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COMPARATIVE STUDY REGARDING THE CAVITATION EROSION BEHAVIOR OF Cu AND Al ALLOYS

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***Abstract* - The paper presents a comparative study regarding the behavior of copper and aluminum alloys during cavitation erosion tests where the results were obtained using an ultrasound installation. The ultrasound installation means (in this case) a cavitation stand (described in the paper) from the „Eftimie Murgu” University of Resita. The tested specimens, each with sizes of 16x16 mm, were taken from copper respectively aluminum alloys castings were analyzed to compare the cavitation erosion resistance and the metallographic structure.**

***Keywords* -** Copper and aluminum alloys, cavitation erosion resistance, metallographic structure

I. INTRODUCTION

Copper and aluminum alloys are used for the casting of water pump rotors, for bearings, piston rods, glides and other castings that are resistant to corrosion and have antifriction properties [1].

In this paper, these alloys resistant to water corrosion are tested to underline their resistance to cavitation erosion as in the papers [2,3].

The cavitation erosion refers to the destruction of the wet surface, as a result of an ensemble of phenomena simulated by mechanical, chemical, electrical and thermal environments, which takes place in the water due to the cavitation phenomenon [4]; phenomenon which is described as a process of formation and development of bubbles or cavities filled with gas and vapors in the liquid mass [5,6].

II. EXPERIMENTAL STAND AND THE WORK PROCEDURE

The experimental stand from the „Eftimie Murgu” University of Resita is presented in Fig. 1:

Fig. 1 Cavitation stand composed of vibrator apparatus, ultrasound generator and digital thermometer

This stand makes part from the ultrasound installations category used in the scientific research of the cavitation phenomenon, respectively of the materials cavitation erosion [7] and it is composed of the ultrasound generator (right side in Fig. 1) and also an piezo-electric converter, a mechanical transformer, a sonotrode, a liquid vessel inside of which a serpentine is introduced to maintain the water temperature and a bracket (Fig. 2) for specimens processed under a cubic shape from copper respectively aluminum alloys.

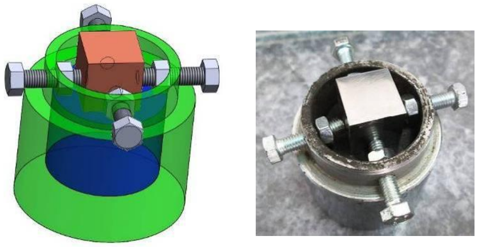

Fig. 2 The 3D design using the SolidWorks software [8,9] and the practical realization of the bracket

The experiment procedure is shown in Fig. 3, with the following specifications:

- according to G32-10 standards (regarding the testing parameters [10]) and the G32-92 standards (regarding the testing method that is used [11]), the parameters values were set at 20 ±0.1 kHz, for the frequency and at 50 μm, for the amplitude, and the method used was the indirect cavitation method [12÷15], which supposes that the sonotrode vibrating in the liquid environment on the top surface of the specimen at a distance of 0.6 mm;
- after each testing period (most were of 30 minutes), the specimens were soaked into alcohol, dried with

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compressed air and then measured for material mass loss by using a digital balance with a reading capacity of 0.01 mg [16,17];

- after a total testing period the obtained values for the realization of experimental curves for the analytic curves of material mass loss and the cavitation erosion rates according to time periods, was presented with the help of graphics.

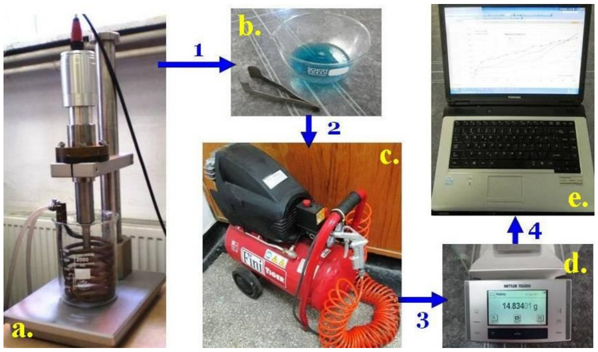


Fig. 3 The main steps of the work procedure of cavitation erosion experimental trials

III. PREVIOUS RESEARCH ON CAVITATION EROSION AND DESCRIPTION OF THE ANALYZED COPPER AND ALUMINUM ALLOYS

The authors present in the paper [18] a study regarding the behavior to cavitation erosion of the following copper alloys: CuAl9, CuAl10Fe2 and CuSn7Pb15.

