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Evaluation of Mechanical Properties of Friction Stir Welded Dissimilar AA2024T351 and AA7075-T6 Alloy

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Abstract: The objective of this study is to apply the concept of Friction Stir welding technique to dissimilar aluminium alloys in order to evaluate the mechanical properties of the weld at the selected process parameters such as tool rotational speed, welding speed and tool pin profile. In this AA2024 T351 and AA7075T6 aluminium alloys were selected for the experimentation. The welding is carried out under different feeds at 80, 90 and 100 mm/min and tool rotation speeds at 1000, 1100 and 1200 rpm using two different tool profiles (threaded cylindrical and triangular). It is found based on the experimentation that the joints produced using triangular tool profile at feed rate of 100mm/min and tool rotation speeds of 1200 rpm produced as high tensile strength when compared with others.

Key words: Dissimilar friction stir welding · Mechanical properties · Tool profiles · Morphology

INTRODUCTION

Friction stir (FS) welding is a solid state joining process which joins the materials below its melting point and has got many advantages over conventional welding techniques, such as no consumable materials, no defects related to solidification of the material, higher weld strength, reduced power consumption [1], etc. This technique was successfully executed in the last two decades in TWI Cambridge [2]. It's an eco friendly concept and can be applied for both ferrous and non ferrous metals and alloys. Ferrous alloys needs expensive tool design [3]. In this concept two metals are joined by mechanical pressure and frictional heat, generated between the tool and material. Applications of FSW lies in the area of light weight transport structures such as boats, trains aero planes, electronic housings, coolers, heat exchangers and nuclear waste containers.

Ranjith *et al*. [4] carried out experimental investigation of friction stir welded dissimilar aluminium alloys of AA 2014 T651 and AA 6063 T651by. The result indicated that that pin diameter has greatest impact on heat generation. N. Shanmuga Sundaram and N. Murugan [5] optimized the FSW process parameters work on heat treatable alloy AA2024 and non heat treatable alloy AA5083 and reported that joints obtained from tapered pin profile tool shown highest tensile strength and tensile elongation. P. Cavaliere *et al*. [6] investigated the mechanical and micro structural properties of dissimilar 2024 and 7075 aluminium and concluded that trend of fatigue life decreasing with the stress amplitude. N. T. Kumbhar and K. Bhanumurthy [7] used AA5052 and AA6061 and investigated that no rigorous mixing of both materials in the nugget, an abrupt change in the micro hardness across the interface in the nugget and inter diffusion of alloying elements is prevailed. S.-K. Park *et al*. [8] investigated effect of material locations on properties of friction stir welding joints of dissimilar aluminium alloys using AA5052-H32 and 6061-T6. The results indicated the proper mixing of both alloys taken place and high tensile strength of 224 MPa is obtained that when AA5052 is in advancing side.

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In this work, a small study has been carried out in the light of above literatures how dissimilar joints made from aluminium alloys AA2024-T351 and AA7075-T6 would respond when they are subjected to tensile loads to evaluate mechanical properties like ultimate tensile strength, yield strength, percentage elongation, micro-macro structural properties and hardness.

Experimental Work

Material Selection: In this work, eight specimens of Aluminium AA2024-T351 and AA7075-T6 aluminium alloys (100x50x5 mm), prepared by machining, cutting and milling processes is considered for investigation. The chemical composition of the AA2024-T351 is 0.001 wt% Si, 0.146 wt% Fe, 4.478 wt% Cu, 0.461 wt% Mn, 1.242 wt% Mg, 0.018 wt% Zn, 0.001 wt% Cr, 0.002 wt% Ni, 0.051 wt% Ti, 0.004 wt% Sb and balance is aluminium. Now, the chemical composition of the AA7075-T6 aluminium alloys 0.001 wt% Si, 0.207 wt% Fe, 1.155 wt% Cu, 0.015 wt% Mn, 2.102 wt% Mg, 6.225 wt% Zn, 0.210 wt% Cr, 0.001 wt% Ni, 0.046 wt% Ti, 0.002 wt% Sb and balance is aluminium. The plates treated by T351 (solution heat treated, stress-relieved by controlled stretching and then artificially overaged in order to achieve the best stress corrosion resistance) were cut and then welded. The mechanical property of the base metal AA2024 is 380 MPa yield strength, 490 MPa ultimate tensile strength 17% Elongation and 72.4 GPa Youngs Modulus whereas the mechanical property of the base metal AA7075 is 503 MPa yield strength, 572 MPa ultimate tensile strength 11% Elongation and 71 GPa Youngs Modulus. Now the point of interest of this work is to investigate the microstructure and mechanical property, when both the base metals were joined.

