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Diminishing Erosion Wear of Centrifugal Pump Rotor Made of Austenitic Stainless Steel by Nitriding Thermochemical Treatments

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Abstract

This paper contains some experimental results about erosion wear behavior of materials types AISI 304 and AISI316 gas and plasma nitrated. Thermochemical treatments parameters are presented, the metallographic structures obtained have been investigated, the hardness and thickness of stratums have been determined, and at wear tests developed in formation water have been performed, taking into account the influence above wear of impingement angles.

Key words: *stainless steels, gas and plasma nitriding, erosive wear.*

Introduction

Service life of a centrifugal pump largely depends on the wear resistance of its sub-assemblies. The main forms of wear are by adhesion, by erosion, by corrosion and by cavitation. These occur at the rotor blades, at the diffuser and at the sealing rings [1, 5, 6].

This paper covers only measures to reduce erosion wear at the rotor blades.

Wear erosion is defined as the degradation through loss of the material under the effect of the impact of abrasive particles in a liquid [1]. If the liquid has corrosive features appear erosion corrosion wear. For erosion to occur, the hardness of the solid particles contained by the fluid must be greater than that of the material hardness from which the pump rotors are made of.

The main factors which influence erosion wear are [1]:
- kinetic energy related to abrasive particle size and density;
- abrasive particle shapes because rounded particles remove material through superficial micro-fatigue while the rough surface particles through splintering;
- physical and mechanical characteristics of the material exposed to erosion;
- impingement angle;
- aggressivity of the fluid which produce erosion-corrosion wear.

Through erosion we reach pitting, shape changes or thinning on surfaces on which the fluid containing abrasive particles moves, resulting in the emergence of vibration and lower performance of the centrifugal pumps due to changing of the rotor blades geometrical shapes.

The main ways to reduce erosion wear of the centrifugal pumps impellers made of austenitic stainless steels are [1, 2, 3, 4]:

- mass reduction of the solid particles through proper filtration of the carrier fluid.
- increasing the hardness of the surfaces exposed to erosion.
- increasing the materials resistance to corrosion.
- obtain a homogeneous structure, devoid of metallographic constituents with large differences in hardness and brittleness.
- avoid the critical impingement angle through the construction of pallets.
- providing dynamic balancing of centrifugal pump impeller.

Characterization of Materials Exposed to Erosion Wear Tests

Among the methods for reducing erosion wear of centrifugal pumps rotors made of austenitic stainless steels the effects of increased surface hardness of the surfaces exposed to erosion by thermochemical treatments in gas nitriding and plasma assisted plasma nitriding have been studied [2, 3, 4].

Experimental tests have been performed on two types of austenitic stainless steels AISI 304 and AISI 316 [7]. They have a wide use due to good behavior regarding oxidation corrosion and feasibility of construction of complex geometry at an affordable price. These steels appear in EN 10088-1 as X5CrNi18-10 and X5CrNiMo17-12-2 and in ASTM as 14401 and 14301 respectively [7].

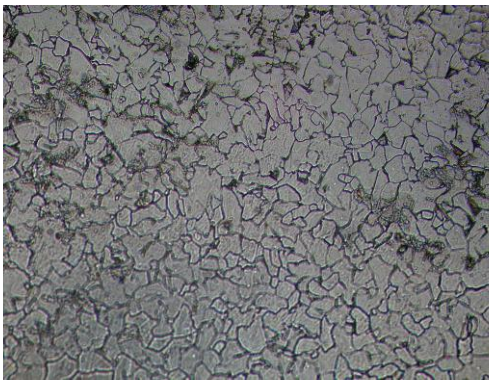
The chemical composition was determined by chemical analysis performed in the laboratory at the Bucharest University Faculty of Physics Magurele, using an optical emission spectrometer type "SPECTROLAB" from the company Spectro-Analytical Instruments. Table 1 illustrates the chemical compositions of the two steels used in the conducted research.

