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Effect of cavitation on the corrosion behaviour of welded and non-welded duplex stainless steel in aqueous LiBr solutions

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Abstract

The influence of cavitation on the corrosion resistance of EN 1.4462, its filler metal, and the welded metal obtained by GTAW was investigated by potentiodynamic curves in LiBr heavy brine solution under static and dynamic conditions at 25 °C. The corrosion behaviour of the tested alloys is modified by the presence of chromates (inhibitor) in the medium. The corrosion potential in the solution with chromates shifted towards the active direction when cavitation was present; on the contrary, in the solution without inhibitor, cavitation led to a noble shift in the corrosion potential favouring the cathodic reaction.

Keywords: LiBr; Cavitation; Stainless steel; Welding; Pitting corrosion

1. Introduction

Cavitation is caused by continuous collapse of numerous bubbles due to localized pressure changes during high-velocity flow [1,2]. If the pressure suddenly falls below the

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vapour pressure, the tensile stress imposed on the liquid generates cavities, because of the numerous small solid and gaseous cavitation nuclei generally present in a real liquid. The cavities collapse violently when they reach a point of greater pressure. This collapse is accompanied by the sudden flow of liquid, which originates stress pulses that can cause plastic deformation on solid surfaces. The magnitude of the impact stress may be as high as 1000 MPa [3–6]. The duration of the pressure pulse from a collapsing cavity is about 2–3 μs [4–6].

Cavitation can appear in absorption refrigeration systems of lithium bromide. This phenomenon takes place at bends, narrowings, valves, etc. Lithium bromide is the most widely used absorbents because of its high hydration heat, good thermal stability, low viscosity, and lack of crystallization problems at usual working temperatures. Besides, LiBr solutions can cause serious corrosion problems on the metallic materials of these refrigeration systems [7–10]. These two facts demonstrate the importance of the study accomplished in this work.

This physical phenomenon leads to mechanical degradation of engineering materials, while corrosion is a process of loss of material. The combined action of both phenomena can produce more damage than if each acts separately [11–14]. However, in other cases, one component may inhibit the harmful effect of the other, resulting in lowering of the total damage [15].

Two solutions can be used to reduce cavitation damage: optimal design of hydrodynamic profiles or application of more cavitation–erosion–resistant materials. The selection of more resistant materials requires a better understanding of erosion mechanisms and of material response on exposure to cavitation stresses. One class of material which could represent cavitation–erosion–resistant materials is the duplex stainless steel (DSS).

In general, stainless steels posses the ability to form passive films. Passivity is a crucial factor in determining the capability of metals to resist corrosion. Investigation of the electrochemistry of a passive metal can reveal not only the structure and composition, but also the electrochemical and corrosion behaviour of the film [16–18]. The localized impact pressures generated by the collapsing cavities are sufficiently large to crack the passive film of most metals which present passive film under static conditions. Cavitation can produce changes in the environment, such as local streaming of liquid, an increase in the diffusion rate of dissolved gases into the cavitating liquid, and the production of reactive species. These changes in the local environment around the corrosive metal can either increase or decrease the corrosion rate and are dependent on the particular metal/electrolyte interface [15].

The characterization of DSS behaviour under severe erosion–cavitation conditions has been carried out by several authors in different media [19–23]. The collapse of bubbles in a particular medium can modify the corrosion behaviour of DSS; studies of this kind were performed by Kwok et al. in 3.5% NaCl solution [19], Al-Hashem et al. in seawater [1], and Vyas and Hansson in chloride solutions [15].

Duplex stainless steels are iron-based alloys; these alloys consist of two phases: ferrite phase and austenitic phase, the ratio of both phases is typically 50:50. It is essential to maintain a ferrite–austenite ratio close to 50:50 [24]. In particular, high ferrite contents can reduce resistance to pitting corrosion, and to stress corrosion [25]. To avoid this phase balance, filler materials are usually overalloyed with 2–4% more Ni than in the base metal [26].