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FOULING OF TITANIUM AND STAINLESS STEEL IN SEA WATER

ABSTRACT

The paper presents results of tests on fouling of titanium and stainless steel in sea water. Specimens of stainless steel were more susceptible to fouling than specimens of titanium. Chlorine dosing prevents fouling of titanium.

Key words: *fouling of titanium and stainless steel, dosing of chlorine*

INTRODUCTION

Titanium and its alloys have high strength, low density and high resistance to chemical corrosion at ambient temperature and at high temperatures up to 450°C during constant work and up to 700°C during short-time work [1]. This metal shows also high corrosion resistance e.g. to crevice corrosion and to pitting corrosion in the marine atmosphere and sea water [2]. All over the world titanium and its alloys are applied in production of yachts [3,4], screw propellers [2,5] and heat exchangers [6]. In literature [7] was written that surfaces of constructions made of titanium that were immersed in sea water were not fouled by living organisms (crustacea and algae). Other authors [8] inform that titanium is fouled by barnacles and seaweed. To clear up contradictory information about fouling of titanium by living organisms in sea water specimens made of titanium were exposed in Gdynia Shipyard basin water on CTO floating corrosion station. Moreover, fouling of titanium and stainless steel was compared. Chlorine dosing in different concentrations to prevent fouling was carried out.

MATERIALS AND EXPERIMENTAL PROCEDURE

Commercial Grade 2 pure titanium and X2CrNi18-9 stainless steel sheets were used. From these sheets specimens of dimensions 2x50x200 mm and also from Grade 2 pure titanium specimens of dimensions 2x45x110 mm were cut out. Chemical composition of tested materials is presented in Tables 1 and 2. Chemical composition of titanium sheet was examined on emission spectrometer ARL 3460 in Rzeszow University of Technology.

On surfaces of investigated specimens was measured roughness with the use of roughness tester TR 100. For all specimens of steel and titanium the average roughness parameters R_z were at the level 2.5 µm.

Table 1. *Chemical composition of commercial Grade 2 pure titanium*

Commercial Grade 2 pure titanium	Chemical composition, % wt					
	C	Fe	N_2	H_2	O_2	Ti
Standard ASTM-B-265	max 0.080	max 0.30	max 0.030	max 0.015	max 0.250	99.34
Certificate 171207R	0.010	0.090	0.010	0.012	0.140	99.75
Control analysis	0.026	0.094	-	-	-	99.85

Table 2. *Chemical composition of X2CrNi18-9 stainless steel*

Steel X2CrNi18-9	Chemical composition, % wt					
	C	Mn	Si	P	S	Cr	Ni
Standard PN-EN 10088-1:2007	max 0.03	max 2.0	max 1.00	max 0.045	max 0.030	17,5-19,5	8-10

Degreased specimens were weighed and immersed in natural seawater in Gdynia Shipyard basin at different depths (Table 3) in the years 2006 and 2007 and other specimens were placed in pipelines at different concentrations of chlorine (Table 4). Surfaces of investigated specimens (immersed in seawater) were checked three times a week. Surfaces of specimens in pipelines were checked at the end of test. The temperature and pH of water were measured twice a day.

Table 3. *Depth of immersion for different specimens*

Specimens marks	Material	Depth of immersion [m]
16	Commercial Grade 2 pure titanium	1
17	Commercial Grade 2 pure titanium	1
18	Commercial Grade 2 pure titanium	1
S1	Steel X2CrNi18-9	4
T1	Commercial Grade 2 pure titanium	4
RR1	Commercial Grade 2 pure titanium	4
RR2	Commercial Grade 2 pure titanium	4
S2	Steel X2CrNi18-9	8
T2	Commercial Grade 2 pure titanium	8

Table 4. *Chlorine concentration for different specimens*

Specimens marks	Material	Concentration of chlorine [mg/l]
10	Commercial Grade 2 pure titanium	0
11	Commercial Grade 2 pure titanium	0
12	Commercial Grade 2 pure titanium	0
1	Commercial Grade 2 pure titanium	1
2	Commercial Grade 2 pure titanium	1
3	Commercial Grade 2 pure titanium	1
4	Commercial Grade 2 pure titanium	3
5	Commercial Grade 2 pure titanium	3
6	Commercial Grade 2 pure titanium	3
7	Commercial Grade 2 pure titanium	6
8	Commercial Grade 2 pure titanium	6
9	Commercial Grade 2 pure titanium	6
13	Commercial Grade 2 pure titanium	10
14	Commercial Grade 2 pure titanium	10
15	Commercial Grade 2 pure titanium	10

RESULTS AND DISCUSSION

When water temperature in Gdynia Shipyard basin reached approximately 14°C fouling of all tested specimens was observed. After 102 days of immersion in 2006 all investigated specimens were fouled by barnacles (Fig. 1) and after 224 days in 2007 – too (Fig. 2-7).

There were five different concentrations of chlorine during the test (0, 1, 3, 6 and 10 mg/l). There was no interaction between solutions of different concentration. Natural seawater flow in pipelines was 5 liters per minute.

