ABSTRACT

Aluminium alloys with small amounts of magnesium, manganese, silicon, zinc, tungsten and other elements have very useful properties and are used as structural materials. The 5000 series alloys (Al-Mg) are used for marine and aerospace structural applications mainly due to their good corrosion resistance, recyclability, specific strength and weldability. These alloys offer weld yield strengths between 140 and 175 MPa, which is about 60% of the base metal strength, resulting in thicker structures and higher dead weight during the fusion welding processes such as Metal Inert Gas and Tungsten Inert Gas welding. Fusion welding processes generally result in lower joint efficiencies, based on yield strength, mainly due to defects such as loss of volatile elements due to evaporation, porosity and coarse columnar grain structure.

Conventional fusion welding processes are found to inadequate in welding of these aluminium alloys in the transportation sector. Fusion welding of AA5083-H321 alloy produced vaporization of alloying elements, loss of strain hardening effect in the weld zone, formation of micro porosities, columnar grains at the fusion line and weldability problems such as solidification cracks. Friction-Stir (FS) welding offers a feasible solution to overcome this problem, as it is a lower heat input solid state welding technique. A number of researchers have explored friction stir welding of alloys and dissimilar metals, which are amenable to fusion welding processes.

In the present work, friction stir welds were made on AA5083-H321 alloy plates. In this study, it was proposed to employ Tungsten Inert Gas (TIG) and Laser Beam (LB) welding to reduce defects in the welds and improve the weld strength of the aluminium alloy. LB welding is a high intensity fusion welding process, which reduces maximum defects, which normally occur in the MIG and TIG welding processes.

Weld microstructures, hardness, and tensile properties were evaluated in as-welded condition for AA5083-H321 aluminium alloy. Microstructural studies revealed that FS welding produced fine recrystallised grains, whereas fusion welding produced cast grains. Fusion welds contained shrinkage voids, micro porosity and macro porosity, formation of columnar grains at the fusion line, and vaporization of alloying elements from the weld zone, whereas friction stir welds were solidification defect-free and retained the alloying elements in the weld nugget. SEM microstructural studies revealed that fragmentation
and formation of intermetallic compounds in the weld nugget, whereas the dissolution of intermetallic compounds were noted down in fusion welded joints.

The hardness studies revealed that the lowest hardness in the weldment occurred at the retreating side of FS welding and at the weld in the case of fusion welding for AA5083-H321 alloy compared to the base metal. The tensile tests indicated a joint efficiency of around 93 % (based on yield stress) for FS welding and 65 % and 85 % for TIG and LB welding respectively. The percentage elongation of FS welds were 68 % of that of the base metal, whereas it was only 50 % for both fusion welding processes.

The FS welded AA5083-H321 had weld yield stress of 245 MPa, which is 39 % greater than weld yield strength of TIG welded AA5083-H321 aluminium alloy (176 MPa). The percentage elongation of FS welded joints were 35 % greater than that of TIG welded joints.

Addition of small amount of Scandium raises the strength of Al-Mg alloys by precipitation hardening upon the formation of Al₃Sc. The presence of the precipitate Al₃Sc increases the mechanical properties of cast scandium added Al-Mg alloys.

Weld microstructures, hardness, and tensile properties were evaluated in as-welded condition for Cast Al-Mg-Sc aluminium alloy. Microstructural studies revealed FS welding produced fine recrystallised grains without casting defects. SEM microstructural studies revealed that fragmentation and formation of intermetallic compounds in the weld nugget.

The hardness studies revealed the lowest hardness in the weldment occurred at the retreating side of FS welding in the case of Cast Al-Mg-Sc alloy compared to the cast base metal. The tensile tests samples failed outside the FS weld zone indicating that the weld was stronger than that of Cast base metal. The FS welded joint yield stress was 40 % higher than that of cast base metal. The percentage elongation of FS welds were 217 % of that of the Cast base metal.

The FS welded Cast Al-Mg-Sc had weld yield stress of 271 MPa, which is 54 % greater than weld yield strength of TIG welded AA5083-H321 aluminium alloy (176 MPa). The percentage elongation of FS welded joints of Cast Al-Mg-Sc alloy were 68 % greater than that of TIG welded joints of AA5083-H321 aluminium alloy.
It has been concluded that sound FS welded joints were obtained for AA5083-H321 aluminium alloy compared to TIG and LB welded joints. The FS welded joints of Cast Al-Mg-Sc aluminium alloy were still better than the FS welded joints on AA5083-H321 aluminium alloy.