CAVITATION EROSION RESEARCH ON C45 CARBON STEEL. PART I: MULTIPLE TESTS OF 180 MINUTES

Codruţa-Oana Hamat, Eftimie Murgu University of Resita, Resita, ROMANIA
Marian-Dumitru Nedeloni, Eftimie Murgu University of Resita, Resita, ROMANIA
Cornel Haţiegan, Eftimie Murgu University of Resita, Resita, ROMANIA
Relu-Costel Ciubotariu, Eftimie Murgu University of Resita, Resita, ROMANIA
Ioan Pădureanu, Eftimie Murgu University of Resita, Resita, ROMANIA

ABSTRACT: This paper presents the experimental results of cavitation erosion research on C45 carbon steel. Besides the description of the material, of the cavitation experimental stand and of the work procedure on laboratory testing, the proper research of cavitation erosion research involve four different tests of 180 minutes on 2 samples of the same material C45, a totaled time of 720 minutes or 12 hours. Also, these obtained results are tabular, graphic, as well in the form of macrophotography presented.

KEY WORDS: Cavitation erosion, C45 carbon steel, tests of 180 minutes.

1. INTRODUCTION

In laboratory research, different metallic materials are experimental tested for their resistance to the cavitation erosion [1] - [5].

Experimental stands from the research laboratories may be particularly: hydrodynamic tunnels, rotating disk and vibratory apparatus.

Through the vibratory apparatus, metallic materials are tested in a short time with good results [6] - [9].

The testing of metallic materials on vibrating apparatus can be done through direct and indirect cavitation method.

In this paper, the experimental cavitation stand is in the vibratory apparatus category and the tested metallic material is C45 carbon steel.

2. DESCRIPTION OF THE C45 CARBON STEEL

According to references [10] and [11] this carbon steel, symbolized as OLC 45, after old Romanian STAS has the C45 alphanumeric symbolization after DIN 17200 1652 Standard and the 1.0503 or 1045 numeric symbolization after Werkstoff No. standard respectively ASTM. The chemical composition and some mechanical properties of this C45 carbon steel after the certificate of the manufacturer, are shown in Table 1 and 2 [12].

Table 1. Chemical composition for C45 [%]

C	Cr	Mn	Ni	P	S	Si	Cu	Fe
0,44	0,16	0,61	0,13	0,007	0,005	0,27	0,26	98,11

Table 2. Some mechanical properties for C45

Rm [N/mm^2]	A [%]
695	13

3. EXPERIMENTAL STAND AND THE WORK PROCEDURE

The experimental cavitation stand [13], according to standard G32-92 [14] and G32-10 [15] operates under the following conditions:

- natural frequency must be within 20 ± 0.5 kHz;
- amplitude value must be set to 50 µm;
- temperature of the liquid in which the cavitation phenomenon occurs, has

values within 25 ± 2 °C and it is measured by a digital thermometer;

- distance between the ultrasonic horn or sonotrode and the sample, is set to 0,6 mm.

This experimental cavitation stand is shown in Figure 1:

Figure 1. The experimental cavitation stand

In the work procedure for the indirect cavitation method, this involves the following:

- the sample is tested for a certain time period of the cavitational attack namely 5, 10 respectively several periods, each of 15 minutes;
- after testing, the sample is soaked in alcohol;
- after this step, the entire sample respectively the exposed surface to the cavitation bubbles is dried with a air stream;
- finally, the sample is weighed on a digital balance accurate to highlight material loss.

4. SAMPLES DESCRIPTION AND EXPERIMENTAL RESULTS

The two samples with cylindrical shape from the same batch of C45 material have the following dimensions: Ø16 x 10 mm.

These samples will be subjected to several periods of cavitational attack namely: a period of 5 and 10 minutes and also 11 periods of 15 minutes.

The four testing surfaces will be noted as: Sample 1-Face 1, Sample 1-Face 2, Sample 2-Face 1 and Sample 2-Face 2.

