Third International Conference on "Materials, Computing and Communication Technologies"
in association with International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)

Effect of Reinforcement of Al_2O_3 Nanofillers on AA5083-H321 Joint by Friction Stir Spot Welding

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ABSTRACT

Friction stir spot welding (FSSW) is a solid-state welding process suitable for producing aluminum alloy spot joints that are principally fascinating due to their weight-saving potential. In the present study, the mechanical properties of friction stir spot welded AA5083-H321 aluminium alloys reinforced with SiC nanoparticles have been investigated. Weld samples were produced with and without the addition of Al2O3 nanoparticles to the joint. Tests were carried out for the micro hardness and lap shear strength of the joints. The cross-section of welds and the fracture surfaces were studied by stereo zoom microscope. It is observed that the reinforcement of Al2O3 nanoparticles significantly influences the weld properties and also changes in the width of the welding area resulting in a change in the joining strength.

Keywords: AA5083-H321, Friction Stir Spot Welding, Aluminium alloy, Lap Shear Test, Hardness

I. INTRODUCTION

The Friction Stir Spot Welding (FSSW) invented by TWI, UK, is being applied more to join the aluminium and magnesium alloys and has more benefits in the aspect of metallurgical, environmental and energy economy over other joining methods [1]. There are many types of FSSW that have been developed by the researchers and many investigations were also made by using all the types of FSSW. The various different types of FSSW are Normal (or) conventional FSSW, Refill FSSW, Stitch FSSW, Swing FSSW, and the newly developed Swept FSSW. Each of these FSSW types has a different level of complexity, and diversity in such a way that in the spot shear area and shear strength, Degree of control in motion, and time to complete the weld.

Aluminum alloys create a center of attention because of their advantageous attributes such as low density, high specific strength, good castability, and good thermal conductivity and also, they are regarded as the most promising candidates to reduce the weight of automobiles in the automotive industry [2-3]. There is some research on spot joining on aluminum alloys using the FSSW process [4–6]. Some of the work on reinforcing the particles during FSW and FSP proved that the particles influence the weld properties [6-7].

Based on previous studies, tool rotation speed plays a major role in the strength of the weld joint followed by the plunge feed rate, Dwell time, and shoulder plunge depth. In the present work, an attempt is made to improve the joint strength of composite FSS welded AA AA5083-H321 by adding Al_2O_3 nanoparticles to the joints with different volume fractions.

II. METHODS AND MATERIAL

Commercially available AA5083-H321 aluminum alloy plate dimensions of 100 mm x 35 mm x 2 mm prepared by EDM machining are used for the FSSW experiments. The overlap area of 35 mm x 35 mm is configured to prepare all the spot-welded specimens. The chemical composition and mechanical properties of the chosen base metal are shown in Tables 1 and 2. The hole was made in the top plate at the tool plunge center in the overlapping area to facilitate the reinforcement of Al_2O_3 particles before spot welding. The Al_2O_3 nanoparticles with an average size of 50 nm have been used to reinforce the aluminum alloy sheet before the welding process. FSSW tool was made of H13 tool steel and hardened to 56-59 HRC. The tool of a pin diameter of 5 mm with thread, shoulder diameter of 12 mm, and a pin length of 2.8 mm was used in this study. The configuration of the Specimen coupon and the weld tool is shown in Fig. 1. The welds were made using a Friction Stir welding setup in the CNC Vertical Machining Centre as shown in Fig. 2. Three different volume fractions of SiC nanoparticles between 0% and 30% were chosen and other parameters such as tool rotation speed, dwell time, and shoulder plunge depth was kept constant for all the experiments. The selected constant parameters are based on the preliminary tests and the available literature [3, 4, 5]. The fabricated joints are shown if Fig. 3.

TABLE I. Chemical Composition of AA5083-H321

Fe	Si	Mn	Mg	Zn	Ti	Cu	Al
0.7	0.5	0.5	0.3	0.1	0.02	0.13	Balance

TABLE II. Mechanical Properties of AA5083-H321

Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)	Density (Kg/m^3)
317	228	16	2660

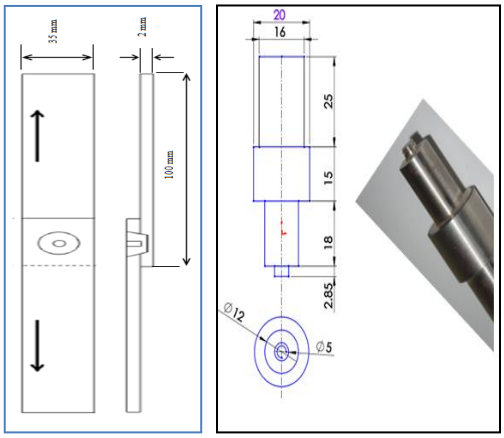

Fig. 1: Lap Shear Test Coupon

After welding, the lap shear test was conducted using a universal tensile machine at a crosshead speed of 1mm/min at room temperature. The Vickers hardness test was conducted in the weld cross-section at a load of 150 kg for evaluating the strength of the weld joint. The hardness survey was taken at a 1 mm constant distance at every indentation.

