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RESEARCH

Research About the Efficiency of Active Anode Protection at Centrifugal Pumps

The aim of the paper is to present the results of experiments made by the authors in order to diminish erosion-corrosion wear at centrifugal pumps for petroleum industry. In electrolytic aggressive liquid mediums, such as crude oil, industrial or urban residual waters, the corrosive part of wear could be reduced, with low costs, by applying cathodic protection with active anodes. Were establish electrochemical parameters and were made erosion tests at 15^0, 30^0 and 45^0 impingement angles, in formation water with 3% sand at 1450 r.p.m., on 3 materials from rotor and body centrifugal pumps. The results obtained confirm that cathodic protection with active anode reduces not only the wear but reduce also the samples surface roughness.

Keywords: wear, erosion, cathodic protection, roughness

1. INTRODUCTION

To pump electrolytic mediums as crude oil in separation units or waste waters are used centrifugal pumps. Gaseous or liquid hydrocarbons are not corrosive in the water absence. In the case of formation waters, corrosion process are intensified by the presence of some active substances, especially dissolved salts, CO2, H2S, bacterial activity and in some cases even by the oxygen. In the water extracted from a formation in which were made acidifying operations contains also HCl. In production fields formation water represents an average of 60…70% of total quantity of extracted fluid, [1]. Corrosion rise with the water percent quantity. Dissolved salts way of action is complex, but the salts mainly raise the water conductibility due to the ionizing effect intensifying the electrochemical corrosion processes. Formation waters contain mainly chlorides of sodium, potassium, calcium, magnesium etc. but also iodides and sulphates.

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Because sodium chloride is in the greatest quantity and has the main effect above corrosion rate is used to be indicated only contains in this salt, in salt kilograms contains in a water wagon or in g NaCl/l water. The rest of chlorides as $CaCl_2$ and $MgCl_2$ presented in formation waters action in different ways depending of the nature, concentration, temperature and pH of the solutions. Magnesium chloride, $MgCl_2$ is extremely dangerous of corrosion point of view if remains in crude oil for refinery, because in distilling processes at high temperatures in the water vapors presence appear HCl. In formation waters are also small quantities of sulphates. Sulphates presence could lead at a specific H_2S corrosion in the micro-organisms presence.

Oxygen is the common agent which intensifies corrosion in neutral mediums. The effect is greater in mineralized waters than in soft waters. Formation waters at drill surface are without oxygen, but in the separation, stoking, transport dissolve the oxygen from atmosphere.

Dissolved oxygen quantities by the water depends of salt contains and temperatures and is around 4 mg O_2/l water (4 ppm), [1]. H_2S represents the most corrosive component of formation waters. The aggressivity of H2S rises in the presence of C O_2, O_2 and water.

CO_2 produce an important corrosion above iron alloys. Pressure and temperature intensify the CO_2 aggressivity, [3].

Taking account of these considerations, crude oils are electrolytic mediums and degradation of metallic equipments has an important corrosive component. A way to reduce wear is to reduce the corrosive part of wear, [3, 4]. Because medium has an explosive potential, the method with impressed current could not be applied. In this case, at centrifugal pumps, the corrosive wear could be reduced by using chatodic protection with active anode.

Paper presents the erosion-corrosion wear results at tests made in the presence of formation water with 3% sand at different impingement angles, with and without active anode made on materials from rotor and body centrifugal pumps. Because sand particles and corrosive character of crude oil the wear mechanism is an erosivecorrosive one. The important quantities of formation water from crude oil make the aggressively of crude oil to depend of formation water aggressively.

To reduce corrosive wear of centrifugal pumps was proposed a cathodic protection with active anode.

2. EXPERIMENTS

Samples were made of carbon steel type OT450 from a real pump rotor, of gray cast type EN GJL HB 215 and EN GJL HB 155 from a real pump bodies. In Table 1 are presented the chemical composition of the tested materials.

