CAVITATION EROSION OF GREY CAST IRON WITH PEARLITE MICROSTRUCTURE

RIEMSCHNEIDER Eduard, BORDEAȘU Ilare, MITELEA Ion, UȚU Ion Dragoș

University Politehnica of Timisoara, Faculty of Mechanical Engineering, Timisoara, Romania, EU

Abstract

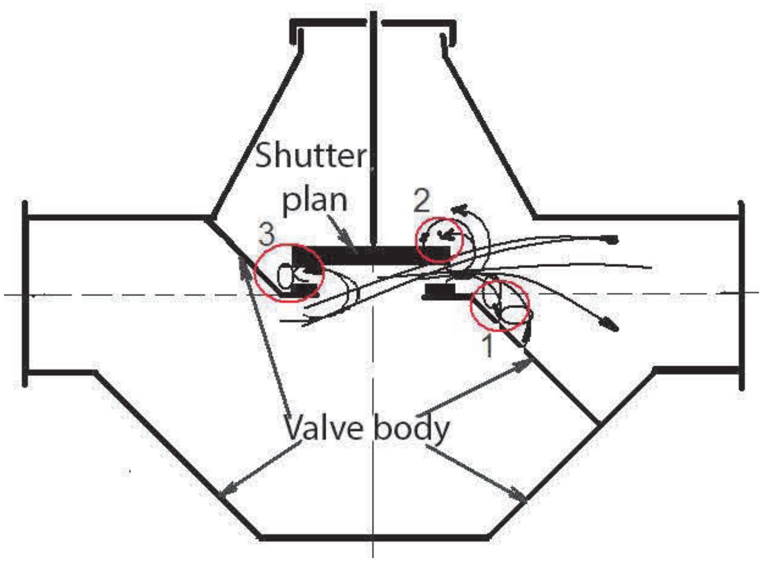
The most negative effect of cavitation is the destruction of the solid surface by micro-jets impact or shock waves generated by implosion or explosion of cavitation bubbles. It is present in all hydro-mechanical equipment where the pressures fluctuate which lead to the appearance and development of these bubbles, as a result of the flow section changing.

The paper analyses the behaviour and resistance to vibrating cavitation of grey cast iron with pearlite microstructure, used for manufacturing of components and shutters valves with metal-metal sealing. The experiment is performed on a standard vibrator device, and the evaluation is made based on microstructural images of eroded surfaces and by comparing the curves and specific parameters with those of quality carbon steel C45, which has in annealed state mechanical properties close of this grey cast iron.

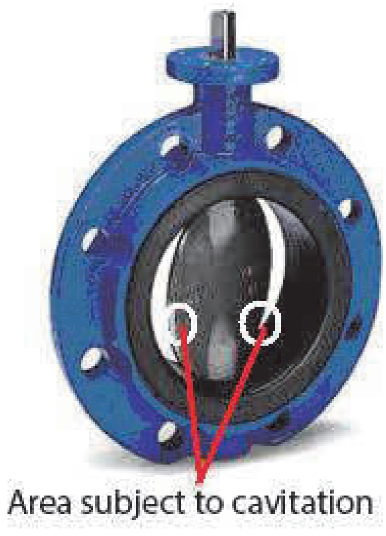
Keywords: Grey cast iron, ultrasound cavitation, microstructure

1. INTRODUCTION

Comparing with the steels, cast irons with lamellar graphite are characterized by a high vibration damping capacity. Therefore, they are mainly used for execution of the components which are mechanically vibrated during exploitation. Their mechanical properties depend on the size, quantity and distribution of graphite lamellar and the nature of the base metal mass. Because of the graphite, the cast irons have a high wear resistance, good machinability in cutting, good thermal shock resistance and a great casting capacity. Among other things, grey cast irons with pearlite microstructure are used in valves and valve bodies, but for large sizes, also by the shutter body which can be a drawer plan (**Figure 1a**) or a flat disk/valve(**Figure 1b**) .



-a-



-b-

Figure 1 Examples of areas subjected to cavitation erosion a - slide valve with plane shutter, b - valve disc with plane shutter

During operation of these components, significant material losses can appear due to loads generated by the solid surface impact with the micro-jets and shock waves produced by the cavitation bubbles implosion from the hydrodynamic field [1 - 6].

