ABSTRACT

Solid state metal joining techniques, such as friction welding, magnetically impelled arc butt welding, explosive welding involving in macro plastic deformation at higher temperatures and cold pressure welding are limited to ductile metals. However, diffusion bonding technique has no such limitations. Diffusion bonding is the joining of two nominally flat surfaces by the action of high temperature and pressure. This process guarantees near base material properties in the joint in addition to the absence of heat affected zone present in welded joints. Hence diffusion bonding is widely used in the fabrication of critical components in aerospace and nuclear engineering to join similar and dissimilar metals and alloys.

The main aim of the present study is to compare the characteristics and mechanism of diffusion bonding in superplastic materials, 'superplastic-like' materials and non superplastic materials. The alloy systems selected are Ti-6Al-4V, $YBa_2Cu_3O_7$ (YBCO) and SU 263 A, that is, one material is chosen from each of the three classes of materials mentioned above.

Titanium alloys have found extensive application in aerospace and chemical industries. Since titanium alloys are expensive, production processes must aim at eliminating material wastage as much as possible. In this context, the combination of superplastic forming and diffusion bonding which enables production of 'near net shape' components in a single step is very attractive. Hence it is necessary to study the diffusion bonding behaviour of the material in the superplastic temperature range.

The low values of fracture toughness and strain to fracture make it difficult for the conventional cold pressing techniques to attain a pore free component in the YBCO system. Interestingly, YBCO exhibits superplastic-like behaviour. This superplastic-like behaviour markedly reduces the stress required to deform the particle. The nickel base superalloy, SU 263 A (an equivalent of Nimonic 263) is extensively used in aircraft body

and aero-engines. The major welding problems of SU 263 A alloy are micro fissuring during fusion welding and strain age cracking during post welding heat treatment. In contrast, diffusion bonding has become attractive for these applications in aerospace industries, as it can eliminate the problems associated with conventional welding.

Though the deformation behaviour and diffusion characteristics vary widely in these three classes of materials, they share a common objective of forming a poreless interface (closure of voids) during diffusion bonding.

In order to study the characteristics of diffusion bonding in the three systems, a specially designed vacuum diffusion bonding set-up was fabricated and used to optimise the diffusion bonding parameters such as temperature, pressure and time. Optical and electron microscopic studies were conducted to assess the porosity (fraction of bonded area) and the grain growth of the base material. The bonds were evaluated by shear tests. The mechanism of bonding was evaluated by theoretical equations and model. The numerically evaluated bonding mechanism was validated by SEPMA (Scanning Electron Probe Micro Analysis).

Among the various combinations studied in the Ti-6Al-4V system only two combinations, - namely 1173 K- 25 MPa - 45 mins and 1200 K- 25 MPa- 45 min, result in good bonding with less degree of grain growth (9.8 and 10.3 microns), thus retaining the superplastic characteristic of the Ti-6Al-4V. The bonding has been identified as due to the combined effect of superplastic flow and power law creep.

In the case of YBCO, the maximum density of 93% was obtained at a temperature of 1173 K and a pressure of 51 MPa. For all the conditions of compaction and for all the stages of densification, the mechanism of bonding was found to be volume diffusion controlled by yttrium

Among the various experiments carried out, bonding of SU 263A at 1323 K-0.9 Yield strength, and for 24 hrs, shows good bonding. The dominant mechanism controlling the diffusion bonding in SU 263 A has been identified grain boundary diffusion and rate controlled by diffusion of nickel.

While the mechanism of bonding in the superplastic system is dominated by time dependent plastic flow, it is dominated by diffusion of individual elements in the other two systems.