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Diffusion bonding of SU 263

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ABSTRACT

Using a specially constructed apparatus, diffusion bonding of SU 263 alloy was studied in the temperature range of 1123–1323 K and compressive stress of 90% of its yield strength at the corresponding temperatures to determine the relative importance of the process parameters, the mechanism(s) responsible for bonding and the joint characteristics. Bond quality was assessed by optical metallography and lap shear testing. The mechanism of bonding was evaluated by grain growth equation. The experimental results were compared with a model developed by Pilling [Pilling, J., 1988. The kinetics of isostatic diffusion bonding in superplastic materials. Mater. Sci. Eng. 100, 137–144] in which the void closure by creep flow and diffusion are considered. Quantified EPMA line scan analysis was carried out to confirm the bonding mechanism and to determine the composition at the interface.

1. Introduction

Diffusion bonding is a solid-state joining process in which two prepared surfaces are joined at elevated temperature ranging from 0.5 to 0.8 T_m (where T_m is the absolute melting temperature) under pressure. The pressure is typically a fraction of the yield strength and so there is no macroscopic deformation. In physical terms, the process of diffusion bonding may be portrayed as the sintering of a planar array of voids at elevated temperature and low pressure.

Diffusion bonding of superplastic materials, in particular in Ti–6Al–4V, is a well-established technique (Pilling et al., 1984; Peck, 1949; Hamilton, 1973; Guo and Ridley, 1987; Ravisankar et al., 2003). But only a few classes of materials exhibit superplasticity. In addition to titanium alloys, a number of superalloys, especially nickel-based superalloys are used in the manufacture of aero-engine components (which are mostly non-superplastic). Due to problems associated with micro-fissuring, strain age cracking and other defects, fusion welding could not satisfy the requirements of the joints for aerospace applications. The extensive use of Inconel 718 in rocket engine components and space shuttle main engines (Chandler et al., 1982) has become possible only because of the advent of diffusion bonding. The nickel base superalloy SU 263 A is extensively used in aircraft parts and aero-engines for the manufacture of combustor chamber, cone components, jet pipes, ignitor branch, pipe inter-connector, flame tube flange, adopter, deflector, etc. The major problems of SU 263 A alloy are micro-fissuring during fusion welding and strain age cracking during post-welding heat treatment. Also, the mechanical properties and corrosion and oxidation resistance are diminished in the weld and/or heat affected zone because of structural changes. It is precisely because of these difficulties in the conventional welding of superalloys;

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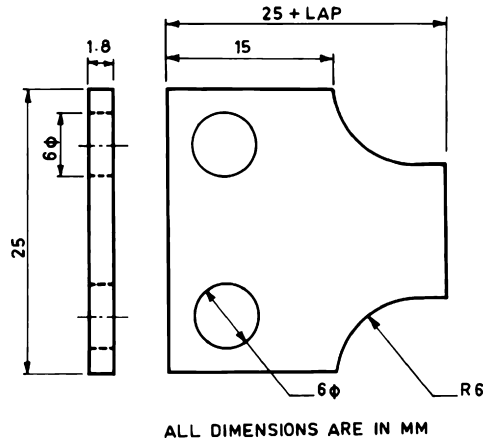

Fig. 1 – One half of the lap shear test piece.

diffusion bonding has become very attractive for applications in aerospace industries. An attempt has been made to establish the diffusion bonding in SU 263 system—a nickel-based superalloy extensively used in aero-engines. A correlation of experimental results with Pilling's model (Pilling, 1988), developed for superplastic material, has also been attempted in this study.

2. Experimental

Alloy SU 263 of composition (wt%) Co 21.6, Cr 20.5, Mo 3.2, Ti 1.12, Al 0.7, balance Ni was received in the form of sheet of thickness 1.6 mm. 30 mm × 30 mm square pieces were cut to prepare the shear-testing specimen and 8 mm × 12 mm pieces to prepare specimens for metallographic studies. As there is no standardisation of the test piece or technique for diffusion bonding joints, the specimen dimensions were selected with a view to easy comparison with earlier findings (Ravisankar et al., 2003; Harver et al., 1985; Partridge and Dunford, 1987).