Tab. 1: Composition of tested materials

Elements, %	Pump element		
	Rotor OT 450	Body pump GJL HB 215	Body pump GJL HB 155
Carbon	0,32	-	-
Mangham	1,05	1,09	0,77
Siliceous	0,35	1,64	2,43
Sulfur	0,008	0,0965	0,0105
Phosphor	0,015	0,0493	0,0027
Nickel	0,03	0,0143	0,0176
Chromium	0,02	0,0161	0,0557
Molybdenum	0,05	0,0026	0,006
Carbon total	-	> 5,1	> 5,1

The tests were made in formation water with composition presented in Table 2.

Tab. 2: Formation water analyze

Characteristic	Value
pH	6,54
Density, g/l	1.064
Impurities, mg/l:	
- suspension	16,60
- oil	1,40
Dissolved gases, mg/l:	
- Oxygen	0,22
- Carbon dioxide	free = 74,80
- Hydrogen sulphide	no
Chemical composition, mg/l:	
Na^+ (K^+)	27.716
Ca^{2+}	3.809
Mg^{2+}	939
Cl^-	51.830
SO_4^{2-}	138
HCO_3^-	482
Fe_2O_3	14
Al_2O_3	13
Minerals	84.941
Probable composition, g/l:	0,640
$Ca(HCO_3)_2$	0,195
$CaSO_4$	9,952
$CaCl_2MgCl_2$	3,676
NaCl	70,438

To evaluate materials corrosion behavior in formation water were made electrochemical tests using a potentiostat EG&G 350 Princeton and an ASTM cell with ECS reference electrode. In Table 3 are showed the values of electrochemical parameters.

Tab. 3: The values of electrochemical parameters

Parameter	GJL HB 215	GJL HB 155	OT 450	Zn Anode
Corrosion current, i_{cor}, μA	3.352	2.218	6.020	4.887
Corrosion potential, E_{cor}, V	-0.160	-0.131	-0.190	-0.537
Corrosion rate, v_{cor}, mm/year	0.045	0.030	0.080	0.074

At electrochemical tests was used Tafel technique. In Figure 1 is presented the results for EN GJL HB 215 material.

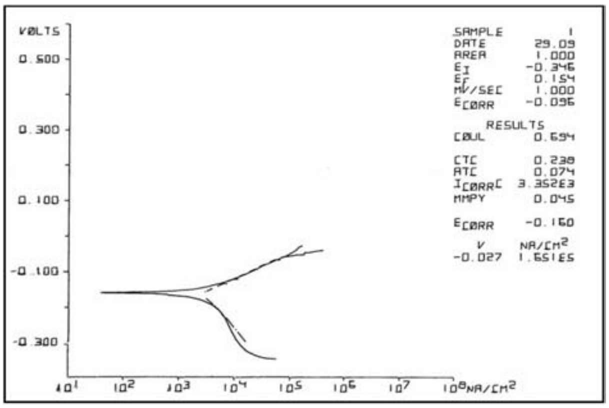

Fig. 1: Tafel curves for material GJL HB 215

In parallel with electrochemical tests was established the corrosion rate by immersion tests. The results are shown in Table 4.

Tab. 4: Corrosion rates obtained by immersion

Parameter	Material		
	GJL HB 215	GJL HB 155	OT 450
Corrosion rate, at 20^{o}C after 504 hours v_{cor}, mm/year	0.0262	0.0150	0.0287
Corrosion rate, at 40^{o}C after 53 hours v_{cor}, mm/year	0.486	0.424	0.497

In Figure 2 is presented the microstructure for sample material GJL HB 215, in Figure 3 the microstructure for GJL HB 155 and in Figure 4 the microstructure for sample material OT 450.

