TUESDAY, AUGUST 24, 2004, A.M.

SESSION 14: SECOND INTERNATIONAL SYMPOSIUM ON AEROSPACE MATERIALS AND MANUFACTURING: DEVELOPMENT TESTING AND LIFE CYCLE ISSUES - HONORING WILLIAM WALLACE

ADVANCED JOINING AND PROCESSING METHODS FOR AEROSPACE MATERIALS
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 14.1 — 8:30
THE EFFECT OF NICKEL ON SULPHIDATION RESISTANCE OF AUSTENITIC HEAT RESISTANT ALLOYS
M. KARAMINEZHAAD, M.R.BATENI, E. KORDZADEH, Metallurgical group, Shahidbahonar University, Kerman, Iran
A. MOEINI, R & D Department, Sarcheshmeh Copper Complex, Kerman, Iran
A series of austenitic heat resistant Fe-Ni-Cr-Al alloys with different nickel contents have been investigated at 1100 °C and 25, 50, 50,100 hours in S/O bearing atmospheres. Before sulphidation test, the specimens were annealed in argon at 1250 °C for 8 hrs. Weight changes were measured using an automatic thermo gravimetric analyzer and corrosion products were analyzed by scanning electro microscope (SEM), energy dispersive X-ray spectrometry (EDAX), X-ray diffraction and optical microscope. The results showed that sulphidation resistance decreased with increasing nickel content. Internal sulphidation controlled by gaseous transport through cracks and pores and the formation of internal sulphide increased when liquid sulphides formed on the surface.

PAPER 14.2 — 8:55
FORMATION OF TITANIUM ALUMINIDES AND NICKEL ALUMINIDES INTERMETALLIC COMPOUND COATINGS ON INCONEL 738
M. ZANDRAHIMI, M.R.BATENI, Metallurgical group, Engineering Department, Shahidbahonar University, Kerman, Iran, and
J.A. SZPUNAR, Mining, Metals & Materials Engineering, McGill University, Montréal, Québec, Canada
Titanium aluminides and nickel aluminides offer the potentials, as coating materials, for high temperature and aerospace applications. In this research, attempt has been made to develop Al-Ti and Ni-Al intermetallic compound coatings on the surface of Inconel 738. The coatings applied through pack cementation and simultaneous diffusion annealing processes. Scanning-electron microscopy (SEM), energy-dispersive X-ray spectrometry (EDAX) and grazing angle X-ray diffraction were used for evaluating of coating structure. It was demonstrated that the pack cementation technique could be used to develop $TiAl_3$ and AlNi intermetallic compounds coating on Inconel 738 substrate. When pack cementation technique is based on a halide-activated pack with aluminum and titanium powders, the coating consists of $TiAl_3$ intermetallic compound phase. Whereas, by pack aluminization of Inconel 738, the coating consists of AlNi intermetallic compound phase.

PAPER 14.3 — 9:20
DESIGN OF A MULTIPLE-LAYERED THERMAL BARRIER COATING STRUCTURE FOR OPTIMIZED THERMAL PROPERTIES
D. WANG, X. HUANG, Department of Mechanical and Aerospace Engineering, Carleton University, Ottawa, Ontario, Canada and
P.C. PATNAIK, NRC-Institute for Aerospace Research, Structures, Materials and Propulsion Laboratory, Ottawa, Ontario, Canada
Further increase in gas turbine engine temperature necessitates continuous development and advancement to thermal barrier coatings. While tremendous effort has been devoted to developing new thermal barrier coating materials and processing methods in order to decrease the thermal conductivity, limited attention has been paid to radiative thermal transport through coatings. It is the purpose of this study to develop a new layered coating structure that can be used to effectively reduce the both radiative thermal transport as well as thermal conductivity, and to demonstrate the mechanism and effectiveness of the proposed multilayered structure. Mathematical modeling based on the multilayer quarterwave stack and simulation results are presented.

