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Transient liquid phase bonding of AA-6063 to UNS S32304 using Cu interlayer

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Abstract

Transient liquid phase bonding of AA-6063 and UNS S32304 was performed in an inert atmosphere using a Gleeble (model 3800) thermo-mechanical simulator. Base metals were machined to rectangular dimensions of 30mm x 15mm. Aluminum samples were fabricated from a U-shaped extruded Al-6063 profile with 2mm thick, while duplex stainless steel samples were in form of coupons with 1mm thick. A copper foil with 99.9% purity and 10µm thickness was used as an interlayer between the base metal sheets. A compression load of 0.2KN was applied horizontally to the specimens. The effect of bonding temperature (550°C, 555°C, 560°C and 570°C) was studied on the microstructure of the joints using light and scanning electron microscopy. Compositional changes across the joint region were studied using energy dispersive X-ray spectroscopy. Although copper diffusion into aluminum results in an Al-Cu eutectic structure, the oxide layer on the aluminum surface controls the dissolution behavior of Cu and extent of wettability with the base metals. Although a defect free joint was produced at 570°C, X-ray diffraction results detected the formation of intermetallic compounds ($FeAl_3$).

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1. Introduction

There is a growing demand for cost effective materials with enhanced engineered properties and this involves the use of dissimilar metals. Although dissimilar metals are being used in the aerospace and oil and gas sectors, the joining of dissimilar metals is still facing numerous challenges and difficulties when compared to the joining of metals with similar compositions. The wide difference in melting points and thermal expansion coefficients of

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dissimilar metals can result in residual stresses within the joint region and this can result in a failure of the joint when conventional fusion welding is used. The formation of intermetallic compounds (IMCs) can easily result in brittle failure of the welding joints.[1-3]

Several methods can be used to join dissimilar metals. Each one has its own advantages and limitations. Selecting the most appropriate method is vital for accomplishing successful joints. Fusion welding processes, solid-state joining, adhesive bonding and brazing and soldering are the most well-known methods for joining dissimilar metals. Unlike fusion welding, solid state diffusion bonding does not require melting of base metals. It can also be considered as a versatile process in terms of work piece thickness and geometry, however the numbers of published articles on diffusion bonding and hybrid joining processes are still quite few compared to arc welding process like: gas tungsten arc welding (GTAW), shielded metal arc welding (SMAW) and gas metal arc welding (GMAW).

Transient liquid phase (TLP) bonding is a type of liquid diffusion welding process, which involves the use of an interlayer placed between the two parent surfaces, heating will be applied to the clamped components to reach a temperature; which is higher than the eutectic liquid temperature of the base metals (aluminum and stainless steel) and filler (copper) until the joint region solidifies isothermally.[4,5] In addition to its lower processing temperature compared to fusion welding[6], TLP has other advantages such as: ability to weld parts with complex geometries and small thickness.[7]

The aim of this research to achieve a sound joint between 6063 aluminum alloy (AA-6063) and duplex stainless steel (UNS S32304) at a temperature lower than conventional welding processes with the advantage of minimizing intermetallic formation by isothermal solidification.

2. Experimental

UNS S32304 and AA-6063 were supplied by (ThyssenKrupp Nirosta, Germany) and (Qalex, Qatar) respectively. Both samples were machined to rectangular dimensions of 30mm X 15mm. Aluminum samples were fabricated from an extruded AA-6063 sheet of 2mm thickness, while duplex stainless steel samples were in the form of coupons witha thickness of 1mm. A copper foil with 99.9% purity and 10μm thickness was obtained from (Goodfellow, UK) was used as an interlayer between the Al and stainless steel sheets.The base metals were polished to 1000 grit surface finish using SiC paper, cleaned with ethanol and dried using hot air. Each joint consisted of 2 overlapped samples and a piece of copper foil sandwiched between them.

The TLP process was conducted using a thermo-mechanical physical simulator called the Gleeble system (model 3800) with a heating and cooling rate of 100°C/min. A thermocouple wire was welded to the edge of Al sample; approximately in the middle of the overlap region at 40 volts using a thermocouple welder (Dynamic system – model 35200).It was connected to the system to ensure an accurate feedback control of specimen temperatures. A compression load of 0.2KN was applied horizontally to the specimens. Bonding temperature was varied between 550°C, 555°C, 560°C and 570°C. Fig.1 shows a demonstration of one sample in the Gleeble system.