EFFECT OF SOME HEAT TREATMENTS ON CAVITATION EROSION RESISTANCE OF THE EN AW - 6082 ALLOY

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Abstract

In its pure form, aluminum is relatively soft, with poor mechanical strength and weak cavitation erosion characteristics. The alloys series 6xxx have as main elements alloying silicon and magnesium, which improve their mechanical properties, making them competitive for many structural applications. The present paper establishes the correlation between the heat treatment, the microstructure and the mechanism of cavitation erosion damage of a deformable alloy, aluminum base. Cavitation tests were conducted on a vibrator with piezo-ceramic crystals that meet ASTM G32 - 2010 requirements. The metallographic examinations by optical microscopy and scanning electron microscopy, coupled with the hardness tests, highlighted the microstructural changes in a cavitationally affected material and the cracks propagation mode.

Keywords: Al-alloy, heat treatment, cavitation erosion, microstructure

1. INTRODUCTION

Cavitation is a complex phenomenon formed by the interaction of some hydrostatic, mechanic, metallurgic and chemical processes. It implies the forming and the subsequent rupture of the holes in the liquids, which are provoked by the local lowering of the hydrostatic pressure under a critical value, and it represents the pressure of the saturation [1]. Momentary decreases of the local pressure can be caused, on one side, by the spontaneous growth of the flow rate, and on the other side, by a expansion of the shock waves during the low pressure phase. The growth and the collapse of the bubbles due to the local pressure fluctuations is accompanied by a sudden fluid flow which can generate a voltage pulse whose value modifies from a couple of hundreds to approximately1000 MPa [1,2]. Rapid tension repetition on nearby solids, erodes the surface of the material through a process which has been likened to fatigue by shock [1,3]. The recent research papers showed that there is a good correlation between the removal rates of materials in the surface area and cyclic deformation parameters. This is why it is considered that a good indicator of the degradation through cavitation erosion is the fatigue process [4]. Generally, there are two ways of reduction the degradation through cavitation erosion, and these are: a) by designing hydrodynamic profiles and b) by utilizing performant materials and thermal and mechanic treatment technologies through which the resistance to this form of degradation grows [1]. Aluminum base alloys can be found in numerous structural engineering applications (hydraulic systems, flanges, drilling equipment, rotors and stators of hydrokinetic brakes which utilize a mixture of water/glycol, etc.) in aviation transport, in automotive and in civil engineering industries.

The development of some thermic treatments for the alloys in the 6xxx series has allowed the fulfilling of some requirements related to specific resistance (Rm/ρ) and a higher resistance to corrosion associated to a high tenacity and a reasonable cost [1,2]. The group of these alloys contains magnesium and silicon as principal alloying elements which greatly influence the morphology of structural constituents. Due to the fact that aluminum is one of the less resistant materials to -cavitation erosion [3], this paper investigates the cavitation behavior of the deformable alloy EN AW - 6082subjected to volumetric thermal treatments.

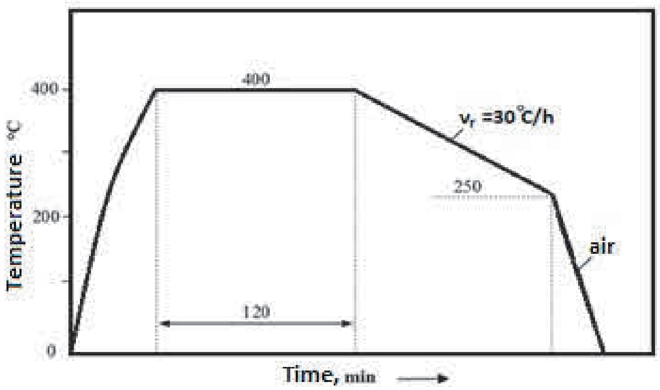


Figure 1 Cycle of recrystallization annealing heat treatment

2. MATERIAL AND EXPERIMENTAL PROCEDURE

The alloy which we are referring to is a part of the deformable materials category, with the highest mechanical resistance form 6xxx series. The chemical composition of the batch of the investigated material is (in wt%): 1.08Si, 0.88Mg, 0.76Mn, 0.48Fe, 0.18Cr, 0.18Zn, 0.015Ti, 0.08Cu, 0.04Sn, Al bal. Out of the laminated semi products in the form of 20 mm thick sheets, which have been thermally treated either by annealing for recrystallization, either by solution treatment followed by artificial aging (see **Figures 1** and **2**), cavitation samples having the shape and dimensions shown in **Figure 3** were performed.

