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MECHANICAL BEHAVIOUR OF FRICTION STIR WELDED AA5083 AND AA7075 ALLOYS

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Abstract: Present investigation delineates manufacturability features of dissimilar joint comprising AA5083 and AA7075 using friction stir welding with straight triangular tool for light combat vehicle application. Friction stir weldments fabricated with placing AA5083 along advancing side by adopting rotational speed of 400rpm, 710 rpm and 1100 rpm with maintaining constant transverse speed of 40 mm/min. These weldments tested for evaluating mechanical properties confined to weld nugget. Friction stir weld nugget shows superior mechanical properties at tool rotation speed of 710 rpm.

Key words: Aluminium alloys, Tool rotational speed, microstructure, tensile strength

1.0 Introduction: Urgency for fuel economy and ease of mobility in transportation sectors opens an opportunity to explore light metals. Lighter materials like magnesium, titanium and aluminium are considered as better supplement to existent steel. Limited availability of magnesium and high cost of titanium, aluminium and its alloys are considered to be potential material [1-2]. It is inconceivable for any industries to deprive of fabrication. High thermal conductivity, coefficient of expansion, chemical affinity to gases and wide solid temperature freezing range associated with aluminium and its alloys led to exhibit several fusion based weld defects such as hot cracking, solidification shrinkage, blow holes, voids and pin hole porosity etc. These defects can be well ruled out by adopting solid state welding i.e. friction stir welding in contrast to fusion welding [3-4].Now a days, incompetency of monolithic weldments in the service sectors such as automobile, air craft, marine and power plants stimulates to adopt dissimilar welding [2]. Present investigation comprises one such dissimilar welding consisting of corrosion resistant AA5083- H111 and high strength age hardenable AA 7075-T 651 for high altitude or light combat vehicle application. Thus, an attempt has been made to identify the scope through following lines. Defect free and maximum weld strength joint of the order of 239MPa attained by positioning AA5xxx along advancing side while AA 7075in retreating side during friction stir welding [5-7]. Friction stir welding of AA5083-H111 and AA7075-T651 alloys with high rotational speed yields more weld defects, decrease mechanical properties. In addition to above using triflute pin and engaging AA5083 in advance side resulted sound weld joints [8-9]. Similar types of outcomes were perceived when higher flow stress material (AA5083-H111) in advancing side leading to thorough mixing in stir zone, but there was no significant effect on tensile properties [10].Saeidi M et.al. Developed mathematical model by considering friction stir welding parameters while joining AA5083-H111 with AA7075-T65. They witnessed variation of experimental ultimate strength and predicted one within the permissible range of the order less than 1%. [11]. Friction stir welding of same aluminium alloys combination, transverse speed of tool did not contribute to appreciable variation of grain size, hardness and weld tensile strength (maximum 267MPa) [12]. Friction stir processed AA5083 aluminium alloys higher wear and corrosion resistances compared to substrate. This is owing to presence of fine equiaxed grains and precipitates in nugget TMAZ and HAZ compared to base [13]. Grain size refinement, distribution of grains and precipitates and mechanical work are accountable for exhibiting better corrosion resistance of AA5454 friction stir weldments [14]. Corrosion behaviour of friction stir welded AA5456 aluminium alloys revealed presence of 'β' precipitates in the nugget susceptible to corrosion attack compared other regions [15]. Irrespective of shoulder profile, friction stir welded AA5083-H111 showed better inter granular resistance than base while friction stir welding with concave shoulder resulted better corrosion resistance because of higher degree of surface finish compared flat shoulder[16]. Nugget and HAZ regions of friction stir welded AA7010 found to more prone to inter-granular attack (IGC) compared to base [17].Non uniform distribution of zinc-magnesium rich phase along the grain boundaries of TMAZ in friction stir welded AA7108-T79 exhibited high corrosion rate [18]. Similarly, grain boundaries of HAZ occupied with copper depleted regions in friction stir welding of AA7075-T651 yielded lower pitting and IGC resistance compared to base [19]. Corrosion resistance of dissimilar friction stir weld AA5083-AA7023 found to intermediate between AA 7023 and AA5083. Non uniform distribution of Al-Mg-Zn precipitates favour galvanic coupling along the interface. Furthermore, intermetallic areas along border line of AA 7023 initiates corrosion [20].Addition of boron carbide in to the nugget zone along with retrogression and reaging (RRA) improve both hardness and corrosion resistance of nugget as compared to friction stirred AA 7075[21]. Kartsonakis et.al. Incorporated three different nano-additives such as multiwall carbon nano tubes, cerium molybdate, and titanium carbide into nugget zone of dissimilar AA 6082-T6 and Aa5083-H111 to understand their influence on corrosion resistance. They found using cerium molybdate as additive rendered higher nugget resistance. This probably due to cerium oxide films on the formation weld nugget area [22]. Similarly, incorporation of alumina into the nugget of dissimilar weld AA5083-H116 with AA7075-T6 aluminium alloys provided excellent corrosion resistance compared to friction stir welded. However, both the dissimilar welds shown inferior corrosion resistance in contrast to base [23]. Thus, the present investigation delineated to understand the influence of triangular probe profile during friction stir welding of AA5083-H111 and AA7075-T651 in addition to effect of boron carbide particles incorporation in to the nugget zone and carrying out a comparative study of mechanical and corrosion behaviour.