One half of the test piece prior to bonding is shown in Fig. 1. The specimen length was adjusted to obtain different overlap lengths. Surfaces to be bonded were polished using 200 grit emery paper and washed in acetone to eliminate loose grit or dirt. Surface roughness was determined using Surfcoder SE-40.

For successful diffusion bonding, the test pieces should be correctly aligned and a vacuum maintained to avoid contamination. The upper and lower part of the jig used is shown in Fig. 2. As the bonding temperature was high, Superni 90 (equivalent to Nimonic 90-composition (wt%) C 0.1, Mn 0.1, Si 0.05, S 0.004, P 0.005, Cr 19.3, Fe 0.38, Co 18.7, Ti 2.5, Al 1.16, and Ni balance) was used to fabricate the jigs. The setup was solutionized at 1356 K for 8 h and aged at 973 K for 16 h to develop strength.

The jig consisted of an upper and lower part. The two halves of the specimen to be diffusion bonded were placed in the bottom portion using four stainless steel screws to prevent misalignment during bonding. A spacer sheet of same thickness as the specimen was provided below one half of the specimen as shown in Fig. 2 to avoid bending of the specimen while fixing in the jig. The top portion of the jig contained a small plunger through which the bonding pressure could be applied. A guide hole is provided both in the top and bottom jig. A pair of stainless steel bolts fixes the top and bottom portion to avoid misalignment during handling the jigs while placing in the vacuum diffusion bonding setup shown in Fig. 3.

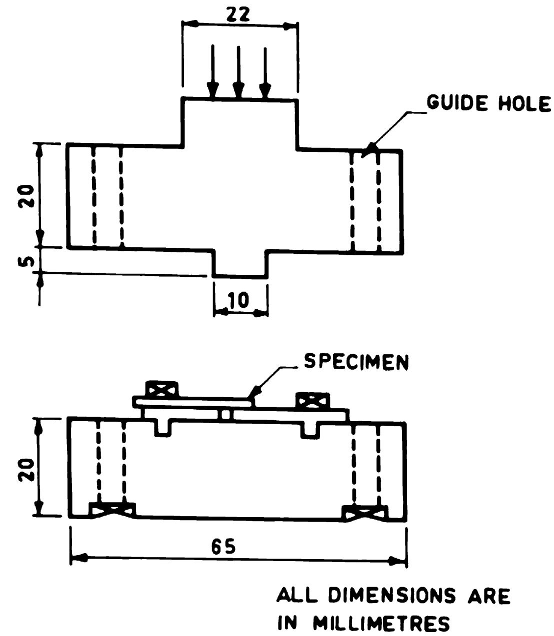

Fig. 2 – A schematic of the jig used for diffusion bonding (front view).

2.1. *Evaluation of the diffusion bonds*

Tensile tests are normally used to evaluate joints in thick sections but such tests are insensitive to the presence of residual voids at the bond interphase (Dunford and Partridge, 1990, 1992). Since most of the SU 263 alloy bonds are made between sheets, shear testing and optical metallography are the common methods of evaluating the bond strength (Harver et al.,

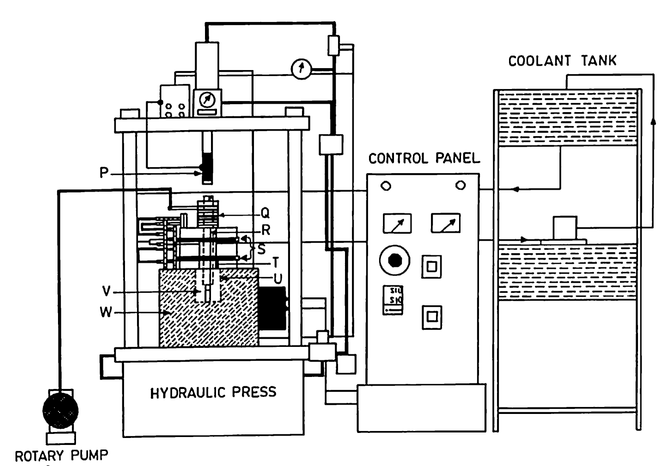

Fig. 3 – Vacuum diffusion bonding unit (P: indicates load cell; Q: bellows; R: groove; S: vacuum sealing; T: hydraulic ram; U: heating chamber; V: jigs; W: vacuum furnace).