After 1920 hours of test in pipelines all specimens were checked. On specimens without chlorine dosing barnacles and marks of barnacles were found. On the rest of specimens barnacles and other fouling organisms were not observed (Fig. 8 – 9).

Fig. 1. Fouling of titanium specimen (depth of immersion 1m - mark 16,17,18)

Fig. 2. Fouling of titanium specimen (depth of immersion 4 m - mark T1)

Fig. 3. Fouling of titanium specimen (depth of immersion 4 m - mark RR1)

Fig. 4. Fouling of titanium specimen (depth of immersion 4 m - mark RR2)

Fig 5. Fouling of stainless steel specimen (depth of immersion 4 m - mark S1)

Fig. 6. Fouling of titanium specimen (depth of immersion 8 m - mark T2)

Fig. 7. Fouling of stainless steel specimen (depth of immersion 8 m - mark S2)

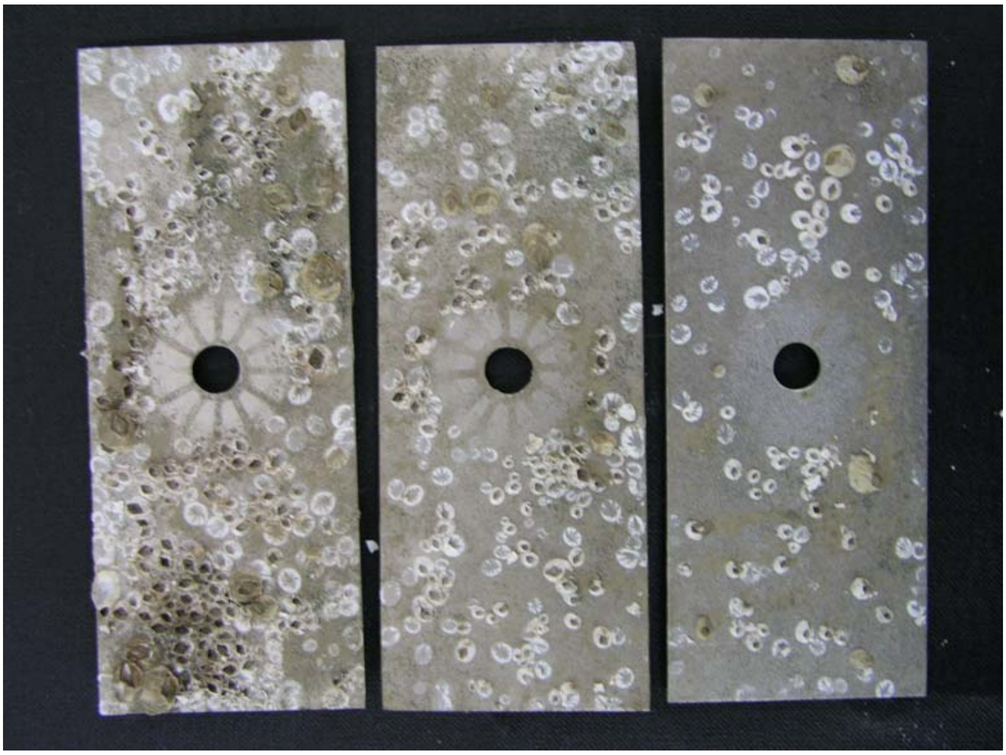

Fig. 8. Fouling of titanium specimen (without chlorine - mark 10,11,12)

