ABOUT CAVITATION EROSION RESISTANCE OF THE AUSTENITIC STAINLESS STEEL HEAT TREATED

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ABSTRACT

Paper presents the experimental results obtained by testing to cavitation erosion the Austenitic stainless steel GX5CrNi19-10 in conformity with SR EN 10283 [20] after solution treatment. The test facility used is of magnetostrictive type with nickel tube. The tests have been carried out in Timisoara Hydraulic Machinery Laboratory. The results have been compared with those of the steel 40Cr10 with good but not excellent cavitation erosions and with the steels used for hydraulic turbines T07CuMoMnNiCr165-Nb and T09CuMoMnNiCr185-Ti. For comparisons have been used the characteristic cavitation erosion curves [1], [2] and it resulted that GX5CrNi19-10 has excellent cavitation erosion qualities.

KEYWORDS

Cavitation; erosion; heat treatment, vibratory device; erosion rate; cavitation erosion time.

1. INTRODUCTION

Among the negative effects of cavitation, one of greatest importance is the erosion of the solid boundaries guiding the flow [1]. Working out hydraulic machinery with total exclusion of cavitation is not possible for economic reasons. Commonly, the running of hydraulic machinery take place with "*industrial allowed cavitation*" for which the power characteristics are not at all affected but cavitation erosion is present, in the limits of prescribed material losses of [1], [2]. The cavitation erosion process is a very complex one and implies two different sides, interacting mutually: the first one is the physical process of the implosion of cavitation bubbles and the other one is the way in which those implosions affect the material [1], [3]. In spite of numerous researches carried out until now, the complexity of the interaction between the implosions and the crystalline structure of the material is not completely cleared up. Anyhow, for the contemporary technique there are not materials that can resist to an intense cavitation action. Instead, for industrial allowed cavitation, the appropriate selection of materials can lead to increased intervals between consecutive repair works and that is highly recommendable from the economic point of view.

In the present work it will be analyzed the cavitation erosion resistance of the Austenitic stainless steel GX5CrNi19-10 subjected to solution heat treatment. The analysis and comparisons will be made using the characteristic values and curves obtained in a vibratory test facility with nickel tube [2].

2. TESTED MATERIAL

2.1 Mechanical and chemical properties

The tested material is the Austenitic stainless steel GXCrNi19-10. Besides cavitation erosion tests, there have been made also tests to obtain the chemical composition, the mechanical properties at environmental temperature and metallographic analyses. For tests, 15 mm diameter probes were taken out from the material. The results are presented in table no. 1. From these tests it results that the specimens are manufactured from the steel GX5CrNi19-10. In agreement with the standard SR EN10283/99, at first, the specimens were subjected to water quenching and afterwards the mechanical characteristics presented in Table 1 were determined.

Table no. 1

<table>
<tr><th rowspan="3">Steel mark</th><th rowspan="3">Status</th><th colspan="13">Steel GX5CrNi19-10. Chemical composition. Mechanical characteristics.</th></tr>
<tr><th colspan="8">Chemical composition [%]</th><th colspan="5">Mechanical characteristics at 20ºC</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Cr</th><th>Ni</th><th>Mo</th><th>$Rp_{0,2}$ MPa</th><th>Rm MPa</th><th>A5% min</th><th>KV J</th><th>HB</th></tr>
<tr><td>GX5CrNi 19-10 1.4308</td><td>CS 1050^0C 30 min H_2O</td><td>0,048</td><td>0,43</td><td>1,49</td><td>0,028</td><td>0,026</td><td>19,1</td><td>10,1</td><td>0,3</td><td>175</td><td>440</td><td>35</td><td>60</td><td>230</td></tr>
</table>

2.2. Metallographic examination

There have been performed macro and micro structural analyses on the specimens, before and after the cavitation erosion tests. The metallographic preparation was carried out according to "General Metallographic Standard" (Stas 4203-74) [21]; "Taking over and Preparation of Metalographic Specimens" and sr en 5000-97 [22] with regard to "Metallographic Structures and Constituents of Ferrous Products". In order to determine the micrographic magnitude of the ferritic, austenitic or Martensitic grain the standard "Metallographic Determinations" sr iso 643-93 [23] was respected, using the reactive presented in Table no. 2.

Table no. 2

Symbol	Name	Composition	Surface Preparing	Precaution
B8	Solution of Chlorine hydride and Nitric Acid	39 ml water 59 ml chl. hydr. 9 ml nitric acid Availability: without limits	Diamond paste 3µm or finely Attack Temperature: Ambient temperature Time of attack: From seconds to minutes	Precaution in using acids

The microstructure of the steel GX5CrNi19-10 obtained with an optic microscope provided with a digital camera is presented in Figure no. 1.

