Selection of Materials for Marine Instruments

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The paper describes the selection of materials for the reliable operation of oceanographic instruments. For selecting the material, raft immersion tests were carried out for one year. Results of the tests are presented. Comparisons between metals were discussed.

Common oceanographic instruments for measuring temperature, salinity, depth, current direction and speed, dissolved oxygen and pH are prone to corrosion when exposed to seawater. Corrosion may seriously affects the electronic part of them also. The failure of the equipment can lead to catastropic happenings, both in cash and human resources. The environmental factors include high hummidity, variable temperature, salinity etc. all potentially determental from corrosion point of view. In order to combat the highly corrosive environments the instruments should be made of corrosion resistant materials with high strength and of low specific gravity. Even though non-metals are corrosion resistant, they have poor strength and fabricability. Because of the importance of the problem, the work was taken up as a part of the work under the comprehensive investigation on the corrosion behaviour of metals in Cochin Harbour (9°58'N, 76°16'E).

Materials and Methos

Carbon steel, stainless steel 304 and aluminium alloy 5086 are the materials selected for the study, taking into consideration the cost factor, specific gravity and the physical and mechanical properties. The metals were cut to 10 x 75 cm from rolled sheets using guillotine with maximum care. As per ASTM (1974) method the metal plates were cleaned and weighed. The test panels were then mounted on mild steel racks of Carnegie Illinois Steel Corporation design (LaQue, 1948). The racks mounted with the metal plates were kept submerged at one metre level from the low water level in the Cochin Harbour. There were thirtynine panels of each of the metals tested. The microbiological film formed on the metallic surfaces was removed at intervals using a very soft bristle brush with maximum care. The hydrographic parameters like temperature, dissolved oxygen, salinity and pH were determined during the period. The corrosion products on them were cleaned as per ASTM (1974) method and corrosion rate determined.

Results and Discussion

The corrosion rates of carbon steel, stainless steel 304 and aluminium HAL 5086 in the fouling free condition as a function of exposure periods are presented in Fig. 1. The monthly variations of salinity, dissolved oxygen, surface water temperature and pH pertaining to this period of study were reported by Pillai & Ravindran (1988). The principal factors which restrict the corrosion

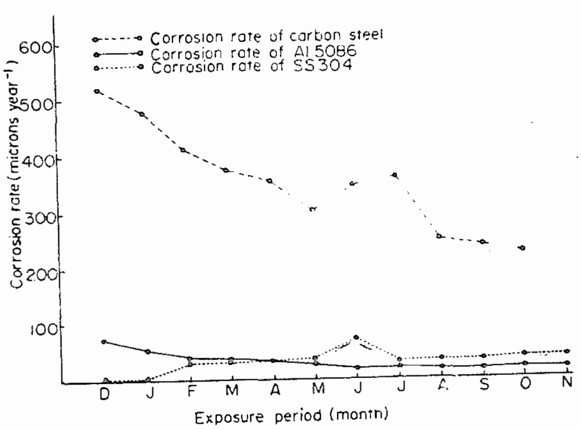

Fig. 1. Performance of materials.

and fouling on metallic panels is the peculiar hydrographic feature of the Cochin Harbour (Pillai & Ravindran, 1983). The carbonsteel registers rapid corrosion rate in the initial period of exposure of one to two months which gradually declined and attained a near constant rate in a period of about 270 days as can be seen from Fig. 1. The panels have high corrosion rate during the pre-monsoon period but the rate was higher during the monsoon period and post-monsoon period. A comparable result was reported by Mishima (1940) who showed that monthly cleaning of specimens had doubled the corrosion rate compared to fouled panels. If an annual corrosion rate of less than 0.13 mm and an annual pitting depth of 1.02 mm are considered in addition to corrosion allowance when instruments are designed, no perforation will occur and reliable operation can be maintained during the designed life time (Jain, 1984). The study showed carbon steel undergoes uniform corrosion and comes to a uniform annual corrosion rate of 0.25 mm. No pitting corrosion was observed throughout the study. Carbon steel can be used only if protective measures are followed throughout its use.

The corrosion of stainless steel was characterised by deep pits progressing into perforations. The panels remained free from pitting for about 30 days, but within a period of 2 months pitting and perforations were noticed. The mode of failure was in the form of long narrow tunnel. The perforations were in the direction of gravity, characterised by the adherent dense ferric chloride. The breakdown of passivity in pits occurs as the maintenance of passive film has not been possible in slow moving water at the test site (Paul & Moran, 1965). Much significance cannot be attached to the corrosion rate of stainless steel based on weight loss as the metal loss is due to severe localised pitting and perforations. The localised attack is even more harmful than uniform attack. While studying the corrosion behaviour of metals in Indian waters, De *et al.* (1968, 1977) observed pitting on 18:8 stainless steel below the base of barnacle and near the supporting holes. The present results show that the corrosion of type SS 304 was 74 microns year^{-1}. As far as the performances of type 304 are concerned neither the weight loss nor the occurrence of crevice attack gives a true picture of the resistance of the alloys to seawater. Results show the environmental factors influence considerably the service behaviour of this alloy.

The corrosion rates of aluminium HAL 5086 for various periods of immersion as a function of the period of exposure is given in Fig. 1. In the present study extending to 360 days, no pitting, no crevice or no edge corrosion was noticed. This observation agrees, with those of Wright & Godard (1954). The graph shows an initial high corrosion rate followed by a slopping rate indicating the influence of the self repaired passive film, the thickness of which reaches a limiting value which is influenced by the temperature, the dissolved oxygen, the pH of seawater and the ions present in the environment. De *et al.* (1968) also observed that the corrosion resistance of aluminium increased with the length of exposure. In view of the total absence of either pitting or crevice corrosion, corrosion rates based on weight loss measurements are meaningful. The uniform corrosion rate of about 17 microns year^{-1} is observed at the end of 360 days of tests. In the compilation of corrosion data of metals and alloys by Schumacher (1979) corrosion rates of structural metal and alloys at various sites of the world have been reported. The high degree of corrosion resistance and the absence of pitting of aluminium attest the cost effectiveness and usefulness of this material for making many sophisticated equipment.

Table 1. *Analysis of variance of corrosion rate*

Source	SS	df	ms	F
Total	1011323.50	43		
Between metals	914715.44	3	304905.15	128.46**
Between months	25402.30	10	2540.23	1.07 N.S
Error	71205.76	30	2373.53	

Analysis of variance was carried out to compare the corrosion rates of carbon steel, stainless steel 304 and aluminium 5086. Significant difference in the average corrosion rates of different metals were observed (Table 1).

The average corrosion rates of these metals are given in Table 2. Comparison among means was carried by using the Least Significant Difference (LSD) which worked out to 42.4. The average corrosion rate of carbon steel exceeds this value from the averages of SS 304 and Al 5086 while the difference between the average corrosion rates of SS 304 and Al 5086 is far less than 42.4. Therefore it can be concluded that while there is no significant difference in the average corrosion rates of SS 304 and Al 5086, the average corrosion rate of carbon steel is very high compared to those of the other two metals.

Table 2. *Mean corrosion rate of different metals (microns year^{-1})*

Carbon steel	353.44
SS 304	30.96
Al 5086	34.82

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