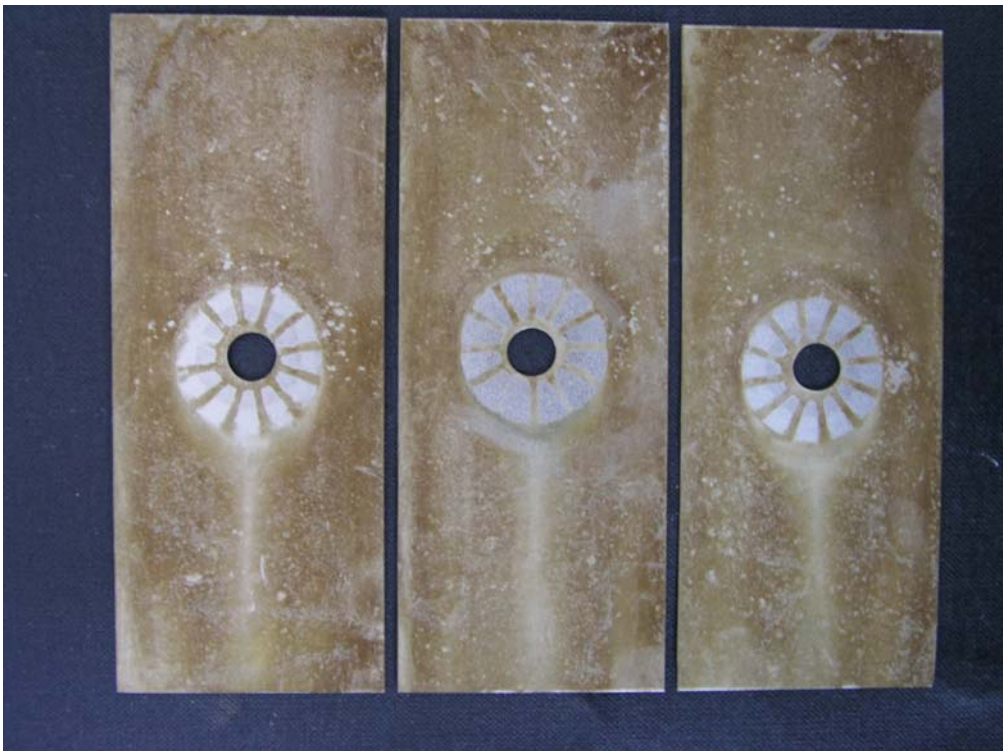

Fig. 9. Fouling of titanium specimen (chlorine concentration of 1 mg/l - mark 1,2,3)

All specimens after drying for two days in ambient temperature were weighed. Mass of barnacles was calculated as the difference between mass of the specimens before and after exposition. Weight of barnacles on the specimens was calculated as average value for three specimens. The results are presented in Fig. 10 - 12.

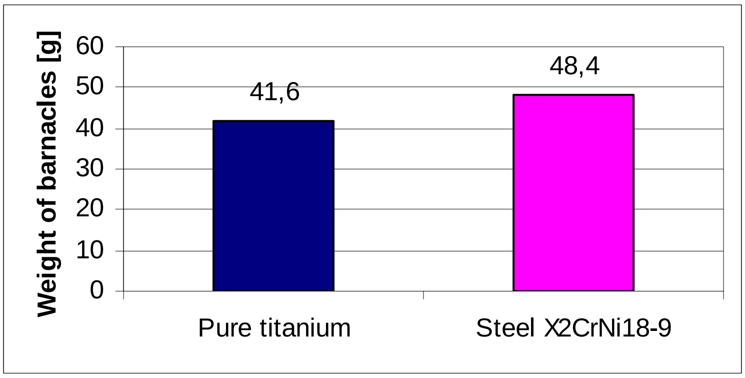

Fig. 10. Weight of barnacles on specimens immersed at 4 m depth

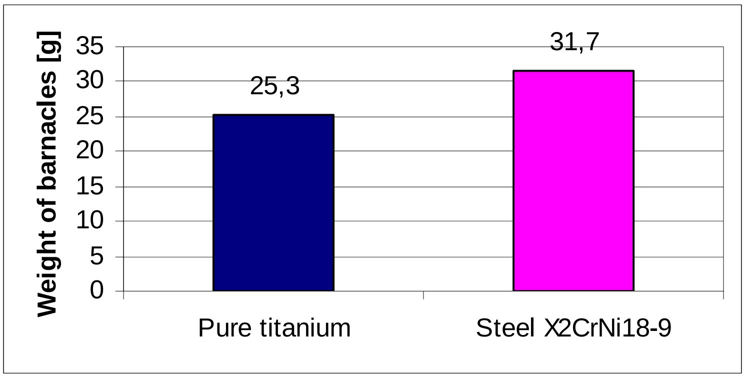

Fig. 11. Weight of barnacles on specimens immersed at 8 m depth

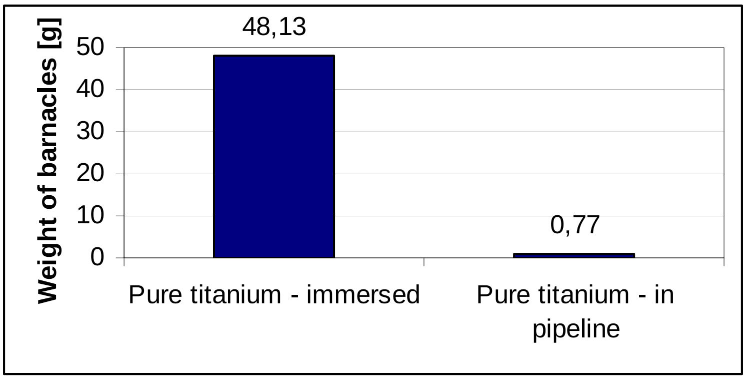

Fig. 12. Weight of barnacles on specimens immersed in seawater at 1 m depth and in the pipeline

SUMMARY

It was found that all specimens immersed at 1, 4 and 8 m depth were fouled. Rate of specimens fouling depends on temperature of sea water. Specimens immersed at 1 and 4 m depths were exposed for a longer time in sea water at temperature above 14°C and had on their surfaces more barnacles than specimens immersed at 8 m. On surfaces of specimens made of X2CrNi18-9 steel approximately 15 – 20 % more barnacles than on the surfaces of specimens made of commercial Grade 2 pure titanium were found.

Chlorine dosing to natural sea water even on the low level (1 mg/l) prevents fouling of titanium. Without chlorine dosage fouling of titanium is like that of every other material susceptible to this process. Less intensive fouling in the case of dynamic flow of sea water was observed.

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