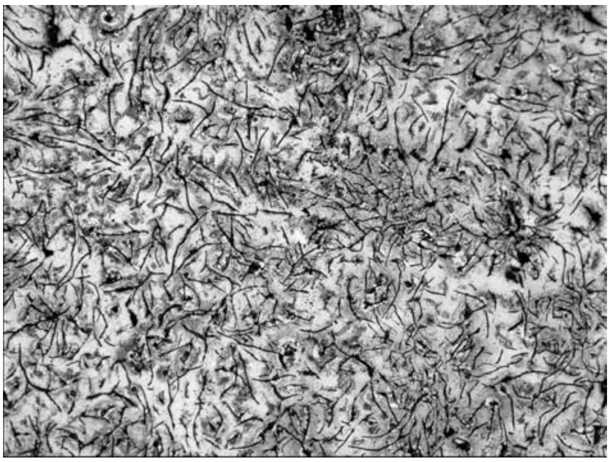

Fig. 2: Microstructure of GJL 215, X200, Nital attack

The microstructure of material GJL HB 215 (Fig.2) is ferritic - pearlite with uniform flaked graphite. The material GLJ HB 155 has also a ferritic – pearlite microstructure (Fig.3) with a greater ferrite percent due to a greater Si% in composition. The graphite is not so uniform having a tendency to agglomerate in nests and the mechanical properties are smaller.

Fig. 3: Microstructure of GJL 155, X200, Nital attack

The material OT 450 is a cast carbon steel with 0.32%C and 1.05%Mn. Due to initial casting the microstructure after ageing, shown in figure 4 is not very uniform.

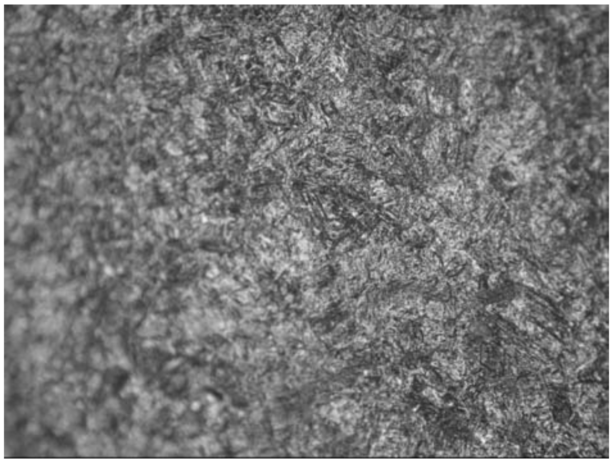

Fig. 4: Microstructure of OT450, X200, Nital attack

The cast carbon steel due to non equilibrium structure (Fig.2) has the greatest corrosion rate and cast iron GJL HB 215 has higher corrosion rate (see Tab.3 and Tab.4) than GJL HB 155 material with a greater ferrite percentin the structure (Fig.4). In pump working conditions the corrosion rates will be greater, due to galvanic corrosion because materials are different, due to pressure, erosion and temperature.

Zn with potential of -0.537V (ECS) will be anode in couple with the rest of tested materials.

To establish the erosion influence were made tests at 15^0, 30^0 and 45^0 impingement angles at 1450r.p.m. (7.6m/s) with and without active anode attached at samples. Was establish wear for tested material samples and also was measured roughness on impact samples face. The working medium was formation water with 3% sand wit size smaller than 0.125mm.

In Figure 5 it is shown the wear results obtained for samples of material GJL215 at 15^0 impingement angles. Roughness was measured on impact samples face at initial time and after 3, 6 and 9 hours of working in the device.

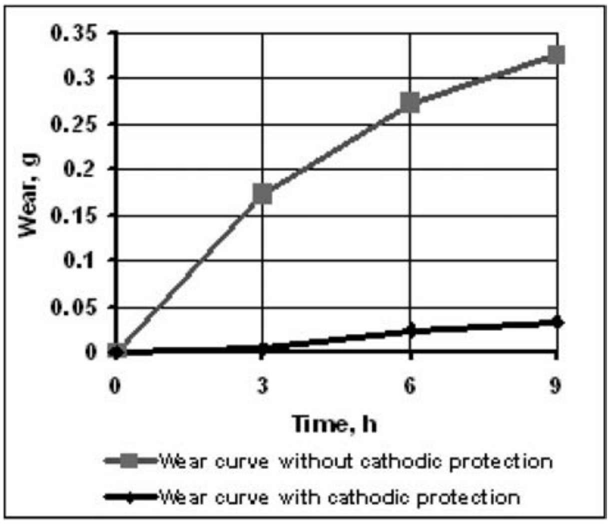

Fig. 5: Wear curve for material GJL HB 215 at 15^0

In Figure 6 it is shown the wear results obtained for samples of material GJL HB 155 at 15^0 impingement angles.

