Duration of the austenitization and cavitation erosion resistance of stainless steel X5CrNi18-10

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Abstract: The cavitation erosion resistance of the stainless steel was studied with ultrasonic vibration equipment, at a frequency of 20 kHz and oscillation amplitude of 50 µm. Varying the holding duration in the annealing solution at a constant temperature, causes changes in both, in the terms of the undissolved austenite chemical compounds (carbides, inter-metallic phases) phases proportion, as well as in the size of the crystal grains.

The cavitation test results were compared with those obtained by standard OH12NDL steel used in the manufacturing of hydraulic turbine blades Kaplan of the Iron Gates I, Romania. Optical and electronic metallographic examinations and hardness tests have shown, that by heat treatment, obtaining a fine and homogeneous microstructure with a high resistance to plastic deformation, provides an improvement in the cavitation behavior .

Keywords: cavitation erosion , austenitic stainless steel , heat treatment duration

1.INTRODUCTION

The lifetime of stainless steels , regardless of structrura their parts used in manufacturing job request by cavitation [9], [11], [13], can be increased by heat treatment volume . This treatment, depending on temperature, duration of maintenance and cooling mode , leading to structural transformation , care, through - a proper routing , increase resistance to cavitation erosion . In this regard, in line with industry research , this paper presents research results of cavitation erosion , conducted on austenitic stainless steel X5CrNi18-10 , subject to three different regimes for release solution annealing (temperature constant (1050 ^{0}C) time Various maintenance , 5 , 25 and 50 minutes and cooling water.

2.THE TEST MATERIAL. THERMAL TREATAMENT APPLYED

Investigated material is stainless steel X5CrNi18-10 recommended to manufacture valves butterfly valves, from hydraulic turbine culvert pipes medium and high falls. Also, eloectodes with the structure of this material are commonly used to repair eroded areas of cavitation on the hydraulic turbine blades and rotors [1], [2], [3], [7], [8].

Values main mechanical properties provided by the manufacturer Inox Service Hungary and measured are:

- Indicated by manufacturer: R_m = 500-700 [N / mm^2],], $R_{p0.2}$ = 196 [N / mm^2], HB = 183 [daN / mm^2];

- Determined in the laboratory: R_m = 550 [N / mm^2],], $R_{p0.2}$ = 226 [N / mm^2], HB = 218 [daN / mm^2].

Chemical composition, prescribed by the manufacturer is [20]: max. 0.07% C, 17.5-19.5% Cr, 8.00-10.50% Ni, Mn max.2.0%, max.1.0% Si, max.0.045% P% S max.0.015, max.0.11% N, remainder Fe; and the experimentally determined is: 0.046% C, 17.95% Cr, 8.11% Ni, 1.46% Mn, 0.89% Si, 0.27% Cu, 0.16% W, 0.024% P, 0.019% S, Fe rest

Since cavitation erosion resistance performance are assessed by comparison with the reference steel OH12NDL, by Russian production used in the manufacture of rotor blades and hydraulic machines from Romania, render and specific mechanical properties and chemical composition of the steel [2], existing archive Laboratory of cavitation:

-mechanical properties: R_m = 650 [N / mm^2], $R_{p0.2}$ = 400 [N / mm^2], HB = 225 [daN / mm^2];

-chemical compozition: 0.1% C, 12.8% Cr, 1.25% Ni, 0.4% Mn, 0.3% Si, 0.9% Cu, 0.09% P, 0.03% S, Fe rest.

Experimental researches of cavitation have been carried out on three sets of samples heat treated by annealing for release in solution, in which the austenitization temperature was kept constant and was variable maintenance times (5 min, 25 min and 50 min), as ciclograma can track in Figure 1.

