TUESDAY, AUGUST 23, 2005, A.M.

SESSION 19B: INTERNATIONAL SYMPOSIUM ON PIPELINES FOR THE 21ST CENTURY IN HONOR OF DOUG BOYD

CORROSION AND SCC
Sponsor: Iron and Steel Section, The Metallurgical Society of CIM
Room: Imperial Ballroom 1
Chairmen: M. SHEHATA, CANMET, Canada and
J. BEEN, NOVA Chemicals Corporation, Canada

PAPER 19B.1 — 9:00 (KEYNOTE)
THE HOLY GRAIL – PREDICTING LOCALIZED CORROSION DAMAGE FROM FIRST PRINCIPLES.
D.D. MACDONALD, Pennsylvania State University, U.S.A. and
G.R. ENGELHARDT, OLI Systems, Inc., U.S.A.

The accumulation of damage due to localized corrosion [pitting, stress corrosion cracking (SCC), corrosion fatigue (CF), crevice corrosion (CC), and erosion-corrosion (EC)] in complex industrial systems, such as power plants, refineries, desalination systems, etc., poses a threat to continued safe and economic operation, primarily because of the sudden, catastrophic nature of the resulting failures. Of particular interest in managing these forms of damage is the development of robust algorithms that can be used to predict the integrated damage as a function of time and as a function of the operating conditions of the system. Because complex systems of the same design rapidly become unique, due to differences in operating histories, and because failures are rare events, there is generally insufficient data on any given system to derive reliable empirical models that capture the impact of all (or even some) of the important independent variables. Accordingly, empirical models have generally failed to provide a robust basis for predicting the accumulation of corrosion damage in complex systems under realistic operating conditions. The alternative prediction philosophy is determinism, in which the development of damage is described in terms of valid, physico-electrochemical mechanisms with the output being constrained by the natural laws. The differential damage is then integrated along the corrosion evolutionary path for the system (i.e., over the future operating "history") to yield the desired integrated damage, which is the quantity that is most useful to an operator. In this paper, we review the theory of predicting corrosion damage within the framework of Damage Function Analysis (DFA), with particular emphasis on the pitting of aluminum in chloride solutions and on the accumulation of damage from SCC in Type 304 SS components in the primary coolant circuits of Boiling Water (Nuclear) Reactors (BWRs). These cases have been selected to illustrate the various phases through which localized corrosion damage occurs.

PAPER 19B.2 — 9:35
STRESS CORROSION CRACKING BEHAVIOUR IN WELDED X-70 LINEPIPE STEEL UNDER NEAR-NEUTRAL PH CONDITIONS.
A.H. ADELEKE, J.L. LUO and D.G. IVEY, University of Alberta, Canada

Double-edge-notched flat tensile samples of X70 steel were used for both slow strain-rate testing (SSRT) and cyclic loading testing with the notch located in the zone of interest, i.e., the weld metal (WM), base metal (BM) and heat affected zone (HAZ). By using both optical and scanning electron microscopy, the stress corrosion cracking (SCC) behaviour with respect to crack morphology and various forms of microstructure was investigated. In all the samples considered, the mode of failure was predominantly transgranular with cleavage facets around the edges of the fracture surface. The BM, with a bainitic microstructure, had the highest resistance to SCC when compared with the mixed microstructures of acicular ferrite-primary ferrite and acicular ferrite-grain boundary ferrite observed in the WM and HAZ, respectively. The effect of microstructure on stress corrosion cracking behaviour is discussed based on experimental observations.

PAPER 19B.3 — 10:00
EFFECT OF PLASTICITY ON STRESS CORROSION CRACKING RATE OF X-52 PIPELINE STEEL IN NEAR-NEUTRAL PH ENVIRONMENT.
X. LI, R. EADIE and J.L. LUO, University of Alberta, Canada

The effect of plastic deformation on near-neutral pH stress corrosion cracking (SCC) also known as environmentally assisted cracking was studied by cracking rate measurements. All the tests were conducted in a synthetic near-neutral pH solution. The traditional potential drop tests using compact toughness (C-T) specimens with 2-3 mm long pre-cracks showed varying plastic deformation by rolling would increase the material's susceptibility to SCC. This was confirmed by cyclic loading tests using double notched flat tensile specimens with 200-300 μm long pre-cracks which gave the same results that the specimen with large scale plastic deformation by tensile loading had a relatively faster crack growth rate than that with only small scale plastic deformation.

