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HIGH-TEMPERATURES CORROSION OF AISI 316L AND AISI 430 STEELS IN DYNAMIC CONDITIONS WITH MOLTEN SOLAR SALT

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ABSTRACT

Potassium nitrate and sodium nitrate in mixing proportion of KNO_3 – NaNO_3 40-60 wt% (also called solar salt) has been successfully used for over a decade as a heat storage medium for concentrated solar power plants. At temperatures of 550 °C, reached in state-of-the-art solar tower systems, corrosion of metallic components in contact with solar salt can become an issue and has caused leaks and plant shut-downs in recently built tower projects. While the corrosion rates of several materials have been determined for different temperatures in static molten salt immersion experiments, there is a lack of corrosion data for dynamic in-service conditions. Fluid dynamics and scale-up are two factors that can influence the corrosion phenomena. In this work, corrosion studies were carried out on austenitic stainless steel (SS) (AISI 316L) and ferritic steel (AISI 430) under dynamic conditions, with long-term immersion in solar salt, on a pilot scale. It was found that AISI 316L steel forming more adherent oxides, presented a significantly lower corrosion rate than the AISI 430 steel, due to the formation of a protective FeCr_2O_4 layer, making it less susceptible to corrosion. The measured corrosion rates are presented and compared to static corrosion tests.

Keywords: High-temperature corrosion, Solar salt, Dynamic corrosion tests, Thermal energy storage

1. INTRODUCTION

Renewable energy implementation represents a key point to reverse global warming and climate change. In last years, there has been an investment in Concentrated Solar Power (CSP) with Energy Storage (TES). Solar Salt is the most energy storage fluid optimized with a melting point of 223 °C and thermally stable up to about 550 °C.

One of the most relevant problems in the use of fluids as a thermal energy storage is their compatibility with construction materials (pipes, valves and tanks). This fact, combined with high temperatures (300-550 °C) make the materials more susceptible to corrosion. Static immersion experiments are suited to screen and compare different candidate materials for molten salt applications [1-2], but corrosion rates derived from these experiments might differ significantly from the rates experienced in a real operating environment of a solar plant [3]. For this reason, it is essential to carry out corrosion studies, in different types of metallic materials and in different conditions.

2. DESCRIPTION

Corrosion tests were performed, under dynamic conditions, with an austenitic SS (AISI 316L) and a ferritic (AISI 430) steel, immersed in 26 kg of solar salt mixture, in a vertical tubular furnace for 3000 h at 550 °C, with a linear stirring speed of 1.3 m/s.



Four replicas were removed for each test time. Three replicates were chemically descaled, using the C1.1 method of ISO 17245, to remove corrosion products and evaluate mass loss. In the fourth replica, corrosion products by X-ray Powder Diffraction (XRD) and Scanning Electron Microscopy (SEM)/EDS on the surface and cross-section were characterized.

Gravimetric analysis showed that the mass gain (Fig. 1a), originated by the formation of oxides, is higher in ferritic steel and this difference is greater, when steel is immersed for longer times. In the mass loss (Fig. 1.b) the curve of the two steel types has the same progression along the time, but with higher corrosion rates in the AISI 430 steel (2.7 mg/cm² in the AISI 316L and 5 mg/cm² in the AISI 430 at 3000 h).

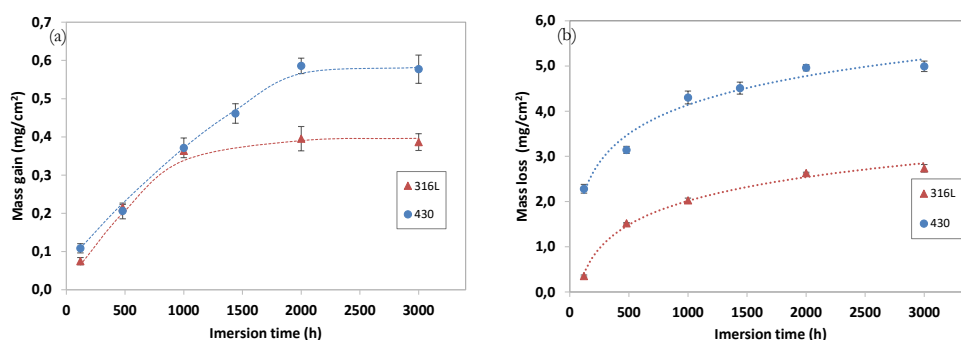


Fig. 1 – Evolution of mass gain (a) and mass loss (b) of AISI 316L and AISI 430 samples over the immersion time in Solar Salt, at 550 °C under dynamic conditions.

