

TUESDAY, AUGUST 24, 2004, A.M.

SESSION 15: SECOND INTERNATIONAL SYMPOSIUM ON AEROSPACE MATERIALS AND MANUFACTURING: DEVELOPMENT TESTING AND LIFE CYCLE ISSUES - HONORING WILLIAM WALLACE

ADVANCED MANUFACTURING TECHNOLOGIES FOR AEROSPACE MATERIALS

Sponsor: Materials Performance and Integrity Section, The Metallurgical Society of CIM

Room: 206

Chairmen: P.C. PATNAIK, M. JHAZI, National Research Council – Institute for Aerospace Research, Ottawa, Ontario, Canada,

M. ELBOUJDAÏNI, CANMET, Ottawa, Ontario, Canada, and

J. LUO, University of Alberta, Edmonton, Alberta, Canada

PAPER 15.1 — 8:30

THE ROLE OF FIRST-PRINCIPLES CALCULATIONS IN THE DEVELOPMENT OF HIGH-TEMPERATURE MATERIALS FOR AEROSPACE APPLICATIONS

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This presentation reports our systematic studies of high-temperature materials from first-principles density functional theory calculations. The strengthening effect of refractory elements on the g/g' interface was systematically studied, and the trend of solid solution strengthening by alloying additions on the Ni binary alloy was investigated. Studies are also extended to the impurity embrittlement on the interface. A new model in terms of bond orders was proposed to investigate the sulfur embrittlement at the g/g' interface of Ni-base single crystal superalloys, and a new mechanism in relieving sulfur embrittlement by alloying additions was proposed. The elastic properties of multi-component Ni solid solutions with 3d, 4d and 5d metals from the periodic table were calculated. Results indicated that multi-component alloying could significantly increase the elastic moduli of Ni solid solutions. As potential candidates of new high-temperature materials, the phase stability, elastic properties and ductile/brittle trend character of L12 Ir₃X, Rh₃X and E21 T₃AlC_{0.5} intermetallic compounds (where X and T are transition metals) were studied from first principles calculations. The potential contributions of atomistic modeling to the development of new high-temperature alloys are highlighted

PAPER 15.2 — 8:55

CONTINUOUS WAVE Nd: YAG LASER WELDING OF CAST MAGNESIUM ALLOY

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The 2-mm butt joints of ZE41A-T5 sand castings were laser welded at different defocusing distances on two surface conditions (as-cast or machined) using a continuous wave 4 kW Nd:YAG laser system at a power of 2.5 kW and a welding speed of 6.0 m/min. Two welding modes (conduction or keyhole) have been observed. The adjustment of defocusing distance can greatly influence the establishment of conduction or keyhole modes. On the machined surface conditions conduction welding is obtained at a power density of 4.0×10^5 W/cm². In contrast, keyhole welding is reached at a threshold irradiance of 1.5×10^6 W/cm². Neither conduction nor stable keyhole modes have been established at a range of power density from 7.7×10^5 to 1.2×10^6 W/cm² on the machined surface conditions. On the as-cast surface conditions keyhole is obtained at a power density as low as 4.0×10^5 W/cm² but good surface quality is obtained at a defocusing of +2 mm. The as-cast surfaces require lower power irradiance for the formation of keyholes indicating that they have higher energy absorptivity for Nd:YAG laser beams probably due to coarse surface morphology.

PAPER 15.3 — 9:20

WELDABILITY AND MICROSTRUCTURAL EVOLUTION OF SINGLE CRYSTAL PWA 1484

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Single crystal nickel-base superalloys such as PWA1484 exhibit superior performance compared to conventional superalloys, and are used extensively in turbine blade applications requiring good high temperature properties. The life

of these blades is typically limited by cracks and erosion. Due to the high cost of these blades, welding techniques are being considered to weld/repair worn components, extending their useful lives and delaying the need for expensive replacement components. However, the sensitivities for solidification cracking and post weld heat treatment cracking are relatively high in these alloys. Electron beam (EB) welding can deliver concentrated heat sources and has the potential to address these issues. Numerous welding trials and structural tests must be conducted to identify the optimum method and welding parameters.