2.0 Experimental details:

2.1 Materials and methods:

Strain hardened AA5083 and AA7075 received in rolled condition. Table-1 represents the detail elemental composition of above selected metals for investigation. Fig. 1 depicts the schematic of tool made of EN-24 steel.

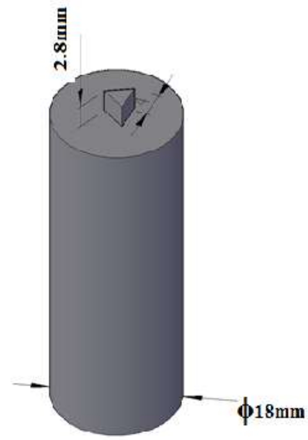


Fig.1 Schematic of tool profile used in dissimilar FSW.

(100x75x3) mm plates cut using waterjet cutting machine prior to friction welding. These plates were firmly secured in key ways using T-bolts on table of FSW machine. Series of trial runs for dissimilar joining attempted to have joint and rotational speeds 400rpm, 710rpm and 1100 rpm adopted along with transverse speed of 40mm/min placing AA7075 along advancing side. Plunge depth of 2.8mm, tool tilt angle 2° and zero offset maintained during friction stir welding.

Table-1: Chemical composition of base alloys in present study

Alloy	**Element (in wt. %)**								
	Si	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**	**Al**
AA7075	0.04	0.15	1.30	0.02	2.30	0.19	5.40	0.05	Bal
AA5083	0.09	0.27	0.01	0.80	4.40	0.07	0.02	0.02	Bal

2.2 Mechanical testing: Tensile specimens machined from weldments using water jet cutting machine. Uniaxial tension test conducted in accord with the ASTM E8 standards with 0.001mm s^{-1} strain rate using tensile testing machine (Model 5582, Instron,). Vicker micro hardness test conducted on both the fabricated weldments in the nugget zone under a load of 300gm. Reported values are based on average of 5 reading along the stir zone of weldments.

2.3 Optical microscopy: Samples cut along the transverse direction of welding from both the weldments. Kellar's reagent used as an etchant for preparing metallurgical specimen. These specimens characterized for understanding the nugget morphology of weldments using optical microscope.