The obtained results aimed the experimental values of the material loss and of the cavitation erosion rate in time, as shown below:

Table 1. The experimental results for Sample 1-Face 1

Accuml. time	Period time	Specimen mass	Accuml. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/h]
0	0	14956.5	0	0.000
5	5	14956.31	0.19	1.620
15	10	14956.26	0.24	0.260
30	15	14956.21	0.29	0.480
45	15	14956.02	0.48	0.760
60	15	14955.83	0.67	1.180
75	15	14955.43	1.07	1.900
90	15	14954.88	1.62	2.340
105	15	14954.26	2.24	2.840
120	15	14953.46	3.04	3.360
135	15	14952.58	3.92	4.020
150	15	14951.45	5.05	4.700
165	15	14950.23	6.27	5.260
180	15	14948.82	7.68	6.020

Table 2. The experimental results for Sample 1-Face 2

Accuml. time	Period time	Specimen mass	Accuml. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/h]
0	0	14948.82	0	0.000
5	5	14948.64	0.18	1.520
15	10	14948.6	0.22	0.208
30	15	14948.56	0.26	0.300
45	15	14948.45	0.37	0.640
60	15	14948.24	0.58	1.240
75	15	14947.83	0.99	1.720
90	15	14947.38	1.44	2.140
105	15	14946.76	2.06	2.760
120	15	14946	2.82	3.300
135	15	14945.11	3.71	3.900
150	15	14944.05	4.77	4.580
165	15	14942.82	6	5.180
180	15	14941.46	7.36	5.700

Table 3. The results for Sample 2-Face 1

Accuml. time	Period time	Specimen mass	Accuml. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/h]
0	0	14963.26	0	0.000
5	5	14963	0.26	2.320
15	10	14962.88	0.38	0.464
30	15	14962.86	0.4	0.200
45	15	14962.78	0.48	0.460
60	15	14962.63	0.63	0.960
75	15	14962.3	0.96	1.600
90	15	14961.83	1.43	2.060
105	15	14961.27	1.99	2.660
120	15	14960.5	2.76	3.720
135	15	14959.41	3.85	4.420
150	15	14958.29	4.97	5.080
165	15	14956.87	6.39	5.920
180	15	14955.33	7.93	6.400

Table 4. The results for Sample 2-Face 2

Accuml. time	Period time	Specimen mass	Accuml. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/h]
0	0	14955.33	0	0.000
5	5	14954.96	0.37	3.180
15	10	14954.85	0.48	0.636
30	15	14954.7	0.63	0.640
45	15	14954.53	0.8	1.080
60	15	14954.16	1.17	1.720
75	15	14953.67	1.66	2.320
90	15	14953	2.33	2.980
105	15	14952.18	3.15	3.680
120	15	14951.16	4.17	4.420
135	15	14949.97	5.36	5.060
150	15	14948.63	6.7	5.760
165	15	14947.09	8.24	6.280
180	15	14945.49	9.84	6.520

Next, the material loss and cavitation erosion rates curves will be presented.

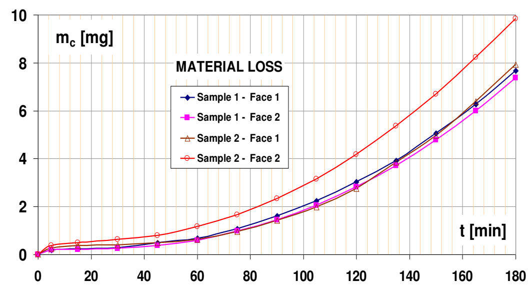


Figure 2. Material loss curve for C45

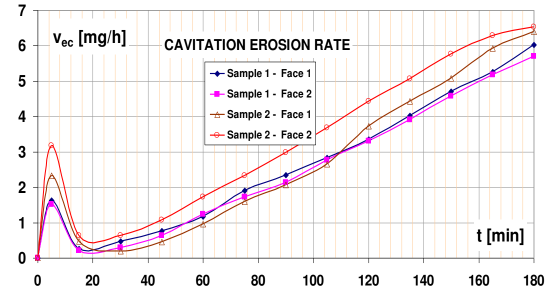


Figure 3. Cavitation erosion rate curve for C45

In Table 5, is intended to achieve an average value regarding the results in tables 1 ÷ 4 and in Figures 4 and 6, are the graphs bellows.