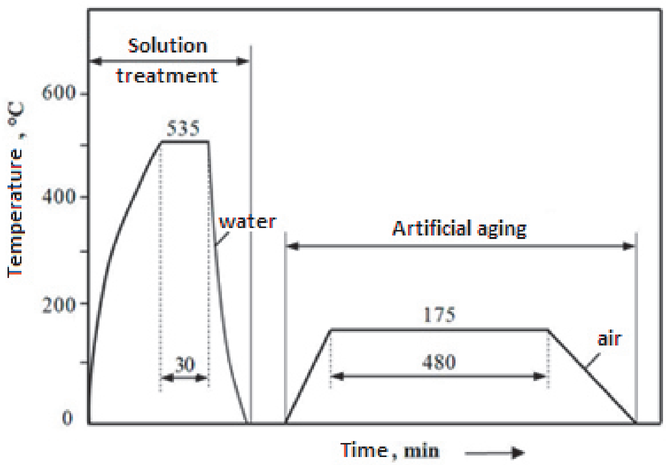


Figure 2 Cycle of solution heat treatment and artificial aging

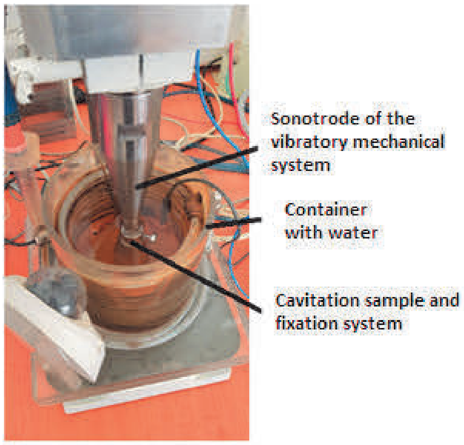


Figure 3 Cavitaction sample

The cavitation tests have been made on a vibration device with piezo ceramic crystals, which respects the standard requirements ASTM G32 - 2010 (**Figure 4**). Considering the low density of the alloy, it has been utilized the indirect testation, with a stationary sample.

For this purpose, it has been designed a support piece out of stainless steel, in which the cylindrical sample made of aluminum alloy has been fixed and tested. The distance between the sonotrode surface of the vibratory mechanical system and the test sample surface was 0.5 mm.

Functional parameters that determine the intensity of cavitation erosion are: the double vibration amplitude, of 50 µm, the fervency, of 20000 ± 2 % Hz and the temperature of the cavitational fluid (tap water from the public network) of 20 ± 2 ºC. To determine the wear rate through cavitation erosion, the test was discontinued at regular intervals, the samples were washed in acetone and dried in a hot air stream and weighed with an analytical balance which can weigh the masses with an accuracy of five decimals.

The surface topography of the cavity tested samples was investigated by optical microscopy and scanning electron microscopy. Functional parameters that determine the intensity of cavitation erosion are: the double vibration amplitude, of 50 µm, the fervency, of 20000 ± 2 % Hz and the temperature of the cavitating fluid (double distilled water) of 22 ± 2 ºC. To determine the wear rate through cavitation erosion, the test was discontinued at regular intervals, the samples were washed in acetone and dried in a hot air stream and weighed with an analytical balance which can weigh the masses with an accuracy of five decimals. The surface topography of cavity-tested samples was investigated by optical microscopy and scanning electron microscopy.

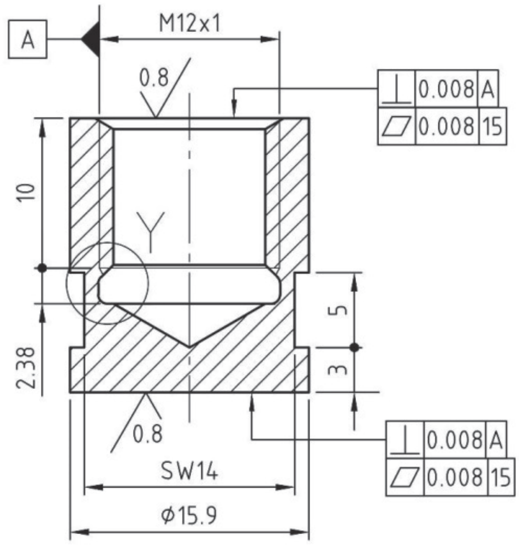


Figure 4 Indirect test details

3. RESULTS AND DISCUSSIONS

The microstructure obtained after the thermal treatments applied consists of grains of solid solution γ with polyhedral shape, some of them having annealing macules. Within the grains and on the separation boundaries there are secondary phase particles [3].