3.0 Results and discussion:

3.1 Microstructure

The microstructure of the weld centre was thoroughly examined using light microscopy. In friction stir welding the weld centre termed as a nugget zone (NZ) of stir zone (SZ) centres are frequently referred to as the stirred zone or nugget [2,6-8]. This zone is subjected to extreme heat and/or plastic deformation. Dynamic recrystalization resulted due to sever heat input causes for fine equiaxed grains in SZ of all the weld joints. The size of grains in SZ increases with increase in tool rotational speed [8-9]. This could be attributed to increase in friction al heat at higher tool rotational speeds causes' grain growth in SZ of weldments. Whereas increase in SZ grain size was noticeable with increase in tool traverse speed during friction welding of 7075 and 5083 by Ahmed [5]. This confirms that tool rotational speed play significant role rather than the traverse speed on SZ grain size. Microstructural study revealed that the specific bands originated from both base alloys: one type of band was created by the alloy 7075, while the other was created by the alloy 5083. Further, EDS analysis confirms the presence of major alloying elements (Al-Zn-Mg-Cu). In particular, the weld centre is contained by Mg and Zn-Mg-Cu bands and shows that the alloy placed on advancing side is more dominant in SZ of fabricated weld joints. However in the presented selected samples characterized for EDS analysis to support the microstructural examinations.Fig.2a and 2b depicts the SZ microstructure of weld joints made at 400 rpm and 710 tool speeds. Vortex like flow with alternative bands of two base alloys in SZ of all the weldments observed. Formation of alternative bands could be due to intense plastic deformation and layered mixing of the base alloys to be joined.

