Contributions for increasing the CuZnPb brass durability to cavitation erosion

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Abstract. Among the materials, often used in manufacturing details subjected to cavitation erosion, such as pump impellers, propellers, fittings, valves body, etc. there are also CuZnPb brasses. Their use in molded or laminated condition, for pieces subjected to cavitation, is of short duration due to degradation through the erosion. For this reason, any method of increasing the extension of life, is beneficial. In this direction are enrolled also the results obtained in this paper, obtained by the cavitation tests made on CuZn39Pb3 brass, subjected to three the volumetric heat treatment regimes. Appreciation of cavitation resistance, of each treatment regime, is based on the evolution of average durability $\bar{\delta}_{cav}$ defined by K.Steller. The research program, conducted on the standard vibration device with piezo ceramic crystals, in the Cavitation Laboratory of the Polytechnic University of Timisoara, shows that the best results are offered by hardening treatment.

1. Introduction

Brass is coper-zinc alloy which depending on the number of the alloing elements (lead, zinc, tin, manganese, aluminium, iron, nickel) receive different properties such as: stifness, processability, ductility, wear resistance, hardness, electric and thermal conductivity, corrosion [1-6].

Brasses have a great applicability in manufacturing because their good working qualities (obtaining semi-finished products by casting, rolling and forging, all of them can be further processed by mechanical machining, heat treatments etc.) and their physical- mechanical characteristics which gives them a great resistance to chemical corrosion and cavitation. The brasses used on industrial scale contain max. 45% Zn.

The work presents researches results on a brass with approximatively 38 % Zn but containing also lead, frequently used in the manufacturing of details exposed to cavitation erosion such as centrifugal pumps (impellers and enclosures), in the structure of hydraulic drive systems (fittings, valves, pump impellers, and hydraulic motors), in the structure of irrigation systems or water supply systems (the

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body and drawer of valves, the impellers and spiral chambers of pumps) and for the propellers of sea and river vessels [7], [8].

From he results obtained in cavitation erosion tests, in the Gdansk Laboratory (Poland) on a device with rotating disk, K. Steller realized that the energy consumed in the cavitation process can be expressed through a parameter named cavitation mean durability ($\overline{\delta}_{cav}$) [1], [2], [9], [10]. Using this parameter, he concluded thath it can be used to express the behavior to cavitation erosion and gives the possibility for ranking the materials upon theire cavitation erosion resistance.

Because the material behavior during the cavitation is not constant, fact proved by the evolution of the specific curves [11-15], but on the contrary depends on small diferences in structure, mechanical properties etc, in the present work there are compared the results obtained with the K. Steller method and the MDER one. For comparisons there were realized reserches upon 4 different state of the same material brass allied with lead.

2. Material and experimental method used

The brass obtained from the company METAL NEF HERMANNSTADT as rods with a diameter of 20 mm, apart from zinc contains also lead as principal chemical elements. In conformity with EN 10204:2004 the symbol is CuZn39Pb3. The material analyzes realized in the Laboratories of Timisoara Polytechnic University show the following results [2], [16]:

- Chemical composition: 57.7 % Cu, 38.49 % Zn, 3.3 % Pb, 0.2 % Fe, 0.1 % Ni, 0.2 % Sn and 0.01 % Al.
- Mechanical characterisitics: fracture strength R_m = 502 MPa, yielding point $R_{p0.2}$ = 365 MPa, fracture elongation = 18 %, the elastic modulus E = 97 GPa, mass density ρ = 8.47 g/cm^3;
- The biphasic structure is formed from the solid solution α and the electronic compound β'.

The selection of this brass with biphasic structure (α of type CFC and β' of type CVC), is made because in many cases there are used for pieces subjected to galling [2], [16]. Frequently there are used for manufacturing bodies taps or valves, details subjected also to cavitation but the literature does not offer data of the behavior to this types of erosion. When this parts transport liquids containing solid particles the damages occur rapidly as a result of the cumulative abrasive/cavitation erosion.

Normally for details used in casting maritime propellers, the used brasses have a Pb content under 0.5 [7], [16], even if their mechanical properties does not have superior mechanical properties to the brasses with 2.5…3.5 % Pb content. Also, brasses with lead content are frequently used in manufacture of valve seating for hydraulic drive systems [5], [14] which are sometimes also subjected to cavitation erosion.