These alloys were tested for a total time of 360 minutes, during which the material CuAl10Fe2 compared to the other two materials analyzed, presented the best behavior to cavitation erosion.

A comparative study is thus presented in this paper regarding the behavior to cavitation erosion of a specimen from the same aluminum bronze type (CuAl10Fe2), which was studied for a total time of 420 minutes, and a specimen of AlSi12, which the cavitation erosion behavior was studied for a total time of 210 minutes.

The reasons and motivations of this differentiation are found in the material quantity lost after the tests were realized.

Starting from the same ideas as in the paper [18], regarding the cavitation erosion behavior of castings realized from copper and aluminum alloys, as being dependent on the structure of alloys in a solid state, respectively on the metallographic phases and constituents, this paper presents the study regarding the analysis of the metallographic structures of these alloys.

The presence of non-metallic inclusions in the structure separated during solidification at the limit of grains belonging to the solid alpha solution, which strongly influence the behavior to cavitation erosion of castings, supposes a connection between the cavitation erosion behavior of castings from these non-ferrous alloys and their metallographic structure.

In Tables 1 and 2 the chemical compositions indicated by Romanian standards for the copper based alloy [19] are presented along with those of the aluminum based alloy [20], and in Tables 3 and 4, the chemical compositions determined for analyzed alloys that represent the study object of this paper are presented.

TABLE 1 Chem. composition set for CuAl10Fe2 alloys [%]

Cu	**Sn**	**Pb**	**Al**	**Fe**
83.0-89.5	0.20	0.10	8.5-10.5	1.5-3.3
Ni	Zn	Mn	Si	Mg
Max. 1.5	Max. 0.50	Max. 1.0	Max. 0.20	Max. 0.05

TABLE 2 Chem. composition set for AlSi12 [%] alloys

Si	**Fe**	**Mn**	**Cu**	**Zn**
10.5-13.5	0.65	0.55	0.15	0.15
Ti	Mg	Ni	Pb	-
Max. 0.20	Max. 0.10	Max. 0.10	Max. 0.10	-

TABLE 3 Chem. composition for the analyzed CuAl10Fe2 alloy [%]

Cu	**Al**	**Fe**	**Sn**
80.1	9.6	2.66	<0.02
Zn	Ni	Mn	-
<0.04	0.19	0.10	-

TABLE 4 Chem. composition for the analyzed AlSi12 alloy [%]

Si	**Fe**	**Mn**	**Cu**
11.4	0.45	0.44	0.01
Zn	Ti	Mg	Zn
0.02	0.01	<0.005	0.02

IV. THE EXPERIMENTAL RESULTS

In Table 5 the experimental results for the specimen from copper alloy are presented, alloy which was subjected to test for a total time of 420 minutes, and its graphic are representation in Figs. 4 and 5; also in Table 6 the results for the specimen taken from the aluminum alloy are presented, alloy subjected to testing for a total time of 210 minutes, and its graphic are representation in Figs. 6 and 7.

TABLE 5 The experimental results for the CuAl10Fe2 alloy

Accuml. time	**Specimen mass**	**Accuml. eroded mass**	**Cavitation erosion rate**
t [min]	m [mg]	m_c [mg]	v_{ec} [mg/h]
0	29848.5	0	0.000
10	29848.4	0.1	0.430
30	29848.37	0.13	0.094
60	29848.32	0.18	0.130
90	29848.24	0.26	0.230
120	29848.09	0.41	0.360
150	29847.88	0.62	0.490
180	29847.6	0.9	1.060
210	29846.82	1.68	1.950
240	29845.65	2.85	2.510
270	29844.31	4.19	3.060
300	29842.59	5.91	3.630
330	29840.68	7.82	3.760
360	29838.83	9.67	3.620