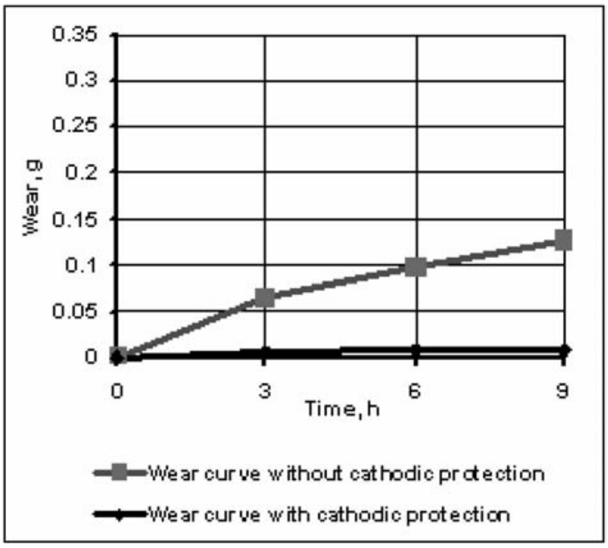

Fig. 6: Wear curve for material GJL HB 155 at 15^0

In Figure 7 it is shown the wear results obtained for samples of material OT 450 at 15^0 impingement angles. Similar behaviors with benefic effect of chatodic protection were obtained for all tested materials at 30^0 and 45^0 impingement angles.

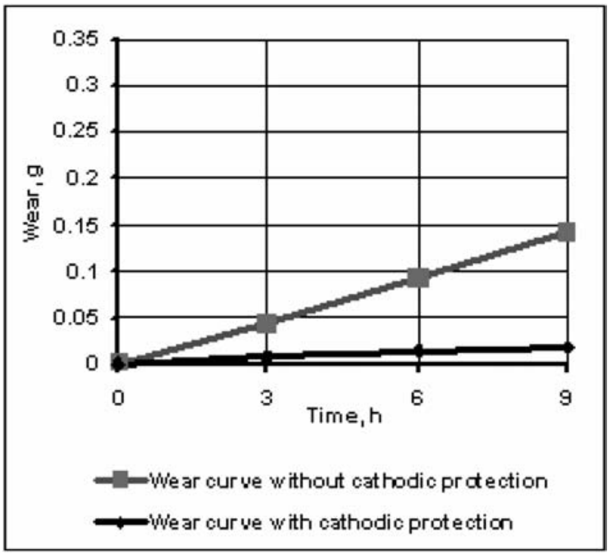

Fig. 7: Wear curve for material OT 450 at 15^0

In Table 4, 5 and 6 are presented the values of gravimetric wear for the 3 tested materials at 3 impingement angles in the presence and in the absence of cathodic protection with Zn active anode.

Tab. 4: Gravimetric wear for material OT 450

Attack angles	Cathodic protection	Time, hour		
		3	6	9
		Wear, mg		
15^o	No	43.7	94.0	143.0
	Yes	8.9	13.1	18.3
30^o	No	40.7	82.0	113.4
	Yes	7.8	8.8	9.6
45^o	No	16.8	35.8	63.0
	Yes	9.1	13.6	18.0

Tab. 5: Gravimetric wear for material GJL HB 215

Attack angles	Cathodic protection	Time, hour		
		3	6	9
		Wear, mg		
15^o	No	17.3	272.5	326.0
	Yes	3.9	24.0	34.1
30^o	No	17.1	36.0	65.0
	Yes	2.4	4.0	5.2
45^o	No	10.0	25.8	56.4
	Yes	2.6	5.4	8.4

Tab. 6: Gravimetric wear for material GJL HB 155

Attack angles	Cathodic protection	Time, hour		
		3	6	9
		Wear, mg		
15°	No	66.2	98.2	127.8
	Yes	5.9	7.2	8.5
30°	No	21.1	28.2	57.3
	Yes	3.5	5.9	6.8
45°	No	18.9	35.5	45.6
	Yes	3.3	4.6	7.0

In the Figure 8 is presented roughness modification curve for material GJL HB 215 at 15^0 Impingement angle.

