ABSTRACT

Diffusion bonding (DB) processes are usually performed in a vacuum furnace, which makes the process and equipment costly and leads to high cycle time. Attempts are made in this work to perform diffusion bonding in non-vacuum conditions, leading to reduced cycle time and improved productivity. The various surface modification techniques employed for the diffusion bonding of pure Cu, AA6082, dissimilar bonding of Al and Cu, wire arc additively manufactured (WAAM) Al alloy, and WAAM Mg alloy AZ31 are discussed.

Low-cost friction stir process (FSP) surface modification was proposed to achieve grain refinement of the faying surfaces and to facilitate the DB of Cu in the Ar environment. Grain growth of fine grains produced by FSP near the interface and grain boundary migration were observed to be the major mechanisms by which bonding has been achieved. Single point diamond turning (SPDT) of Cu has resulted in the generation of nano-level surface roughness, brought the bonding surfaces in close contact, and facilitated low-pressure bonding. The bonding ratio and shear strength were observed to increase with the rise in bonding temperature from 600°C to 800°C in accordance with the Arrhenius relationship.

Solid state diffusion bonding of Al alloys is challenging owing to the formation of a tenacious oxide layer that acts as a barrier for the diffusion of atoms and results in poor metallurgical joint. A novel liquid Ga treatment of the faying surfaces was employed to isolate the polished surface from ambient conditions and to prevent reoxidation, which has facilitated diffusion bonding of highly reactive Al alloys and Mg alloys in a non-vacuum furnace. The dispersion of Ga is limited only to the diffusion-reaction zone. The dispersion of Al at the interface is the same as that of the base metal (BM), indicating the effectiveness of surface treatment that has resulted in enhanced diffusion of Al across the interface in ambient conditions.

Direct bonding of AA6082 with Cu has resulted in the formation of deleterious intermetallic compounds (IMCs) and cracks are observed in the bonded region. DB with electrodeposited Ni interlayer has prevented the interdiffusion of Al and Cu atoms, and the formation of brittle IMCs is avoided. Thus, successful Al-Cu bond formation could be achieved.

The joining of additively manufactured (AM) components by solid-state joining is gaining significant research attention these days as the industry wants to produce large components through AM. It is significant to join/repair AM components without inducing fusion defects such as heat-affected zone (HAZ), porosity, cracking, warpage, etc. Diffusion bonding is a suitable joining process for a homogeneous joint microstructure that resembles the parent metal owing to the void closure and grain boundary (GB) growth across the contact. High-integrity diffusion bonded joint of WAAM Al-Si alloy and AZ31 is achieved in a non-vacuum furnace with a special interface treatment. The uniform elemental distribution at the interface, like the parent metal, emphasizes the enhanced interdiffusion of atoms across the joint line and the formation of a void-free joint.

Microwave hybrid heating (MWHH) was proposed as an energy-efficient and rapid post-process heat treatment (PPHT) method for the WAAM AZ31 Mg alloy. Non-uniform microstructure in the build direction, owing to the prevailing thermal history during the WAAM process, is a major drawback and leads to anisotropic mechanical properties. PPHT is generally employed to improve the mechanical properties of WAAM components. Homogeneous grain size distribution was achieved through MWHH post-processing, and uniform microhardness could be observed from the bottom to the top layer.