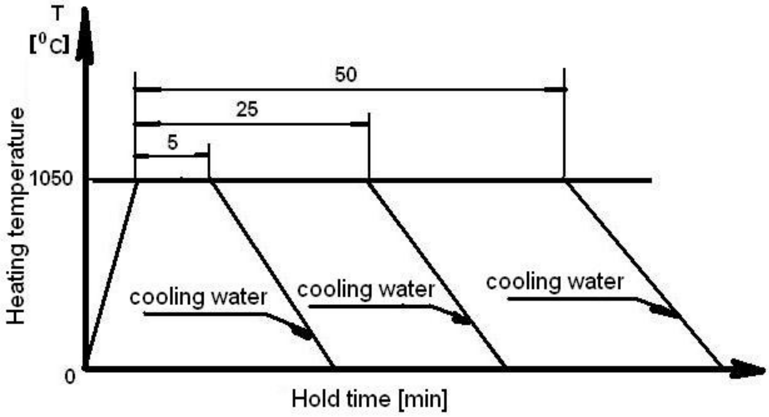
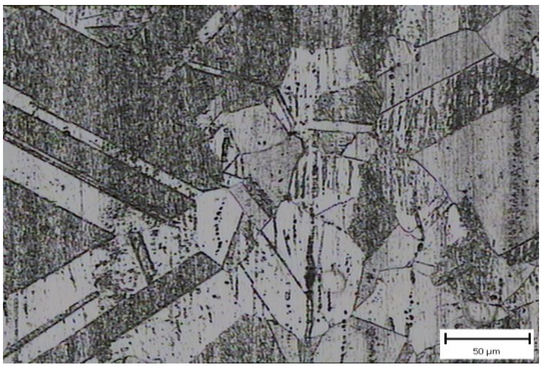
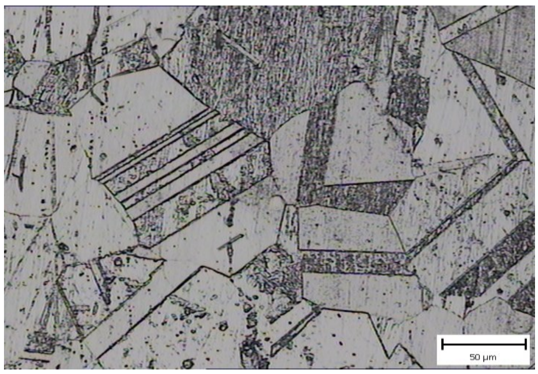


Fig.1 heat treatment Ciclograma

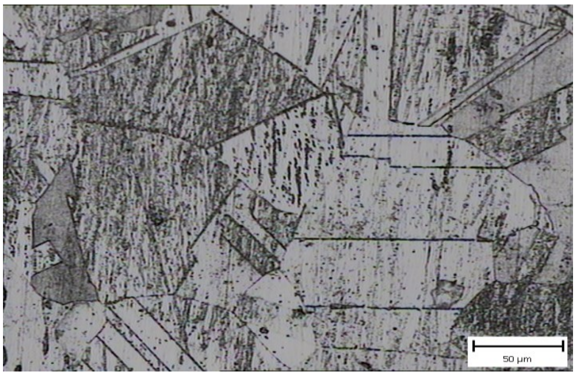
The analyzes made on optical microscopy carried out have shown that by increasing the residence times of increased crystalline grain size from 35 µm to 60 µm (Figure 2 a, b , c) as a result of increasing the phenomena of diffusion of the alloying elements carbon and alloying elements .



a)



b)



c)

Fig.2 Microstructure austenitizate samples at constant temperature and variable durations maintenance : a-1050 ^{0}C / 5 min . / Water ; b- 1050 ^{0}C / 25 min . / water c- 1050 ^{0}C / 50 min . / water

Hardness measurements showed that by increasing the duration of maintenance on temperature placement in the solution, its values decrease. The duration of maintenance for 5 minutes were obtained average values of approx. 225 HV1, for 25 min approx. 198 HV1 and for the 50 minutes, approx . 187 HV1 .

Since this mechanical property has an important influence on resistance to impact surface microjets and shock waves generated by the implosion of cavitation bubbles [3], [4], [5] , [6], [11] resulting need to correlate the heat treatment parameters annealing for release in solution (heating temperature , duration of maintenance , cooling rate) in order to increase resistance to attack destructive cavitation .

3. APPARATUS AND TEST METHOD USED

Research cavitation erosion resistance was made on crystal piezoelectric vibrator device T2 standard [9], [10], [12], following the procedures defined by international standards ASTM G32-2010 [13]. The device is in the cavitation laboratory of the University Politehnica. In addition to the procedures defined by ASTM G32 rules were respected and customs surging experience in this field for over 70 years. They relate to the manner of preparation, cleaning / washing and storage of experimental samples, measurement of mass weathered, eroded surface photographing and analyzing the optical microscope and scanning electron microscope, and the total duration of cavitation attack, limited to 165 min and divided into 12 periods intermediate 5, 10 and15 minutes [2], [3].

