

Flow-induced corrosion behaviour of low alloy steel in the presence of mono-ethylene glycol

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Abstract. The flow-induced corrosion behaviour of welded low alloy steel in 1 wt. % NaCl environment containing monoethylene glycol at 0°C and 25 °C respectively, was investigated. A modified submerged impinging jet rig was adopted to simulate the low temperature environment. Varying speeds between 1 and 3 m/s were used to study the degradation mechanism of the welded steel. Also, the ratio of MEG: 1 wt. % NaCl was kept at 1:4 for the MEG/NaCl solution. Static corrosion condition was also studied and compared with the flowing conditions. Results indicated that the alloy degraded with observable weight loss in pure 1wt. % NaCl at both temperatures whereas there was very negligible weight loss in all the samples in MEG/NaCl solution.

1. Introduction

It is well documented that flow can aggravate corrosion susceptibility of steels by accelerating mass transfer rates of the reacting species and by destroying the protective film formed on the surface of the steel [1]. The localized attack on the film is said to be due primarily to high near-wall turbulence and the stress developed in the protective film. Other authors argued that mechanical stress and chemical dissolution acting simultaneously are responsible for iron carbonate removal during flow accelerated corrosion [2]. The scale breakdown can happen for a variety of reasons, many of them related to fluid flow [2]. It is hypothesized that following the scale damage, a galvanic effect is established between the scale covered surfaces (cathode) and the scale-free surface (anode) leading to propagation of localized attack.

Meanwhile, as reported by Aribó et al. [3], hydrate formation is a flow assurance problem in wet-gas transportation in deep water wells at high pressure and low temperature [4]. One way to resolve this flow assurance challenge is the addition of thermodynamic and hydrate inhibitor such as the ethylene glycol [4, 5]. In the course of doing the job of dehydration, mono-ethylene glycol (MEG) has also been found to inhibit corrosion [6-8].

Monoethylene glycol (MEG) has also been reported to cause an increase in density and viscosity of the aqueous solution [9-10]. Addition of monoethylene glycol (MEG) to wet gas influences CO₂ corrosion by lowering the dew point of water which causes a decrease in Top-of-the-Line Corrosion [9, 11]. Also, there is a decrease in corrosion rate at the bottom of the line when with addition of monoethylene glycol to water phase [11-12]. MEG has also been reported [13] to adsorb on steel



surface affecting the anodic reaction of the corrosion process. This report shows that monoethylene glycol inhibits CO₂ corrosion.

This research is however an attempt to study the behavior of monoethylene glycol in interaction with chloride environment at a low temperature under dynamic conditions. This is because most literature reported the inhibitive performance of MEG under static corrosion conditions. One other innovation of this work is that very low temperature flowing condition is adopted.

2. Method

Welded low alloy steel (sectioned into HAZ, parent metal, Weldment) with chemical composition shown in Table 1 was adopted for this research. A submerged impinging jet reported by Aribio et al. [14] was modified by incorporating a compartment around the reservoir to house ice blocks (Figures 1). 1 wt. % NaCl electrolyte and 1 wt. % NaCl and MEG in ratio 4:1 to MEG were used as the corrosive environments. Experiments were conducted at 25°C and 0°C, respectively. Meanwhile temperature of 0°C was achieved by using the adapted rig in Figure 1 with the reservoir placed inside a plastic cooler. Ice block was then packed around the reservoir containing the electrolyte. A digital thermometer was used to monitor the temperature of the electrolyte. Each experiment was conducted for 1 hour and the weight loss determined by a digital weighing balance. Meanwhile flowing speed was varied between 1- 3 m/s. All experiments were conducted in triplicate and the average results reported.

