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Influence of flow velocity on erosion-corrosion performance of 90º carbon steel elbows in potash brine

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Abstract**—** In this study, the effects of flow velocity and solid concentration on erosion-corrosion behavior of AISI 1018 long-radius steel elbows (Schedule 40) in saturated potash brine were investigated. Potash brine containing 10 and 30 wt% of silica sands flowing at 2.5, 3.0, 3.5 and 4.0 m/s through a continuous loop with pipe internal diameter of 2.54 cm was used as the slurry. All experiments were conducted at 30 °C. The surface damage on elbows was evaluated using scanning electron microscopy (SEM). It was found that material loss per unit area was greater at high slurry velocity and solid concentration. Corrosion pits were visible on the elbow surfaces at low slurry velocities, but pits were not formed at higher velocities. Mechanical damage was concluded to be the dominant degradation mechanism at high flow velocities.

Keywords- wear; erosion-corrosion; potash brine; pit; carbon steel

I. INTRODUCTION

The common occurrence of pipeline damage in the mineral processing industry is often attributed to erosion-corrosion. It is a process that occurs when abrasive solids suspended in a flowing corrosive liquid interact with the pipe internal wall resulting in significant material loss that may cause the pipe to leak or fail catastrophically. Pipe locations that experience abrupt changes in the flow direction, such as elbows, are subjected to severe hydrodynamic intensities occasioned by high angle impact by the particles in the moving fluid as well as change in flow regime at varying positions in the elbow [1].

It is widely acknowledged that the flow velocity and solid concentration are some of the key parameters that influence the wear behavior of pipeline materials subjected to erosion-corrosion [2]–[9]. Liu *et al.* [10] studied the effect of fluid flow velocity on the erosion-corrosion behavior of carbon steel elbows in 3.5wt % sodium chloride solution containing quartz sand particles as erodent. They discovered that the erosion-corrosion rate of elbow samples increased with increasing flow velocity. Zeng, Zhang and Guo [11] investigated the erosion-corrosion performance at different locations in a stainless steel elbow using a flow loop and reported that the maximum erosion-corrosion rate occurred at the outer wall of the tested elbow outlet. Khayatan, Ghasemi and Abedini [12] compared the erosion-corrosion performance of pure titanium at different impingement angles. Their data showed that maximum degradation rates occurred at an impingement angle of 40º.

It is well known that the minimum material loss rate during erosion-corrosion of elbow occurs at the inlet section [10], [11]. The aim of this study was to investigate the effect of slurry flow velocity on the exit section of AISI 1018 steel elbow during erosion-corrosion in a slurry consisting of saturated potash brine and silica sand.

II. EXPERIMENTAL PROCEDURE

In this study, long radius 90º 1018 steel elbows (schedule 40) were used. The chemical composition range (in wt%) of the steel is presented in Table 1. A typical optical image of the microstructure of the as-received elbows is shown in Fig. 1. The specimen for microstructure observation was prepared using standard metallographic methods. It was cut from one of the procured elbows and ground using SiC papers of 320, 400, 600, 800 and 1200 grit sizes. This was followed by polishing with 3 µm MD-Dac and 1 µm MD-Nap polishing clothes and finally etched for 30 s using Nital solution consisting of 2% nitric acid and 98% ethanol. A Nikon eclipse MA-100 inverted optical microscope was used to examine the microstructure which consists of a mixture of 82% ferrite and 18% pearlite.

Erosion-corrosion tests were conducted at 30 ºC for 120 h in a flow loop (diameter of 2.54 cm) using ASTM G119-09 [13]. Solid concentrations of 10 and 30 wt% and slurry flow velocities ranging from 2.5 m/s to 4 m/s were used. Fig. 3 shows a diagram of the flow loop used in this study. The operating temperature was controlled with the aid of a heat exchanger placed within the slurry tank.