The present work aims to establish the anti-cavitation performances of a cast iron with pearlitic microstructure used for execution of some casted parts from the machinery and hydraulic equipment componence [6].

2. RESEARCH METHODOLOGY

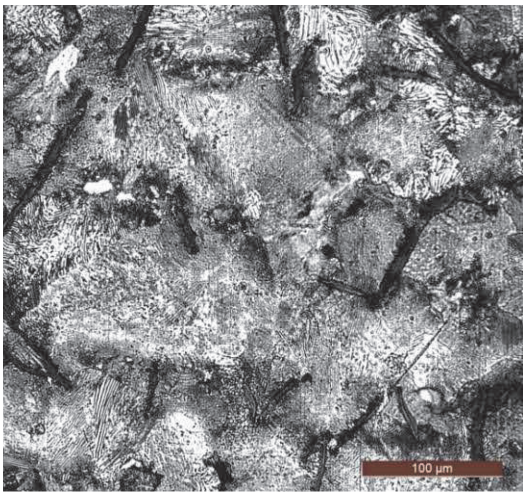
The investigated material was a cast iron EN-GJL-200 which, after the stress annealing heat treatment at 525 ± 10 ° C, has the following mechanical base characteristics values: tensile strength R_m = 247 MPa and Brinell hardness HB = 165 daN /mm^2. It is used for casting of disc shutter and valve bodies whose wall thickness is between 5 ... 80 mm.

As material for comparison was used a C45 carbon steel heat treated by annealing for softening with the following mechanical characteristics: HB = 163, Rm = 572 MPa, yield stress $Rp_{0.2}$ = 304 MPa, elongation El. 5 = 26 %, reduction of area Z = 49 %, rapture toughness KCU = 42 J / cm^2.

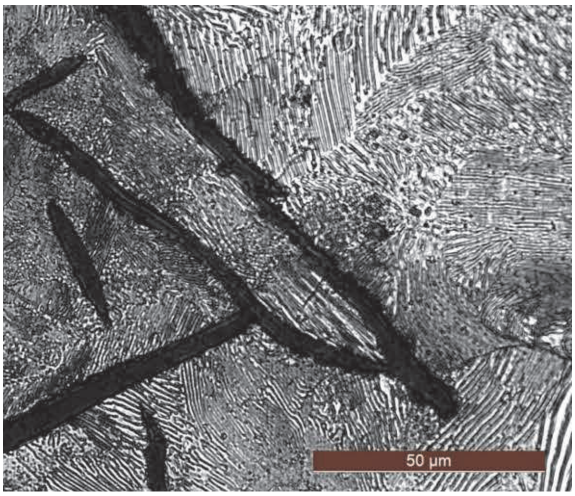
Cavitation experiments were performed on three sets of samples in drinking water from the public network on standard vibrating equipment with piezo-ceramic crystals from the Cavitation Laboratory of the University Politehnica Timisoara in strict accordance with international norms ASTM G32-2010 [6]. The test duration, as the laboratory methodology requests, was 165 minutes, being divided in 12 periods of 5, 10 and 15 minutes [7]. The performing test procedure by samples preparation, mass loss measuring, recording, processing and interpretation of experimental data are specific to the laboratory and meets the international standard [4 - 6].

3. EXPERIMENTAL RESULTS

Optical microscope metallographic examination of the analysed cast iron (**Figures 2a, b**) shows a microstructure composed of a lamellar pearlite matrix arranged in the form of colonies with different dispersion grades of the two constituent phases (**Figure 2b**), rare phosphorous eutectic islands and graphite inclusions with random distribution (**Figure 2**).



-a-



-b-

Figure 2 Microstructure of grey cast iron, EN-GJL-200: a and b represent lover and greater magnification. Etching, NITAL 3%

Diagrams from **Figures 3** and **4** present the experimental results of the cavitation test, expressed by the values obtained for the mass loss (M) and erosion rate (v) at various attack duration, approximated by analytically drawn curves with exponential equations in the form of [6]:

$M(t) = A \cdot t \cdot (1-e^{-B \cdot t})$, respectively $v(t) = A \cdot (1-e^{-B \cdot t}) + A \cdot B \cdot t \cdot e^{-B \cdot t}$ (1)

The parameters A and B are statistically established.

