

## Corrosion of mild steel, copper and brass in crude oil/seawater mixture

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Mild steel, copper and brass coupons were introduced in natural seawater containing varying amount of crude oil. Mild steel showed higher rate of corrosion in seawater containing oil and lower corrosion rate in natural as well as artificial seawater. Copper and brass showed higher rates of corrosion in natural and artificial seawater but lower corrosion rates in seawater containing crude oil. For all the above metals corrosion was almost nil in 100% crude oil.

Crude oil of varying concentration in seawater may contribute to corrosivity towards metals and alloys. This may vary with several factors like dissolved oxygen, temperature, salinity and pH<sup>1</sup>. It has already been reported that bacteria can produce oil degradation products which may accelerate corrosion.<sup>2-4</sup> Since oil droplets and thin oil films are generally present in the seawater, a laboratory study has been carried out to see the effect of crude oil content in seawater on the corrosion properties of mild steel, copper and brass. These metals are selected because they are widely used in various marine operations.

In the present study Bombay High crude oil containing 88.39% w/w n-alkanes, 9.1% w/w aromatic and 2.23% w/w polar fraction was used in sterile seawater to assess corrosion of various metals and alloys. Commercial grade mild steel (C-0.2%, Si-0.05%, Mn-0.26%, P-0.05%, S-0.04%, Fe-rest), copper (Cu-98.53%, Ni-0.05%, Cr-0.02%, Zn-1.4%) and brass (Zn-32.55%, Cu-rest) were used for the present study. The experimental media (125 ml) consisted of artificial seawater,<sup>5</sup> natural seawater ( $2.7 \times 10^{-4}$  g.l<sup>-1</sup> oil content) and natural seawater containing 2 different oil fractions (2.86 and 3.6 g.l<sup>-1</sup>). Oil fractions were estimated using standard procedures<sup>6</sup>. Fractions containing > 3.6 g.l<sup>-1</sup> could not be obtained since this was the maximum water soluble fraction in seawater. One flask containing 100% crude oil was also used in the experiment. The flasks containing preweighed metallic coupons (2 × 5 × 0.2 cm) were kept on a rotary shaker for 30 d (100 rpm) at room temperature (28° ± 2°C). After 30 d immersion in the respective media, the coupons were removed, dried in a desiccator and weighed to estimate the loss in weight. The corrosion rate was expressed as loss of

metal in mg per square decimeter per day (mg.dm<sup>-2</sup>.d<sup>-1</sup>). The dissolved oxygen in the media was estimated<sup>5</sup> at the beginning of the experiment and the values were in the range of 4.13-4.66, 3.99-4.56 and 4.23-4.79 ml.l<sup>-1</sup> in the media containing mild steel, copper and brass coupons respectively. The pH of the medium remained unchanged. Another set of coupons (1 × 1 × 0.2 cm) treated in a similar manner, were used to study the surface topography of the corrosion products formed using SEM.

Constant agitation of experimental flasks produces emulsions of oil-water phase of two forms. Water-in-oil, which is the stable floating emulsion formed at the air-water interface and oil-in-water emulsion, which occurs in water as small drops.<sup>8</sup>

Corrosion rate increased with increasing concentration of oil in natural seawater (Fig. 1). Corrosion of mild steel was relatively low in artificial (38.8 mg.dm<sup>-2</sup>.d<sup>-1</sup>) and in natural seawater (25.27 mg.dm<sup>-2</sup>.d<sup>-1</sup>) as seen in Fig. 2A, B, however corrosion rate of the coupons in flasks containing 2.86 and 3.6 g.l<sup>-1</sup> oil was higher (40.67 and 65.49 mg.dm<sup>-2</sup>.d<sup>-1</sup> respectively). Corrosion of mild steel remained almost negligible in the flask containing 100% crude oil (Figs. 1, 2E).

In the case of copper and brass, corrosion rate was higher in natural seawater (35.32 mg.dm<sup>-2</sup>.d<sup>-1</sup> and 18.97 mg.dm<sup>-2</sup>.d<sup>-1</sup>) followed by artificial seawater (22.42 and 13.12 mg.dm<sup>-2</sup>.d<sup>-1</sup>). SE micrographs of brass coupons exposed to artificial seawater showed flaky corrosion products on the surface (Fig. 3A). Corrosion rate showed a gradual decrease from 20.47 to 19.05 mg.dm<sup>-2</sup>.d<sup>-1</sup> in copper coupons and 0.71 to 0.17 mg.dm<sup>-2</sup>.d<sup>-1</sup> in the case of brass coupons as the oil concentration increased. Copper and brass coupons showed least corrosion of 0.72 and 0 mg.dm<sup>-2</sup>.d<sup>-1</sup> respectively in 100% oil (Fig. 3B-E).

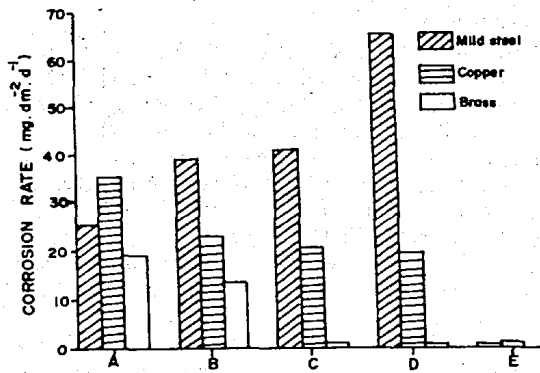


Fig. 1—Corrosion rate of metals in natural seawater (A), artificial seawater (B): natural seawater with 2.86 g.l<sup>-1</sup> oil (C), 3.6 g.l<sup>-1</sup> oil (D) and 100% crude oil (E)

The corrosion rates of copper and brass decreased in the media containing increasing concentration of oil. Although, the trend in copper and brass remained the same, corrosion rates were higher in case of copper as compared to brass.