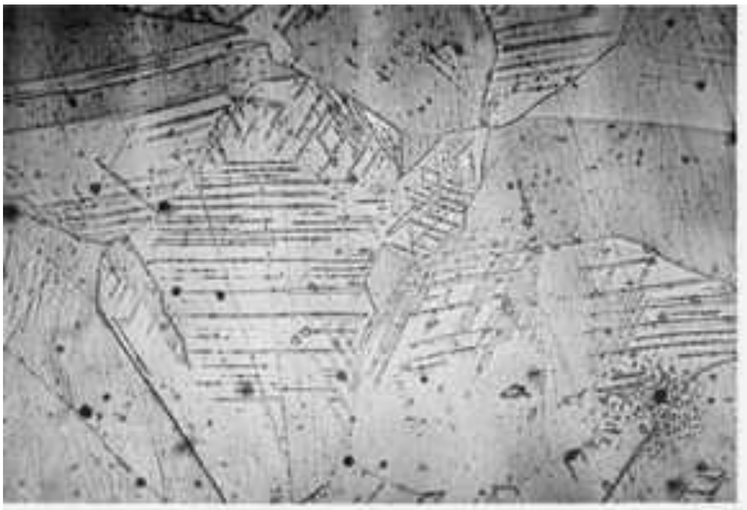


Figure no. 1 Steel GX5CrNi19-10
Steel GX5CrNi19-10; HT: 1050ºC/30 min/ water; Mo 500x

It can be clearly seen that the investigated steel has:

- austenitic structure with macles in some grains
- the granulation is G = 8 in agreement with the ASTM standard.

2.3 Researches upon the cavitation erosion of the specimens manufactured from GX5CrNi19-10

In conformity with the ASTM standard [19] the tests were carried out on three probes, in distilled water at the temperature T = 20±1ºC.

- pressure at the liquid surface: p = pat;
- power: P = 500 W;
- specimen diameter: d=14 mm;
- specimen immersion: h = 3mm.

The total duration of the cavitation attack of 165 minutes was divided in 12 periods, as follows: one of 5 minutes, one of 10 minutes and 10 of 15 minutes. At the beginning and at the end of each period the specimens have been washed successively in current water, distilled water, alcohol, acetone, after that desiccated in a hot air current and finally weighed in an analytical balance with six characteristic figures.

3. EXPERIMENTAL RESULTS

The measured and computed data are presented in “Testing Bulletin” and subsequently the following cavitation erosion characteristic curves have been obtained:

- Variation in time of the cavitation eroded mass ma(t), Fig. 3;
- Variation in time of the cavitation erosion velocity v(t), Fig. 2.

The cavitation attack was realized at Timisoara Hydraulic Machinery Laboratory in a vibratory magnetostrictive test facility with nickel tube. The facility is characterized by the following parameters:

- vibration amplitude: A = 94 µm;
- frequency: f = 7000±3 Hz.

Observation: The value m_a in the “Test Bulletin” is obtained averaging the mass losses of the three tested specimens.

Testing Bulletin

Magnetostictive facility with nickel tube
Material: stainless steel GX5CrNi19-10
Test liquid: distilled water
Control amplitude: 47 µm
Mean frequency: 7000±3% Hz
Temperature of the working liquid: 20±1ºC

Tabel no. 3

Time <min>	Eroded Mass m_ax10^3 <g>	Erosion Velocity Vx10^5<g/min>
0	0	0
5	1,8	0,4
15	2,89	0,54
30	6,55	1,92
45	8,73	2,94
60	10,61	3,97
75	12,11	5,3
90	12,88	6,6
105	13,16	7,9
120	13,5	9,3
135	13,5	10,6
150	13,5	11,9
165	13,5	13,2