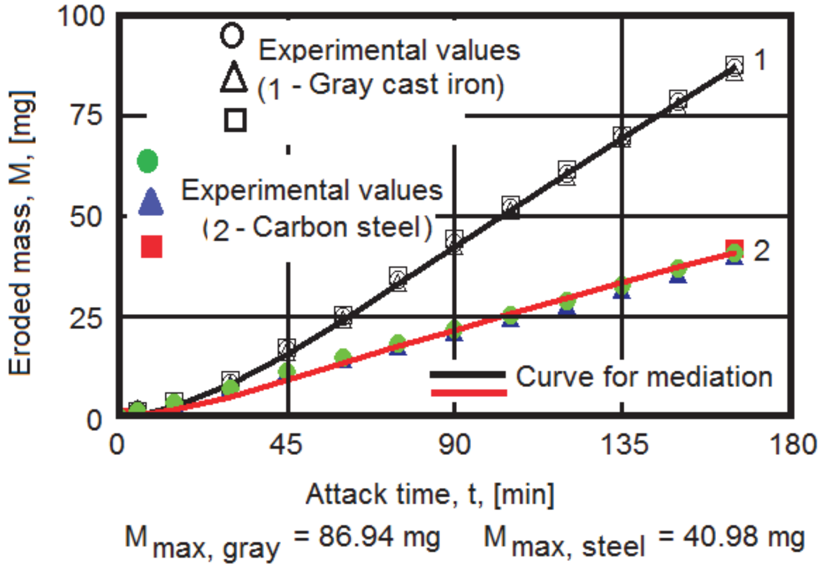


Figure 3 Variation in the duration of an attack cavitation eroded mass vibratory

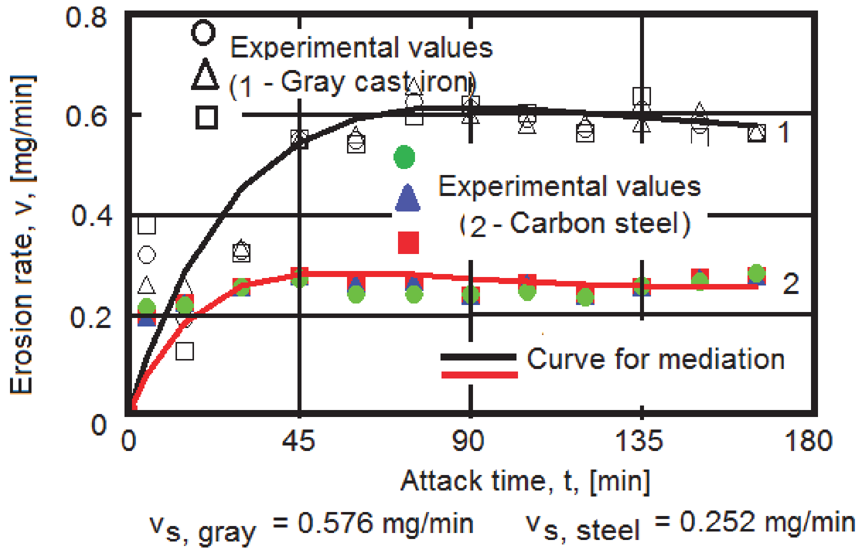


Figure 4 Variation of erosion rate with the cavitation attack duration

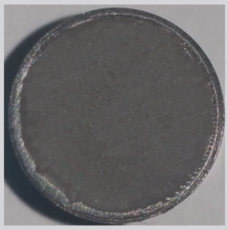
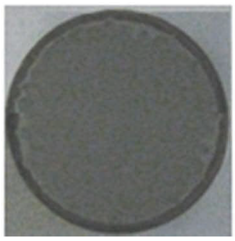
The reduced dispersions of the experimental points towards the mediation curves M(t) and v(t), which characterize the cast iron with pearlitic microstructure (the curves labelled with 1, **Figure 3**) demonstrate that, as the graphite does not significantly influence the hardness, the attacked surface suffers a constant degradation. However, due to the stress concentration effect given by the lamellar graphite, the mass losses of the cast iron tested for 165 min are with approx. 112 % higher than specific to the C45 steel (**Figure 3**).