In the present work we give the experimental results obtained upon four types of specimens, using the mentioned brasses: three of them were subjected to volume heath treatments and the fourth, for comparisons, is the untreated material (the material in the delivery state).

In Figure 1 is given a diagram presenting the applied heat treatment: quenching (heating at 800^{o}C/ and maintaining the specimen 40 minutes) followed by cooling in water and two types of tempering’s (at 400^{o}C and 250^{o}C with 40 minutes of maintenance, followed by one hour of cooling in air).

In order to interpret the results the following notations were made: A- the untreated material; B – quenched and tempered at 400^{0}C; C – quenched and tempered at 250^{0}C, D – only quenched.

The hardness measurements of the surface subjected to cavitation were done in 8 points for each type of specimen and we have obtained the following mean results: 128 HV0.5 for state A; 133.8 HV0.5 for state B; 147.9 HV0.5 for state C; 167 HV0.5 for state D.

There was applied the current experimental procedure of our laboratory [11-15], and the strict maintenance of ASTM G32-2010 prescriptions [17]. For each type of state were tested three specimens. The water temperature was maintained at 22±1^{0}C, for the whole testing time (165 minutes).

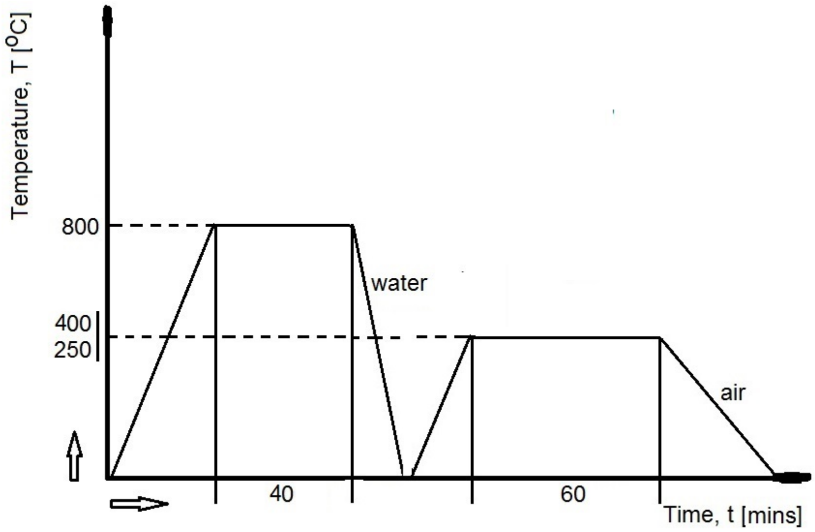


Figure 1. Heat treatments cycles

3. Experimental results

Upon the mass losses registered at each intermediate period (one for 5 and 10 minutes and afterword ten for 15 minutes) were determinate the volumes of the lost material with which were computed the curves $\bar{\delta}_{cav}(t)$, which expresses the evolution of the material resistance at cavitation erosion. The values of the experimental cavitation durability were determinate with the relation:

$$\bar{\delta}cav(t) = \frac{t(e^{3\alpha(t)}-1)}{3V(t)\alpha(t)} \tag{1}$$

where

$$\alpha(t) = \frac{3[tV(t)-V1(t)]}{t^2V(t)} \tag{2}$$

$$V(t) = At(1-e^{-Bt}) \quad \text{- is the volume eroded during } t \tag{3}$$

$$V1(t) = \int_0^t V(t)dt \quad \text{-is the area under the curve V(t)} \tag{4}$$

The evolution of the average cavitation erosion durability is presented in Figure 2.

