MONDAY, AUGUST 23, 2004, P.M.

SESSION 3: SECOND INTERNATIONAL SYMPOSIUM ON AEROSPACE MATERIALS AND MANUFACTURING: DEVELOPMENT TESTING AND LIFE CYCLE ISSUES - HONORING WILLIAM WALLACE

HIGH TEMPERATURE MATERIALS FOR AEROSPACE
Sponsor: Materials Performance and Integrity Section, The Metallurgical Society of CIM
Room: ALBION B
Chairmen: P.C. PATNAIK, M. JAHAZI, 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 3.1 — 14:00 (PLENARY LECTURE)
DEVELOPMENTS IN AEROSPACE MATERIALS: HISTORICAL PERSPECTIVES AND FUTURE PROSPECTS
W. WALLACE, NRC-Institute for Aerospace Research, Structures Materials and Propulsion Laboratory, Ottawa, Ontario, Canada
The aerospace industry celebrated 100 years of powered flight in 2003, and the remarkable achievements that have occurred during the past 100 years are in no small way due to major developments in materials. Modern alloys for airframes, engines and other major sub-systems have evolved through the intelligent application of new processing concepts involving melting, casting, hot and cold working, heat treatment and more recently vapour phase processing. Alloy design has evolved in parallel to allow maximum benefits to be achieved from these processing advances. However, the pace of development seems to be slowing and future gains are likely to be made by learning how to extract major value from aerospace assets. Understanding the modes of deterioration and establishing cost effective lifetimes by holistic life cycle management seem to be the way of the future. Extending component lifetimes by repair, rejuvenation and refurbishment are all viable possibilities and they offer great opportunities for Canada, which, traditionally, has been a major user of modern aerospace materials rather than a supplier. The challenges for metallurgist, physicists and engineers will be no less than in the past and should create new business opportunities for Canada. The scenario described above will be developed by calling upon examples drawn from the author's experience.

PAPER 3.2 — 14:25
OXIDATION CHARACTERISTICS OF THE THIRD GENERATION SUPERALLOY CMSX-10
A. AKHTAR and R. REED, Department of Metals and Materials Engineering, The University of British Columbia, Vancouver, British Columbia, Canada
Oxidation of the third generation cast single crystal, nickel-base superalloy CMSX-10 is examined using isothermal tests at 900°C and 1000°C for times ranging from 20 hours to 100 hours. X-ray diffraction, scanning electron microscopy and energy dispersive secondary X-ray analysis were used to characterize the microstructure. It was found that the external scale formed at 1000°C is made up of (Ni,Co)O and the spinel $NiCo_2O_4$. The ($\gamma + \gamma'$) microstructure of the superalloy transforms into the intermetallic β phase prior to the onset of internal oxidation. Internal oxidation results in the formation of $(Ni,Co)Ta_2O_6$ and $(Ni,Co)WO_4$. No evidence was found for the formation of alumina (Al_2O_3), and the spinels $NiCr_2O_4$ and $NiAl_2O_4$ in this third generation superalloy. Results of the laboratory investigation are compared with those of an aero-engine turbine blade removed from service and examined earlier.

PAPER 3.3 — 14:50
THE EFFECT OF VARYING REFRACTORY ADDITION LEVELS ON OXIDATION BEHAVIOR OF SINGLE CRYSTAL NICKEL BASED SUPERALLOYS
D.Y. SEO, R. KEARSEY, P. AU, and P.C. PATNAIK, NRC-Institute for Aerospace Research, Structure, Materials and Propulsion Laboratory, Ottawa, Ontario, Canada,
Three Ni-base superalloys (7.5%Cr+5%Co+2%Mo+1%Ti+5%Al and Ni balance (wt%)) containing different amounts of W and Re were produced in the single crystal condition utilizing the Bridgman casting process. In the as-cast condition, microsegreagation of Re, Cr, and Mo increased with nominal Re levels. In order to investigate the effect of different levels of refractory addition on oxidation behaviour, button shaped samples were prepared by EDM. Isothermal oxidation testing of the alloys was conducted at 1000^{o}C for 277 hours under 3 ppm moisture content of air by using a thermogravimetric analyzer (TGA). An alloy with 2 wt% of W and Re exhibited less weight gain compared to two other alloys with either higher content of W or Re. Microstructures and chemical compositions of oxides in the tested samples were characterized with an optical microscope, a scanning electron microscope with EDS, and XRD. Several oxides such as Al, Cr, Ni, and Ta oxides were formed and have unique microstructures. SEM, EDS, and XRD