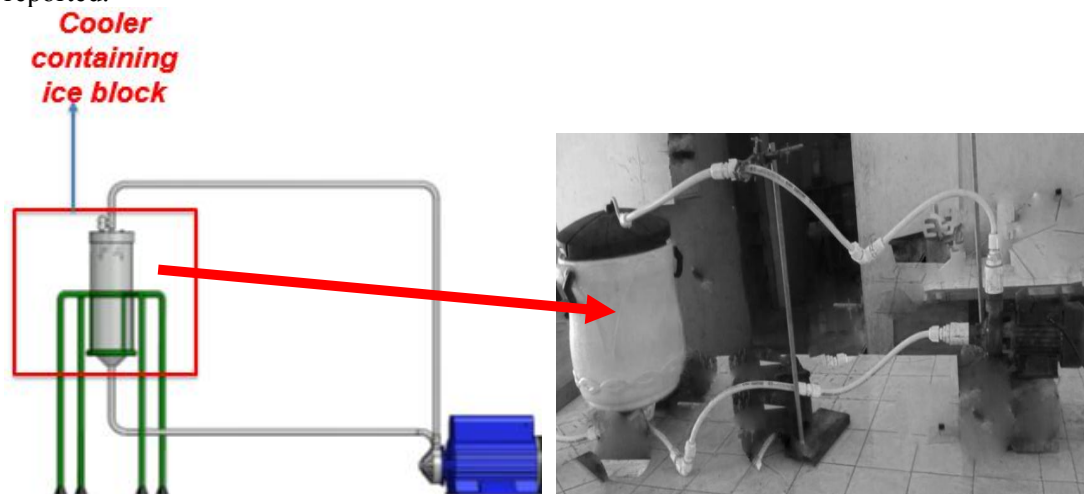


Figure 1: Adapted submerged impingement jet rig

Table 1: Chemical composition of the low alloy steel

| | C | Mn | Si | P | S | Cr | NI | Mo |
|-------|------|-----|-----|------|------|------|------|------|
| Wt. % | 0.18 | 1.3 | 0.3 | 0.25 | 0.10 | 0.30 | 0.30 | 0.12 |

3. Results

3.1. Weight loss in NaCl environment at 0°C and 25°C.

Figures 2a and 2b Show the weight loss analysis of the samples in 1 wt. % NaCl at 0°C and 25°C. It is observed that at static condition, the weld metal exhibited low weight loss while the parent metal and heat affected zone showed substantial weight loss. When the materials were subjected to flow conditions, all the zones of the welded metal showed increase weight loss with increase speed. As expected, flowing conditions enhanced more material loss for all materials. However the weld metal showed higher resistance to material degradation compared with HAZ and weld metal.

3.2. Weight loss in MEG/NaCl environment at 0°C and 25°C.

Figures 3a and 3b indicate a very negligible weight loss in all samples in the presence of MEG/NaCl as compared to NaCl at 0 °C and 25 °C in Figure 2. It can be observed that all the zones of the welded alloy showed negligible weight loss at static condition. The HAZ has the highest loss in weight while the weldment showed the highest resistance. The decrease in the weight loss of the weld metal may likely be due to the presence of high corrosion resistant alloying elements that are likely to be present in the filler metal used during the welding operation.

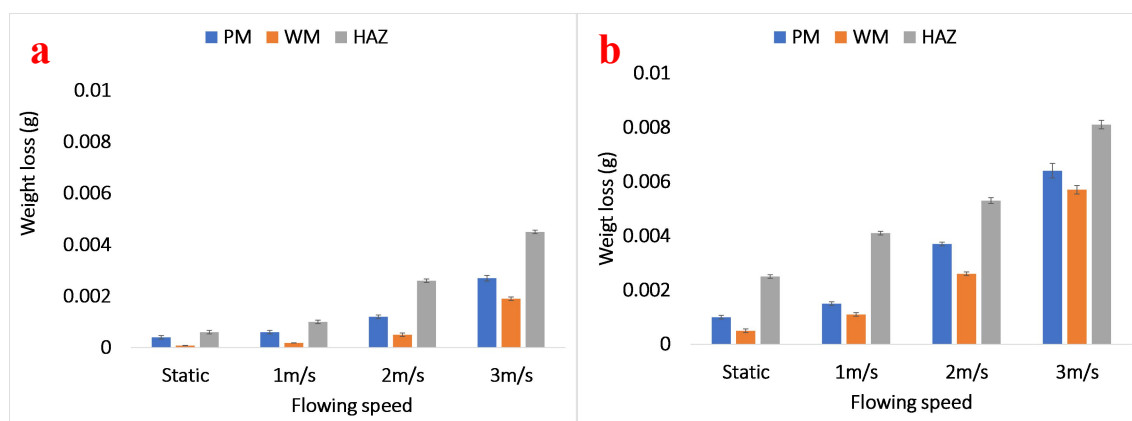


Figure 2: Material loss in 1 wt. % NaCl at 0°C (a) and 25°C (b)