Table 1: Mechanical Properties of D2 tool

Properties	Unit	Tool material
Hardness temperature	°C	982-1024° C
Poisson's ratio		0.27-0.30
Thermal conductivity	W/mk	24.2
Tensile strength (ultimate)	MPa	640-2000

Tool Material: The tool material selected is D2 which has high carbon, high chromium alloy tool steel. It is a tool steel with high dimensional stability in heat treatment. The tool pin used for the welding work contains cylindrical profile. The properties and dimension of D2 tool steel are shown in Table 1 and Figure 1. respectively.

Process Parameters: The range of process parameters are considered based on the literature survey. The welding speed or feed is 80 -100 mm/min and tool rotational speed 1000-1200 rpm are applied for fabricating the joints.

Joint Fabrication: In the present investigation, all the experiments were carried out using the MITSUBISHI CNC 700/70 series machine. The table size is 1016x508x508 mm and the maximum spindle speed is 8000 rpm. The motor spindle power is 20 HP. The metal plate is clamped rigidly to the table of the CNC machine. The D2 tool steel is rotated into the joint line between the metal plates. The tool shoulder is made in intimate contact with the surface of the work piece. The pin is traversed back and forth. The pin produces mechanical stirring in the work piece and the frictional heat is generated principally due to shearing action of the shoulder. The CNC-VMC machine is shown in Figure 2 (a) and work piece clamping position is shown in Figure 2(b).The fabricated joints are shown in Figure 3(a) and tensile specimen in Figure 3 (b).