In the erosion rate diagram from **Figure 4**, there is an overlap of the experimental points at certain exposure times (45, 60, 105, 120, 150 and 165 minutes), which shows the quite similar behaviour of the three samples at specific cavitation attack duration. Both the experimental data points dispersion, and the evolution mode of the mediation curves, according to the data from literature about the behaviour of the material to the cavitation attack [3, 5 - 6] shows that the microstructure is beneficial to the parts subjected to low intensity cavitation, such as disc and the valve body at certain operating conditions (opening angle of the shutter disk) during the flow control stage.

From the comparison with the C45 steel (curve 2, **Figure 4**) results that the erosion rate (according to the value which tends to stabilize (parameter v_s)) increases with about 128 %.

Table 1 exemplifies the samples surface images of the two metallic alloys, affected by cavitation after two values of the attack duration, so that selected to highlight the changes caused by the impact with micro-jets and shock waves developed by the hydrodynamic cavitation mechanism [4].

Table 1 Macro-graphs of the eroded surface

MIN	0	90	165
Grey cast iron EN-GJL-200			
Steel C45			

From **Table 1** clearly shows, that during increasing the cavitation attack duration the eroded area becomes wider and the caverns more profound. They confirm that the analysed cast iron has a lower cavitation erosion resistance compared than of the C45 steel.

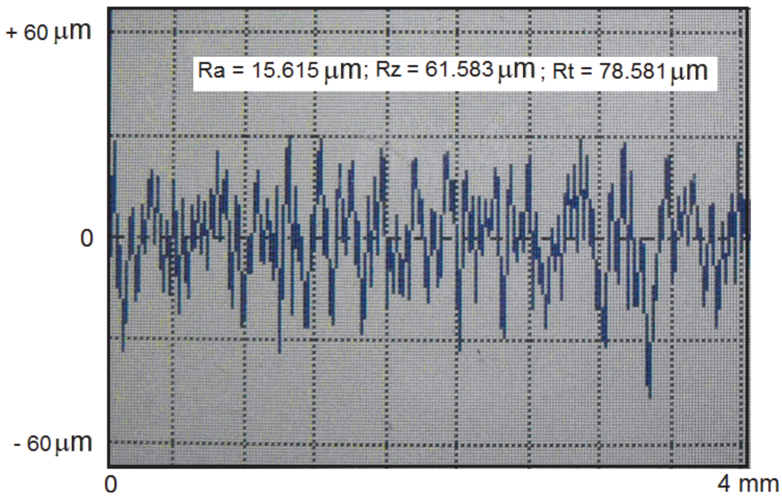


Figure 5 Roughness profile-grams, cast iron EN-GJN-200

Roughness profile-grams (**Figure 5** and **Figure 6**) recorded with a Mitutoyo SJ 201P device, achieved in random areas on one of each set of the three samples, showing an uniformity of the erosion depth (in 4 mm of length). By cast iron samples, all the roughness values are over two times higher than those specific to C45 steel. These results are in accordance with previous findings referred to the analysis of the experimental data points variance towards the mediation curves M(t) and v(t) and are a consequence of the negative effect of the graphite lamellar on the cast iron mechanical resistance.

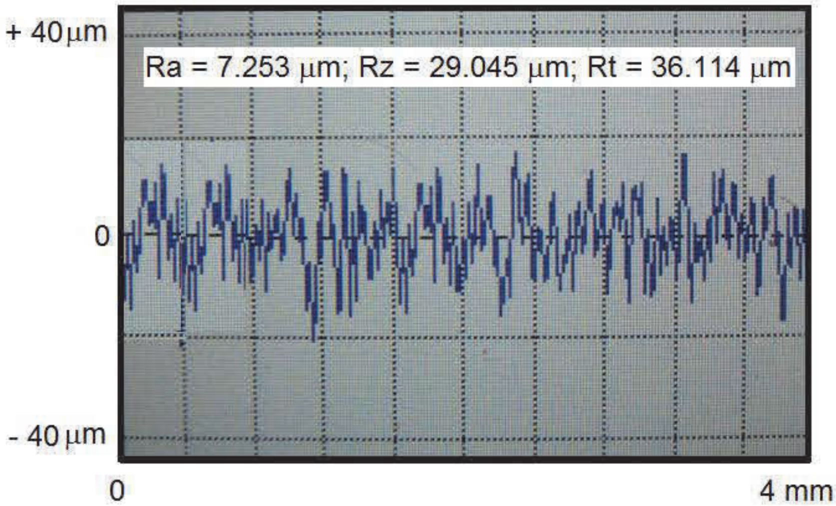


Figure 6 Roughness profile-grams of steel C45

The metallographic examination of the cavitated samples cross-sections for the for 165 min. (**Figure 7**) demonstrates that the initiation of the sample degradation occurs on the interface graphite-pearlite, the cracks extending over the entire length of the graphite lamellar and subsequently penetrating to the base metal.

