PHENOMENOLOGY OF DEGRADATION BY CAVITATION FOR HEAT TREATED Cu-Al-Ni-Fe BRONZES

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Abstract
At room temperatures, the bronzes with about 10% Al have an equilibrium microstructure composed from „α” aluminum solid solution in copper and from the eutectoid “α+γ” (γ being the compound Cu₃₂Al₁₉). The nickel presence improves the mechanical properties and wear resistance both at low and high (500…600°C) temperatures. The iron presence lead to grain finishing, improvement of mechanical properties and increased antifriction qualities. The alloys with 9-11% Al and addition of Ni, Fe, Mn could be hardened by two heat treatments: quenching and aging through dispersion.

Keywords: special bronze alloys, heat treatment, cavitation, characteristic curves, vibratory test facility

1. INTRODUCTION
Identifying and developing solutions to increase the life of the machine components operating in cavitation regime, functional components with enhanced reliability in the water, has forced researchers to focus their studies to analysis of materials both in terms of resistance to cavitation, erosion as well as in terms of phenomena that occur in the structure of the material by cavitation attack. New orientation of cavitation erosion research is to identify the mechanisms that cause changes at micro aspect and establishing manufacturing technologies of materials component structure and physico-mechanical characteristics are able to confer resistance to cavitation attack.

Changing properties of the surface layer by volume heat treatment by classical annealing, laser surface treatment and ion implantation can lead to increased approximately 2-3 times the cavitation incubation period, so its delay the appeared time. Materials with crystalline structure with faces centered are isotropic and less sensitive to strain rate increase. The good behaviour is observed for nickel and copper and the lower is for aluminium. Depending on the composition and thermal regime, copper alloys can be single phase or multiphase. Copper alloys are composed of phase α, and the phase β, or phase combination of α and β or solid solution and dispersed products. Phase α is plastic and has a low strength in cavitation corrosion process. Phase β is hard and a plastic behaviour lower. Percentage growth of β phase has the effect the cavitation improvement. The main objective studied in experimental testing had the focused the optimal region identification of heat treatment to obtain the improvement in cavitational process for brass alloys.

2. APPARATUS AND RESEARCH METHOD. MATERIAL INVESTIGATION.
The ultrasound cavitation testing has been performed using a specialized equipment manufacturer after the ASTM G32-2010 norm. The work medium was normal water with a temperature kept at 22 +/- 1 0C, with refrigeration equipment. The ultrasound equipment was designed for a processing frequency of 20 kHz +/- 200Hz, with a micro vibration amplitude of 50µm +/- 2,5 µm. Were tested a range of three specimens of each type of material, the version without and with heat treatment. The specimens were weighed as prescribed with a super finished surface with roughness of Ra= 0,2 -0,8 µm. The total duration of exposure was 165 min, with intervals of 5 min, 10 min and 10 intervals of 15 minutes each. After each interval the specimens were weighed to an accuracy of five decimal places, determine the mass loss by erosion cavitation, the
average depth of erosion (MDE) and also erosion rate (MDER). The cavitation erosion surfaces were investigated using the optical microscope and also scanning microscope SEM. In tables 1 and 2 are presented the mechanical properties and chemical composition for naval brass investigated. The chemical composition was obtained with X ray INNOV-X-SYSTEMS spectrometer.

Tab.1

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Al</th>
<th>Fe</th>
<th>Ni</th>
<th>Mn</th>
<th>Cu</th>
<th>Si</th>
<th>Mo</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPCO 45</td>
<td>11,19</td>
<td>3,6</td>
<td>4,61</td>
<td>0,66</td>
<td>79,16</td>
<td>0,69</td>
<td>0,0306</td>
<td>0,0490</td>
</tr>
<tr>
<td>AMCO M4</td>
<td>12,01</td>
<td>5,12</td>
<td>4,83</td>
<td>0,84</td>
<td>76,41</td>
<td>0,7</td>
<td>0,0169</td>
<td>0,0469</td>
</tr>
</tbody>
</table>

Tab. 2

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Rm</th>
<th>Rp 0.5</th>
<th>A5</th>
<th>HB30</th>
<th>HRB</th>
<th>R_cM</th>
<th>E</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPCO 45</td>
<td>814</td>
<td>512</td>
<td>15</td>
<td>228</td>
<td>98</td>
<td>483</td>
<td>117</td>
<td>7,53</td>
</tr>
<tr>
<td>AMCO M4</td>
<td>1000</td>
<td>793</td>
<td>8</td>
<td>286</td>
<td>29</td>
<td>538</td>
<td>124</td>
<td>7,45</td>
</tr>
</tbody>
</table>

The data from tables 1 and 2 showed that the brass AMCO M4, with high percent of Ni, Al and Mn, has the superior mechanical properties which can lead to high cavitation strength.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS.