TABLE I. CHEMICAL COMPOSITION OF 1018 STEEL

Fe	C	Mn	Mo	P	S
Balance	0.19-0.21	0.42-0.45	0.001	0.012-0.018	0.005-0.01

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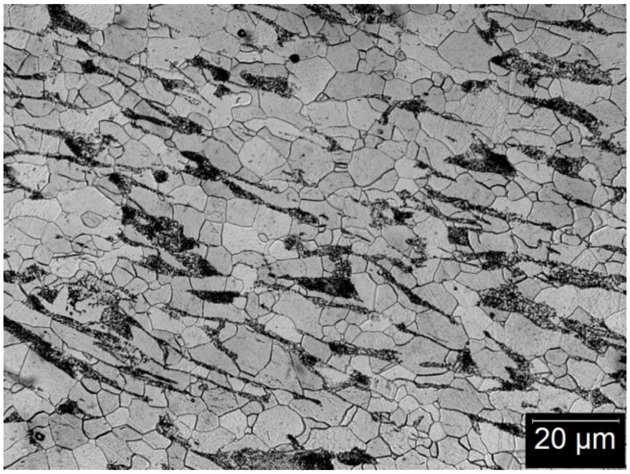

Fig. 1. Optical micrograph of 1018 steel elbow

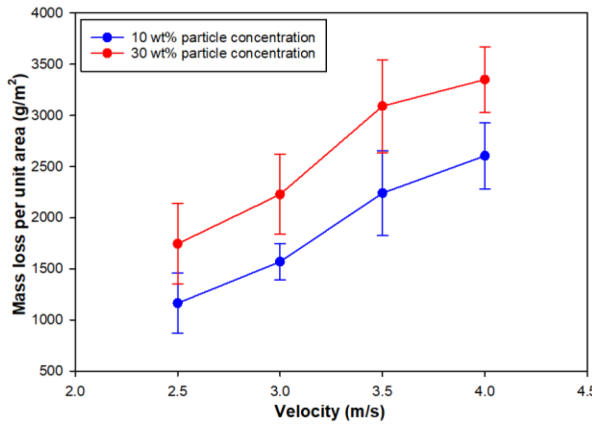

Fig. 2. Mass loss per unit area of elbows at different flow velocities after 120 h.