results indicated that Al or Ni oxides would be more dominant depending on the levels of refractory addition. The oxidation behaviour of the single crystal Ni-base superalloys containing different levels of W and Re can be elucidated in terms of the microsegregation behaviour as well as the oxide type.

COFFEE BREAK — 15:15 – 15:45

PAPER 3.4 — 15:45

MODELING STRESS RELAXATION AT HIGH TEMPERATURES INVOLVING DELAYED ELASTICITY

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Deformation in a material at any temperature is known to consist of two major components – a reversible (elastic) part and an irreversible part (often called plastic). What is not universally known is the fact that at high temperatures greater than about $0.4T_m$, where T_m is the melting point in Kelvin, the reversible part includes not only elastic but also a delayed elastic (recoverable but time dependent) component. A very simple computational model is presented here for a constant-strain stress relaxation test (SRT) on the basis of a three-component constant-stress rheological equation derived from strain relaxation and recovery test (SRRT) data. It is shown that the rapid stress reduction during the early periods of relaxation when the stresses are high is governed primarily by delayed elasticity irrespective of the imposed strain level. This is in contradiction to the popular concept prevailing today. The asymptotic approach to a quasi-stable stress rate at longer times and lower stresses is, however, controlled by viscous flow (power-law creep). The validity of the theory is examined by comparing the predictions with experimental results obtained for a titanium-base alloy Ti-6246 at $0.45T_m$.

PAPER 3.5 — 16:10

WEAR-RESISTANT TIC-REINFORCED STELLITE ALLOY COMPOSITES

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M. X. YAO, Deloro Stellite Inc., Belleville, Ontario, Canada
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Two cobalt-based superalloys, Stellite 694 and Stellite 712, were functionally graded with reinforcement of titanium-carbide particle for high-temperature wear/corrosion applications. The designed composite specimens were fabricated using powder metallurgy (P/M) technique, combined with hot isostatic pressing (HIP). Calorimetric effects of the alloy powders were investigated using the differential scanning calorimetry (DSC) technique, which provided the basis of the sintering cycles designed. The phases present in the microstructures of the materials were analyzed using SEM and X-ray diffraction. The wear resistance of the materials was evaluated on a pin-on-disc tribometer. It was demonstrated that adding titanium-carbide particles to the alloys has increased significantly their wear resistance. It was also found that the HIP process had improved the density of the sintered specimens and thus enhanced their wear resistance.

PAPER 3.6 — 16:35

MICROSTRUCTURE AND PERFORMANCE OF STELLITE ALLOY COMPOSITES REINFORCED WITH NI-COATED TIC PARTICLES

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P.C. PATNAIK, NRC-Institute for Aerospace Research, Structures, Materials and Propulsion Laboratory, Ottawa, Ontario, Canada, and
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Stellite 712 composites were developed with the reinforcement of bare TiC or Ni-coated TiC particles using HIPing powder consolidation technique. The emphasis of this research was on the effect of the Ni coating on the TiC particles and the HIPing conditions on the microstructure and performance of the composites. Calorimetric effects of the mixed composite powders were investigated using the differential scanning calorimetry (DSC) technique before the HIPing process, which provided the basis of the HIPing cycles designed. The microstructures of the composites were examined using SEM with EDX. The hardness and wear resistance of the materials were evaluated respectively. It was found that the HIPing temperature influenced the microstructure and the performance of the materials. The Ni coating on the TiC particle has improved the fracture toughness of the composites, but detracted the wear resistance. The experimental results and relevant mechanisms were discussed.