Investigations into Dissimilar Joining of Titanium Alloy (Ti-6Al-4V) with Magnesium Alloy (AZ31B) using Arc-Based Welding Processes

LUCKY (2019MEZ8417), Research Scholar, Department of Mechanical Engineering

Abstract: This study focuses on the dissimilar joining of AZ31B magnesium alloys with Ti-6Al-4V titanium alloys using arc-based joining processes. Gas tungsten arc welding (GTAW) and gas metal arc welding- cold metal transfer (GMAW-CMT) or cold metal transfer welding (CMT) were employed to join the sheets in lap joint configuration. In GTAW, joining of 2 mm thick sheets were processed at welding speed of 0.13 m/min and welding current of 60 A. Mechanical analysis using tensile-shear tests shows that joints without defects at macroscopic as well as microscopic level can sustain a load of 2073 N. These joints can elongate up to 3.52%.

In GMAW-CMT joining processes, joints can be processed in heat inputs ranging from 35-42 J/mm. In similar thickness combination i.e. 2 mm thick AZ31B and 2 mm thick Ti-6Al-4V, joints can be processed at heat input of 35 J/mm with load bearing ability of 1870 N. While in dissimilar thickness combination with 2 mm thick AZ31B and 1.2 mm thick Ti-6Al-4V, joints can be processed in heat inputs of 35 and 37 J/mm resulting in the maximum load bearing capacity of 1760 N. In another dissimilar thickness combination (1 mm thick AZ31B and 2 mm thick Ti-6Al-4V), joints are best processed at heat input of 37 J/mm with a load-bearing ability of 1614 N. This joint has sustained elongation of 1.94 mm at 33 mm gauge length, which is the maximum among all the processed joints.

In next part of studies, role of coating on the influence of joint properties (microscopically and mechanical) is analysed. Copper-coating with an average thickness of 7 μm proved detrimental to the joint properties in the terms of mechanical strength. While higher thickness at approximately 16 μm results in failure to process the joints. Joints in dissimilar thickness combination processed at heat input of 40 J/mm have shown the growth of Cu-based reaction layer consisting of Mg_2Cu intermetallics with diffusion of Al towards AZ31B weld zone and Ti-6Al-4V base metal interface. This strengthens the joint interface between AZ31B weld metal and Ti-6Al-4V. However, these joints have failed from the weaker zone (region between AZ31B weld metal and AZ31B base metal) with a maximum load of 1040 N. In joints with Ni coating, joints with similar thickness combinations show the improvement in strength with 3% increase in load bearing capacity in comparison to the joints with no coatings. These joints have sustained a maximum load of 1930 N. In dissimilar thickness combinations, joints could sustain a maximum load of 1484 N at heat

input of 37 J/mm. Interfacial region shows the formation of localised intermetallics in the form of layer, ring and cubic like precipitates. Cubic precipitates include Al-Ni base intermetallics. Presence of reaction layer in the form of layer or ring shows that there is Ni combined with Mg. Mg-Ni based intermetallics are generated at interface towards AZ31B weld zone side. These reaction layers are localised, and their profile is concentrated at several locations of interface. This layer has shown the best response in the lap joints between AZ31B and Ti-6Al-4V sheet with similar thickness combinations.

Joints with bimetallic Cu+Ni coatings show the best one response in the term of joint strength, where a 5% improvement of load bearing capacity is observed in similar (Both AZ31B and Ti-6Al-4V, 2mm thick) as well as dissimilar thickness combinations (2 mm thick AZ31B and 1.2 mm thick Ti-6Al-4V). Metallurgically, joints with similar thickness combinations obtained at heat input of 37 J/mm, have shown a systematic growth of intermetallics at joint interface, consisting of Cu-Mg and Ti-Cu intermetallics at interface, then Ni-Al intermetallics and lastly Cu-Mg in AZ31B weld zone. These appear as distinct layers as revealed by energy dispersive spectroscopy. Mechanically, these joints at a heat input of 37 J/mm have sustained a load of 1980 N, which is highest among joint processed using cold metal transfer welding. Joint with dissimilar thickness combinations have sustained load in range of 1850 N which is also 5% higher in their category.

In corrosion analysis using salt immersion tests, it was found that joints suffer serious damage in sea water conditions. 3.5 weight % NaCl solution was used to simulate the saline environment conditions. Analysis showed that there is massive damage to the AZ31B base region near the weld zone causing its degradation more in comparison to the weld metal zone. This damage is owing to double action of OH^- and Cl^- ions resulting in the formation of $Mg(OH)_2$ and $MgCl_2$ corrosion products.

In bioresorbability analysis using simulated body fluid (SBF), it shows that up to 48 hours of immersion, there is dissolving of Mg in SBF in small amounts. Also, there is formation of a thin white layer over Ti-6Al-4V region. This deposited layer consisted of Mg and minerals dissolved in SBF including Ca, Na and P etc. At 72 hours of immersion, there is increase in degradation rate of Mg, resulting in significant weight loss of implants. But there is also formation of thick layer over Ti-6Al-4V consisting of Mg, Ca, P etc. Analysis showed that bioactivity with minimal loss of weight of implants is at peak during 48 hours on immersion in SBF.