TUESDAY, AUGUST 24, 2004, P.M.

SESSION 27: SECOND INTERNATIONAL SYMPOSIUM ON AEROSPACE MATERIALS AND MANUFACTURING: DEVELOPMENT TESTING AND LIFE CYCLE ISSUES - HONORING WILLIAM WALLACE

FATIGUE BEHAVIOUR AND LIFE MANAGEMENT OF AEROSPACE MATERIALS AND COMPONENTS II
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 27.1 — 14:00
TAILORED MICTROSTRUCTURE OF ZIRCONIA AND HAFNIA-BASED THERMAL BARRIER COATINGS WITH LOW THERMAL CONDUCTIVITY AND HIGH HEMISPHERICAL REFLECTANCE BY EB-PVD
J. SINGH, D.E. WOLFE, Applied Research Laboratory, Penn State University, University Park, Pennsylvania, U.S.A.
R. MILLER, J. ELDRIDGE and D.-M. ZHU, NASA-GRC, Cleveland, Ohio, U.S.A.

This paper discusses microstructural changes produced by two novel approaches using electron beam physical vapor deposition (EB-PVD) in which periodic strain fields/microporosity was incorporated within the large columnar grains of ZrO_2-8wt.%Y_2O_3 (8YSZ). The traditional columnar microstructure of partially stabilized zirconia has been slightly modified to produce a lower thermal conductive thermal barrier coating (TBC) by periodically interrupting the condensing vapor resulting in microstructural modifications with diffuse or sharp interfaces and morphological changes on the sub-micron scale without changing the composition of the TBC. These microstructural modifications resulted in a 20-30% reduction in the thermal conductivity, 28-56% increase in hemispherical reflectance, improved oxidation cyclic life (over 100%), and better strain tolerance as compared to standard ZrO_2-8wt.%Y_2O_3 deposited on platinum-nickel-aluminide and CoNiCrAlY bond-coated MAR-M-247 test samples. The TBC with tailored microstructures were examined by various techniques including scanning electron microscopy (SEM), x-ray diffraction (XRD), steady-state laser heat flux technique, and hemispherical reflectance.

PAPER 27.2 — 14:25
ELECTRONIC STRUCTURES, ELASTIC AND THERMAL PROPERTIES OF HEXAGONAL ALN, NBN-BASED NITRIDES FOR AEROSPACE APPLICATIONS
K. CHEN, L. ZHAO and P.C. PATNAIK, NRC Institute for Aerospace Research, Structures, Materials and Propulsion Laboratory, Ottawa, Ontario, Canada

Metal nitrides are widely used to fabricate hard coating for aerospace applications. The traditional approach to the selection of materials for coating deposition is based on “informed guessing” or “trial-and-error”. The work presented in this paper represents the first step towards “rational design” of protected coating from materials selection viewpoint. Elastic properties of hexagonal AlN- and NbN-nitrides were calculated using ab initio density functional theory within the generalized gradient approximation. The calculated elastic moduli and thermal expansion coefficients of pure AlN and NbN are in good agreement with experimental results, and are compared favorably with other theoretical calculations. Alloying effects on elastic and thermal-physical properties of these nitrides are examined, and the trend of elastic properties of these nitrides with the alloying additions are identified. The Cauchy pressure and the ratio G/B (shear modulus (G) divided by bulk modulus (B)) are then used to assess brittle/ductile behavior of these nitrides accompanying alloying additions. Potential applications of these results for coating design are discussed.

PAPER 27.3 — 14:50
ADVANCED PROGNOSIS FOR LIFE CYCLE MANAGEMENT OF FUTURE AND LEGACY AIRCRAFT PROPULSION SYSTEMS—A CANADIAN PERSPECTIVE
X.J. WU, J. BIRD and P.C. PATNAIK, NRC-IAR, Structures, Materials and Propulsion Laboratory, Ottawa, Ontario, Canada

Prognosis and health management (PHM) is an evolving suite of technologies intended for application to the life cycle management (LCM) of mission/safety critical systems, with anticipated results to

- Reduce life cycle cost

- Enhance operational safety and readiness
- Assist maintenance decision-making
- Enable autonomic logistics

While it is emphasized in the United States that future multi-mission fighter aircraft such as Joint Strike Fighter (JSF) must have PHM capabilities, Canadian initiatives also recognize the need to implement such schemes for future and legacy military and civil aerospace systems.