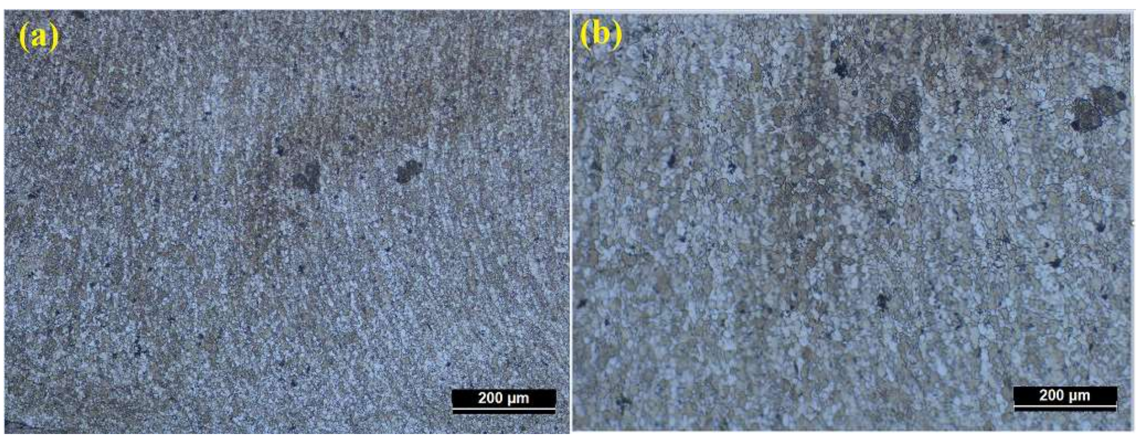


Fig.2 SZ microstructure (a) 400 rpm and (b) 710 rpm

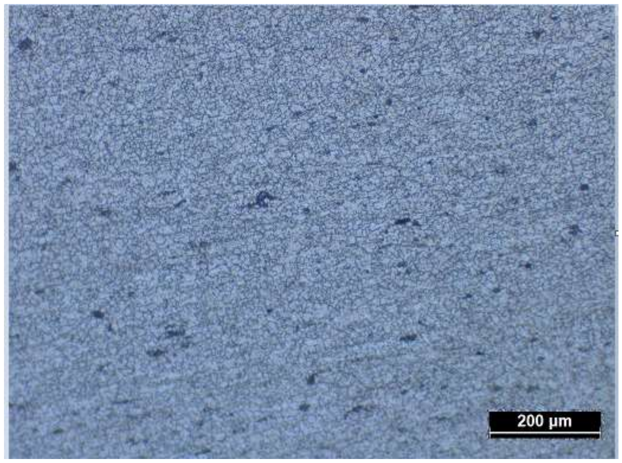


Fig.3 SZ microstructure of weld joint fabricated at 1100 rpm

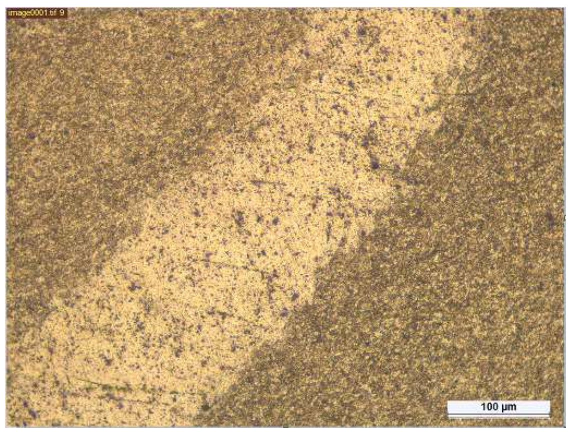


Fig.4 Alternatives layers of AA5083 and AA7075 weld joint fabricated at 400 rpm

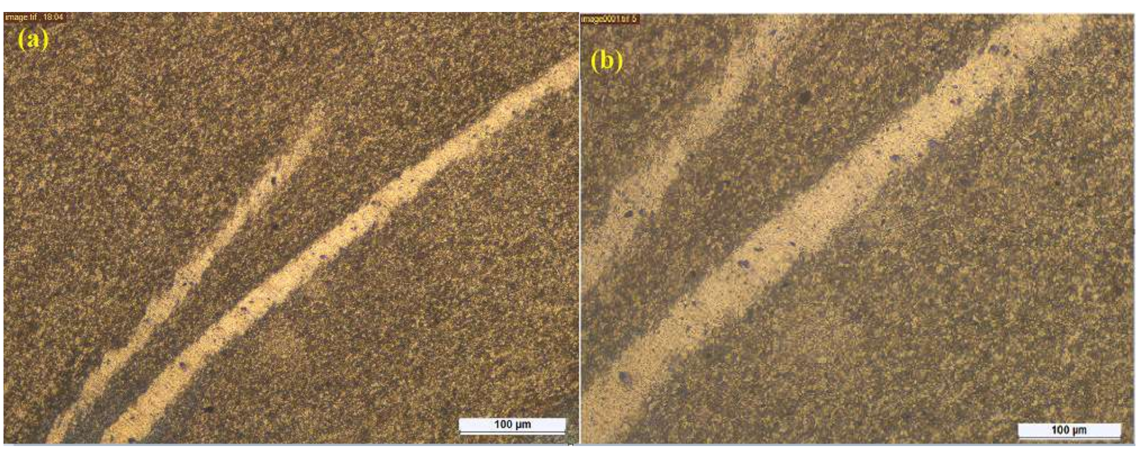
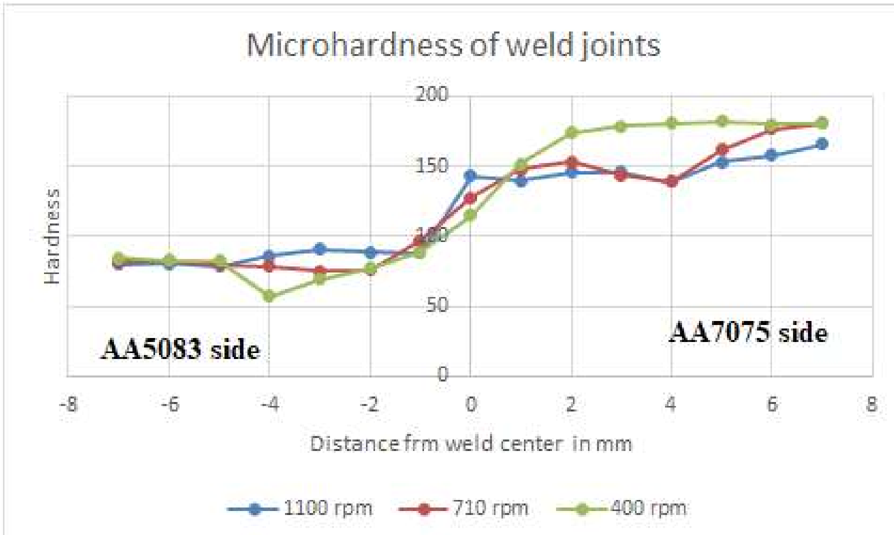


