ABSTRACT

Welding of aluminum based materials to steel is of particular interest to the engineers, because the resulting products combine the very different but favourable properties of each material. The resulting products have a desirable combination of high thermal conductivity and low density of aluminum, and low thermal conductivity and the high tensile strength of steels. The demand for aluminum and aluminum matrix composite/steel joints and has therefore increased in many significant applications including cryogenics, structural engineering, marine engineering, nuclear engineering, spacecraft, rocket fuel tanks and high vacuum chambers owing to their superior properties. In all these critical applications the strength of the dissimilar joint and joint interfacial properties are very important. Failure in these joints is a matter of great concern since that would result in massive losses. However, welding of dissimilar materials has great difficulties because of the formation of inter metallic compounds, presence of oxides at the interfacial region, inferior weld strength at the inner region of the joint interface, and more quantity of material consumption during the joining process.
In the present work, a low cost programmable logic controller based friction stud welding machine has been developed successfully to weld dissimilar materials up to a diameter of 12mm. This partially automated single-shot process is simple, energy efficient, environmentally sound, as there is no smoke, slag, flux, gas, or filler metal. Joining of different combinations such as AA 6063/AISI 1030 and Aluminum hybrid matrix composite/AISI 1030 steel joints were carried out successfully in the newly developed machine.

During friction stud welding of AA 6063 with AISI 1030 steel, the dissipation of frictional heat from the weld center results in temperature gradient across the welded joint, causing different zones with different microstructures. SEM micrograph reveals the presence of three distinctive regions in the heat affected zone namely, fully plasticized deformed zone, partially deformed zone and unaffected base metal zone. EDX analysis confirms the presence of FeAl₃ as the intermetallic compound found at the joint interface. The micro hardness values were measured across the welded joint. At the interfacial region, there is an increased plastic deformation. This is due to the rise in heat input during friction stage and applied upsetting load in the forging stage. Consequently, there is an increase in hardness at the interfacial region of the welded joint.
Experimental results show that the use of AA 1100 interlayer enhances the strength of AA 6063/AISI 1030 joints. The interlayer acts a buffer to reduce the heat affected zone and intermixed zone that appears near the weld interface has a tendency to reduce the thickness of brittle intermetallic compound at the interface. It is found that 40.97% increase in impact strength could be achieved when an appropriate AA1100 interlayer is used in friction stud welding of AA 6063/AISI 1030 joints. Use of interlayer minimizes the consumption of metals since the axial shortening distance is reduced. On an average 21.33% reduction in material consumption and thereby reduction in material cost could be achieved with the use of interlayer. SEM evaluation on the fractured surface of the specimens was carried out. Cleavage fracture showing river pattern was observed with 0.5mm interlayer where as brittle-ductile mixed mode fracture was observed with 1.3mm interlayer. Ductile mode fracture with dimples was observed with 1.3mm interlayer. Micro voids absorb a lot of energy, and consequently the toughness is increased. Hence, the dissimilar joint made using 0.95mm interlayer have high joint strength.

Silicon carbide and graphite particulates reinforced AA6063 matrix composite was developed successfully using stir casting method and the joining feasibility of AISI1030 with AA6063-6SiCp-3Grp hybrid composite was tried out by friction stud welding technique. Rotational speed and interlayer sheet thickness contribute about 39% and 36% respectively in
determining the impact strength of the welded HMC/steel joints. It is observed that rotational speed is the most significant factor with 71% of contribution in determining axial shortening distance. Based on the experimental results, regression model has been developed to predict impact strength and axial shortening distance with reasonable accuracy.

Numerical simulation of friction stud welding process using ANSYS has been carried out and the simulated results are compared with experimental results. The simulation results were in good agreement with the experimental values for friction stud welding of mild steel-aluminium combination. The numerical model developed can be used as an industrial tool to predict temperature distribution and thermal behaviour of the dissimilar joints.

A finite difference based pin fin model has been developed for better understanding of the friction stud welding process. Using a micro annulus based analytical model the heat flux generated at the interfacial region is predicted. When compared with the measured data at a distance of 5mm and 10mm from the weld interface, the analytical values show fair agreement with the experimental values. Though similar trend is achieved the computed temperature profile is not exactly matching with the experimental data, particularly in the cooling part. This is due to zero axial shortening assumption in the FD model.