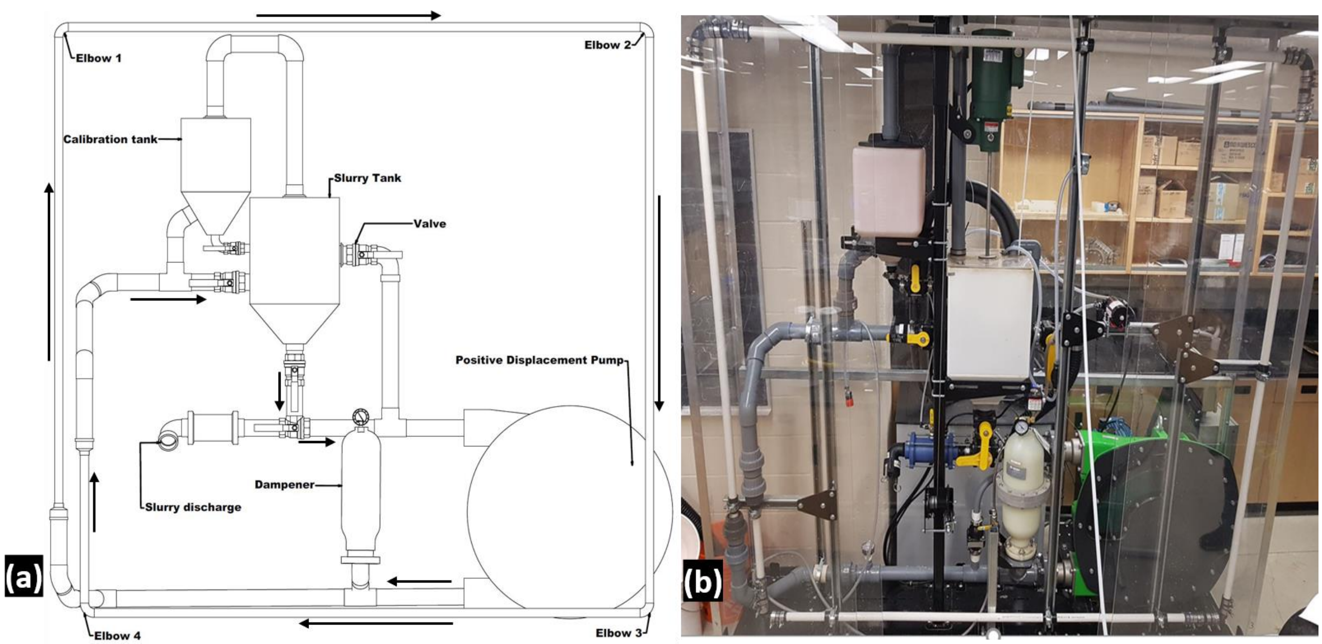

Fig. 3. Diagram of the experimental erosion-corrosion flow loop: (a) schematic (b) pictogram

The average weight loss of four 1018 steel elbows placed strategically at different locations in the loop was determined. The wear surfaces of tested elbows were evaluated using JEOL JSM-6010LA scanning electron microscope (SEM) to understand the dominant damage mechanisms.

III. RESULTS AND DISCUSSION

A. Weight Loss Measurement

The mass loss per unit area obtained for the tested elbows under different velocities and solid concentrations is presented in Fig. 2. Mass loss per unit area was affected by changes in both flow velocity and solid concentration. It increased with increasing slurry flow velocity and solid concentration. This is probably due to increase in mechanical interaction between the elbow surface and sand particles as slurry flow velocity and sand concentration increased.

B. Surface Characterization

Fig. 4 shows typical SEM micrographs obtained for the exit sections of tested elbows after 120 h in the loop. Fig. 4(a) shows the presence of corrosion pit and erosion-corrosion wear