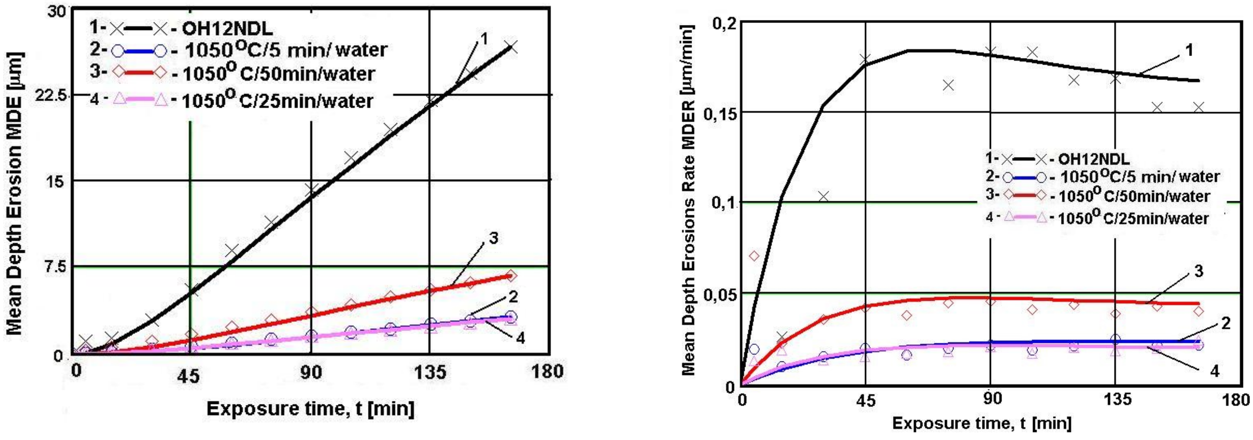
It should be mentioned that, throughout the research, device functional parameters that determine the intensity of cavitation erosion were maintained at prescribed by ASTM standards (vibration frequency = 20000 Hz ± 1%, double vibration amplitude = 50 micrometres temperature distilled water = 21 ± 1 ^{0}C, electronic ultrasonic generator power = 500 W). The diameter of the sample surface exposed to cavitation attack vibrating requirements imposed by ASTM G32, is 15.8 mm.

For each heat treatment regime, as is customary and experimental requirements, three samples were investigated.

4. EXPERIMENTAL RESULTS. ANALYSIS AND DISCUSSION

Evaluation of cavitation behavior and erosion resistance and vibrators, obtained by heat treatments is performed by comparing the experimental curves and mean height of characteristic parameters with standard OH12NDL of steel , mainly martensitic structure [2] . The diagrams are shown in Figure 3, with the values obtained experimentally and their mediation curves , giving developments cavitation attack duration , cumulative average penetration depth of erosion (MDE) and breakthrough speed (MDER) .

Mediation curves were built relationships established in the laboratory by Bordeasu analytically [2]



a) b)

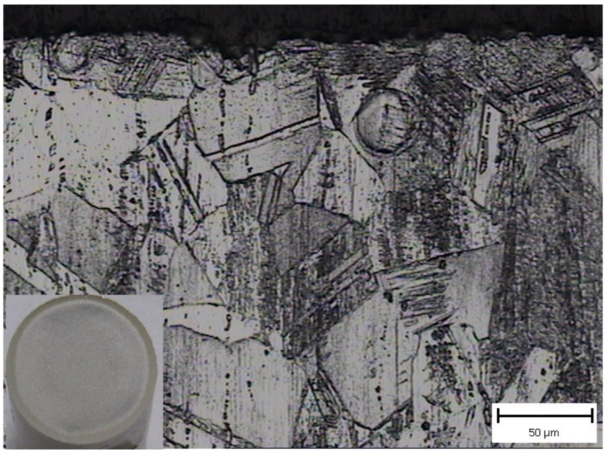
Fig.3 Vibratory cavitation erosion specific curves :

a) variation of mean depth of penetration attack duration cavitation erosion

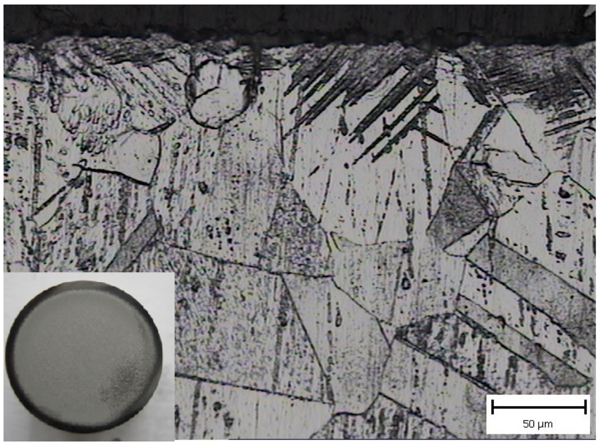
b) the variation in average speed of penetration attack duration cavitation erosion