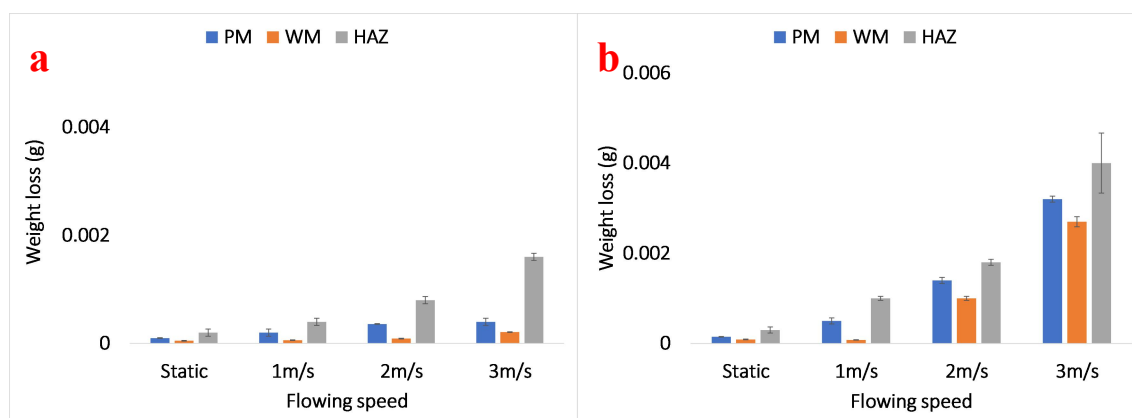


Figure 3: Material loss in 1 wt. % NaCl/MEG at 0°C (a) and 25°C (b)

4. Summary of Discussion

Monoethylene glycol (MEG) has been reported to increase the viscosity of water and hence lower the diffusivity of active species causing corrosion [6, 11]. It has also been argued that solution polarity which increases the solvation energy of iron ions is decreased with addition of MEG [6]. Lower solution polarity and hence lower solvation energy impair the activation and driving force for corrosion activity. Aside this other authors have also argued that MEG acts like anodic inhibitor blocking the anodic sites. This invariably reduces iron dissolution and hence lower corrosion rate [13]. Other authors also reported that solution conductivity is significantly decreased and hence higher Ohmic drop is expected with addition MEG [16]. With all the illustrations above it is not surprising that the corrosion susceptibility of all the sections of the welded alloy decreased with addition of 20 wt. % of MEG to the NaCl solution.

Influence of flow rate on Materials degradation is a subject area that has been widely reported. Higher hydrodynamic influences corrosion rate by moving the corrosion species towards reaction area and

moving the corrosion products away from the surface of the anode. Hence higher corrosion rate is expected at higher flowing rates [1].

Effects of temperature on the corrosion behaviour of the alloy in the presence of MEG can be thus explained. It has been argued that thermal degradation of MEG occurs at higher temperatures [1]. It is expected that at 25°C, the thermal oxidation of MEG may result in the formation glycolic, oxalic and formic acids which are corrosive agents capable of instigating corrosion [1]. Aside this it is a known fact that corrosion species become more aggressive as temperature of the electrolyte increases.

5. Conclusions

Results indicated that the alloy degraded with observable weight loss in pure 1wt. % NaCl at both temperatures whereas there was very negligible weight loss in all the samples in MEG/NaCl solution. The presence of MEG limits the dissolution of iron into the solution by adsorbing on the steel's surface.

Acknowledgements:

Thanks to **Ezekhume Emmanuel and Adeoye Abiodun** for helping with some of the experiment setup and data collection in the laboratory

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