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CORROSION OF MILD STEEL AND STAINLESS STEEL BY MARINE *VIBRIO* SP.

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ABSTRACT

Microbially induced corrosion (MIC) of stainless steel and mild steel coupons exposed to media with and without a bacterial culture *Vibrio* sp. was studied using Scanning Electron Microscope (SEM). Pitting type of corrosion was noticed which was more severe on mild steel than that of stainless steel.

Key-words: Corrosion, fouling, bacterium, steel.

The attachment of bacteria to inanimate surfaces in the marine environment and the establishment of macrobial communities on the solid surfaces is a complex phenomenon (Merker and Smit, 1988). It is suggested that bacterial adhesion occurs mainly due to the physical forces attracting the cells to the surface (Dexter, 1976). The physical forces involved are the Van der waal's forces of mass attraction and electrostatic forces due to interaction between ionic groups in the surrounding medium (Parsegian and Gingell, 1972; Nir and Andersen, 1977). Once the contact is established between the cell and solid surface, the cells get adhered to it by active secretion of polymers. Adhesion is further strengthened by polymers of higher molecular weight polymers which are mainly polysaccharides (Jones, Roth and Sanders, 1969). A wide range of chemical activities of microbes can result in the breakdown of the various kinds of protective coatings, thus exposing the metal to microbial corrosion.

A considerable amount of work has been done on microbially induced corrosion (MIC) of metals and their alloys (King, Miller, and Smith, 1973; Postgate, 1984; Hamilton, 1985 and Gaylarde and Videla, 1987). However, the exact mechanism for the dissolution of the metal is not fully understood.

Microbial corrosion leads to the deterioration of process equipments when exposed to marine environment, resulting in severe economic losses. Keeping in view the importance of steel alloys for the marine installations, the present attempt to study the effect of a marine bacterium on mild steel and stainless steel using scanning electron microscopy is made.

Mild steel and stainless steel coupons (5x5 mm) were cut and abraded with emery paper of 0-0000 grades (Sharma, Sanyal and Pandey, 1987). These coupons were then rinsed with acetone followed by distilled water, air dried and kept in a vacuum desiccator until the commencement of the experiment.

A fouling bacterial culture was isolated from the microfilm developed on stainless steel panels exposed to seawater at 1 m depth for nine days at Dona Paula. The isolate was purified by repetitive streaking using Zobell marine agar. Purified culture was routinely maintained on nutrient slants. The isolate was identified as *Vibrio* sp. using standard identification methods (Beech, Davenport, Goswell and Burnett, 1974). The bacterium was grown in a nutrient broth. The formula of nutrient broth was identical to that of Zobell marine agar except for the absence of agar which was used as medium. Before use, the medium was sterilized at 120°C for 20 minutes.

A loop full of culture from the slant was inoculated in the above medium and allowed to grow for 24 hours. Bacterial cells were inoculated from overnight liquid broth cultures to different experimental flasks prepared as indicated below.

Replicate (3) coupons, each of stainless steel and mild steel were then placed in 12 separate 250 ml Erylenmeyer flasks containing 75 ml of nutrient broth. Another set of flasks each containing 75 ml of nutrient broth with replicate coupons was used as control. All the flasks were sterilized in an autoclave at 120°C and 15 lb pressure for 10 minutes. The effect of autoclaving on the coupons were taken care of by using blanks. The first set of 12 flasks was inoculated with the bacterial culture (0.1 ml) and the biofilm formed was observed using SEM. Loss in weight of the coupons was significant. The coupons were removed at five days interval for a period of 30 days. After removal the coupons were kept in 5% formalin for 10 minutes, rinsed in distilled water, and dried in acetone. They were then mounted on Aluminium stubs using gluteraldehyde (5%) as a fixative. The coupons were then sputter coated with gold (10 nm thickness) and used for SEM observation.

Mild steel

The results indicate the occurrence of corrosion on mild steel coupons within the first 10 days of exposure to pure culture. The pressure of bacterial cells and corrosion products, could be clearly seen on the surface (Fig.1a). With the increase in the immersion period increased (20 days), mild steel coupons showed more corrosion products (Fig.1b). The coupons were cleaned mechanically using a nylon brush and then treated with a pickling solution containing 2% antimonyl trioxide and 5% stannous chloride in 5% hydrochloric acid. On cleaning, severe pitting corrosion on the surface could be seen (Fig.1c). Control coupons exposed for the same period is shown in Fig.1d. Further, prolonged exposure of mild steel to the culture (30 days) resulted in an excessive accumulation of corrosion products on the surface (Fig.1d).