Comparison with standard steel OH12NDL considered of University Politehnica Timisoara Laboratory as with good resistance to cavitation [2], [3], [11], shows that thermal annealing treatment for release in solution, regardless of the length of austenitization offers a substantial increase resistance to cavitation erosion. The growth after penetration erosion rate ratio MDER, Figure 3b is about 8.35 times the duration of the maintenance treatment 25 minutes at about 7.26 times the duration of maintaining for 5 minutes at about 3.80 for the hold time of 50 minutes. We believe that these increases are achieved effect better balance between mechanical properties, the hardness increase, which does not exceed the level that may adversely affect cavitation resistance by weakening ties crystal [7], [8], and presence of chemical elements (sulph to a lesser extent and nickel in greater proportion) who favor cavitation attack behavior.

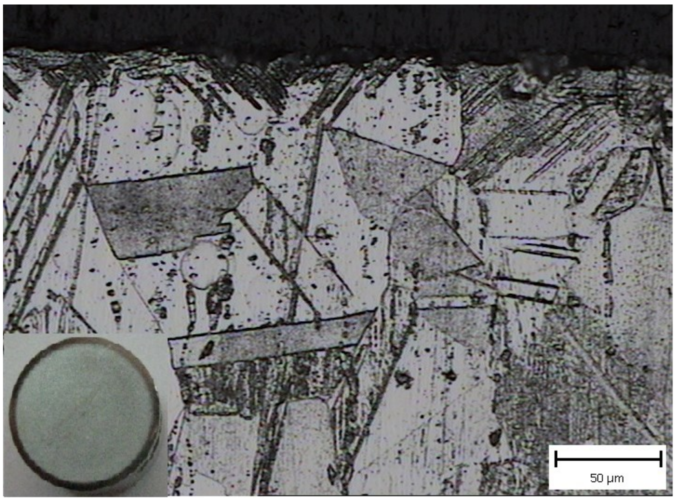
It also finds that, regardless of the specific curve, there is a significant difference between the curves developments MDE (t) -to maximum 0.183 µm after 165 minutes of cavitation erosion, fig. 3a and MDER (t), fig. 3b-up to 0.03 µm/min for austenitizate samples for 25 minutes and 5 minutes at the same temperature of 1050 ^{0}C. The explanation lies in the mechanism of transformation occurred by heat treatment and destruction, almost identical to the exposed surface, as shown in pictures taken at the end of the attack (165 minutes) with camera and especially at the optical microscul fig.4.



a)-5min



b)-25 min



c)-50 min

Fig.4 Macro and optical micrographs (x 200) surface eroded by cavitation for 165 minutes

The images in Figure 4 show that regardless of the duration of maintaining the entire exposed surface erosion is one uniform, with a lower depths developments for maintaining heat treatment lasting 25 minutes (Figure 4b) and somewhat higher for evidence-term maintenance of 50 minutes (Figure 4c). However, there is a mechanical hardening and phase-surface layer with a thickness of 60 .... 90 µm, caused by mechanical action of cavitation bubble implosion and induction of martensitic transformations.

Behavior, slightly different cast and spots surface structure are explained on the one hand, differences emerged in the degree of formal solution of chromium carbides and intermetallic phases, and on the other hand, changes in size crystal grains. It is estimated that both phenomena have determined the Vickers hardness variations, affecting cavitation resistance, as shown in evolutille specific curves, Figure 3.

5. **CONCLUSION**

The research results presented show that austenitic steel X5CrNi18-10 by hardening heat treatment for release in solution at 1050 ^{0}C with cooling water increases its resistance to cavitation erosion, well above the standard martensitic steel OH12NDL, reference hydraulic turbine blades and rotors from the hydro Romanian and Russian.

The heating temperature used to hold time of 25 minutes, and quenching in water compared with the times for maintenance for 5 minutes and 50 minutes provides the greatest increase in resistance to cavitation erosion, due to the difference in the release solution carbides of chromium and intermetallic phases, and crystalline grain size of the change.

Cracks initiated from the cavitational bubble implosion are located mainly on the crystalline grain boundaries and along maclelor annealing, and the mechanism of degradation is the ductile fracture.

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