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Cavitation Erosion Research for AlSi12 Alloy Tested at Different Time Periods

This paper presents cavitation erosion research for 2 batch of an AlSi12 alloy. The tests were made on a cavitation stand in laboratory, using the stationary specimen method. This alloy is not subject to cavitation, but the experimental research highlight the behavior of AlSi12 alloy when the time periods are different. The research results are presented through graphs and representative images.

Keywords: *cavitation erosion, AlSi12 alloy, time periods*

1. Introduction

Cavitation phenomenon is a process of formation, development and collapse of cavitational bubbles in the liquid, due to the pressure difference. The cavitation produces cavitation erosion on materials used in manufacturing the components of the hydraulic turbines.

For laboratory testing of material resistance to cavitation erosion, are using different apparatus and experimental devices. Currently, the experimental researches are made on vibratory apparatus, and the most tested materials, are the stainless steel materials [1].

On the vibratory apparatus, the research is done by two methods: the direct and the indirect cavitation method or the stationary specimen method. To obtain the best results in laboratory, according to current standards, are made tests of metallic and nonmetallic materials, of experimental devices parameters and of test time or time periods.

In general, when is using the direct cavitation method, the standard period or the characteristic time period is 15 minutes. In the research through the stationary specimen method regarding the time period, study were made by the author of the reference [2]. Such a study is presented in this paper to see the behavior of a AlSi12 alloy at different time periods, study made on the cavitation stand belonging to the CCHAPT Centre of "Eftimie Murgu" University of Resita, using the stationary specimen method.

2. The work procedure

According to the standards G32-92 [3] and G32-10 [4], the distance between the sonotrode and the specimen or sample is 0,6 mm, the parameters of cavitation stand are 20 kHz for the natural frequency and 50 μm for the amplitude.

In this research there are 2 different batches of AlSi12 alloy. From tensile test specimens, as is shown in Figure 1, were processed 2 samples to the shape of a cube with edges of 16 mm.

Figure 1. Tensile test specimens of AlSi12 alloy.

The two samples of AlSi12 alloy will be subject to different time periods of 8, 15 and 30 minutes, and from the obtained results the material loss and and cavitation erosion rate depending on time the characteristic graphs will be drawn.

Before and after cavitation erosion, the surfaces of the two samples of the 2 batches will be highlight through specific images. The chemical composition of the AlSi12 alloy with more than 88 % Al [5] are shown in Table 1 and 2.

Table 1.

Chemical composition (batch 574 of AlSi12 alloy) [%]							
Cu	Fe	Mn	Mg	Si	Zn	Ti	Al
0,01	0,47	0,44	< 0,005	11,03	0,03	0,01	Bal

Table 2.

Chemical composition (batch 570 of AlSi12 alloy) [%]							
Cu	Fe	Mn	Mg	Si	Zn	Ti	Al
0,01	0,45	0,44	< 0,005	11,4	0,02	0,01	Bal

3. Experimental results

The obtained results for standard time periods of 8 minutes are presented in Table 3, and the curves and images with eroded surface obtained are shown in Figures 2 and 3 respectively 4.

Table 3.