Table 1. Chemical analysis [% by mass] of the studied steels

Steels according to En 10088-2	%C	%Mn	%Si	%P	%Cr	%Ni	%S	%N	%Cu	%Co
AISI 304	0.062	1.83	0.95	0.035	18.64	8.32	-	-	-	-
AISI 316	0.020	1.81	0.48	0.030	16.68	10.06	0.030	0.073	0.44	0.09

In Figure 1, the metallographic structures of the tested stainless steels without thermochemical treatment are shown.

Structure of steel AISI304 (200X)



Structure of steel AISI 316 (200X)

Fig. 1. Metallographic structures of not treated tested steels

As observed (fig. 1) the AISI 304 and 316 stainless steels present at ambient temperature an austenitic structure with low α ferrite. Complex carbides $M_{23}C_6$ are dispersed in austenite and could be shown at greater magnification.

Gas nitriding was achieved at Neptun Campina in an vertical oven type VEA 10 with a useful space of 800x1200 and an output of 360 kW. The treatment has been carried out in two stages with the change of nitrogen concentration and temperature, each step being performed for 7 hours and air cooled according to the diagram presented in Figure 2.

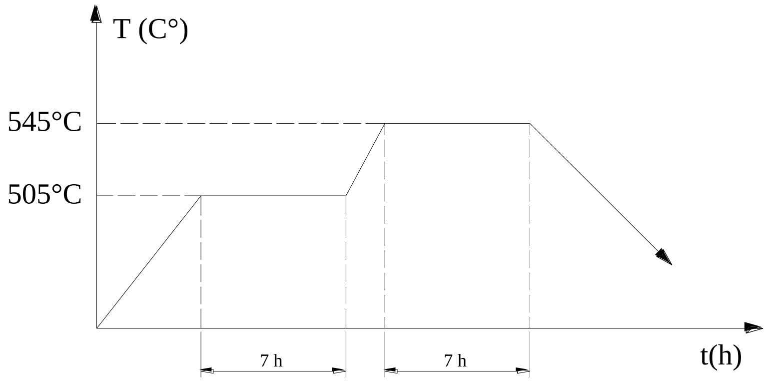


Fig. 2. Treatment diagram for gas nitriding

In the first step of treatment, nitrogen concentration in furnace chamber was 38% and in the second step of 60%.

The plasma-assisted plasma nitriding was conducted at the National Institute for Laser Physics, Plasma and Radiation from Bucharest Magurele in a URANOS (Unité de Réaction Assistée par plasma pour la Nitruration et l'Oxydation des Surfaces) type reactor. The treatment was done in a period of 8 hours at a temperature of 480 ^{0}C in an environment with a concentration of 18-25% N_2 and 75-85% H_2 according to the diagram in presented in Figure 3. The first 0.5 hour period corresponds to the removal of the layer of oxides on the surface of the treated samples.

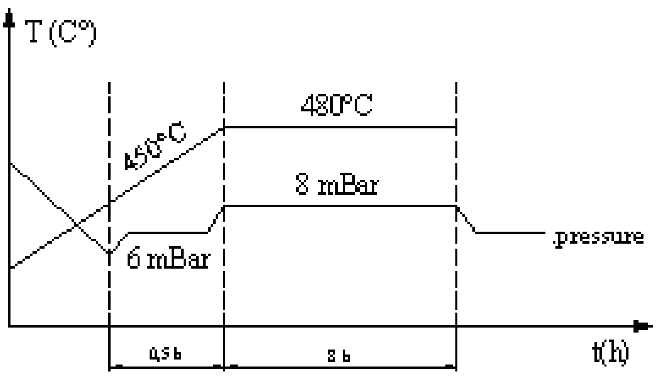


Fig. 3. Treatment diagram for plasma nitriding

Depth of the nitrided stratums was established based on microhardness measurements and it is presented in Table 2.