Weldability is studied over a range of material conditions, welding parameters, and directions. The influence of welding parameters on the fusion zone microstructure and resultant weldability is investigated using combination of microscopic examination and micro-hardness testing. This paper summarizes some of the results of a feasibility study conducted to understand the effects of welding parameters on localized microstructural features, cracking sensitivity, and mechanical properties of autogenously EB welded coupons of single crystal PWA1484.

PAPER 15.4 — 9:45

RESISTANCE WELDING OF THERMOPLASTIC COMPOSITES

A. YOUSEFPOUR, M. SIMARD, M.-A. OCTEAU, M. LARAMÉE and M. HOJJATI, NRC Institute for Aerospace Research, Advanced Manufacturing Technology Centre, Ottawa, Ontario, Canada

The need for effective and reliable joining methods grows as the use of advanced thermoplastic composites becomes widespread in aerospace industry. An experimental investigation of resistance welding of APC-2/AS4 thermoplastic composite laminates is presented. In this method, a heating element is placed between the bond-surfaces then the interface is heated by passing electrical current through the heating element. The polymer at the weld interface is melted due to resistance heating, then diffuses and consolidates under applied pressure, resulting in a weld. APC-2/AS4 prepreg, APC-2/AS4 commingled, and different grades of metal mesh heating elements were considered. A custom made resistance welding rig was designed and developed to perform lap-shear welds. The mechanical performance of the welds was quantified using single lap shear tests. The effects of different heating elements on the mechanical performance of the resistance-welded parts were investigated. Also, quality of the welds was examined under optical microscopy.

COFFEE BREAK — 10:10 – 10:40

PAPER 15.5 — 10:40

THE INFLUENCE OF PLATINUM ON GAMMA - GAMMA PRIME EQUILIBRIUM IN SUPERALLOYS.

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The role of platinum on the relative stability of gamma – gamma prime equilibrium is only qualitatively known, and may bear upon the stability of a superalloy under a protective coating. The binary phase diagrams Ni-Pt and Al-Pt, and the Ni-rich corner of the Ni-Al-Pt ternary, are reviewed and simple self-consistent thermodynamic models are derived. These thermodynamic models are incorporated into a database used to predict the gamma-gamma prime equilibrium for single crystal superalloys. In small concentrations, platinum is predicted to increase the temperature stability, but not the proportion, of the gamma prime phase over the gamma phase in third generation alloys such as CMSX-10. Another effect of platinum addition is to significantly lower the solidus temperature. These findings are compared to experimental data in the literature.

PAPER 15.6 — 11:05

CHARACTERIZATION OF THE BEHAVIOR OF PALNicro BRAZING ALLOY FOR STAINLESS STEEL JOINTS

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Brazing is a low-cost process used extensively in the manufacturing and repair of aircraft gas turbine engines. Components within the compressor stage of the engine experience relatively low temperatures (600-700°C), therefore joints of stainless steels are typically employed. In such joints, a Pd-Ni-Cr-Si-B (PalNiCro™) brazing alloy is used as a sealant, however brazing procedures are not well understood. The wetting behavior of PalNiCro™ on AISI 347 was evaluated with respect to contact angle. A microstructural evaluation was carried out with variable joint clearances. Microhardness profiles were performed to investigate the presence of hard secondary phases, which were later confirmed by electron microscopy.

The results indicated an equilibrium contact angle of 10° within 100 seconds. The average microhardness of the braze layer and base metal were approximately 550 and 205 VHN, respectively. At the interface, a diffusion zone was present containing carbides and borides.

PAPER 15.7 — 11:30

THE INFLUENCE OF PROCESSING PARAMETERS ON TLP JOINING OF INCONEL 617 ALLOY

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In the present work TLP bonding of Inconel 617 is investigated. The influence of the main processing parameters i.e. time and thickness of the interlayer were studied with optical and scanning electron microscopy. Boron containing interlayers with two different thicknesses were used and the influence of various holding times from 5 min to 24 hours on the microstructure of the bond region was investigated.

The results indicated that, for the testing temperature of 1065°C and holding times above 2 hours with an interlayer of 25.4 microns thick no liquid phase was observed. The same phenomenon occurred only after 6 hours for a 76.2 microns thick interlayer. Precipitate growth started at grain boundaries and continued inside the grains. The composition, size and morphology of the precipitates were studied using electron microprobe analysis. No noticeable changes were observed in the grain size of the base metal with increasing holding times.