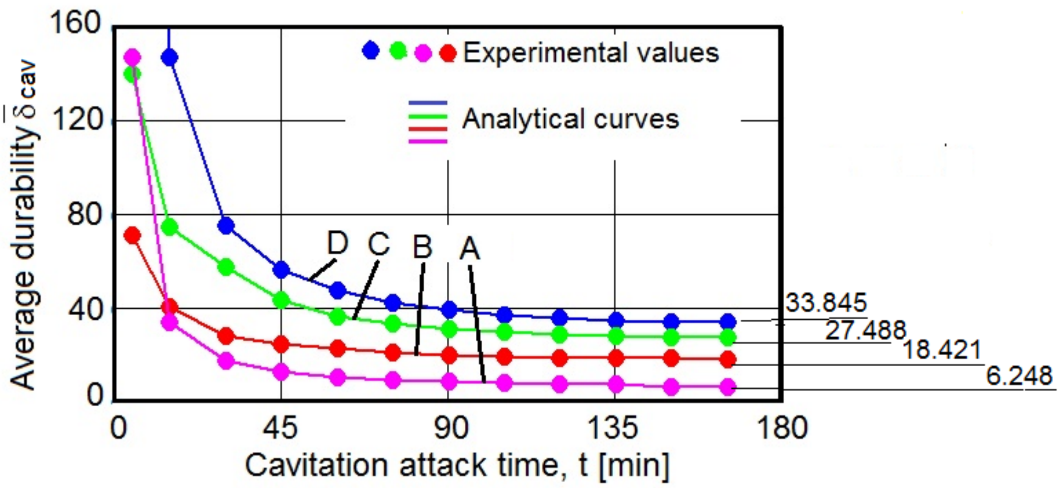


Figure 2. Average durability variation with cavitation exposure duration

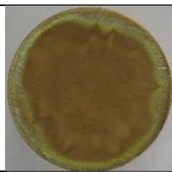
The curve shapes show that the durability of the exposed surfaces has the tendency to decrease towards some stable value. This behavior can be explained by the increase of the attacked layer hardness and the penetration of the air in the created caverns. This air acts as a bumper for the shock waves or the micro jets. This phenomenon can also be seen in the shape of erosion velocities curves.

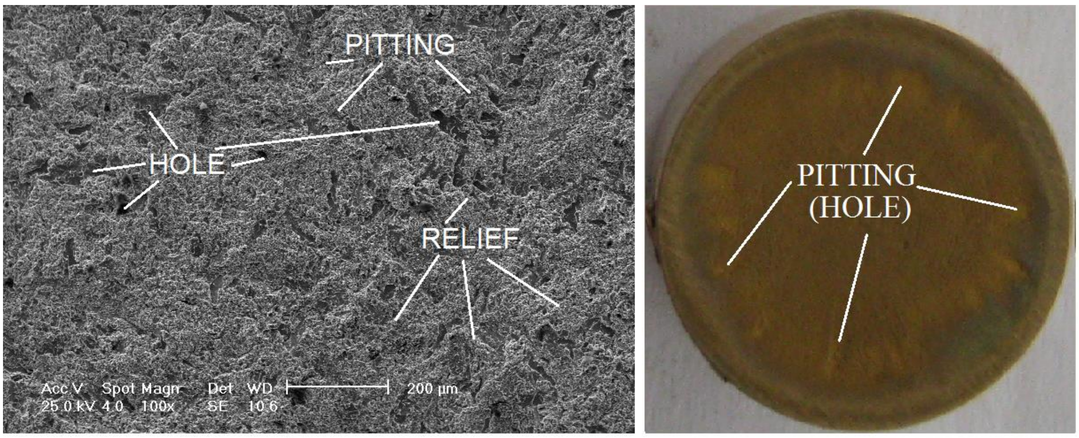
Taking as reference those final values, we obtained the following increases:

- for the state simply quenched: 441%;
- for the state quenched and tempered at 250°C: 339 %;
- for the state quenched and tempered at 400°C:194 %.

In Table 1 and Figure 3 are given global and peculiar images of the eroded surfaces after different exposure times.

Table 1. Evolution of surface degradation with the exposure duration

Exposure time	0 min	15 min	60 min	120 min	165 min
Brass in delivering state **(A)**					
Quenched and tempered 800/40+500/1h **(B)**					
Quenched and tempered 800/40+250/1h **(C)**					
Quenched 800/40 **(D)**					



a) b)

Figure 3a. Specimen A (x 100)