Fig. 2. Experimental setup on CNC

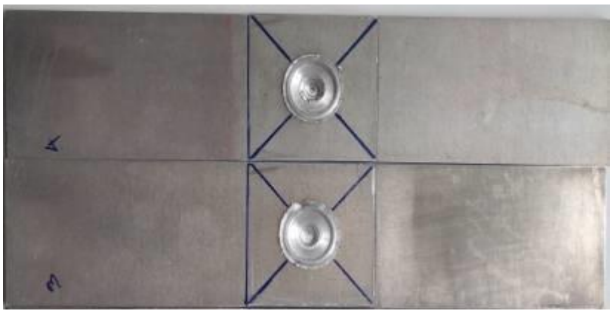

Fig. 3. FSS welded samples

III. RESULTS AND DISCUSSION

A. Hardness survey

The hardness values across the different regions of stir zone (SZ), Heat affected zone (HAZ), and thermo mechanically affected zone (TMAZ) section and base material (MB) are measured in order to understand the hardness variation in the friction stir spot welded joints. This is to determine the differences between the hardness of the base material, stir zone and other sections. The different section of the cross-sectioned FSS welded sample is shown in Fig 4.

The results were obtained from the five different welding speeds from each specimen as shown in Fig. 5. The noticeable increase in hardness value in the weld made by the Al2O3 volume fraction of 26 % because of the presence of nanoparticles was higher. In the all-welded conditions, the higher hardness value was obtained in the stir zone area followed by the TMAZ and HAZ because of fine grain structure due to the association of very high temperature during the welding process, In addition, the parent material has the same value because of an inadequate supply of heat generation to change the strength. The hardness values are the maximum in the nanoparticles reinforced samples compared with the sample made without the addition of nanoparticles because of the relationship with grain size, dislocation density, and presence of reinforcing particles [12-14].

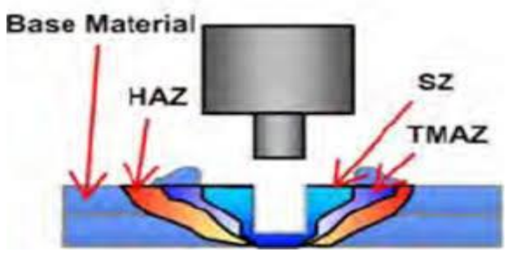

Fig. 4 Cross-section of FSSW joint showing different weld zones

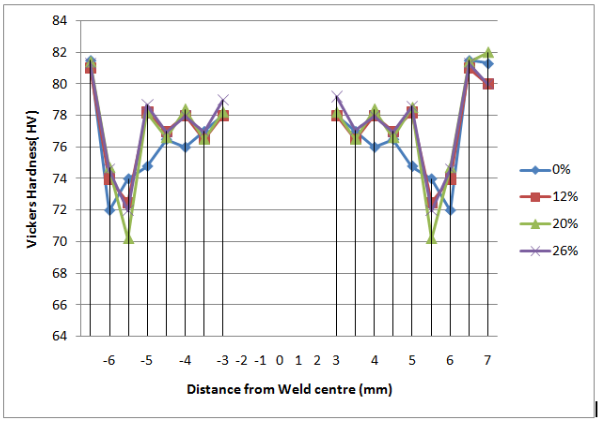

Fig. 5. Lap shear strength of FSSW joints

B. **Lap Shear Test**

The welded sample in the universal testing machine is shown in Fig. 6. The maximum lap shear load of the FSSW specimens with different volume fractions of nanoparticles is shown in Fig. 7. The lap shear load was measured in the longitudinal rolling direction at room temperature. As seen, the lap shear fracture load increases gradually with the increasing of the volume fraction of nanoparticles. The maximum lap shear load of 2.4 KN is obtained at a volume fraction of 26%. The increase in the strength of FSSW joints is most likely due to the nanoparticles distribution in the stirring area and dislocation density of the welded joint [15].

Fig. 6. A Photograph of lap shear test

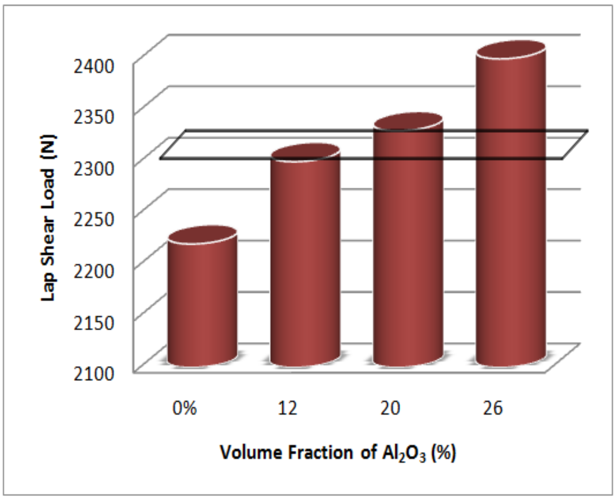

Fig. 7. Lap shear strength of FSSW joints

IV. CONCLUSION

An investigation of the mechanical property of the FSS welded 6061 aluminium alloy by adding the Al_2O_3 nanoparticles was done. The following conclusions have been made from the present investigation based on the experimental result.

The addition of nanoparticles in the weld joint influence the mechanical property of the joint.

The lap shear load increases with the increase in the volume fraction of nanoparticles. The maximum lap shear load obtained in the FSSW at the nanoparticles volume fraction of 26% is 2400 KN.

The hardness of the stir zone increases with the increase in the volume fraction of nanoparticles. The maximum hardness was measured at the stir zone of all the samples. Further study on optical and scanning electron microscopes analysis would give a better understanding of the strength variation of the joints.

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