Table 5. The average value of the 4 tests

Accuml. time	Period time	Accuml. eroded mass	Cavitation erosion rate
t [min]	t [min]	mc [mg]	vec [mg/h]
0	0	0	0.000
5	5	0.37	3.180
15	10	0.48	0.636
30	15	0.63	0.640
45	15	0.8	1.080
60	15	1.17	1.720
75	15	1.66	2.320
90	15	2.33	2.980
105	15	3.15	3.680
120	15	4.17	4.420
135	15	5.36	5.060
150	15	6.7	5.760
165	15	8.24	6.280
180	15	9.84	6.520

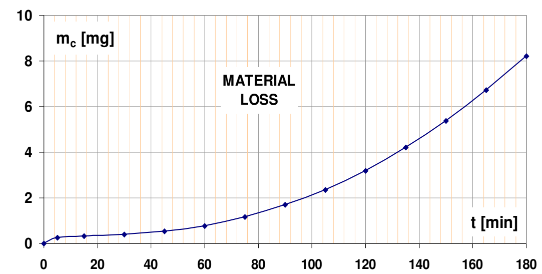


Figure 4. Material loss curve for C45 Steel (average value)

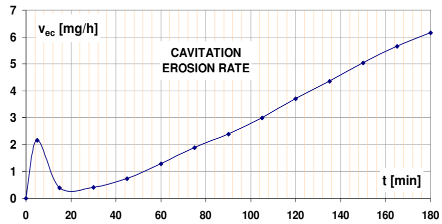


Figure 5. Cavitation erosion rate curve for C45 Steel (average value)

Figures from namely 6 to 9 show more macro photos before and after the cavitation of the two samples of C45 steel as follows:

- figure 6: images before cavitation;
- figure 7: macrostructures before the cavitation;
- figure 8: images after cavitation;
- figure 9: macrostructures after the cavitation.