Morphological analysis (Fig. 2) shows that the oxide thickness increases with time and the oxide layer on the AISI 430 steel is thicker than on the AISI 316L steel, which is in agreement with the gravimetric analysis.

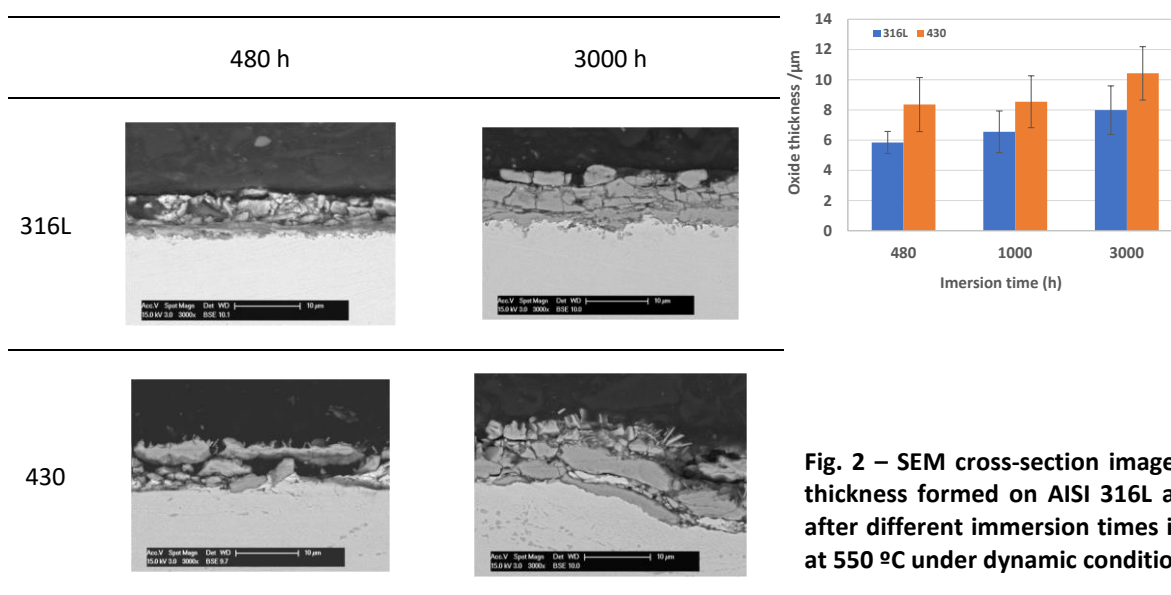


Fig. 2 – SEM cross-section images and oxide thickness formed on AISI 316L and AISI 430 after different immersion times in Solar Salt, at 550 °C under dynamic conditions.

As for chemical composition, both steel types formed Fe and Cr oxides, while at the same time, there is a migration of Cr to the steel surface, which in the case of AISI 316L steel creates a protective layer of FeCr₂O₄,



identified by XRD, that prevents and minimizes the progression of the corrosion. In AISI 430 steel, despite the presence of Cr, no compounds containing Cr were identified (by XRD), possibly because it is in small quantity in the outer layer. While being almost absent in the outer layer of the oxide scale, Cr-concentration is present in the inner layer.

In the AISI 430 steel only hematite was identified, except at 3000 h where some magnetite was detected. In the AISI 316L steel, besides the previously mentioned oxides, it was found FeCr_2O_4 , MgO and MgFe_2O_4 , which were detected at the lowest times, being Mg one of the salt impurities.

3. CONCLUSIONS

The long-term corrosion effect of solar salt on AISI 316L and AISI 430 steel types was studied under dynamic conditions (speed 1.3 m/s) at 550 °C, to simulate the working conditions in a CSP installation. The corrosion rate determined by the gravimetric method showed that the corrosion of AISI 316L steel is lower than the AISI 430 steel, in part due to the protective layer formation of FeCr_2O_4 . The oxides formed in AISI 430 steel are less adherent, which allows the progression of the salt to the substrate, making it more susceptible to corrosion. Corrosion rates are higher under dynamic conditions than under static conditions over short test periods. However, for long periods the corrosion rate is of the same order of magnitude.

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