

MONDAY, AUGUST 22, 2005, P.M.

**SESSION 7: INTERNATIONAL SYMPOSIUM ON MATERIALS
DEGRADATION: INNOVATION, INSPECTION, CONTROL AND
REHABILITATION**

CORROSION BEHAVIOUR, CHARACTERIZATION AND APPLICATIONS

Sponsor(s): Material Performance and Integrity, The Metallurgical Society of CIM

Room: Bannerman

Chair(s): G.P. GU, CANMET, Canada

PAPER 7.1—14:00 (KEYNOTE)

**ENVIRONMENTAL ATTACK IN ADVANCED INDUSTRIAL GAS TURBINES, A PROBLEM WITH NEW MATERIALS
& ALTERNATE FUELS.**

P.C. PATNAIK, NRC - Institute for Aerospace Research, Canada

Performance of industrial gas turbine engines in terms of power output, reduced cooling and efficiency have been continuously increasing in parallel with aero gas turbines due to the advances made in the development of new materials, protective thermal barrier coatings (TBCs) and the advanced diagnostics to monitor service induced problems such as hot corrosion, thermal and thermo-mechanical fatigue and other operational issues. Environmental attack (hot corrosion and high temperature oxidation) is a common degradation mode in the hot section of the Gas Turbine. Hot Corrosion occurs when Na or K bearing compounds in the environment or in the fuel combine with other contaminants such as S and Pb or V to form corrosive sulphates or vanadates thus attacking the protective oxide on the turbine airfoil. These problems pose far more threat to new turbine engine materials such as directionally solidified, single crystals and ceramic matrix composites (CMCs). The CMCs due to their increased temperature capability, when used in the combustion chamber is likely to reduce the peak temperatures attained during combustion and therefore provide the benefits of reduced emissions of oxides of C and N. These issues will be reviewed critically and their impact will be assessed on Gas Turbine lives.

With respect to alternate fuels, past experience has shown that utilization of residual oils and coal derived fuels in gas turbines have resulted in complex deposition and corrosion processes. In recent years biomass derived alternate fuels have been used either through a gasification cycle or through direct firing of the biomass derived liquid fuel with a view to reduce Green House Gases (GHGs) and improve the climatic conditions. In both cases, the resulting high temperature corrosion processes (in the presence of alkaloids in the fuel) are also very complex, leading to premature removal of hot section components. Technology solutions mitigating these fundamental problems will be reviewed and solutions presented.

PAPER 7.2—14:30

GALVANIC COUPLING BETWEEN CARBON STEEL AND STAINLESS STEEL REINFORCEMENTS.

S. QIAN, National Research Council Canada, Canada

D. QU, Hokkaido University, Japan and

G. COATES, Nickel Institute, Canada

Galvanic corrosion is potentially a major concern associated with the application of stainless steel reinforcement bar (rebar) which is in direct (electrical) contact with carbon steel reinforcement in concrete structures. Judicious use of stainless steel rebar in both new construction and repair of older structures is a viable cost-effective option for extending service life and reducing maintenance costs, but questions had arisen about the possibility of increased corrosion due to galvanic effects. This paper investigates the galvanic coupling behaviours of 3 different stainless steels and carbon steel. Tests were performed both in electrochemical cells and with specimens in concrete inside a humidity chamber. The results show oxygen reduction on stainless steel is the rate-determining step for galvanic coupling of these two metals. It is much lower than for passive carbon steel. Therefore, the galvanic coupling of stainless steel with carbon steel will not increase the risk of corrosion on carbon steel reinforcement.

PAPER 7.3—14:55

**EFFECT OF HEAT TREATMENT ON THE CORROSION PROPERTIES OF NANOCRYSTALLINE CO-1.1WT% P
ALLOY.**

H. JUNG and A. ALFANTAZI, University of British Columbia, Canada

The corrosion properties of nanocrystalline Co-1.1 wt% P and the heat-treated Co-1.1 wt% P alloys were studied in deaerated 0.1M H₂SO₄ solution using polarization and impedance measurements. The potentiodynamic polarization tests revealed that all samples exhibited active anodic dissolution without a distinct transition to passivation up to -0.1 VSCE. Enhanced corrosion resistance of nanocrystalline Co-1.1wt% P compared to that of pure nanocrystalline Co

deteriorated by the heat treatment process. The corroded surface after potentiodynamic polarization scan of the heat treated sample at 350°C showed porous P enriched layer and the heat treated sample at 800°C corroded uniformly showing the second phase precipitates.