Figures 5 and **6** show the characteristic cavitational erosion curves of the investigated alloy for the two thermal treatment variants applied. They indicate the variation of mass losses and their velocity, with the duration of the cavitation attack generated in the vibration device.

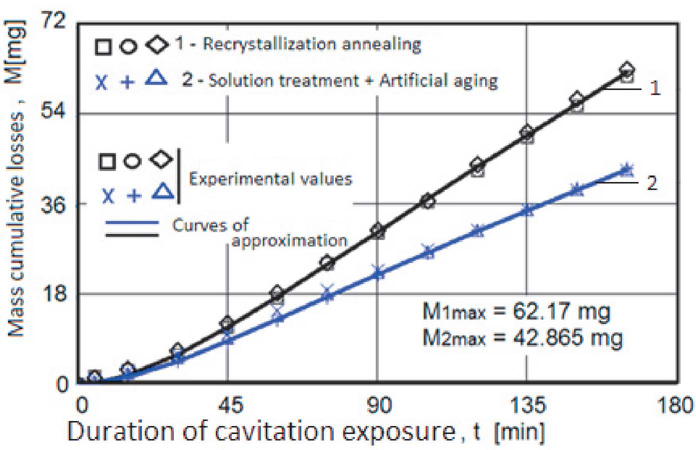


Figure 5 Variation of mass losses with the duration of the cavitation attack

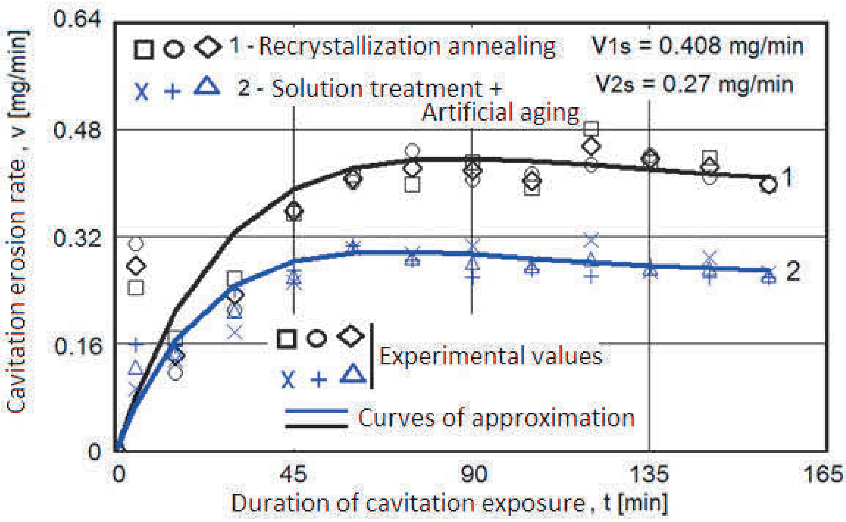
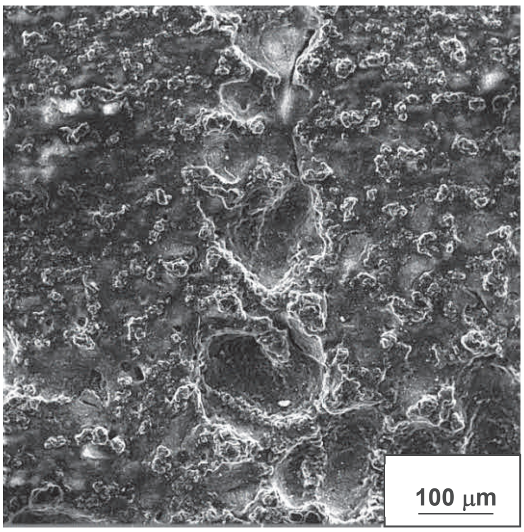