With respect to five major technological areas of PHM, i.e., i) advanced sensors, ii) diagnosis, iii) data fusion, iv) life consumption evaluation, and v) reliability/risk assessment, there has been advanced technologies developed by NRC and others within Canada:

- Aircraft/engine instrumentation and airborne data recording systems
- Signal analysis and data fusion
- On-line engine health monitoring
- Physics based models for engine material failure modes and life prediction
- Autonomic crack growth analysis for damage tolerance of engine components
- Mission severity analysis algorithm
- Probability, reliability and risk assessment

This presentation reviews the above technologies in relevance to PHM, emphasizes the need to have physics based models and outlines the future R&D needs for integration and implementation of these technologies suitable for the advanced and legacy aircraft.

COFFEE BREAK — 15:15 – 15:45

PAPER 27.4 — 15:45

THE INFLUENCES OF HOLDING AT TEMPERATURE ON FATIGUE FAILURE OF A TITANIUM METAL MATRIX COMPOSITE

M.G. HADIANFARD, School of Engineering, Shiraz University, Kerman, Iran

The effect of holding at temperature on fatigue life of a 10 vol% particulate SiC reinforced Titanium alloy has been investigated. The influence of holding time at 600^{o}C on fatigue of this material has been studied by using tension-compression tests, scanning electron microscope and image analysis. The specimens were heated to 600^{o}C by using a controlled atmosphere furnace; hold at this temperature for time ranging from 0 to 100 hours, and then fatigue tested at room temperature under controlled constant plastic strain. The number of cycle to failure found to decrease with increasing of the holding time. In addition the fracture mechanism and number of debonded particles has been significantly influenced by holding time at 600^{o}C.

PAPER 27.5 — 16:10

CREEP BEHAVIOR OF ALUMINIUM NITRIDE AND CORRELATION WITH THE MICROSTRUCTURE

M. AZZAZ, Laboratoire de Science et Génie des Matériaux, Bab Ezzouar, Algeria

In this paper, we report on new mechanical tests, at high temperatures, performed with a supposed better aluminium nitride (AlN) material, containing fewer oxygen. Our purpose was twofold: (i) check whether creep resistance is modified and hopefully enhanced and (ii) determine the elementary mechanisms controlling plastic deformation through transmission electron microscopy (TEM) observations of deformed samples up 10% strain in compression at elevated temperatures (1823-1923 K) under constant stress in the range 150-250 MPa.

Stationary rates are lower by an order magnitude than those previously measured in AlN with higher oxygen content. All dislocations imaged by TEM look undissociated, which clearly relates the formerly observed wide dissociation to oxygen in excess.

PAPER 27.6 — 16:35

DETECTION METHODS FOR NUCLEATION AND SHORT FATIGUE CRACKS IN 2024-T3 ALUMINUM ALLOY

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Due to economic factors, many aircraft in service today are near (or over) 30 years of age even though they were initially designed with a service objective of 20 years. Improved damage management models are therefore needed for use in life prediction and management of aging fleets of aircraft.

Currently, the generally accepted procedure in fatigue life prediction methodologies is to back calculate the equivalent initial flaw size (EIFS) using established long crack growth data once the fatigue performance had been evaluated. However, it was observed from studies carried out at the National Research Council Canada that the majority of the fatigue life (up to ~95%) was in the nucleation and short crack regimes. As a result, it seems that the significance of the short crack regime has been underestimated and must be further investigated and fully understood before an accurate holistic life prediction methodology can be realized.

Unlike long cracks, local microstructural features such as grain boundary and size, inter-particle spacing, and texture play the primary roles in the short crack growth regime.

An extensive study has been carried out to evaluate different crack detection and monitoring techniques in the short crack regime for AA2024-T3. The results will be presented in detail.

PAPER 27.7 — 17:00

NANOSTRUCTURED HYBRID ORGANO-SILICATE COATINGS WITH ENCAPSULATED INHIBITORS FOR ACTIVE CORROSION PROTECTION OF ALUMINUM ALLOYS

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Corrosion protection properties of the hybrid organo-silicate coatings on aluminum substrate can be significantly improved by means of encapsulation of organic corrosion inhibitors within the coating material. In order to achieve sustained release of corrosion inhibitor and long-term corrosion protection, a secondary chemical equilibrium of either ion-exchange interaction with the coating matrix or cyclodextrin-assisted molecular encapsulation of the inhibitor has been employed. Several organic corrosion inhibitors, such as mercaptobenzothiazole, mercaptobenzimidazole, mercaptobenzimi-dazolesulfonate, and thiosalicylic acid have been examined by a group of electrochemical methods including potentiodynamic scan, electrochemical impedance spectroscopy, and scanning vibrating electrode technique. It has been found that the formulations that contain β-cyclodextrin demonstrate superior corrosion protection capabilities as the complexation equilibrium results in a continuing delivery of inhibitor to corrosion sites. The approach is considered a promising way for active corrosion protection of high-strength aluminum alloys when integrity of barrier coating is compromised.