In general, corrosion rate of mild steel was higher followed by copper and brass in all types of media, except in natural seawater in which copper exhibited higher rate as compared to mild steel and brass. The low corrosion of brass in all types of media could be attributed to the more nobility as compared to the other two metals. The decreasing trend in corrosion rate of copper and brass in media containing increasing concentration of oil suggests the inhibitory action of oil, as lubricants, hydraulic

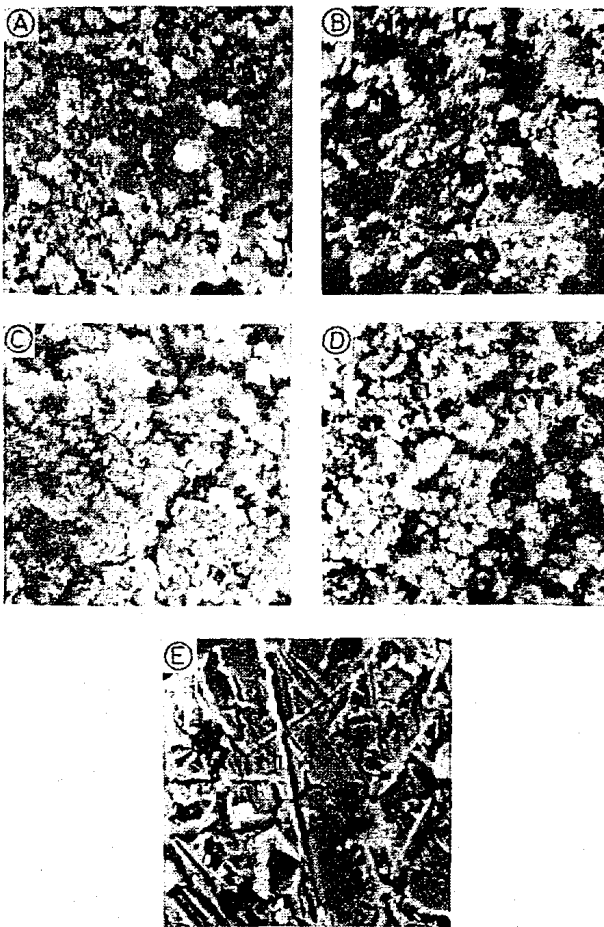


Fig. 2—SEM ( $\times 2000$ ) of mild steel coupons after 30 d exposure to different media : A-artificial seawater without oil, B-natural seawater containing traces of oil ( $2.7 \times 10^{-5}$ ), C-2.86 g.l<sup>-1</sup> oil in natural seawater, D-3.6 g.l<sup>-1</sup> oil in natural seawater E-100% crude oil

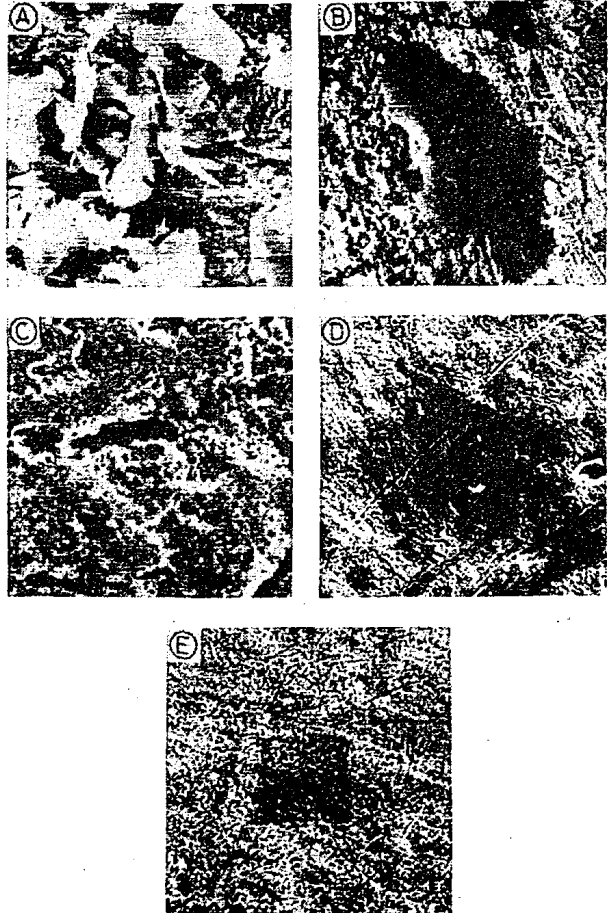


Fig. 3—SEM ( $\times 2000$ ) of brass coupons after 30d exposure to different media: A-coupons in artificial seawater showing flaky corrosion product, B-natural seawater containing traces of oil ( $2.7 \times 10^{-5}$  g.l<sup>-1</sup>), C-natural seawater containing 2.86 g.l<sup>-1</sup> of oil, D-natural seawater containing 3.6 g.l<sup>-1</sup> of oil, E-100% crude oil

fluids, greases etc, are well known for their corrosion inhibitory properties<sup>9</sup>. Since the corrosion is an electrochemical process, electrolyte is an essential medium for the progress of corrosion reaction. The lowest corrosion of metals under study in 100% oil suggests poor electrochemical action of the oil.

The present investigation suggests that the mixing of crude oil in seawater may accelerate corrosion in mild steel whereas, for copper and brass it can decrease corrosion. The reasons for increased corrosion rate of mild steel in the media containing increasing concentration of oil is not known and needs further detailed investigation.

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