Accuml. time	**Specimen mass**	**Accuml. eroded mass**	**Cavitation erosion rate**
t [min]	m [mg]	m_c [mg]	v_{ec} [mg/h]
390	29837.06	11.44	3.730
420	29835.1	13.4	4.110

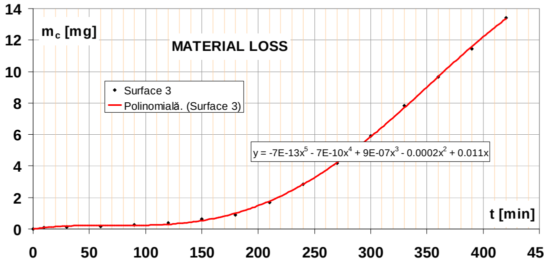


Fig. 4 Material loss curve for CuAl10Fe2

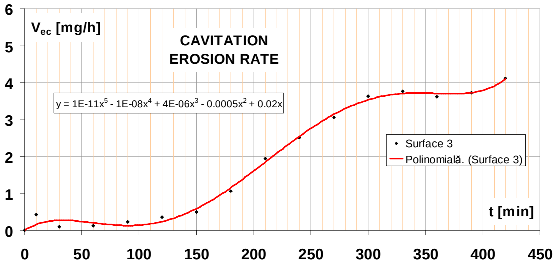


Fig. 5 Cavitation erosion rate curve for CuAl10Fe2

TABLE 6 The experimental results for AlSi12 alloy

Accumul. time	**Specimen mass**	**Accuml. eroded mass**	**Cavitation erosion rate**
t [min]	m [mg]	m_c [mg]	v_{ec} [mg/h]
0	10623.8	0	0.000
10	10622.21	1.59	17.660
30	10610.91	12.89	41.148
60	10584.9	38.9	44.080
90	10566.83	56.97	33.750
120	10551.15	72.65	35.030
150	10531.8	92	42.990
180	10508.16	115.64	44.230
210	10487.57	136.23	38.130

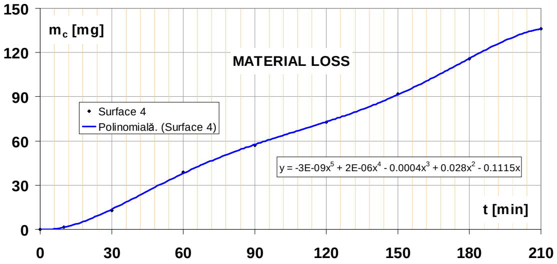


Fig. 6 Material loss curve for AlSi12

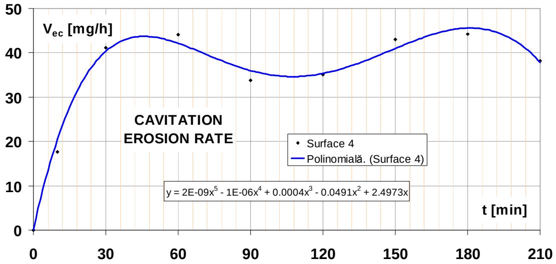


Fig. 7 Cavitation erosion rate curve for AlSi12

In the case of each of the two specimens from copper and aluminum alloys subjected to experiments regarding their cavitation erosion resistance, the cumulated mass loss during the experimental testing exponentially increased, so that at the end of these test the following results were obtained (in ascending order): 13.4 mg for CuAl10Fe2 and 136.23 mg for AlSi12.

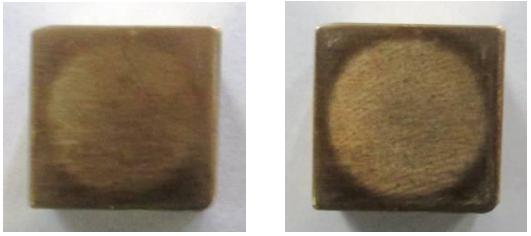
Due to the fact that the most important cumulated mass loss is present in the specimen taken from the AlSi12 alloy, in which the testing time was ½ smaller in comparison to the total testing time of the CuAl10Fe2 alloy, the prolongation of the testing time not being necessary for this specimen is clearly explained.