Table 2. Maximum hardness and thickness of nitrided stratum

Material	Gas nitriding		Plasma nitriding	
	Max. $HV_{0,5}$	Thickness, μm	Max. $HV_{0,5}$	Thickness, μm
304	1500	194	910	31
316	1523	183	801	16

Erosion Wear Test Conditions

The selected erosion wear test medium consisted of formation water from the water supply tank of an injection station, the latter having a high quantity of suspended sand particles and a high potential for corrosion. The main characteristics of the formation water used were: pH = 6.6, and the chemical composition with Na^{+} 79.58 g/l, Ca^{z+} 4.41 g/l, Mg^{z+} 0.90 g/l, HCO_3^{-} 0.92 g/l and Cl^{-} 133 g/l with a sand content of 10 g/l collected from water supply tank. The sand particles collected for erosion testing are silicon (SiO_2) based, chemically inert, possessing high hardness (7 Mohs scale or 1500 Vickers scale). Sand granulometry curve determined by sieving it is shown in Figure 4.

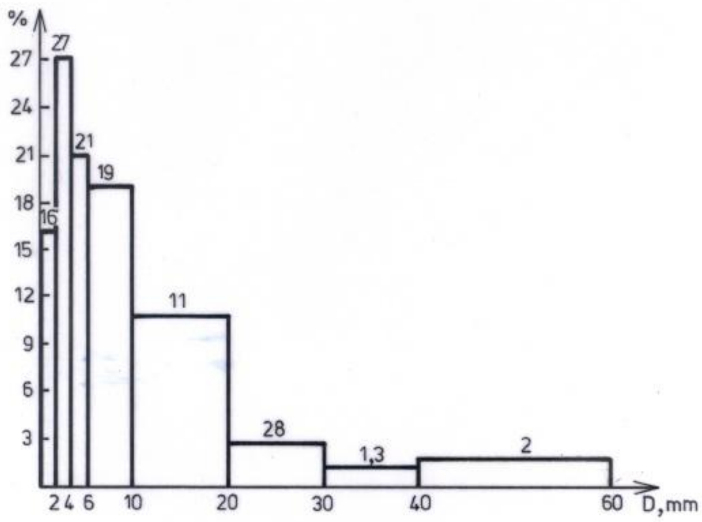
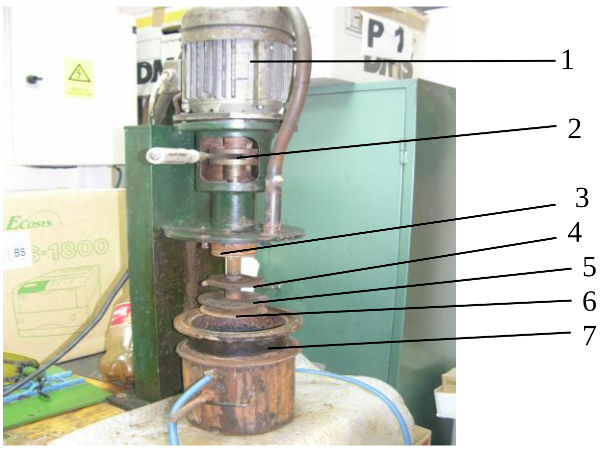


Fig. 4. Sand granulometry curve

Erosion wear tests of samples made of steels AISI 304 and AISI 316 untreated, gas nitrided and plasma nitrided was performed using an existing device in Tribology and Corrosion Laboratory of Petroleum-Gas University of Ploiesti whose constructive phase preparation for mounting specimens is presented in Figure 5, [5, 6].



1-electric motor; 2-locked coupling studs for fixing samples;
3-rotating shaft; 4-upper disk; 5-lower disk; 6-conical disk; 7-double wall tank.

Fig. 5. The erosion test device

Erosion wear tests were performed on three sets of samples untreated, gas nitrided and plasma nitrided, the weight loss was determined by weighing with an analytical balance after one hour, 4 hours and 10 hours. The specimens were mounted at an angle of 15^0 and then 30^0 angles corresponding to the input-output angles of the blades of the centrifugal pumps. Construction of specimens tested it is shown in Figure 6.