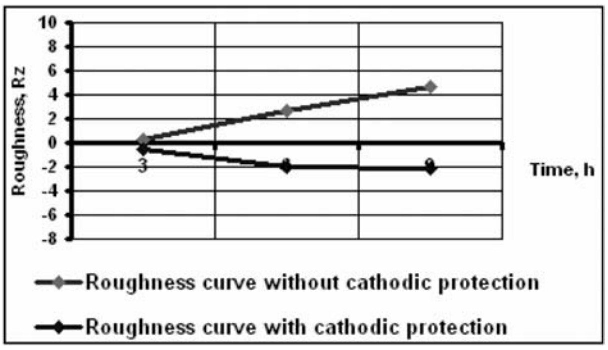

Fig. 8: Roughness modification curve for surface material GJL HB 215 at 15^0

In Figure 9 is shown roughness modification curve for material GJL HB 215 at 30^0 impingement angles.

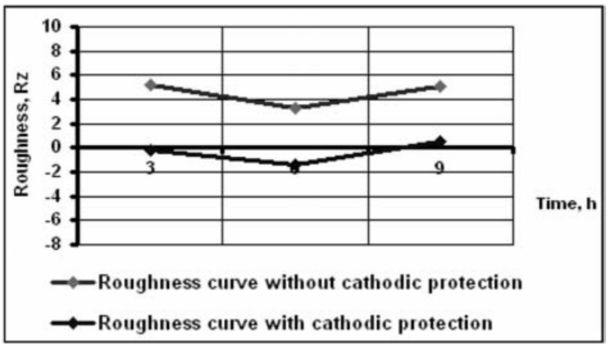

Fig. 9: Roughness modification curve for surface material GJL HB 215 at 30^0

Roughness modification curve for sample material surface GJL HB 215 at 45^0 impingement angles is presented in Figure 10.

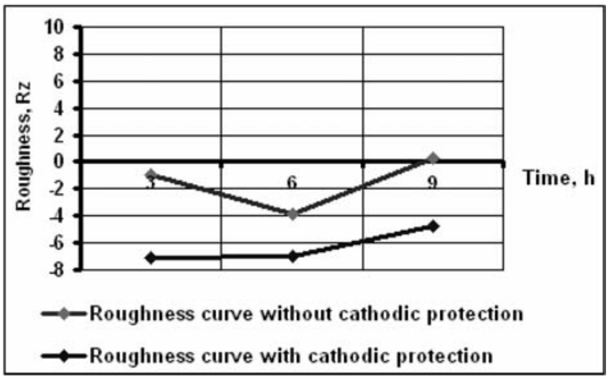

Fig. 10: Roughness modification curve for surface material GJL HB 215 at 45^0

Similar behaviors with benefic effect of chatodic protection above roughness were obtained for all tested materials. In Table 5 and 6 are presented the values of roughness modification for surface of samples GJL HB 155 and OT 450 at 3 impingement angles in the presence and in the absence of cathodic protection with Zn active anode.

Tab. 7: Roughness modification for sample material surface GJL HB 155

Attack angles	Cathodic protection	Time, hour		
		3	6	9
		Roughness modification Rz, µm *)		
15 0	No	+0.85	+1.82	+2.22
	Yes	-0.31	-0.03	-0.42
30 0	No	+0.11	+2.31	+4.36
	Yes	-1.13	-2.21	-2.46
45 0	No	+4.07	+6.87	+3,23
	Yes	+0.56	-0.05	-0.46

*) Sign (+) roughness grows;
Sign (–) roughness decrease.