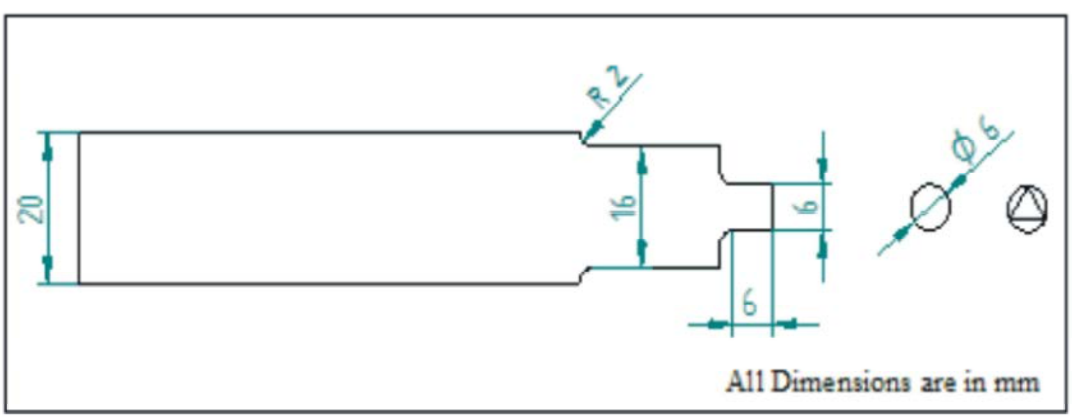

Fig. 1: Schematic view of the FSW tool

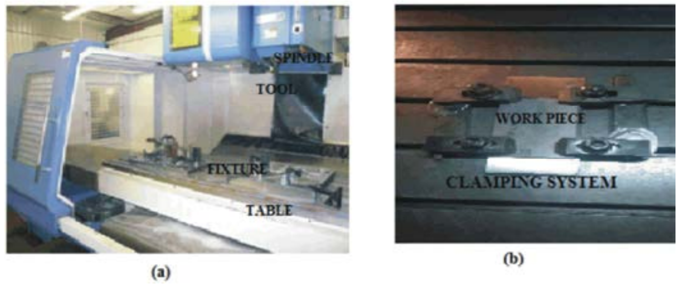

Fig. 2: CNC-VM and Work-Piece clamping system

Fig. 3: Welded Joints and Tensile Specimens

RESULTS AND DISCUSSIONS

Morphological Studies: Macro structural and micro structural analysis was carried out for various specimens welded under different process parameters. It is found by examining the specimens under magnification 20X using De-Winter Inverted Trinocular Metallurgical Microscope that joint fabricated at speed of 1200 rpm and feed rate of 100 mm/min using triangular profile tool showed the proper mixing of two alloys at the interface and producing the good mechanical properties. From the macro image it is found that no cavity is formed and shouler also have no fragmentation with proper mixing of 2024 and 7075 without any defect. The macro image is shown in Figure 4.

The micro structure reveals that effective stirring by the tool pin and production of heat, resulted in good fusion of the process at the interface of the nugget zone and the parent metal. Further interface zone is without any defect and grains at the nugget region are finer due to fragmentation with heat. The micro images are shwon in Figure 5.

Evaluation of Tensile Property: The mechanical properties of FSW specimens were evaluated using tensile tests. The specimens for determining the tensile property were prepared using a wire cut EDM machine in accordance with ASTM B557M. The specification and dimension of the specimen is shown in Figure 6.

The tensile tests are performed on all welded specimens using Universal testing machine (UTM) and stress versus strain graphs are drawn with respect to various feeds and speeds as shown in Figure 7 and 8 respectively. From the graphs, it is evident that with an increase in tool rotational speed, tensile strength increases. When rotational speed increases the heat input within stirred zone increases due to higher friction heat which in turn results in more intense stirring and mixing of materials around the rotating pin which in turn increases the temperature of the metal. The rotating tool stirs the welding speed enables the linear motion of the tool pushing the stirred material from front to the back of the tool pin. Frictional heat is generation due to mechanical rubbing of the tool shoulder and pin with the work piece material. The welding speed determines the exposure time of the heat produced due to friction per unit length of the weld and subsequently affects the grain growth and precipitates. At lower welding speeds heat generation is more and rate of cooling is slow resulting in coarsening of grains and dissolution of precipitates[14]. Lower welding speed causes improper consolidation of material which leads to reduction in tensile strength of the material.

Hardness Survey: The micro-hardness profile of Friction Stir Processed samples for different feed rate is shown in the Figure 9.

