ABSTRACT

Diffusion bonding (DB) is a solid state metal joining process which is suitable for similar or dissimilar metal joining applications. In the present work, different dissimilar material combinations with and without interlayer is successfully carried out. The joints were analyzed for its metallurgical and mechanical properties. The objective of this study is to develop a joining method with large equipment capable of adopting vacuum, partial vacuum and inert gas environment for dissimilar metal combinations and to conduct a complete study of the joints in terms of metallurgical and mechanical aspects.

The DB of AISI 304L stainless steel with low-carbon steel grade AISI 1018 steel with AISI 304L stainless steel interlayer, direct DB of duplex stainless steel (DSS) SAE 2205 with medium carbon steel AISI 1035 and Ti-6Al-4V with AISI 304L was performed with the view of replacing cladding and surface coating. These experiments were conducted in vacuum environment by varying the process parameters like temperature, pressure and bonding time. A new technique was adopted to break the surface asperities and oxide layer by applying impulse pressures well below the bonding temperature before subjected to the bonding process. The optimum parameters were identified for each material combination. More emphasis was given on analytical aspects of joint quality assessment and devised methods to improve the quality of the joints.
The metallurgical characterization of the bonded samples were carried out by optical microscopic examination, scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDAX) and X-ray diffraction analysis (XRD). The mechanical properties were assessed for different DB joints using specially designed fixtures for tensile and shear testing. The hardness values were measured using vicker’s microhardness tester for various samples. The fractured surfaces were examined with SEM to identify the mode of fracture.

The optical and SEM examinations revealed grain growth in the base metals, segregation of carbides and formation of intermetallic compounds at the interface. The recrystallization at the interface was observed because of diffusion of various elements between two base metals during DB. At the interface, presence of voids and discontinuities were noted for the samples processed at lower temperatures and pressures. The SEM examination revealed the presence of sigma phase and chi phase at the interface of the DB samples made between DSS and medium carbon steel.

The EDAX and XRD analyses of the bonded samples for the three different metal combinations confirmed the presence of hard intermetallic compounds and secondary phase particles at the interface. The variations of elemental concentration across the interface in the diffusion-bonded samples were measured and presented. The diffusivity of various elements was studied by drawing concentration profiles of various samples.
It was observed that the strength of joints was compared with the strength of the base metals. The bonded samples obtained between low-carbon steel grade AISI 1018 to stainless steel with interlayer, exhibited a maximum tensile strength of 340.6 MPa that is 98.38% of the base metal strength. SAE 2205 (a dual phase alloy) and AISI 1035 yielded a maximum tensile strength of 360.9 MPa, which is 79.6% and 88.7% of the base metals; duplex stainless steel and medium carbon steel, respectively. The diffusion-bonded samples possessed a maximum tensile strength of 242.6 MPa which is 41.6% and 25.3% of the base metals, AISI 304L and Ti–6Al–4V (dual phase alloy), respectively. The diffusion coefficient (D), pre-exponential constants ($D_0$) and activation energy ($Q$) values for different elements were calculated for different material combinations and presented.

The DB of dissimilar metals was carried out to suggest a better method to apply for the manufacture of products for corrosion resistant application. The presence of hard phase particles at the interface is advantageous for the manufacture of armour plates. These plates require resistance to shock wave and impact forces. To overcome cost effectiveness and time consumption, stacking of plates one over another and performing DB is suggested.