Further, Table 7 presents the maximum value of accumulated material loss, the maximum value of cavitation erosion rate and the number of the accumulated time periods.

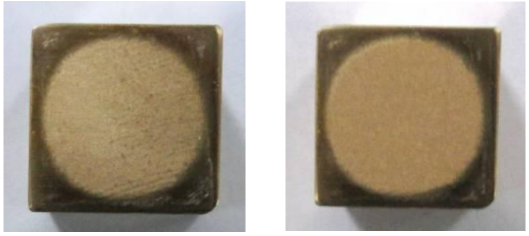
TABLE 7 Comparative studies of the most important values

Alloy type	**Max. value of accumul. material loss**	**Max. value of cavitation erosion rate [mg/h]**	**Number of accumulated time periods**
CuAl10 Fe2	13.4	4.110	15 (1 – 10, 1 – 20, 13 – 30 minutes)
AlSi12	136.23	44.230	8 (1 – 5, 1 – 10, 6 – 15 minutes)

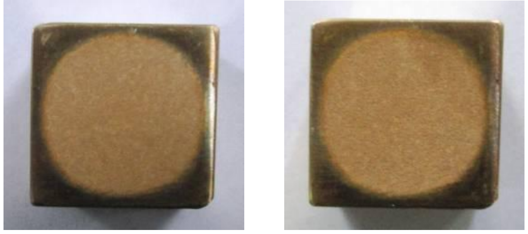
Taking into consideration the aspect of eroded specimen surfaces of the alloys tested, in Fig. 8 the frontal surfaces of the specimen taken from the copper alloy is presented, and in Fig. 9, the frontal surfaces of the specimen taken from the eroded aluminum alloy is presented.



a) 60 min. b) 120 min.

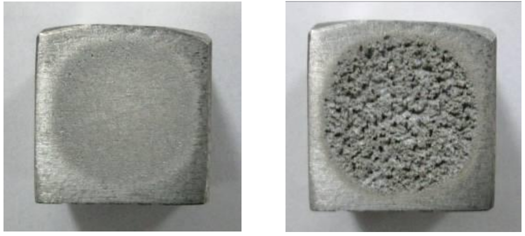


c) 180 min. d) 300 min.

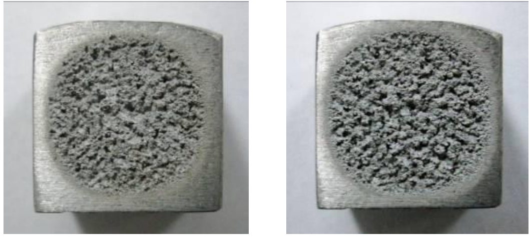


e) 360 min. f) 420 min.

Fig. 8 Images of the eroded surface for specimen of the CuAl10Fe2 alloy



a) 10 min. b) 90 min.

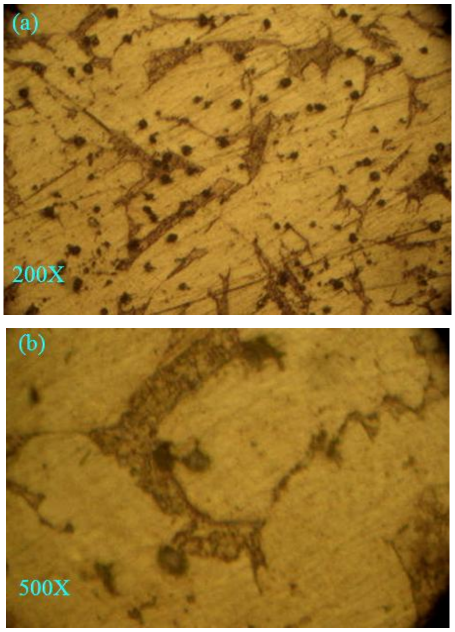


c) 120 min. d) 210 min.