Fig. 4: Macro Image

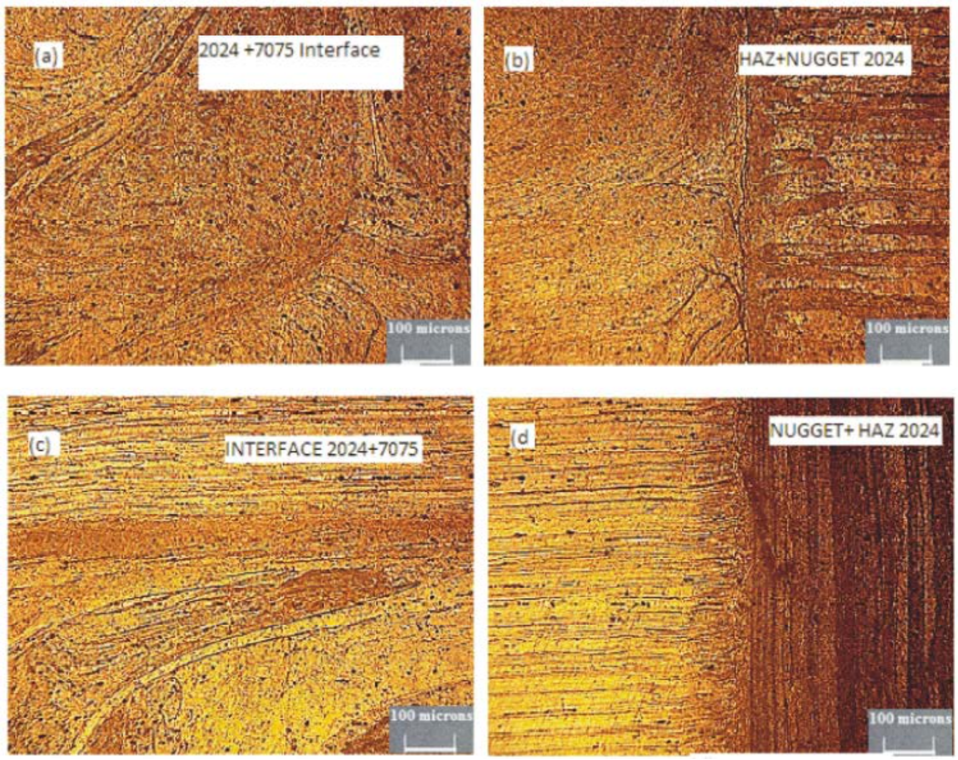

Fig. 5: Micro images of the aluminium 2024 and 7075 aluminum alloy

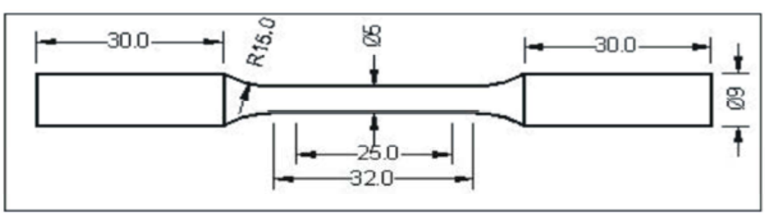

Fig. 6: Dimensions of Tensile Specimen

The weld quality has been assessed by means of micro-hardness measurement. The reason for hardness enhancement in weld region is due to the reduction of both grain size and residual work hardening produced during the process as a result of severe deformation and increased friction heat. This area contains a low density of big grains and high density of fine grains. Recrystallization phenomena occur in the Nugget zone. Tool geometry also contributes to obtain a smallest equiaxed grain size on the stirred zone. Inhomogeneous attenuation of micro hardness values is obtained in both sides leading to decrease of material