From bars laminate were performed cylindrical specimens according to ASTM G32-2010 norm, which were supposed to heat treatment quenching at variable temperature of 890 and 860°C with cooling in water and Recovery at 520 and 860°C, with cooling in air, according figure 1.

![Fig. 1 Thermal treatment with quenching followed by recovery](image)

The alloy microstructure after heat treatment are presented in figure 2, material AMCO 45 and figure 3, material AMCO M4.
The specimens were tested at ultrasonic cavitation erosion, the loss of mass were determined by analytical balance with accuracy of 0.01 mg. The eroded surfaces by ultrasonic cavitation 165 minutes were assessed by optical microscopy and scanning electron microscopy. Time evolution of cavitation degradation, evidenced by optical microscopy and digital images are presented in Figure 4 for AMCO 45 alloy without heat treatment and heat treatment, respectively, in Figure 5.

For a clearer image of cavitation erosion evolution for AMPCO 45 alloy in these two situations without heat treatment and with heat treatment, laboratory data obtained were processed statistically representing the dispersion bands using error the estimated and the regression polynomial curve. These representation
illustrated in Figure 6, using the cumulative mass loss (average of three samples), the average erosion penetration depth (MDE) and for the rate of erosion (MDER) were obtained for AMPCO 45 alloy without heat treatment figure 6A and 6B with heat treatment.

![Graph A](image)

**Fig. 6 A** Mass loss variation and erosion rate variation with cavitation time in minute, AMPCO 45, without heat treatment

![Graph B](image)

**Fig. 6 B** Mass loss variation and erosion rate variation with cavitation time AMPCO 45, with heat treatment

Ultrasound cavitation damage time evolution, for AMCO M4 alloy heat treated are presented in images 7 with optical microscopy representation, and also for AMCO M4 without heat treatment in figure 8.

![Optical Microscopy Images](image)

**Fig. 7** Optical microscopy of cavitation damage of material AMCO M4 without heat treatment
Fig. 8 Optical microscopy of cavitation damage of material AMCO M4 with heat treatment

For a clearer image of cavitation erosion evolution for AMCO M4 alloy in these two situations without heat treatment and with heat treatment, laboratory data obtained were processed statistically representing the dispersion bands using error the estimated and the regression polynomial curve. These representation illustrated in Figure 9, using the cumulative mass loss (average of three samples), the average erosion penetration depth (MDE) and for the rate of erosion (MDER) were obtained for AMCO M4 alloy without heat treatment figure 9A and 9B with heat treatment.

Fig. 9A Mass loss variation and erosion rate variation with cavitation time in minute, AMCO M4, without heat treatment

Fig 9B Mass loss variation and erosion rate variation with cavitation time AMCO M4, with heat treatment

Investigations of energy dispersion X-ray (EDX) conducted for these two alloys tested in erosion cavitational shows a decrease in aluminum concentration analyzed surfaces due to compounds expulsion during cavitation process. AMCO 45 alloy without heat treatment had a loss of aluminum percentage in the central zone from 11.9% to 9.12%, and for AMCO M4 alloy without heat treatment has an aluminum percentage loss
in the central area of 12.01 % to 10.94%. The erosion cavitation surface analysis with scanning electron microscope, Figure 10 A and the optical microscope, Figure 10B shows a specific uniform degradation surface with small craters appeared on the edge limit of the grains.

**Fig.10** Micrographic image surface investigation for alloy AMCO 45

4. **CONCLUSIONS**

1. Quenching heat treatment for implementing the recovery solution followed by aging lead to an increase of cavitation erosion for naval bronzes for alloy AMCO 45 about 2 times, and about 2.5 times for AMCO M4 alloy compared with material alloys without heat treatment.

2. Better strength in erosion cavitation process for AMCO M4 alloy compared with AMPCO 45 alloy is a consequence of the higher alloying components which leads to higher values of all characteristics of mechanical strength.

3. EDX investigations of areas degraded by cavitation for these two types alloys AMPCO 45 and AMCO M4, with and without heat treatment show a decrease in aluminium concentration, a phenomenon due to the expulsion of its inter metallic compounds with alloying elements presents in the chemical composition.

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REFERENCES