Cumulated time	Time period	Sample mass	Eroded mass		Cavitation erosion rate	
			Period	Cumulated		
t	Δt	m	Δm	m_c	v_{ec}	
[min]	[min]	[mg]	[mg]	[mg]	[mg/min]	[mg/h]
0	0	10153.5	0	0	0.0000	0.000
3	3	10152.9	0.6	0.6	0.2968	17.805
8	5	10150.61	2.29	2.89	0.6496	38.978
16	8	10142.96	7.65	10.54	1.1731	70.388
24	8	10131.84	11.12	21.66	1.4381	86.287
32	8	10119.95	11.89	33.55	1.5606	93.637
40	8	10106.87	13.08	46.63	1.4750	88.500
48	8	10096.35	10.52	57.15	1.4631	87.788
56	8	10083.46	12.89	70.04	1.7763	106.575
64	8	10067.93	15.53	85.57	1.7712	106.275
72	8	10055.12	12.81	98.38	1.5981	95.887
80	8	10042.36	12.76	111.14	1.5981	95.888
88	8	10029.55	12.81	123.95	1.4563	87.375
96	8	10019.06	10.49	134.44	1.4962	89.775
104	8	10005.61	13.45	147.89	1.5912	95.475
112	8	9993.6	12.01	159.9	1.4881	89.288
120	8	9981.8	11.8	171.7	1.3469	80.813
128	8	9972.05	9.75	181.45	1.2312	73.875
136	8	9962.1	9.95	191.4	1.1219	67.312
144	8	9954.1	8	199.4	0.8744	52.462
152	8	9948.11	5.99	205.39	1.0131	60.788
160	8	9937.89	10.22	215.61	1.1800	70.800
168	8	9929.23	8.66	224.27	1.0387	62.325
176	8	9921.27	7.96	232.23	1.0056	60.338
184	8	9913.14	8.13	240.36	1.1069	66.413
192	8	9903.56	9.58	249.94	1.2656	75.938
200	8	9892.89	10.67	260.61	1.0725	64.350
208	8	9886.4	6.49	267.1	0.5500	33.000

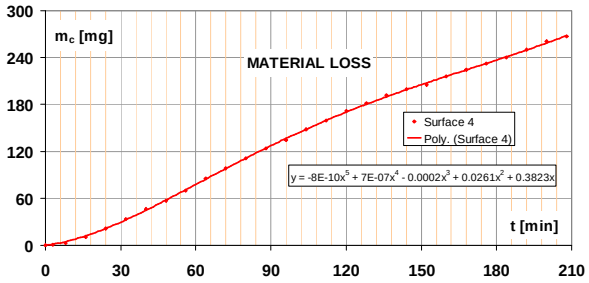


Figure 2. Material loss curve of surface 4 (batch 574 of AlSi12 alloy).

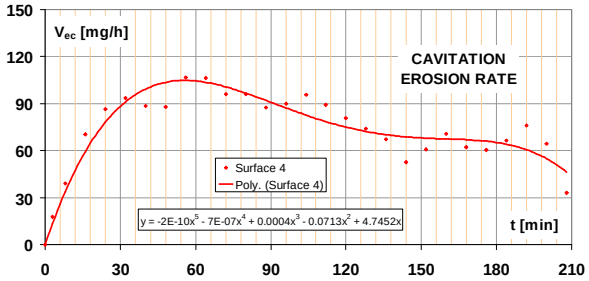


Figure 3. Cavitation erosion rate curve of surface 4 (batch 574 of AlSi12 alloy).

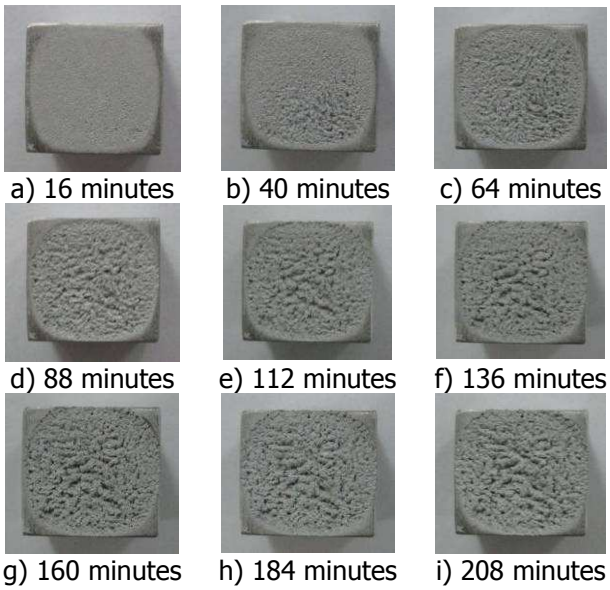


Figure 4. Images of the eroded surface for the time periods of 8 minutes.

The experimental results for time periods of 15 minutes are presented in Table 4, and the characteristic curves and images with the eroded surface are shown in Figures 5, 6 and 7.

Table 4.

