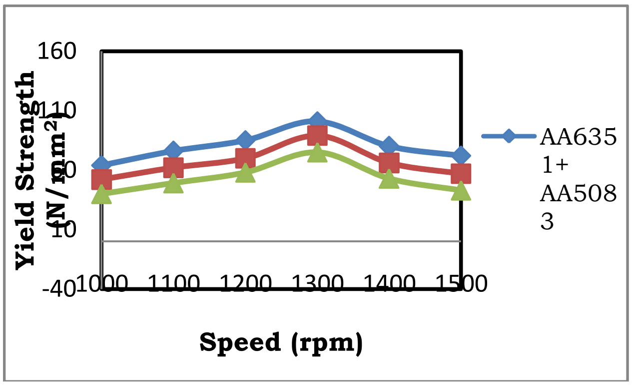

Fig.7 Effect of the rotational speed of tool on yield strength for pure dissimilar aluminium alloy, and the effect of copper and brass addition on dissimilar aluminium alloy combinations.

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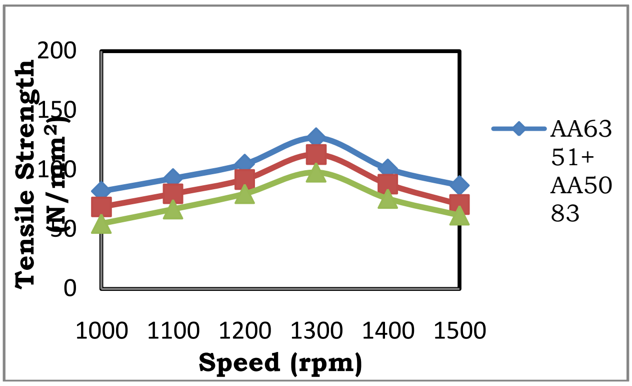

Fig.8 Effect of the rotational speed of tool on tensile strength for pure dissimilar aluminium alloy, and the effect of copper and brass addition on dissimilar aluminium alloy combinations.

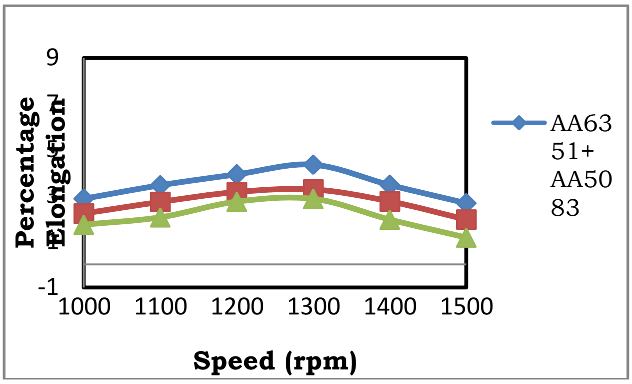

Fig.9 Effect of the rotational speed of tool on percentage elongation for pure dissimilar aluminium alloy, and the effect of copper and brass addition on dissimilar aluminium alloy combinations.

Conclusions

The following conclusions arrive from the present work.

- Tensile values (yield strength, tensile strength and percentage elongation) are lower at the 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 an 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 a 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 a dissimilar aluminium alloy combination of AA6351 with AA5083.

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