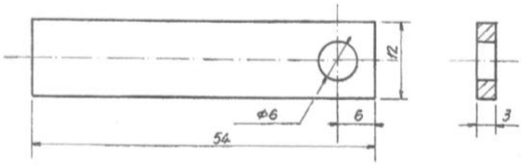


Fig. 6. Erosion wear test samples construction

Results

In Figure 7, are shown the erosion wear curves of the two material steels type AISI 304 and AISI 316 untreated, gas nitride treated and plasma nitride treated.

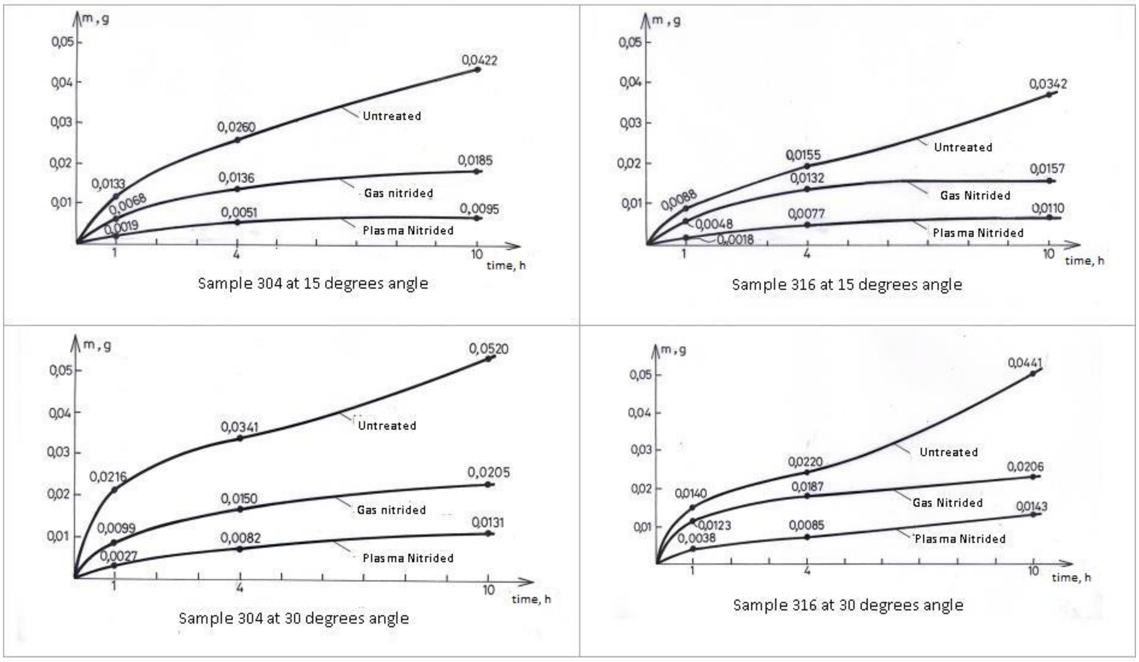


Fig. 7. Erosion wear curves

Note that there is an important distinction between the erosion behaviors of the three states, and also depending of impingement angle.

Conclusions

Formation water shows a high aggressiveness due to both the chemical composition and the presence of grains of sand.

Increased surface hardness by nitriding treatments provides a significant reduction of wear by erosion.

By increasing the impingement angle from 15^0 to 30^0, erosion wear increases both in untreated condition and also when gas or plasma nitriding thermochemical treatment was applied.

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Reducerea uzurii erozive a rotorului pompei centrifuge confecţionat din oţel inoxidabil austenitic prin tratamente termochimice de nitrurare

Rezumat

Lucrarea conţine unele rezultate experimentale privind comportarea la uzare erozivă a materialelor de tip AISI 304 şi AISI 316 nitrurate in gaze şi nitrurate în plasmă. Sunt prezentate tratamentele termochimice şi au fost cercetate structurile metalografice obţinute, s-au determinat duritatea şi grosimea stratului nitrurat şi s-au efectuat teste de uzare în apă de zăcământ cu o concentraţie de nisip de 10g/l la unghiuri de impact diferite.