Fig.5 Alternatives layers of AA5083 and AA7075 weld joint fabricated at (a) 710 rpm (b) 1100 rpm

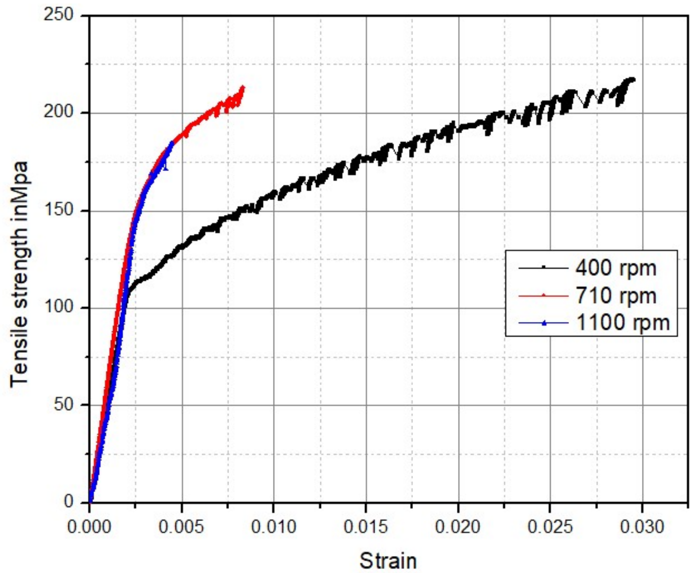
3.2 Micro-hardness

The results of the vickers microhardness test showed a clear correlation between the weld joint micro hardness and the tool rotational speed. The micro hardness values increases with increase in tool rotating speed [8-9]. The rise in temperature and shear strain rate during welding depends on tool rotational speed and it further affects the weld joint micro hardness. The frictional heat produced at the contact between the tool and the workpiece rises with increased rotational speeds, raising the temperature. The material softens at a higher temperature, facilitating more plastic deformation and improved alloy mixing. As a result, the microstructure becomes more homogenous, increasing the micro hardness. SZ hardness of all the weld joints is higher than the hardness of softer alloy (AA5083) and it confirms that alloy placed on advancing side is more dominant is SZ of weld joints [2,8,10].



3.3 Tensile strength

The results of tensile test showed that weld joint tensile strength significantly influenced by tool rotational speed. Tensile strength of weld joint increases with increase in tool rotational speed up to 710 rpm and beyond this any increase in tool rotational speed causes decrease in strength of the weldments. The material experienced excessive heat at higher rotational speeds, which led to grain growth and decreased tensile strength. The material was not well mixed at slower rotating rates, which led to a weak joint. Further, microstructure of the weld joint revealed a distinct boundary between the two alloys at low tool speeds, indicating inadequate mixing. The contact got more diffuse as the tool speed rose, indicating better mixing. The material showed evidence of excessive heat input at high tool speeds, including grain growth and porosity. This could affected the tensile strength of weld joints fabricated at higher rotational speed.



4. Conclusions

AA5083 and AA7075 aluminium alloys successfully welded by friction stir welding technique and the following conclusion observed

- Tool rotational speed significantly influenced the SZ microstructure of fabricated weld joints. Grain size increases with increase in tool rotational could be due to severe heat input at high tool rotational speeds.
- Micro-hardness profile along the transverse sections of the weld joints indicates that defects like voids and pore formation at high speeds resulted low hardness at high tool speeds.
- Tensile strength of weld joints increases with increase in tool rotational speed up to 710 rpm and any further increase in tool speeds decreases the joints tensile strength.

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