COFFEE BREAK — 10:25 – 10:45

PAPER 19B.4 — 10:45

ROOM TEMPERATURE CREEP AT THE CRACK TIP AND ITS EFFECT ON FATIGUE CRACK GROWTH RATE IN A X-70 PIPELINE STEEL.

D. NIE, J. ZHAO, T. MO and M. REN, Dalian University of Technology, China

This paper studied the phenomenon of room temperature creep deformation at crack tip and its effect on fatigue crack growth rate of a X-70 pipeline steel using compact-tension (CT) specimen on a MTS 810 testing machine. Time-dependent deformation at the crack tip under constant load was observed in this steel at room temperature and the amount of deformation produced was seen to depend on loading rate and the magnitude of stress intensity factor. It is found that there exists a critical stress intensity factor below which the deformation decreases with time when the applied load remains constant. It is also found that the occurrence of room temperature creep obviously affects the subsequent fatigue crack growth rate. The observed behavior was explained based on dislocation theory.

PAPER 19B.5 — 11:10

A REVIEW ON THE INITIATION OF ENVIRONMENTALLY ASSISTED CRACKING IN LINE PIPE STEEL.

M.T. SHEHATA, M. ELBOUJDAINI and R.W. REVIE, CANMET, Canada

Environmentally assisted cracks in linepipe steels are initiated either as a result of stresses in combination with environmental effects, as in stress corrosion cracking (SCC), or as a result of trapped hydrogen in the steel, as in hydrogen-induced cracking (HIC). To understand better the mechanism of the crack initiation process, key metallurgical and environmental elements that can affect the cracking phenomena were investigated and are reviewed in this paper. The complexity of both cracking phenomena results from the dependence of SCC and HIC on multiple metallurgical, mechanical, and environmental parameters that may all influence both crack initiation and propagation; e.g., composition, microstructure and non-metallic inclusions in the steel, applied stress, water chemistry in the field, and ionic concentrations in the groundwater near the pipe surface to name a few for SCC. In addition, for HIC phenomena, one can add the concentration of H2S in the fluids transported in the pipe as well as concentration of CO2, pH, etc. In this paper, cracking of linepipe steels is analyzed critically, with particular attention to the crack initiation process. The paper is divided into two parts: The first part covers SCC and the second covers HIC.

PAPER 19B.6 — 11:35

PROGRESS IN UNDERSTANDING OF PIPELINE SCC: INITIATION AND PROPAGATION.

W. CHEN, University of Alberta, Canada and
W. ZHENG, CANMET, Canada

Pipelines can develop stress corrosion cracks in either intergranular or transgranular form. Since the mid-1980s, numerous colonies of transgranular cracks have been found across Canada and many other countries in the world. While the intergranular form of cracking has been well studied in the past 40 years, the mechanisms governing SCC in near-neutral pH environment, i.e., the transgranular form of the cracking, are yet to be understood in greater depth. Over the past ten years or so, a large number of research publications have been available on this subject and this paper summarize our latest progress in understanding the mechanistic aspect of the problem.

Better understanding of the role of mill scale surface and the steel metallurgy in crack initiation has been indicated in the recent literature. However, the initiation of SCC in the lab research still relies on loading conditions that are far more aggressive than those encountered in the field. Most crack growth studies in the past are also performed under very aggressive mechanical conditions, which could have prevented the observation of environment effects. However, more recent research at lower K or Delta K ranges seems to suggest a strong role of the environment. Naturally, modeling of growth should reflect the effect of the environment, steel metallurgy, and the changing mechanical properties of the pipe steel with time. For a specific steel in a given environment, the crack growth rates tended to increase with the strain rate, indicated either by the nominal applied loading frequency or by the calculated crack tip opening rate. Future research needs to address the issue of concurrent growth of multiple interacting cracks.

More attention should also be given to concurrent initiation of multiple cracks in a colony, as failure is usually caused by a coalesced crack not by an individual crack. The effect of soil environment should not be limited to the chemistry of soil solution; other factors such as cathodic processes, the variation of environment with time and physical conditions of coatings should also be considered as part of the study.