



## Erosion–corrosion of mild steel in hot caustic. Part II: The effect of acid cleaning

Rihan Omar Rihan, Srdjan Nešić \*

*The Department of Mechanical Engineering, University of Queensland, Brisbane, Qld 4000, Australia*

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### Abstract

Corrosion rates of 1020 steel in 2.75 M NaOH solution at a temperature of 160 °C and velocities of 0.32 and 2.5 m/s were studied. The focus was on the effect of the acid cleaning which was performed by using strong, inhibited sulphuric acid in between the exposures to caustic. In situ electrochemical methods were used to measure the corrosion rate such as the potentiodynamic sweep and the polarization resistance method. Also used were the weight-loss method and scanning electron microscopy (SEM).

Eight electrodes/coupons were used to monitor the metal loss rate, four were placed at the low velocity section, while the other four were placed in the high velocity section of a high temperature flow. The first three coupons in each section were placed within the disturbed flow region, while the fourth was placed in a fully developed flow region.

During the exposure of mild steel to the inhibited acid, following the first caustic period, the corrosion rate increased significantly to between 3 and 10 mm/y with a few electrodes experiencing as high as 50 mm/y. The second caustic period following the acidic period typically started with very high corrosion rates (20–80 mm/y). The length of this corrosion period was typically 2–3 h with a few exceptions when the high corrosion period lasted 7–10 h. Following the very high corrosion rates experienced at the beginning of the second caustic period, the corrosion rates were reduced sharply (as the corrosion potential increased) to nearly the same levels as those observed during the passive part of the first caustic period.

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\* Corresponding author. Tel.: +1 740 593 9945; fax: +1 740 593 9949.  
E-mail address: [nesic@ohio.edu](mailto:nesic@ohio.edu) (S. Nešić).

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## 1. Introduction

In bauxite refineries which utilize the “Bayer process” in the production of aluminium oxide (alumina), a caustic solution is passed through a series of heat exchangers in order to recuperate heat. During the heat exchange process solids form on the steel surfaces by precipitation (often referred to as *scaling*) what reduces the thermal efficiency of the heat exchangers and if left unchecked can reduce or even completely stop the flow through the heat exchanger rendering it inoperable. To prevent this, the flow of caustic is occasionally interrupted and an inhibited strong acidic solution is circulated through the heat exchangers to dissolve the scale.

It was reported by Newton et al. [2] and Rubenis [1] that the corrosion rate of the mild steel heat exchanger headers was significantly increased by this cleaning (descaling) operation. The assumption was that the cleaning process also removed the protective passive film and exposed the bare steel surface to caustic at the beginning of the subsequent caustic period. It was suspected that the corrosion rate increased significantly after the inhibited acid cleaning period when compared with a stable corrosion rate observed after several days of operation [2]. Probes removed from the service before the acidic period started had major damaged areas covered with scale, which indicated that the damage had occurred early during the caustic period. Rubenis [1] stated that the ferrite steel matrix corroded only when the concentration of the inhibitor in the acid dropped below a critical value. To prove these findings in a controlled laboratory setting and to establish the exact magnitude and timing of the critical events, the previously conducted study of corrosion of mild steel in hot strong caustic solutions [3] was extended to include the effect of the *acid cleaning* period.

## 2. Experimental

In this new set of experiments, the whole cycle (caustic/acidic/caustic) was simulated. The conditions and duration of the two caustic periods was identical to the conditions reported in the previous paper [3]. The two caustic periods (where 2.75 M NaOH solution at 160 °C was used) were separated by an acidic period, in which a 13 wt% inhibited sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) was circulated for 1.5 h at a temperature of 50 °C in order to remove the protective film. Corrosion was monitored as in the previous study [3]:

- Polarization resistance method was the primary technique used to measure the corrosion rate in situ at different time intervals during the experiment.
- Potentiodynamic sweeps were used primarily to obtain an indication of the corrosion mechanisms and determine the Tafel slopes for the anodic and cathodic reaction.
- Weight loss was used to calculate the time-averaged corrosion rate during the experiment.
- Scanning electron microscopy was used to investigate the appearance of the corroded surface and to check for presence of the protective surface film.

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