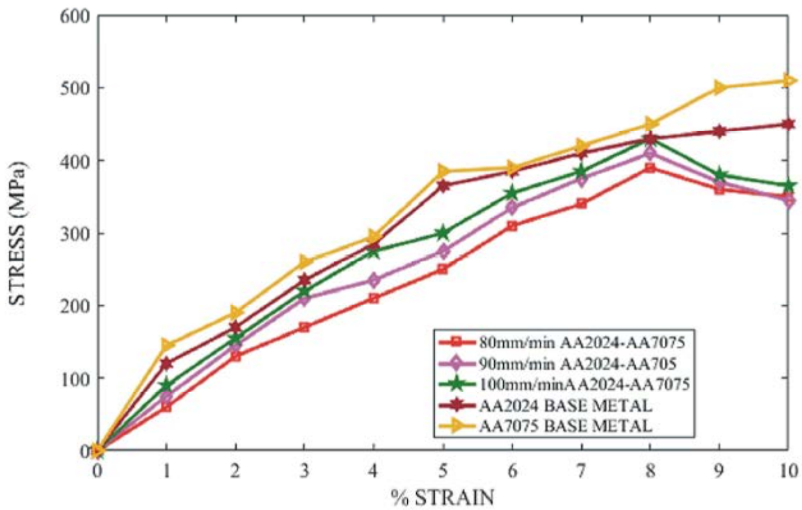

Fig. 7: Stress-strain curve for various feed rate

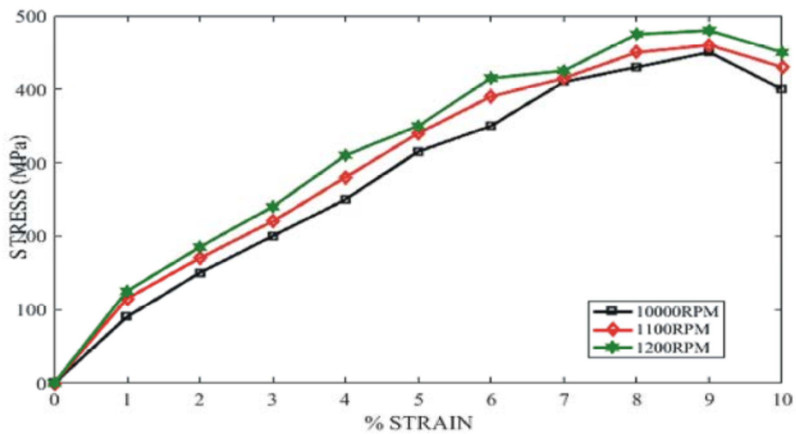

Fig. 8: Stress-strain curve for various tool rotation speeds

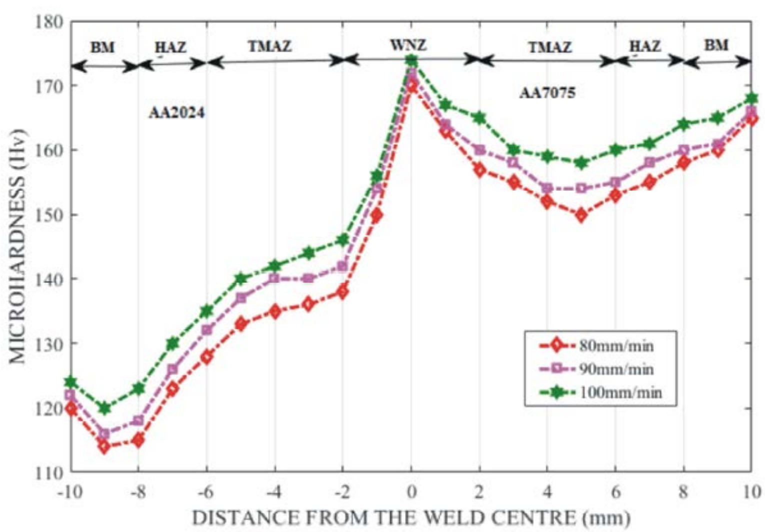

Fig. 9: Micro-Hardness profile of the dissimilar weld

mechanical characteristics. Relatively high hardness of DXZ is due to small grain size, while the lower hardness of TMAZ and HAZ is due to dissolution of strengthening precipitates and due to coarsening and clustering of precipitates respectively and is in accordance with previous researchers.

CONCLUSION

The dissimilar aluminium alloys AA2024 T351 and AA7075T6 alloys were successfully welded by friction stir welding. Based on the experimentation results, the following conclusions can be attributed to the fabricated joints.

- The micro structural characteristics revealed that effective stirring of tool pin is imperative fact which intensified production of heat resulted in good fusion of the process, without any defect and finer grins at the interface of the nugget zone and the parent metal.
- It is found that the specimen welded using triangular tool profile has no cavity and without any defect.
- The joint fabricated at speed of 1200 rpm and feed rate of 100 mm/min showed the proper mixing of two alloys and high tensile strength.
- Lower welding speed causes improper consolidation of material which leads to reduction in tensile strength of the material.

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