PAPER 14.4 — 9:45

CATHODIC ELECTRODEPOSITION OF PROTECTIVE ZIRCONIA COATINGS

X. PANG and I. ZHITOMIRSKY, Materials Science and Engineering Department, McMaster University, Hamilton, Ontario, Canada

The outstanding thermal and chemical stability, excellent mechanical properties and biocompatibility of zirconia and alumina have made these materials important candidates for fabrication of advanced protective coatings on metals, graphite/carbon fibers and biomedical implants. Nanostructured polymer-ceramic composite films containing zirconia and alumina were synthesized on metallic substrates by combining cathodic electrosynthesis of inorganic particles with electrophoretic deposition of cationic polyelectrolytes. Thick crack-free oxide and composite coatings were obtained using this newly developed technique. The deposits were studied by thermogravimetric analysis, X-ray diffraction analysis, scanning electron microscopy and atomic force microscopy. The mechanisms of deposition are discussed.

COFFEE BREAK — 10:10 – 10:40

PAPER 14.5 — 10:40

FORWARD AND REVERSE NUMERICAL MODELING OF THE NANOINDENTATION OF COATINGS

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The finite element method (FEM) has been applied to investigate the stress fields and deformation of a TiN/Ti-6Al-4V coating/substrate system subjected to nanoindentation. MSC Patran and MSC Marc were used to prepare the three-dimensional finite element models and to perform the simulations of the Vickers nanoindentation experiments. Pure silicon and TiN/Ti-6Al-4V coating/substrate system were analyzed. The properties of the materials were assumed to be homogeneous and isotropic with a linear hardening behavior. The reverse method was used to extract material properties, such as the yield stress and strain hardening coefficient, from the numerical results by comparing the simulated indentation load vs. penetration depth (P-h) curves with those obtained experimentally. Both non-linear elastic and non-linear elastic-plastic analyses were carried out for the coating/substrate system. The results are given for four different coating thicknesses.

PAPER 14.6 — 11:05

DEVELOPMENT OF A ROBUST PTA HARDFACING PROCESS USING THE TAGUCHI METHOD

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Hardfacing overlays are commonly applied on the shroud Z-section of turbine blades for enhanced wear resistance. Among various processes that are used to apply the hardfacing overlays, the plasma transferred arc (PTA) welding process offers several advantages including lower heat input, less base material dilution, rapid process time, and reduced operating cost associated with the capability to apply materials in the powder form. The development of a robust PTA process is crucial for overlay performance and repeatability, particularly in the aerospace industry where a quality intensive manufacturing environment prevails. For this reason, the Taguchi method of experimental design was selected to develop a test plan. A 4-factor 3-level (L9) orthogonal array (OA) was used in the experiment. The L9 OA allows for a more detailed (3 level) investigation of critical process parameters, namely plasma gas flow rate, traverse speed, powder feed rate, and arc current. Two hardfacing materials, Stellite 694 and Tribaloy T-800, both Co-based wear resistant alloys, were investigated by deposition onto a cast IN738 Ni-based superalloy substrate. Performance measurements of the hardfacing deposits included deposit hardness, substrate hardness, deposit density (porosity), degree of cracking/inclusions, and a quantified visual inspection. The procedure resulted in optimized PTA hardfacing parameters for both Stellite 694 and Tribaloy T-800 on IN738 turbine blade material.

PAPER 14.7 — 11:30

DEGRADATION OF A THERMAL BARRIER BOND COATING – A PHYSICS-BASED MODEL

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In this study, a physics based model has been presented, considering the growth of the thermally grown oxide (TGO) layer on the bond coating of a thermal barrier coating. Using diffusion equations, a model has been developed to physically describe the oxidation process. The mathematical equations representing the diffusion formulations have

been solved numerically. The computed results show the depletion of *Al* in the bond coating as it diffuses both towards the super-alloy substrate and towards the TGO produced in between the bond coating and the ceramic TBC top layer.