Fig. 9 Images of the eroded surface for specimen of the AlSi12 alloy

V. COMMENTS ON THE METALLOGRAPHIC STRUCTURES

In Fig. 10 the metallographic structures of copper alloys are presented, realized on specimens subjected to cavitation erosions resistance trials.



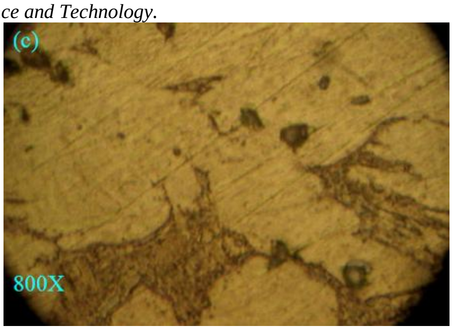


Fig. 10 Metallographic structures of the specimen from the CuAl10Fe2 alloy

In the structure of the CuAl10Fe2 alloy, the α solid solution and the $\alpha+\gamma_2$ eutectoid can be observed (intermetallic compound $Cu_{32}Al_{19}$), but in smaller sizes, fact which indicates the realization of corresponding modifications produced by the iron added for alloy alignment.

In the structure of the copper alloy, small separations of the $FeAl_3$ compound can also be observed, which are uniformly distributed in the α solid solution (Fig. 10 b and c).

In this case, the intermetallic compound $Cu_{32}Al_{19}$ is found in a less distributed form in the interior of crystals from the α solid solution; but its separation under the shape of interrupted networks can be observed at the limit of crystals from the solid solution.

In Fig. 11 the metallographic structures of aluminum alloys are presented.

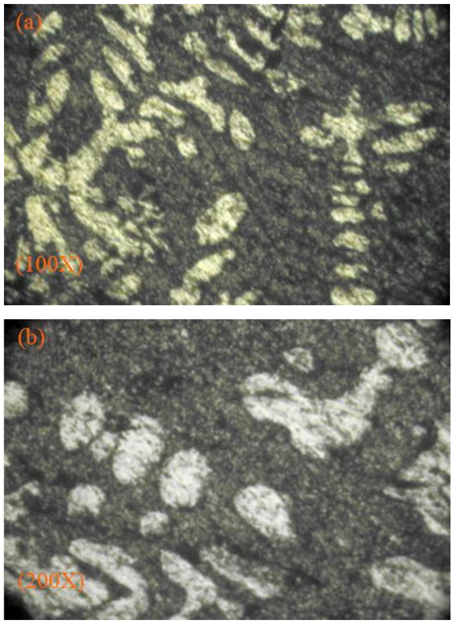


Fig. 11 Metallographic structures of the specimen taken from the AlSi12 alloy

The structure of the specimen taken from the AlSi12 alloy is composed of the α solid solution and from normal, fine and uniformly distributed eutectic in the matrix of the α solid solution.

Even if the eutectic presents a fine structure which may determine an increase in tensile strength, stretch resistance and elongation resistance, the cavitation erosion behavior of alloy is very poor.

VI. CONCLUSIONS

The following conclusions can be made:

- the specimen taken from the AlSi12 aluminum alloy, after evaluation, has presented a cumulated mass loss of 10 times bigger than in the case of the CuAl10Fe2 bronze aluminum alloy;
- even if the aluminum, respectively the aluminum alloys are considered to be the most resistant materials to water corrosions, as a result of fine and resistant film formation of Al_2O_3, from the point of view of cavitation erosion resistance presents poor results in comparison to bronze aluminum alloys;
- for the extremely poor behavior of the AlSi12 alloy during the testing regarding the cavitation erosion resistance, the use of such an non-ferrous alloy is not recommended in the execution by casting of components of water pumps, especially rotors;
- the most favorable behavior, resulted in this study, is represented by the CuAl10Fe2 alloy, which according to the results of the tests may be recommended for the producing of water pumps components and pump rotors.

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