Tab. 8: Roughness modification for sample material surface OT 450

Attack angles	Cathodic protection	Time, hour		
		3	6	9
		Roughness modification Rz, µm *)		
15°	No	+3.19	+5.87	+9.09
	Yes	-3.33	-4.10	-0.31
30°	No	+1.44	+1.67	+3.78
	Yes	-1.41	-1.63	-2.65
45°	No	-4.43	-3.40	-6.13
	Yes	-0.09	+1.13	-0.83

*) Sign (+) roughness grows;
Sign (–) roughness decrease.

Profilograms were established, with Surtronic 3+ device, on impact samples face at initial time and after 3, 6 and 9 hours of working in the erosion device. A sample of profile modification is presented in Figure 11.

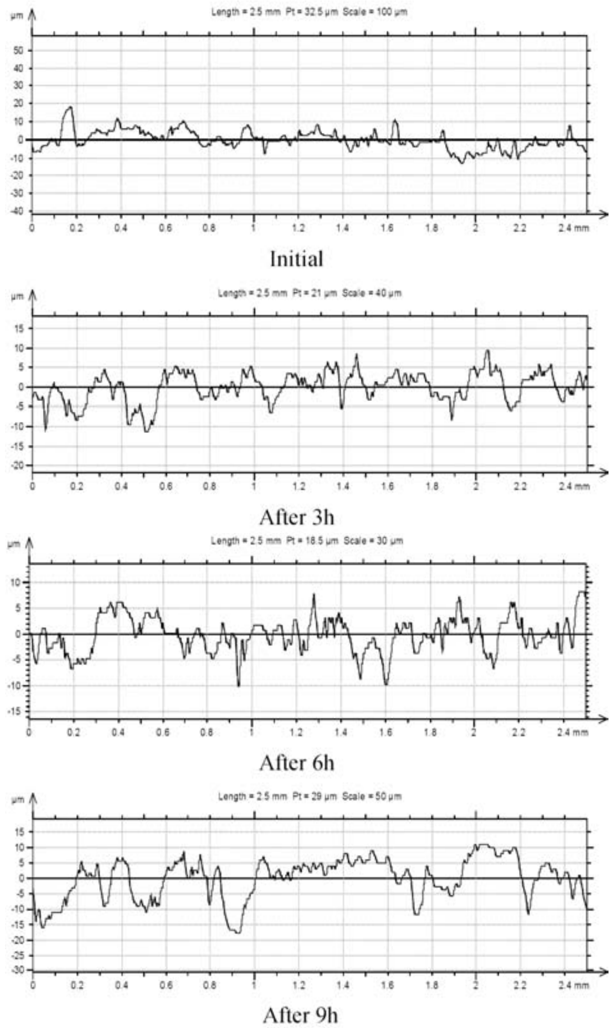

Fig.11: Profilograms for surface material OT 450 at 30^0

3. CONCLUSIONS

In electrolytic aggressive liquid mediums, such as crude oil, industrial or urban residual waters, the corrosive part of wear could be reduced, with low costs, by applying cathodic protection with active anodes.

Zinc material has a anodic behavior in couple with tested materials in formation water.

Temperature sensible raises the corrosion rate. At 40^0C the corrosion rate was 5…10 times greater then at 20^0C.Cathodic protections with active anodes reduce erosion wear at all tested materials and impingements angles. Also cathodic protection improves surfaces roughness. For roughness the critical impingements angles for sample materials GJL HB 155 and OT 450 is 15^0 and for material GJL HB 215 without cathodic protection 15^0 and 30^0 and 15^0 with cathodic protection. These critical angles must be avoided.

The benefic results of cathodic protection with active Zn anode presented, was also confirmed at tests made on centrifugal pump stand and in industrial conditions.

The obtained results presented permit the paper authors to formulate a patent to protect centrifugal pumps with active anodes.

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