Cumulated time	Time period	Sample mass	Eroded mass		Cavitation erosion rate	
			Period	Cumulated		
t	Δt	m	Δm	m_c	v_{ec}	
[min]	[min]	[mg]	[mg]	[mg]	[mg/min]	[mg/h]
0	0	10327.87	0	0	0.0000	0.000
5	5	10327.04	0.83	0.83	0.4447	26.680
15	10	10317.02	10.02	10.85	1.4092	84.552
30	15	10286.72	30.3	41.15	1.7767	106.600
45	15	10263.72	23	64.15	1.2920	77.520
60	15	10247.96	15.76	79.91	0.9283	55.700
75	15	10235.87	12.09	92	0.7687	46.120
90	15	10224.9	10.97	102.97	0.6670	40.020
105	15	10215.86	9.04	112.01	0.6053	36.320
120	15	10206.74	9.12	121.13	0.6497	38.980
135	15	10196.37	10.37	131.5	0.7757	46.540
150	15	10183.47	12.9	144.4	0.7473	44.840
165	15	10173.95	9.52	153.92	0.7020	42.120
180	15	10162.41	11.54	165.46	0.5720	34.320
195	15	10156.79	5.62	171.08	0.3033	18.200
210	15	10153.31	3.48	174.56	0.1607	9.640

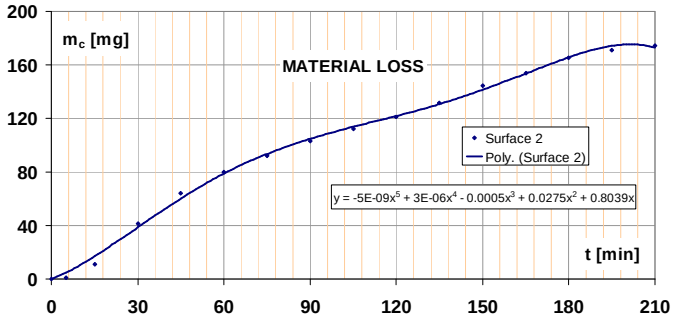


Figure 5. Material loss curve of surface 2 (batch 574 of AlSi12 alloy).

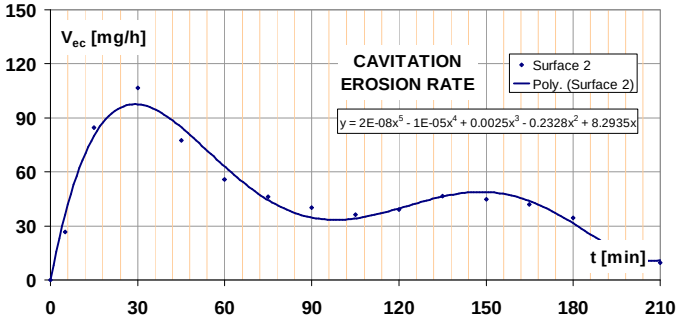


Figure 6. Cavitation erosion rate curve of surface 2 (batch 574 of AlSi12 alloy).

