ABSTRACT

Aluminium alloys with small amounts of copper, magnesium, silicon, manganese and other elements have very useful properties and are used as structural materials. Al-Cu alloy 2219 and Al-Mg alloy 5083 are two widely used alloys in aerospace and marine industries. AA2219 (Al-6.5%Cu) is age hardenable, and exhibits good strength at elevated as well as cryogenic temperatures. It also exhibits acceptable corrosion resistance. It has excellent weldability characteristics. However, the weld zone of the AA2219 fusion welds softens due to melting of the strengthening precipitates and its joint strength is only about 40% compared to that of the base material in T87 condition. The fusion welds also exhibit poor ductility.

AA5083 (Al-4.5%Mg) is an alloy with moderate strength, excellent corrosion resistance and low cost used extensively in commercial marine applications. A magnesium content of about 4.5% provides good strength and high corrosion resistance to sea water. An important issue in the fusion welding of aluminium-magnesium alloys is the vaporization of magnesium. The selective vaporization of magnesium from the weld metal causes lowering of mechanical properties and corrosion resistance of the welds.

Conventional fusion welding processes are found inadequate in welding of these aluminium alloys. Fusion welding of AA2219 to AA5083 alloys is not possible as Cu and Mg brought together in the liquid state would
result in the formation low melting eutectic phase and solidification cracking. Friction Stir welding is 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 dissimilar metals and alloys. Several different dissimilar aluminum alloy combinations have been successfully friction stir welded with good joint efficiencies.

In the present work, friction stir welds were made on 2219-2219, 5083-5083 and 2219-5083 joints. The process parameters for 2219-5083 welds were optimized using the Taguchi L16 Orthogonal Design of Experiments. The rotational speed, transverse speed, tool geometry and ratio between the tool shoulder diameter and pin diameter were the parameters taken into consideration for optimization. The optimum process parameters were determined with reference to the tensile strength of the joint. The ANOVA table for the mean and SN ratio were calculated and their main effects were plotted. The investigation showed that the D/d ratio is a highly significant factor and plays a major role in affecting the tensile strength of 2219-5083 joints. The predicted optimal value of tensile strength was confirmed by conducting the confirmation run, using the optimum parameters. This study showed that defect free, high efficiency welded joints can be produced using a wide range of process parameters, and recommends the parameters for producing the best joint tensile properties.

Weld microstructures, hardness, and tensile properties were evaluated in as-welded condition. Microstructural studies revealed that the nugget region was primarily composed of alloy 2219, which was placed on
the advancing side. The hardness studies revealed that the lowest hardness in the weldment occurred in the heat-affected zone on the alloy 5083 side, where tensile failure was observed to take place. The tensile tests indicated a joint efficiency of around 95% (based on the UTS of the softer material, i.e. AA5083), which is substantially higher than what can be achieved with conventional fusion welding of joints between same alloys i.e. 2219-2219 and 5083-5083.

The Scanning Electron Microscopy (SEM) examination revealed that the nugget region showed a large number of second-phase particles, distributed in two different size ranges. The coarser particles were in the size range of 2-5µm and the finer particles were of sub-microscopic size, which could not be clearly revealed in this study. Transmission Electron Microscopy (TEM) examination clearly revealed the grain size (1 to 2 µm) in the 2219 region of the weld nugget and the large number of uniformly distributed fine second-phase particles (less than 250 nm in size) were observed in the 2219 region of the weld nugget corresponding to the sub-microscopic particles noted in SEM examination.

Electron Probe Micro Analysis (EPMA) studies of nugget zone showed that the mix up of material was not uniform across the region. Copper and magnesium elemental mappings revealed that certain portions of the nugget contained more of 2219 and less of 5083. In several other regions, the nugget chunks of each alloy could be found without any significant mixing as indicated by the Cu and Mg elemental mappings. The pitting corrosion results indicate that there was noticeable improvement in the pitting potential values
of the welds. The weld nugget region exhibited better pitting corrosion resistance compared to other regions. This was mainly due to the recrystallization and very fine grain structure present in the nugget. Salt fog apparatus was used for testing the general corrosion behaviour of the welds. The difference in weight loss gradually increases from 16 hours to 48 hours and corrosion rate decreased initially, from 16 to 32 hours and again increases from 32 to 48 hours. It was found that the welds exhibited corrosion behavior similar to the base materials.

It has been concluded that sound welded joints between AA2219 and AA5083 can be made using friction stir welding process. Optimum welding parameters have been identified to achieve high joint efficiency and the corrosion resistance of such a joint remained as good as that of the base materials.