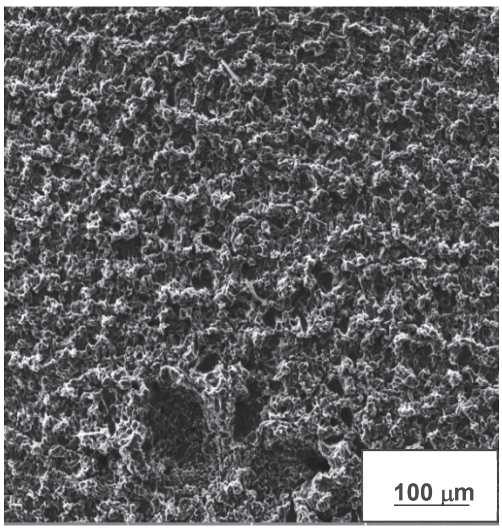
Figure 6 Variation of cavitation erosion rate with attack time

The main observations deduced from the analysis of these curves can be summarized as follows:

- mass losses continue to increase with the duration of the cavitation attack, reaching values of approx. 62 mg on the annealed samples and approx. 43 mg on samples subjected to solution heat treatment followed by artificial aging;
- rate of cavitation erosion decreases by approx. 1.5 times by applying of solution heat treatment + artificial aging compared to the structural status obtained recrystallization annealing;
- the initiation of the erosion stabilization period takes place after 90 minutes to the samples and after 60 minutes to tall and aged samples.

Survey analysis of eroded surfaces at the scanning electron microscope shows that initiation of the material removal phenomenon takes place in areas with large intermetallic phase particles having a low deformation capacity. **Figure 7** illustrates the surface images of heat treated samples by annealing for recrystallization that has been tested at cavitation varying the attack time. It is noted that uneven surface degradation occurs in the first minutes of attack, with alternating areas of fine pinhole material and larger section microcrackers (**Figure 7a**), and as the demand time increases, there is a uniformity of the pinching arrangement and an increase in its size (**Figure 7b** and **7c**).

a) 

b) 

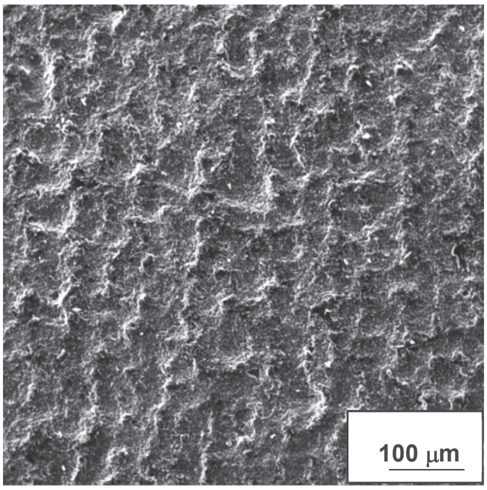
c) 

Figure 7 SEM images of the cavity surface at variable attack times: a) t = 2 min; b) t = 5 min.; c) t = 165 min

4. CONCLUSIONS

The solution heat treatment followed by artificial aging causes a 50 % reduction in cavitation erosion rate compared to recrystallization annealing.

The obtained results demonstrate that the cavitation erosion of the alloy under investigation is initiated by removing the fragile phases of chemical combinations.

With the increase duration of a cavitation attack uniform grain degradation of the solid solution occurs, the breaking phenomenon having a ductile character.

REFERENCES

[1] MRÓWKA-NOWOTNIK, G. and SIENIAWSKI, J. Influence of heat treatment on the micrustructure and mechanical properties of 6005 and 6082 aluminium alloys. *Journal of Materials Processing Technology.* 2005. vol. 162-163, pp 367-372.

[2] WANG, Q. G. and DAVIDSON, C. J. Solidification and precipitation behaviour of Al-Si-Mg casting alloys. J. *Material Science*. 2001. vol. 26, pp 739-750.

[3] FORTES PATELLA, R., CHOFFAT, T., REBOUD, J.-L. and ARCHER, A. Mass loss simulation in cavitation erosion - Fatigue criterion approach. *Wear.* 2013. vol. 300, pp 205-215.

[4] GOTTARDI, G., TOCCI, M., MONTESANO, M. and POLA, A. Cavitation erosion behaviour of an innovative aluminium alloy for Hybrid Aluminium Forging. *Wear*. 2018. vol. 394-395, pp 1-10.