Stainless steel

No significant change was observed in stainless steel for the first 15 days except for the presence of a few bacteria on the surface. However, a thick bacterial film was seen after 20 days exposure (Fig.2a). Presence of a few micro pits could be seen on a magnified section (Fig.2b). On further exposure, to the culture (30 days), a thin film probably of oxide

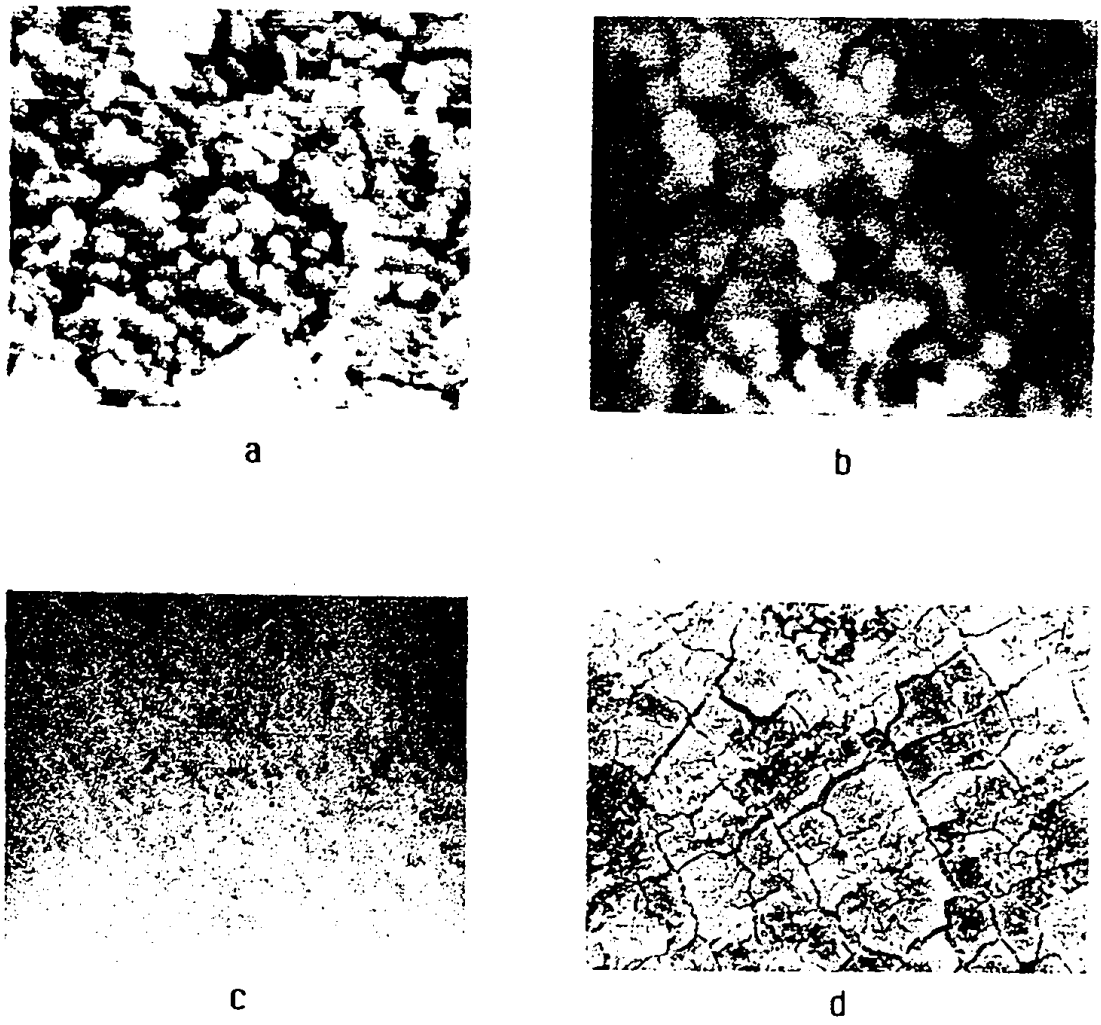

Fig.1. Scanning electron micrographs of mild steel surface.
a. Surface showing corrosion product and bacterial cells (10 days exposure, x 2000); **b.** surface showing corrosion product and bacterial cells (20 days exposure, x 2000); **c.** surface beneath the corrosion product after cleaning, showing severe pitting (20 days, x 800) and **d.** surface showing excessive corrosion product (30 days exposure, x 400).

was noticed (Fig.2c). Similar observation has been made by Westlake, Semple and Obuekwe (1986). Presence of crevice type of corrosion which might have been produced by the cracks present in the corrosion product layers was also noticed (Fig.2d). As observed for mild steel, the removal of bacterial film and corrosion products (following the same procedure adopted for mild steel) from stainless steel revealed the presence of pits

