CP4

ELECTROCHEMICAL ASSESSMENT OF CORROSION-FATIGUE DEGRADATION STAGES

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https://doi.org/10.34637/zz27-pa50

ABSTRACT

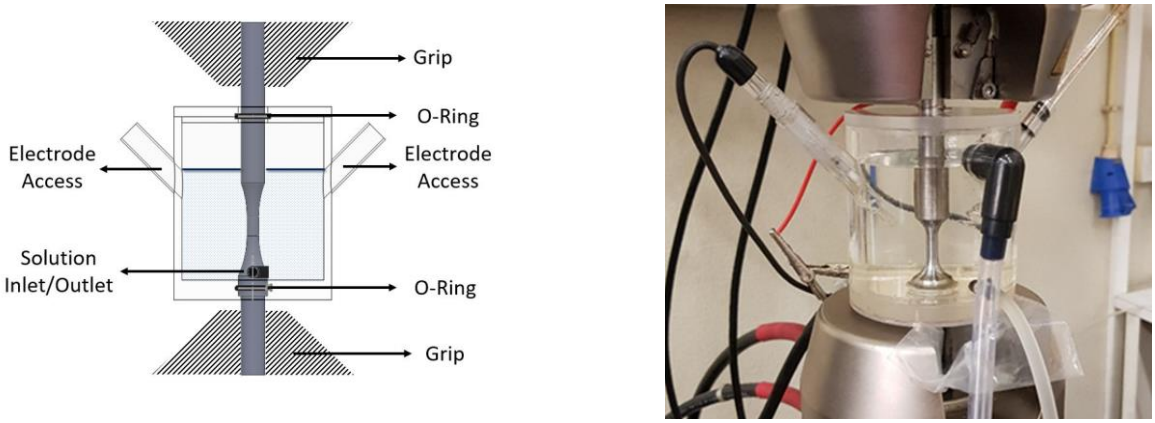
The study is focussed on the joint effect of corrosion and mechanical cyclic stresses observed on mooring chains of Floating Production Storage and Offloading (FPSO) units. The tests were performed using grade R4 steel in artificial sea water, under stress-controlled and fully reversed loading. The corrosion-fatigue degradation was monitored using open circuit potential measurements simultaneously with the cyclic mechanical load. The open circuit potential response varies during the corrosion-fatigue test, depending on the stage of degradation of the material. This technique has proven to be capable of identifying important phenomena, such as crack initiation and crack propagation, on the material under corrosion-fatigue loading condition.

Keywords: Corrosion-fatigue, Corrosion potential, Grade R4 steel

1. INTRODUCTION

Many offshore structures undergo corrosion-fatigue (CF) during the in-service period, which leads to significant costs and constitute a technological challenge. While the synergetic nature of CF makes its assessment very complex, electrochemical properties were used in previous studies to assess the damage evolution in CF experiments [1]. Recent studies [2] have shown that the corrosion potential evolution during corrosion-fatigue tests can provide information on the damage mechanism. The electrochemical measurements under spontaneous state are influenced by mechanical stress and strain presences [3], however, their relationship is not straightforward. The present study focuses on the monitoring of in-situ CF testing and assessment the detrimental phenomena of grade R4 steel. The degradation evolution was monitored using corrosion potential measurements during the application of the cyclic mechanical loading. For the purpose, an electrochemical cell in which the specimen was submitted to cyclic stress and compression was constructed – Fig. 1. The cyclic load was applied with a ratio $R = S_{a,min}/S_{a,max}$ = -1, with S_a=applied stress,

with a frequency of 1.0 Hz. For the results presented, the stress went from +500 MPa to -500MPa. The open circuit potential was monitored for a time interval with a frequency much higher than that of the applied load vs. the Ag/AgCl (sat) reference electrode. For a certain number of cycles, *N*, and considering the number of cycles to corrosion fatigue failure, N_f, the evolution of the potential transients was observed and interpreted.



(a) (b)

Fig.1 – Electrochemical cell schematic (a) and image of the experimental set-up (b).

Note: in the results presented, only the specimen (working electrode) and a reference electrode were used.

2. DESCRIPTION

The open circuit potential (OCP) acquired signal reveals small cyclic fluctuations around a mean value – Fig. 2, with same frequency of the mechanical loading (1.0 Hz) and three distinctive responses were identified. At the first stage, the OCP signal showed a pure sinusoidal waveform, with ~0.5 mV of amplitude, which is assigned to a purely elastic deformation of a damage-free material. At the second stage, the signal has a smaller amplitude while a visible distortion suggests the presence of heterogeneities on the specimen, such as pits or cracks.

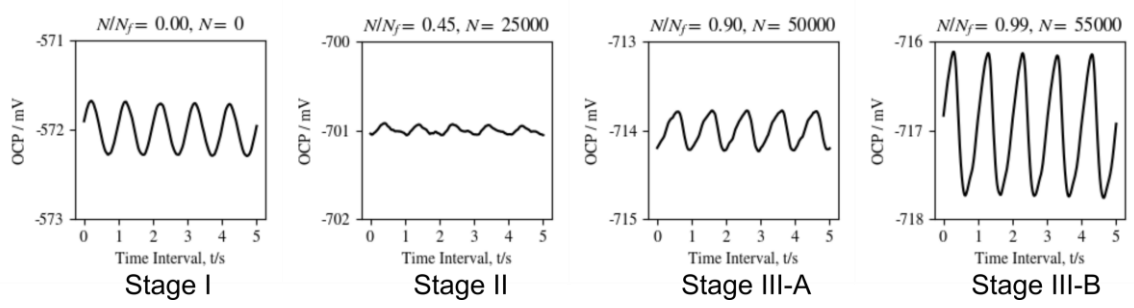


Fig. 2 – Typical corrosion potential response shapes during CF tests (Sa = 500 MPa, R = -1).

At this point, corrosion products were visibly accumulated on the surface of the specimen. In the final stage, beyond ~90% of CF life, the OCP response resembles a sawtooth shape, with higher amplitude, which is likely associated with the crack propagation under the tensile cycle. A rapid growth of the amplitude was also observed at the final cycles.

3. CONCLUSIONS

The corrosion-deformation damage was monitored by the periodic fluctuations of the OCP, which is strongly correlated with the stage of degradation. A sinusoidal-type potential fluctuation in the initial stage, followed by a distorted waveform in the second stage and sawtooth wave form on the third stage, were identified. The first and second stages are likely related to the crack initiation regime whereas the third stage is associated with the crack propagation regime.

ACKNOWLEDGEMENTS

Funding by Petrogal S.A./ISPG Brasil S.A., ANP (Brazil, Contract number 19103-1), CNPq (Contracts 310063/2018-3), F. Apoio Pesquisa do Distrito Federal (Contract 0193.001522/2016), CAPES (Finance Code 001) and FCT (contracts UIDB/50022/2020, UIDB/00100/2020, UIDP/00100/2020).

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