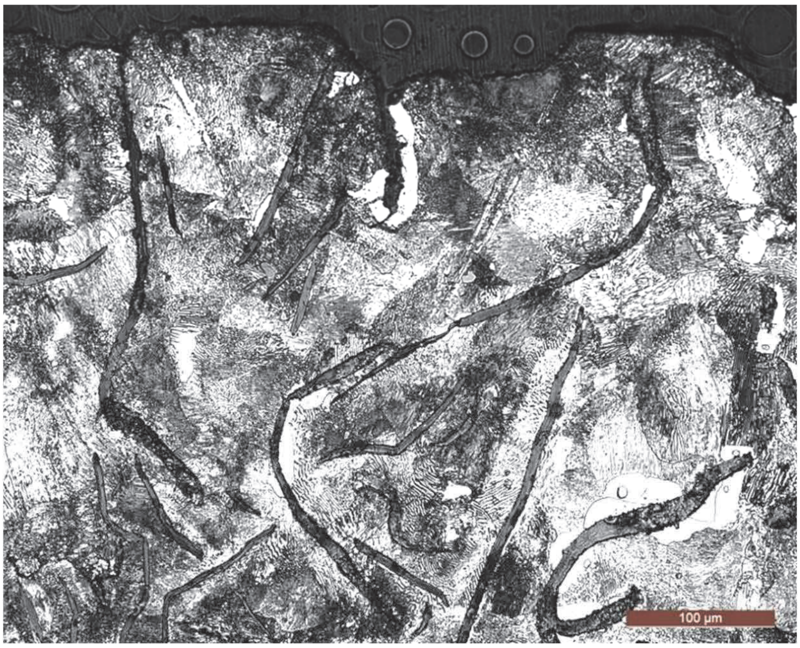


Figure 7 Microstructure of the cavitated sample cross section cavity for 165 min. Etching, NITAL 3%

4. CONCLUSIONS

1) The cavitation erosion resistance of the pearlitic cast iron EN-GJL-200 heat treated by stress relieving annealing at 525 ± 10 °C and defined by the mass loss rate is approx. 1/4 from of the annealed C45 carbon steel.

2) The surface roughness values of the cast iron samples after 165 min. cavitation attack are over 2 times greater than of the annealed C45 steel samples.
3) The structural degradation is initiated on the interface between the non-metallic constituent (graphite) and the pearlite matrix and it is developed through the fragmentation and removal of graphite lamellar that acts as stress concentrators.

REFERENCES

[1] WARREN, D.A. et al The role of ferrite in Type 316H austenitic stainless steels on the susceptibility to creep cavitation. *Materials Science and Engineering,* 2015, vol. 635 A, pp. 59 - 69.

[2] ZHEN, L. et al Vibratory cavitation erosion behaviour of AISI 304 stainless steel in water at elevated temperatures. *Wear*, 2014, vol. 321, pp. 33 - 37.

[3] STELLER, J., BOLESLAW, G.G. *International Cavitation Erosion Test Final Report*, 560/1519/2015, Gdansk, 2015.

[4] FRANC, J.P. et al *La Cavitation, Mecanismes phisiques et aspects industriels.* Press Universitaires de GRENOBLE, 1995.

[5] FRANK, J.P., MICHEL, J.M. *Fundamentals of cavitation*. Kluwer Academic Publishers-Dordrecht/Boston/London. 2004.

[6] BORDEAŞU. I. *Eroziunea cavitațională a materialelor.* Universitatea Politehnica Timisoara, 2006 - report.

[7] MITELEA, I. et al Ultrasonic cavitation erosion of nodular cast iron with ferrite-pearlite microstructure*. Ultrasonics Sonochemistry*, 2015, vol. 23, pp. 385 - 390.