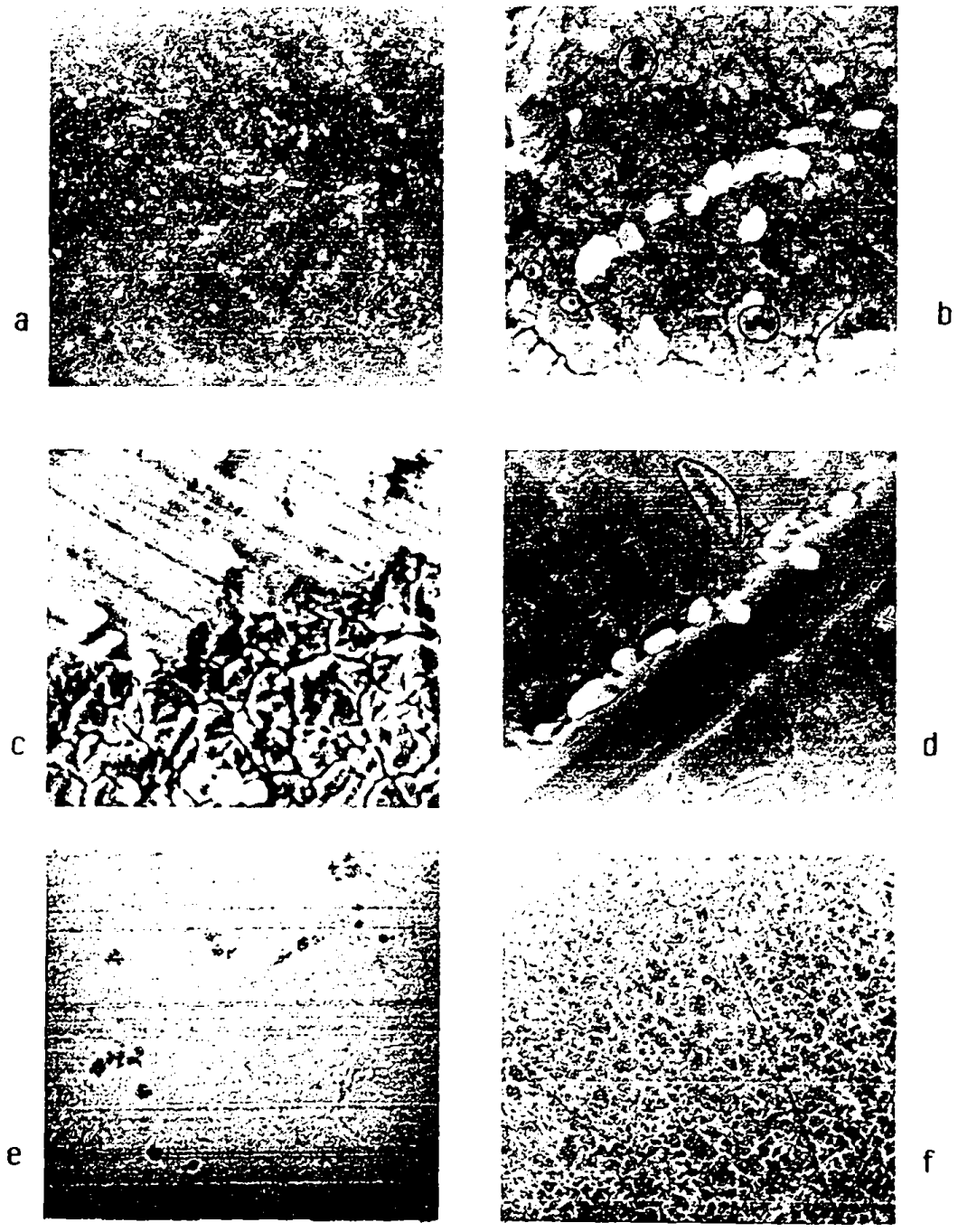

Fig.2. Scanning electron micrographs of stainless steel surface. **a.** 20 days exposed with thick bacterial growth (x 400); **b.** magnified version of **a** showing micro pits (x 800); **c.** surface film overlying corrosion product (30 days exposure, x 2000); **d.** surface showing crevice and pits (30 days exposure, x 800); **e.** surface beneath the corrosion product after cleaning (30 days exposure, x 800) and **f.** surface of control coupon (30 days exposure, x 800).

(Fig.2e). A control coupon of stainless steel (30 days) is shown in Fig.2f. However, pits on stainless steel were few as compared to these on mild steel. Pitting corrosion was comparatively more severe on the latter. One of the reasons for this could be that the passive film is more resistant on stainless steel as compared to mild steel.

The corrosion – pitting as well as crevice type – could be due to chemical changes taking place at the metal biofilm interface or beneath the microbial slime. These chemical changes could be due to the trapping of metabolic products at the interface. Pope, Duquette, Johannes and Wagner (1984) have shown that the consumption of oxygen by micro-organisms causes its depletion whereas carbon dioxide and hydrogen are produced as a result of the fermentative type of metabolism. The carbon dioxide forms carbonic acid in solution and could thereby enhance corrosion.

This experiment shows that corrosion was comparatively more severe on mild steel than on stainless steel and provides a simple method to study corrosion, using a pure bacterial culture.

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