COFFEE BREAK—15:20-15:45

PAPER 7.4—15:45

DEVELOPMENT OF CORROSION-RESISTANT LOW ALLOY STEELS FOR COMMERCIALIZATION.

B. VOYZELLE, G.P. GU, N. BOUZOUBAË, E. ESSADIQI, CANMET, Canada and
N. FORTIN, B. WOLMAN, Norambar Inc., Canada

The deterioration of highway and bridge infrastructure has received considerable attention in recent years because of due to the billions of dollars that would be needed for repair and rehabilitation. A major contributing factor to this problem is corrosion of steel reinforcement. Good corrosion resistance and relatively low price reinforcing steels are therefore essential for maintenance, cost reduction and service-life extension of the steel reinforced structures. This article narrates the development of low alloying steels that persists good corrosion resistance with reasonably low price. Topics include steel microstructures, CCT diagrams, mechanical properties, corrosion performance, industrial application and economic aspects.

PAPER 7.5—16:10

STUDY OF N-GAAS CORROSION BEHAVIORS BY ELECTROCHEMICAL METHODS AND XPS.

Y. HUANG, J.L. LUO and D.G. IVEY, University of Alberta, Canada

Corrosion of GaAs in aqueous electrolytes is a major limitation in implementing GaAs-based photoelectrochemical solar energy conversion systems. In this work, the corrosion behaviour was investigated by electrochemical methods and surface analysis approaches, in both H₂SO₄ and NH₃·H₂O solutions. Open circuit measurements showed that the cleaned GaAs surface was very sensitive to water/air. The impedance for n- and p-GaAs showed that an inductive loop only appeared at a high corrosion rate because a reaction intermediate is the oxidant for a further decomposition step in combination with a chemical reaction with water. The results suggest that the same corrosion/decomposition mechanism occurred on both n- and p-GaAs and also in the two solutions. When the surface hole concentration was low, the hole injection or generation process was the rate-determining step. At large reverse bias on n-GaAs, with high hole concentration or forward biasing of p-GaAs, the corrosion rate was limited by a Faradaic adsorption process, involving an adsorbed intermediate. The different surface compositions after corrosion in the two solutions can be explained by the dissolution of As(0). The further oxidation of As(0) to As(III) in NH₃·H₂O solution is still slow, as suggested from x-ray photoelectron spectroscopy (XPS) analysis.

PAPER 7.6—16:35

CHARACTERIZATION PITTING CORROSION OF 90/10 CUPRO-NICKEL CHILLER TUBES.

G.P. GU, J. LI, M. ELBOUJDAÏNI, W. REVIE CANMET, Canada and
A. DAY, Public Works and Government Services Canada (PWGSC), Canada

The in-serviced 90/10 cupro-nickel tubes in a water chiller system suffered from severe corrosion damage during relatively short service. This has caused unexpected down times. Microstructural investigation using SEM, electron microprobe and focused ion beam microscope indicated that pitting corrosion has resulted in local nickel depletion. During the corrosion process, copper appeared to have re-deposited around the corrosion pits, which accelerated the local corrosion.

PAPER 7.7—17:00

CORROSION OF ALUMINUM COMPONENTS IN THE GLASS CURTAIN-WALL OF A BUILDING.

F.N. SMITH, Consultant, Canada

Corrosion was observed on the aluminum pressure plates and dress-caps that hold the glazing in place on a curtain-walled building. For aesthetic purposes, the original design required the dress-caps (which have an L-shaped cross-section) to be externally clad with thin copper sheet. The building is situated in the downtown area of a busy Canadian city. Since the aluminum was in direct contact with the copper trim, galvanic corrosion developed that resulted in damage to the aluminum components. Soluble corrosion products washing off the copper trim also contributed to the accelerated corrosion of the aluminum. The aluminum pressure plates and dress-caps are being systematically replaced with components made of fibre-reinforced plastic. The outside of the new dress-caps will be clad with thin copper sheet in order to preserve the original appearance of the building.