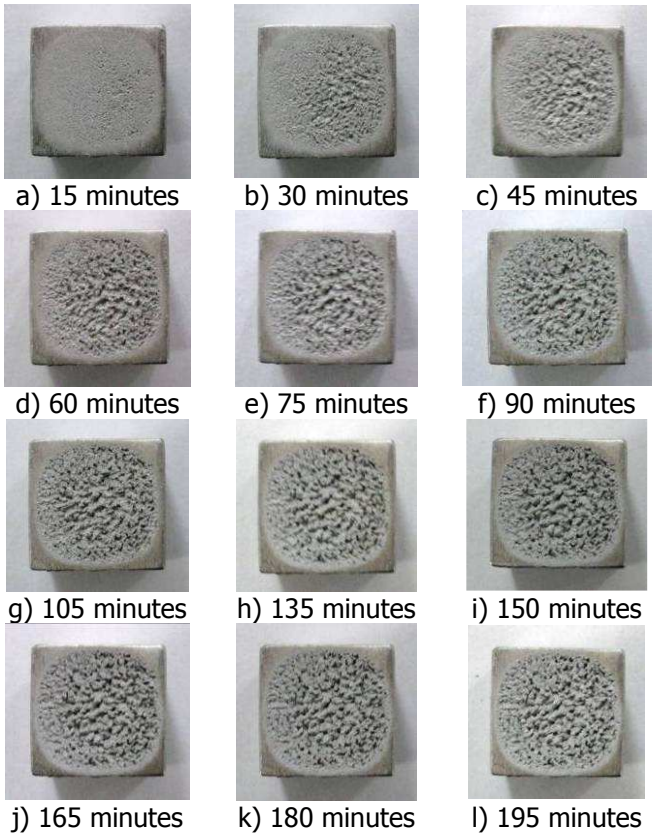


Figure 7. Images of the eroded surface for time periods of 15 minutes.

The results for the standard time periods of 30 minutes are presented in Table 5, the characteristic curves in Figures 8 and 9 and the images with eroded surface in Figure 10.

Table 5.

Cumulated time	Time period	Sample mass	Eroded mass		Cavitation erosion rate	
			Period	Cumulated		
t	Δt	m	Δm	m_c	v_{ec}	
[min]	[min]	[mg]	[mg]	[mg]	[mg/min]	[mg/h]
0	0	10623.8	0	0	0.0000	0.000
10	10	10622.21	1.59	1.59	0.2943	17.660
30	20	10610.91	11.3	12.89	0.6858	41.148
60	30	10584.9	26.01	38.9	0.7347	44.080
90	30	10566.83	18.07	56.97	0.5625	33.750
120	30	10551.15	15.68	72.65	0.5838	35.030
150	30	10531.8	19.35	92	0.7165	42.990
180	30	10508.16	23.64	115.64	0.7372	44.230
210	30	10487.57	20.59	136.23	0.6355	38.130

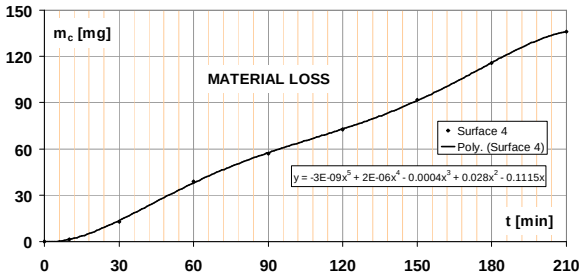


Figure 8. Material loss curve of surface 4 (batch 570 of AlSi12 alloy).

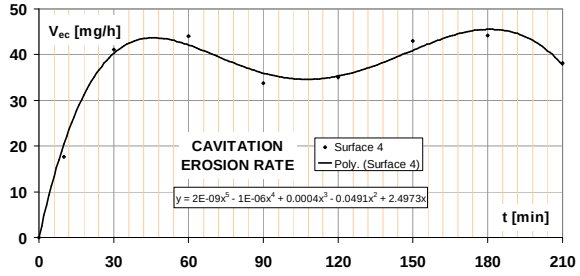
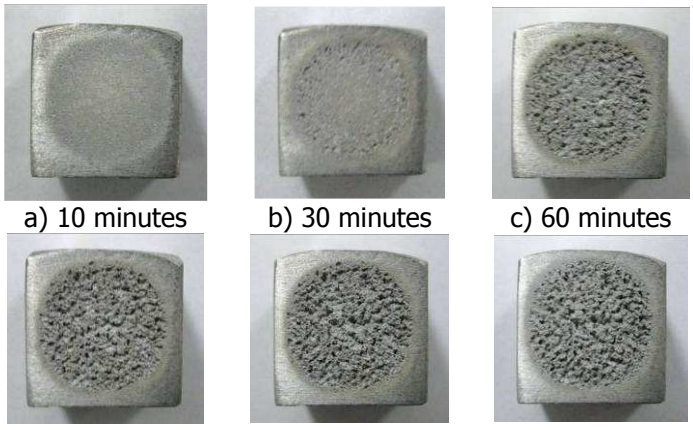


Figure 9. Cavitation erosion rate curve of surface 4 (batch 570 of AlSi12 alloy).



a) 10 minutes b) 30 minutes c) 60 minutes

d) 90 minutes e) 120 minutes f) 150 minutes

Figure 10. Images of the eroded surface for the time periods of 30 minutes.