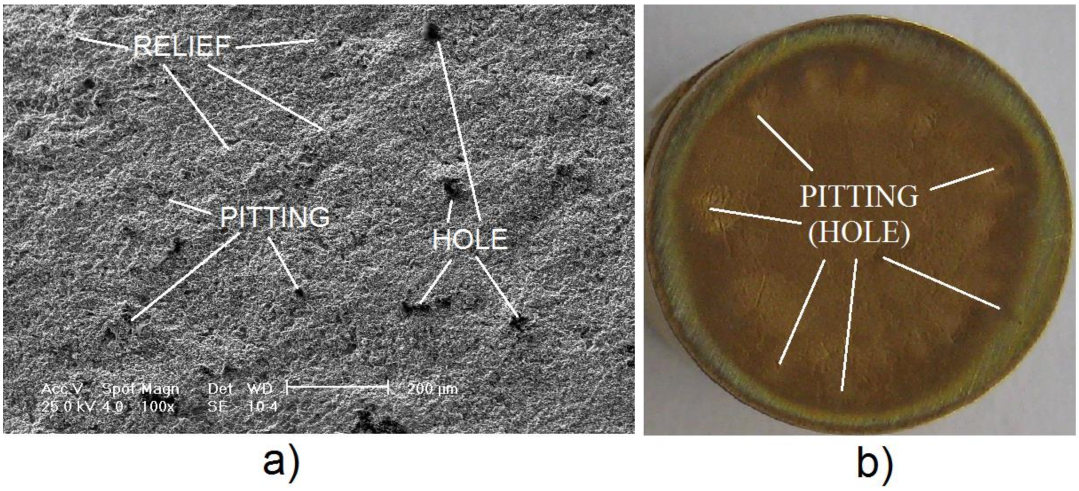


Figure 3b. Specimen B (x 100)

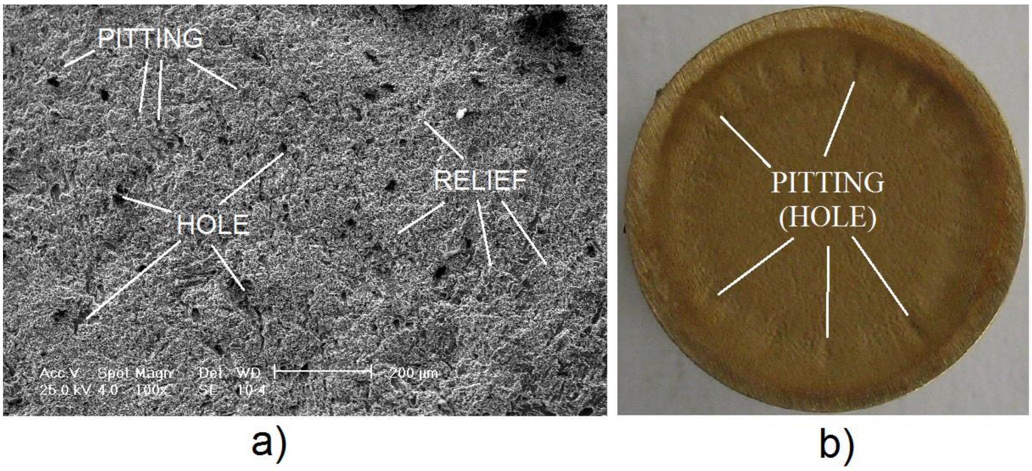


Figure 3c. Specimen C (x 100)

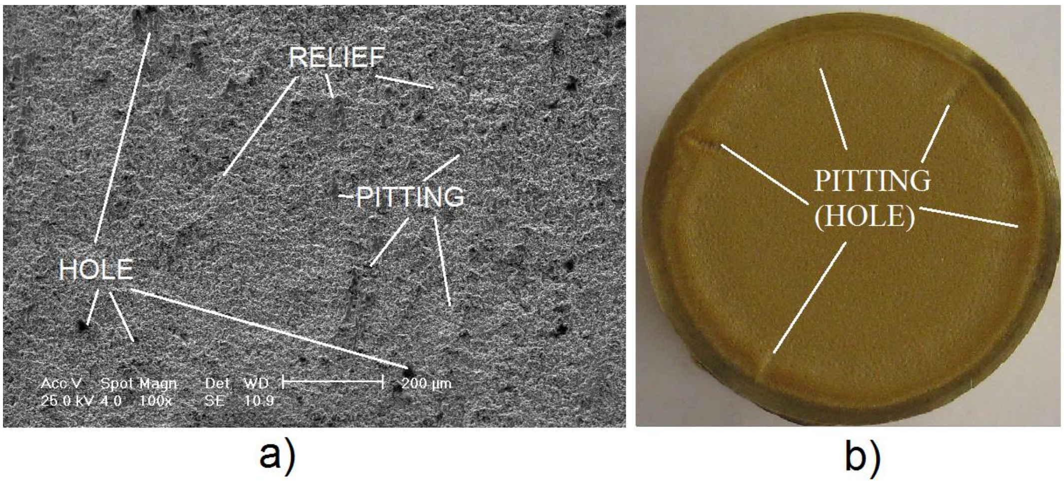


Figure 3d. Specimen D (x 100)