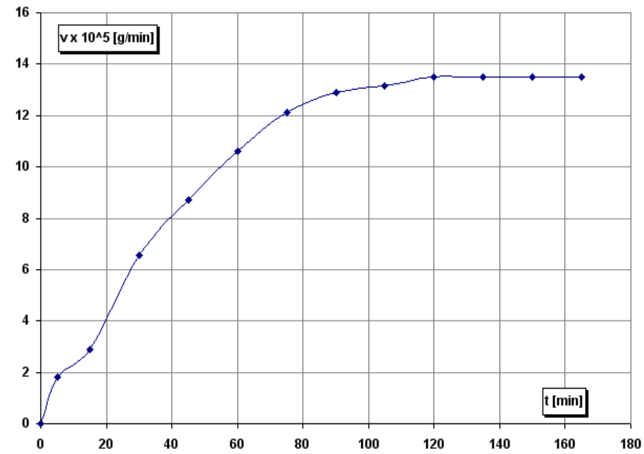


Figure no. 2 Cavitation erosion velocity

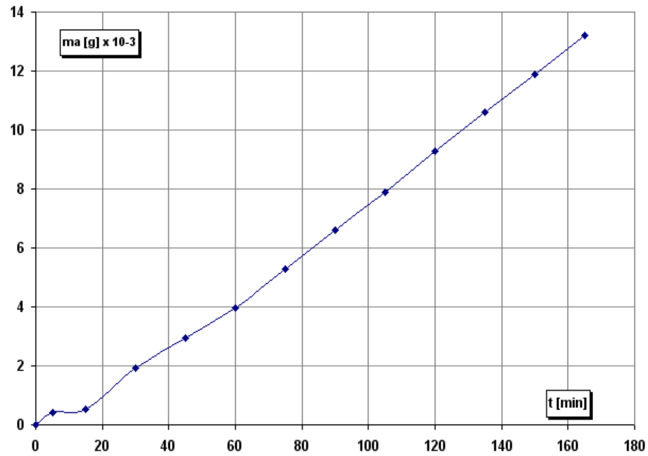
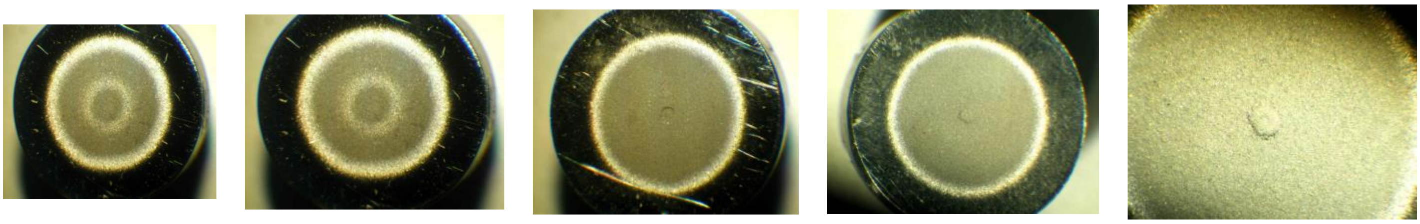


Figure no. 3 Cavitation eroded mass

The macroscopic structure of the steel GX5CrNi19-10 for different cavitation test duration is presented in Figure no. 4.



75 min MO 10X | 105 min MO 10X | 165 min MO 10X | 165 min MO 10X | 165 min MO 20X

Figure no. 4 The macroscopic structure of the steel GX5CrNi19-10 for diferent cavitation test duration

4. ANALISYS OF EXPERIMENTAL RESULTS

From Table no. 3 and Figure no. 3 it results that the total lost mass is very restrained m_a = 18.26 mg.

The characteristic curve cavitation erosion velocity function of time (Figure no. 2) presents a stabilization value vs = const. at a very low level.

The velocity in time curve presents a maximum erosion velocity equal with the stationary one $v_{max} = v_s$ and differs from the curves v(t) analyzed in [2], [3], [10], [12] for which in the first 30 minutes it presents a maximum value of the velocity $v = v_{max}$ and after that the curve shows an attenuation, till the stabilization value $v = v_s$ is attained.

In Table no. 4 there are made comparisons between the eroded masses after 165 minutes of cavitation attack and the steady state erosion velocities for many steels used in the manufacturing of hydraulic machinery [2], [3], [5], [6], [10].

The cavitation erosion of the specimens takes place slowly, gradually and without important craters.

Table no. 3

Steady state erosion velocity and eroded mass		
Steel mark	$v_s x10^5$ <g/min>	m_a $x10^3$ <g>
GX5CrNi19-10	12.50	18.26
40Cr10	35.00	45.00
GX5CrNiMo13-6-1	22.00	32.00
T07	13.60	14.50
T09	15.00	15.00

Where T07 <=> T07 CuMoMnNiCr 165-Nb
T09 <=> T09 CuMoMnNiCr 185-Ti

5. CONCLUSIONS

The austenitic steel GX5CrNi19-10 before heat treatment has an austenitic structure with carbides precipitated at grain boundaries.

After the recommended heat treatment, the grain boundaries carbides were dissolved and the homogeneity of austenite is improved.

The cavitation erosion resistance of the steel GX5CrNi19-10 became better in comparison with other steels used commonly in manufacturing the hydraulic turbines runners.

The tests carried out with the stainless steel GX5CrNi19-10 certify a good behavior at cavitation erosion and it is useful to undertake studies for employing it in hydraulic machinery manufacturing.

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