Communication

Influence of Solid-State Diffusion during Equilibration on Microstructure and Fatigue Life of Superalloy Wide-Gap Brazements

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The influence of solid-state diffusion-controlled solute-loss into additive powder particles (APPs), as determined by particles size, during the equilibration stage of wide-gap brazing, on microstructure and fatigue behavior of a brazed aerospace superalloy was studied. The results, which experimentally confirm previously reported numerical model simulation results, show that, in order to avoid degradation of fatigue life of wide-gap brazement, adequate solute-loss into the APPs, which is necessary to prevent their complete melting, but has not been generally considered, is imperative.

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Precipitation-strengthened cast nickel-based superalloys are used for manufacturing hot-section components of aero and land-based gas turbine engines, because of their remarkable high temperature mechanical strengths and hot-corrosion resistance. The demand for higher efficiencies, which require turbine engines to operate at higher temperatures, has led to increased degradation of engine components through higher levels of creep, fatigue, and oxidation. It is generally more economically attractive to repair damaged parts instead of going for a complete replacement. Traditional repair techniques, such as welding, are commonly used in the repair of many superalloy components. However, precipitation-strengthened cast nickel-based superalloys, like Inconel 738 (IN 738), are generally difficult to weld because of their high susceptibility to weld cracking.[1–6] Wide-gap brazing is an alternate technique for joining and repairing gas turbine engine components made of difficult-to-weld superalloys.[7–11] The technique often involves the use of composite powder mixture as the interlayer material. The powder mixture consists of regular brazing filler alloy powder that contains melting point-depressant (MPD) solute and an additive powder alloy that is essentially free of the MPD solute, usually the base-alloy powder. The use of the powder mixture reduces undesirable liquid-phase erosion of the base material and also enables desirable enrichment of the joint region with the base-material alloying element for enhanced joint properties.

During wide-gap brazing, the brazing powder particles (BPPs), which normally have a lower melting temperature than that of the additive powder particles (APPs), melt completely, which in turn produces solutal melting of the APPs. It is generally assumed that APPs only undergo partial melting during wide-gap brazing. The main thrust for the solutal melting of the APPs into the surrounding molten brazing filler alloy is to reduce the concentration of the MPD solute in the liquid to the equilibrium liquidus value at the brazing temperature. In analytic brazing models, this equilibration process is often assumed to exclusively involve the addition of solvent element from the solid powder particles to the surrounding liquid without concomitant transfer of the MPD solute from the liquid into the particles by solid-state diffusion within the particles.[12] This is due to the difficulty in modeling simultaneous solid-state solute-transport within APPs and their melting by the surrounding liquid. Nevertheless, a recent more rigorous and robust numerical modeling of the process has shown that equilibration of the liquid occurs not only by solutal melting of the APPs but also through solid-state diffusion-controlled solute-loss from the liquid into the APPs.[13] The analysis shows that for a given volume ratio of APPs to BPPs, the extent of solutal melting of the APPs is influenced by the extent of the solute-loss into the APPs. A factor that significantly influences the extent of solute-loss is the size of the APPs. Accordingly, the main objective of the current research, is to study the extent of solute-loss effect, as determined by the size of APPs, on the microstructure and fatigue life of a wide-gap brazement of IN 738 superalloy, and the results of the study are reported and discussed in this communication.

The base-alloy used in this study is cast polycrystalline IN 738 superalloy with the chemical composition of (wt pct) 0.11C, 15.84Cr, 8.5Co, 2.48W, 1.88Mo, 0.92Nb, 0.07Fe, 3.46Al, 3.47Ti, 1.69Ta, 0.04Zr, 0.012B, and balance nickel. The brazing filler alloy that was used was Nicrobraz 150 with the chemical composition of (wt pct) 15Cr, 3.5B, 0.03C, and balance Ni. Two types of IN 738 superalloys powder with different particle sizes, fine and coarse, of averages sizes of 25 and 85 μm, respectively, were used as the APPs. A mixture of 50 pct BPPs and 50 pct APPs was used to produce two types of interlayer materials, one containing the fine APPs and the other containing the coarse APPs. In addition, for baseline comparison, a 100 pct brazing alloy powder was also used for brazing some specimens. The wide-gap brazing, in the form of surface deposition to simulate surface damage repair (Figure 1), was performed in a brazing vacuum furnace at a pressure of ~10^{-5} Torr, at 1423 K (1150 °C) for 1 hour. Brazed specimens were sectioned by the EDM and prepared by standard metallographic techniques for microstructural examination by optical microscopy (OP) and scanning electron microscopy (SEM) techniques. Initial OP

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