Figure 3. Aspects of the eroded surfaces after 165 minute of cavitation exposure (images obtained with the microscope OPLIMPUS SYX7)

Those images are in agreement with the shape of the durability curves in Figure 2 and show that, the exposed surfaces of the specimens treated by quenching followed by tempering at 250°C present the best behavior at the erosion produced by vibratory cavitation. For the certification of the $\bar{\delta}_{cav}$ parameter for the evaluation of cavitation erosion resistance, in Figure 4 there are presented also the well-known curves of mean depth erosion against time.

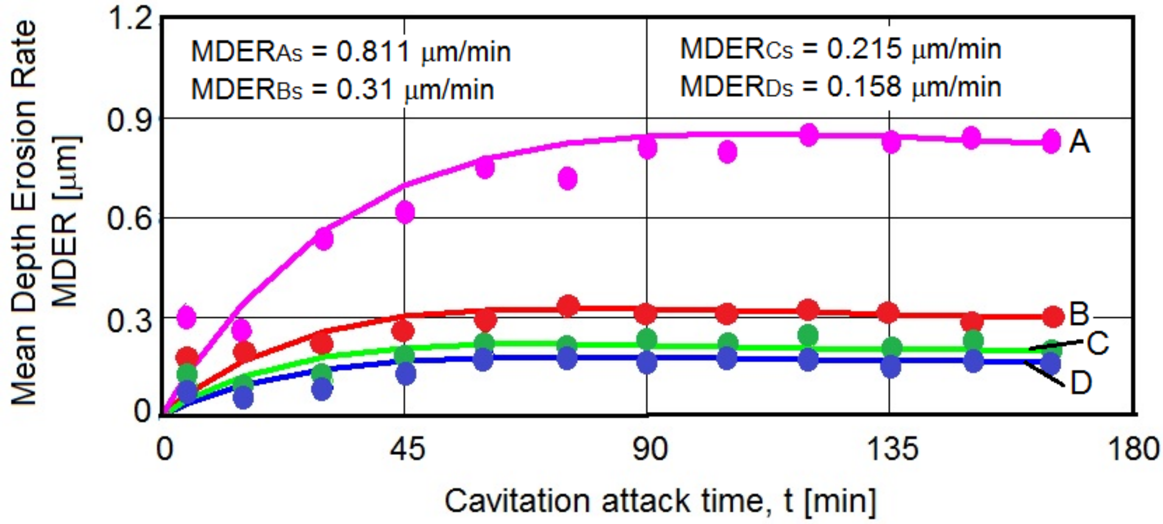


Figure 4. Mean depth erosion rate variation with cavitation exposure time

It is noted the those curves are very similar the those for $\bar{\delta}_{cav}$(t), especially in the stabilization zone. In comparison with the delivery state of the material there are the following differences:

- for quenched state: an increase of 413 %;
- for quenched and tempered at 250 °C: an increase of 277 %;
- for quenched and tempered at 400 °C : an increase of 167%.

The hierarchy mode, taking into account the values obtained by those two curves ($\bar{\delta}_{cav}$(t), and MDER (t)), is similar, but it appears evident increases in the figures (413 in comparison with 441, 277 to 339, respectively 167 to 194). Choosing one of the ways depends on the followed purpose (putting into evidence the influence of the structure or of one of the mechanical properties, etc.

4. Conclusions

The parameter "mean cavitation durability $\bar{\delta}_{cav}$" introduced by K. Steller is a good indicator to characterize the behavior to cavitation erosion.

The results of the present research show that the ranking of the 4 types of specimens (same material but different heath treatments) both with the method of MDER (Mean Depth Erosion Rate) and the mean cavitation durability $\bar{\delta}_{cav}$ is similar.

The use of one or the other of those two parameters depends by what it wants to be highlighted, as influence factor.

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