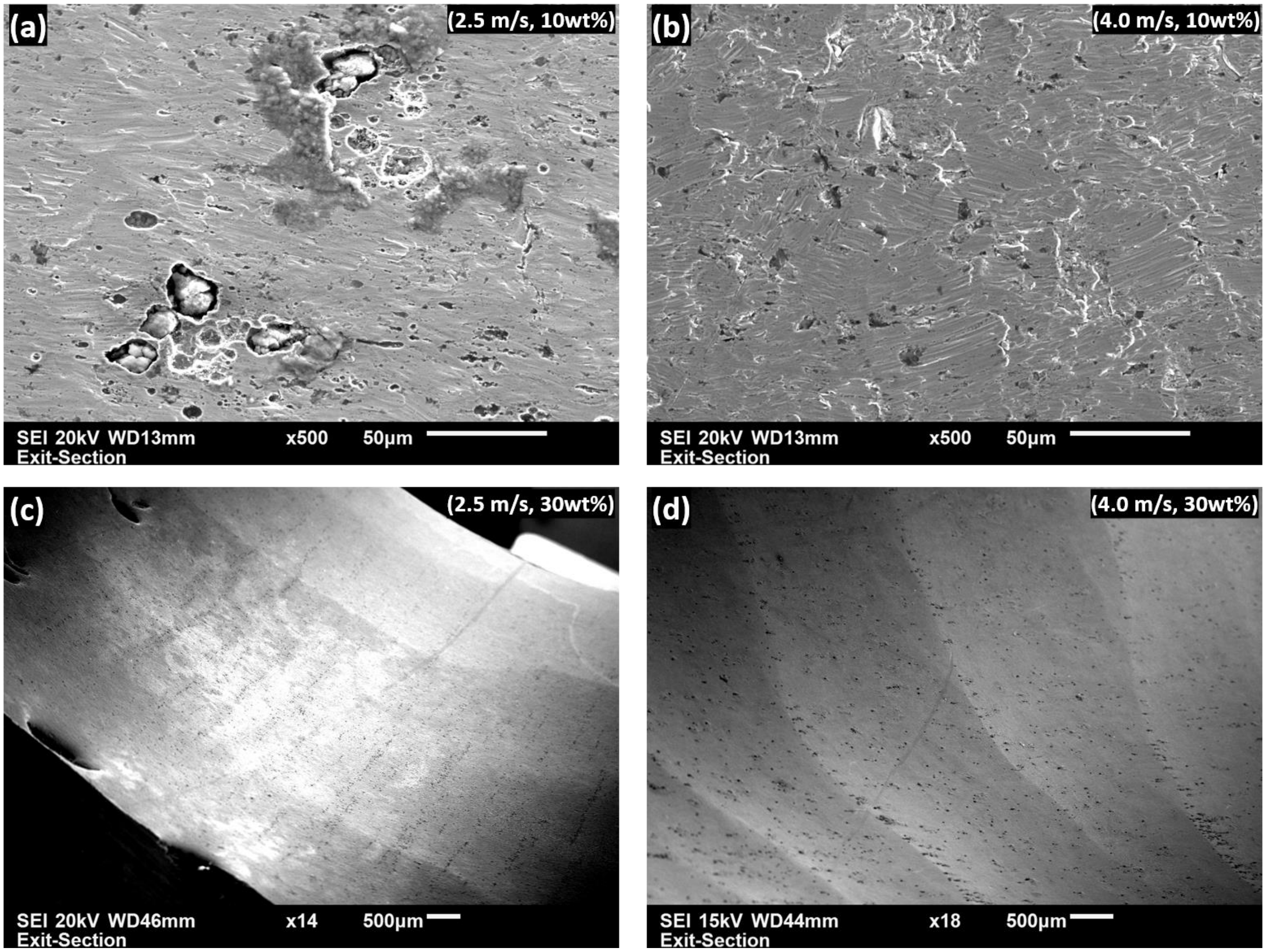

Fig. 4. Typical SEM micrographs of the elbows subjected to erosion-corrosion after 120 h: (a) and (c) exit section at 2.5 m/s; (b) and (d) exit section at 4.0 m/s.

scars (grooves) for elbows tested in a potash slurry containing 10 wt% flowing at 2.5 m/s. However, corrosion pits are not observed in the elbow subjected to a slurry flow velocity of 4.0 m/s shown in Fig. 4(b). The presence of grooves is an indication that mechanical erosion contributed to the material degradation process, while the formation of corrosion pits indicates that corrosion played a role during erosion-corrosion of elbows at low velocities. At high slurry velocities, mechanical damage appears to have played a more prominent role in material degradation than corrosion. This can be due to the fact that more particles strike the elbow surface and subsequently increase the depth of particle impingement into the surface. Fig 4(c) and 4(d) shows the surface morphologies of elbow tested at 2.5 m/s and 4.0 m/s using a particle concentration of 30 wt%. It can be observed that ridges formed on the elbow surface due to interactions with the sand particles over the test period. Few corrosion pits were observed on the surface of elbows tested at a slurry flow velocity of 2.5 m/s, which is consistent with what was observed for elbows tested with a slurry containing 10 wt% solid concentration.

IV. CONCLUSIONS

The mass loss per unit area of 90º steel elbows due to erosion-corrosion in saturated potash brine solutions containing silica sand were determined and the wear surface of the inner section of the elbows was investigated using a scanning electron microscope. The conclusions below are drawn from the experimental results.

1. Degradation of the tested elbows at low velocities was dominated by corrosion attack as evidenced by the presence of corrosion pits on the elbow surface. On the other hand, erosive wear due to particle impingement was the dominant damage mechanism at high slurry velocities.
2. Material loss per unit area increased with increasing flow velocity and solid concentration.

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