The sample from batch 574 was tested on two surfaces namely: surface no. 4 for standard time periods of 8 minutes and surface no. 2 for standard time periods of 15 minutes. The sample from batch 570 was tested only on one surface namely surface no. 4 for the standard time periods of 30 minutes.

Table 6 present the maximum value of erosion on time period and on cumulated, the maximum value of cavitation erosion rate and the number of the cumulated time periods.

Table 6.

Batch type / surface	Maximum value of erosion [mg]		Maximum value of cavitation erosion rate [mg/h]	Number of cumulated time periods
	Period	Cumulated		
574 / S4	15,53	267,1	106,575	27 (1 – 3; 1 – 5; 25 – 8 minutes, for 208 minutes)
574 / S2	30,3	174,56	106,6	15 (1 – 5; 1 – 10; 13 – 15 minutes, for 210 minutes)
570 / S4	26,01	136,23	44,23	8 (1 – 10; 1 – 20; 6 – 30 minutes, for 210 minutes)

The analytical curves from Figures 2, 3, 5, 6, 8 and 9, were interpolated resulting the polynomial equation 1 (with standard deviation $R^2 = 0.9998$), eq. 2 (with $R^2 = 0.8939$), eq. 3 (with $R^2 = 0.9981$), eq. 4 (with $R^2 = 0.9671$), eq. 5 (with $R^2 = 0.9999$), and eq. 6 (with $R^2 = 0.9869$).

$$M = -8 \cdot 10^{-10} t^5 + 7 \cdot 10^{-7} t^4 - 0{,}0002\, t^3 + 0{,}0261\, t^2 + 0{,}3823\, t \quad (1)$$

$$v_{ec} = -2 \cdot 10^{-10} t^5 - 7 \cdot 10^{-7} t^4 + 0{,}0004\, t^3 - 0{,}0713\, t^2 + 4{,}7452\, t \quad (2)$$

$$M = -5 \cdot 10^{-9} t^5 + 3 \cdot 10^{-6} t^4 - 0{,}0005\, t^3 + 0{,}0275\, t^2 + 0{,}8039\, t \quad (3)$$

$$v_{ec} = -2 \cdot 10^{8} t^5 - 1 \cdot 10^{-5} t^4 + 0{,}0025\, t^3 - 0{,}2328\, t^2 + 8{,}2935\, t \quad (4)$$

$$M = -3 \cdot 10^{-9} t^5 + 2 \cdot 10^{-6} t^4 - 0{,}0004\, t^3 + 0{,}028\, t^2 - 0{,}1115\, t \quad (5)$$

$$v_{ec} = 2 \cdot 10^{-9} t^5 - 1 \cdot 10^{-6} t^4 + 0{,}0004\, t^3 - 0{,}0491\, t^2 + 2{,}4973\, t \quad (6)$$

Figures 11, 12 and 13 shows images of the tested surfaces before and after the cavitation test.

a)  b)  c) 

Figure 11. Surface images before cavitation a), after cavitation b) and the macrostructure of eroded surface c), for time periods of 8 minutes.

a)  b)  c) 

Figure 12. Surface images before cavitation a), after cavitation b) and the macrostructure of eroded surface c), for time periods of 15 minutes.

a)  b)  c) 

Figure 13. Surface images before cavitation a), after cavitation b) and the macrostructure of eroded surface c), for time periods of 30 minutes.

4. Conclusion

Both batches of AlSi12 alloy have a very low resistance to cavitation erosion this is due to the large share of aluminum in the chemical composition.

There are some differences when the time periods differ, in this case the tested time periods of 8 and 15 minutes are recommended for the non-ferrous materials in the obtaining the characteristic cavitation erosion curves.

The surfaces tested at 8, 15 and 30 minutes, have lost each of the initial mass 267,1 mg, 174,56 mg respectively 136,23 mg.

References

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