An integrated hard- and soft-ware triboelectrochemical test rig for tribocorrosion experiments

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Abstract: Tribocorrosion is a degradation mechanism resulting from the interaction of mechanical (wear) and chemical (corrosion) phenomena. This interaction leads to surface damage that does not correspond to the simple sum of wear and corrosion taken separately. Testing tribocorrosion of material pairings thus requires the capability not only to control the mechanical and chemical test parameters but also to identify the relative contribution of corrosion and wear in the overall material degradation. This paper describes a novel laboratory tribocorrosion test set-up combining in one experiment the control of mechanical input (load, velocity, and frequency) and output (friction and wear) parameters as well as the control of corrosion phenomena through a series of dedicated electrochemical methods (open circuit, potentiostatic and potentiodynamic measurements). The possibilities offered by this set-up are illustrated by selected case studies.

Keywords: tribocorrosion; friction and corrosion; tribotechnic

1 Introduction

Tribocorrosion is a material degradation arising when tribological contacts operate in corrosive environments, typically aqueous solutions. Many engineering systems suffer of tribocorrosion: marine structures, food processing equipment, biomedical implants, water bearing lubricants, pumps, seals and many others. In tribocorrosion materials degradation is determined by the interplay between corrosion and mechanical wear. This synergistic effect can profoundly influence the corrosion and wear behaviour of the contact [1]. The combination of wear test rigs with electrochemical instrumentation in a single experimental set-up (triboelectrochemistry [2]) allows one to quantify these synergistic effects and to identify the crucial factors determining materials degradation in tribocorrosion [3].

This paper describes a novel experimental set-up dedicated to tribocorrosion experiments. The originality resides in the close integration of a classical pin-on-disc

reciprocating tribometer with a digital potentiostat. The two apparatuses are connected and controlled by the same computer. The software allows for the simultaneous control of electrochemical and mechanical parameters as well as the parallel monitoring and/or quantification of friction, wear and electrochemical parameters such as potential, current [1–3], polarization resistance [4] and impedance [5].

The possibilities of this new comprehensive tribocorrosion instrument are illustrated using examples concerning sea applications and food industry. The effect of electrode area on the electrochemical response during rubbing of stainless steel in chloride solutions is illustrated.

Tribocorrosion experiments of stainless steel in fruit juice demonstrated the corrosivity of such liquids. The data can be quantitatively interpreted in term of recent tribocorrosion models [5, 6].

2 Test at open circuit potential

This technique consist in recording the open circuit

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potential (OCP), i.e., the potential difference spontaneously established between the working electrode (the metal being investigated) and a reference electrode placed in the solution close to the working electrode. The OCP results from an electrochemical kinetic equilibrium between cathodic and anodic reactions. Rubbing is expected to affect the reaction kinetics and thus the OCP.

The potential drops at the onset of rubbing due to enhancement of the corrosion reaction (removal of passive film).

Due to galvanic coupling between wear track and rest of electrode, the extent of drop depends on the surface area of the sample (Fig. 1).

3 Test at applied potential

A selected potential E is imposed to the metal sample by using a three-electrode set-up including the working electrode (the metal being investigated), the reference electrode and the counter electrode. The three electrodes are connected to a potentiostat, which maintains the selected potential between working and reference electrodes by passing an appropriate current between working and counter electrodes. The current is measured at fixed potential as a function of

Fig. 1 Evolution of the OCP of a 316L stainless steel electrodes of different surface areas when rubbing against a 6 mm Al_2O_3 ball (electrochemically inert) in 0.5 M sodium chloride solution (reciprocating motion, normal load 5 N, 5 mm stroke, 1 Hz). Rubbings starts at 200 s and stops at 1200 s.

the time to follow the evolution of the electrochemical kinetics.

Removal of the passive film by abrasion results in an sharp increase in current (corrosion rate) as show in Fig. 2.

The experiment can be run in frequency tuned mode (current averaged over one motion cycle, i.e., 1 sample per second) or in the time resolved (higher sampling rate) to detect changes of current over single strokes (Fig. 3).

Integration and conversion of the current curve (Fig. 2) yields directly the metal amount lost by wear activated corrosion.

Fig. 2 Evolution of the current of a 316L stainless steel electrode when rubbing against a 6 mm Al_2O_3 ball in 0.5 M sodium chloride solution (reciprocating motion, normal load 5 N, 5 mm stroke, 1 Hz). Rubbings starts at 200 s and stops at 1200 s. Curves for two independent measurements at different data acquisition sampling rates are shown.

Fig. 3 Zoom of Fig. 2 with superimposed sinusoidal displacement curve.

4 Polarisation curves

This technique corresponds to the classical electrochemical corrosion tests called polarisation curve. It consists in sweeping the potential at constant rate using the function generator incorporated in the potentiostat. Friction runs simultaneously potential. This test allows for rapid identification of the relevant corrosion reaction affected by friction.

Rubbing does not affect the cathodic reaction (reduction of dissolved oxygen) but, by abrading the passive film, significantly influences the anodic oxidation of the 316L stainless steel (Fig. 4).

Fig. 4 Polarization curve with and without rubbing (Al_2O_3 counter part, reciprocating motion, normal load 5 N, 5 mm stroke, 1 Hz) of a 316L stainless steel in commercial fruit juice.

5 Conclusion

This instrument offer innovative opportunities to directly integrate electrochemical measurements into tribological

data for routine and/or advanced tribocorrosion experiments.

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