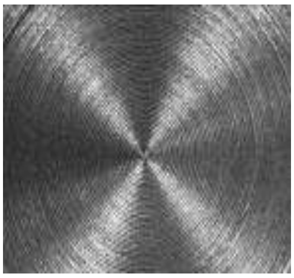

Sample 1- Face 1


Sample 1 - Face 2

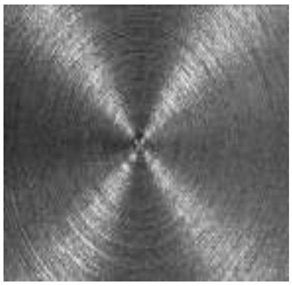

Sample 2 - Face 1


Sample 2 - Face 2

Figure 6: Images of the surfaces of two samples before the cavitation


Sample 1- Face 1


Sample 1 - Face 2


Sample 2 - Face 1

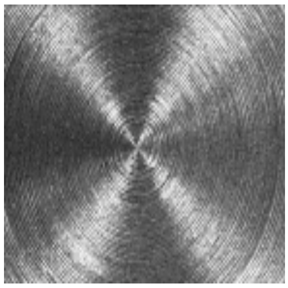

Sample 2 - Face 2

Figure 7: Macrostructures of the surfaces of two samples before the cavitation

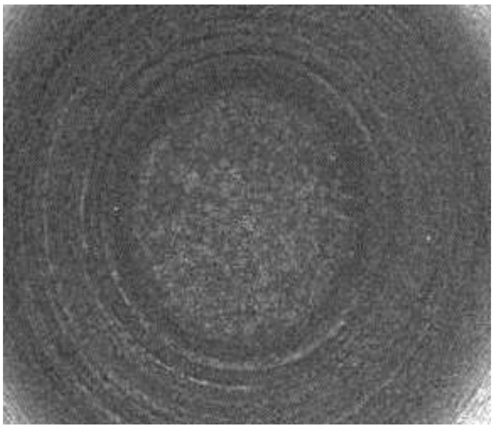

Sample 1 - Face 1


Sample 1 - Face 2

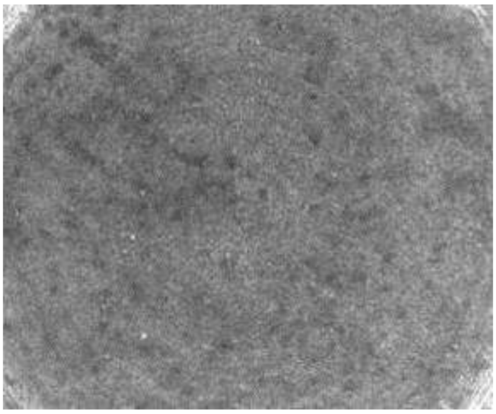

Sample 2 - Face 1

Sample 2 - Face 2

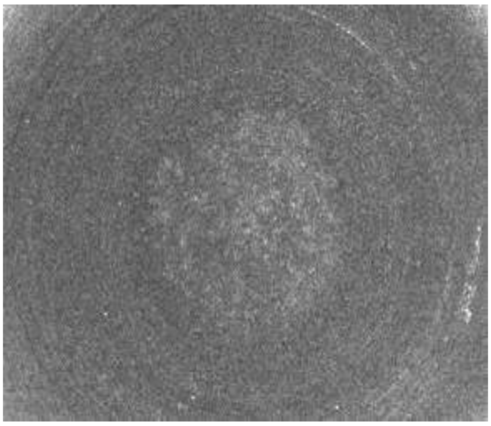
Figure 8: Images of the surfaces of two samples after the cavitation



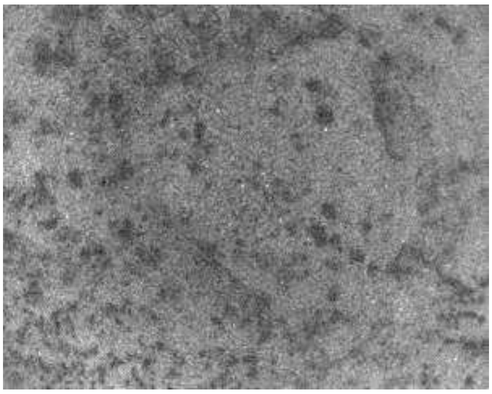
Sample 1 - Face 1



Sample 1 - Face 2



Sample 2 - Face 1



Sample 2 - Face 2

Figure 9: Macrostructures of the surfaces of two samples after the cavitation

5. CONCLUSION

It notes that areas 1 and 2 of the sample 1 and surfaces 1 and 2 of samples 2 have lost each of their mass by: 7.68, 7.36, 7.93 respectively 9.84 mg, the stronger being the surface denoted by Sample 1 - Face 2.

First 3 curves in Figure 2 overlap area, which does not happen for the corresponding curve of face 2 of the sample 2.

The cavitation erosion rate graph shows that the curves are very similar for the 4 tests, the good surface resistance is also denoted by Sample 1 - Face 2, and the lower surface is denoted by Sample 2 - Face 2.

Images taken with a camera and macro structure made with a stereo-microscope for the 4 areas of the 2 samples after the cavitation, were presented at a higher resolution to see the destruction by cavitation.

ACKNOWLEDGMENTS

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132395.

REFERENCES

[1] Bordeaşu, I. Eroziunea cavitaţională a materialelor (Cavitational erosion of materials), Politehnica Printing House, Timişoara, 2006.

[2] Cojocaru, V., Câmpian, C.V, Frunzaverde, D., Miclosina, C.O. Residual Stresses Analysis of Weld Overlays Coatings Used for the Repairs at Kaplan Turbine Runner Blades Areas Damaged by Cavitation Erosion, „Recent Researches in Environment, Energy Planning and Pollution”, Proceedings of the 5th WSEAS International Conference on Renewable Energy Sources (RES '11), 2011.

[3] Nedelcu, D., Nedeloni, M.-D., Lupinca, C.-I. Cavitation Erosion Research on the X3CrNi13-4 Stainless Steel, Materials Science Forum, Vol. 782, 2014.

[4] Lupinca, C.-I., Nedeloni, M.-D., Nedelcu, D. Gray Cast Iron Behaviour in Cavitation Erosion, Materials Science Forum, Vol. 782, 2014.

[5] Frunzaverde, D., Câmpian, C.V., Cojocaru, V., Marginean, G., Baran, M., Ciubotariu R. Influence of welded layers thickness on the cavitation erosion resistance, Proceedings of 6th WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD '10), 2010.

[6] Chen, H., Li, J., Liu, S., Chen, D., Wang, J. Affected zone generated around the erosion pit on carbon steel surface at the incipient stage of vibration cavitation, Chinese Science Bulletin, vo. 53, no. 6, 2008.

[7] Mânzână, M. E., Ghiban, B., Ghiban, N., Bordeaşu, I., Miculescu, F., Marin, M. Different Aspects of Cavitation Damages in Some Stainless Steels, Analele Universităţii Eftimie Murgu, anul XVIII, nr. 1, 2011.

[8] Lupinca, C. I., Nedeloni, M.D. Comparative study regarding the cavitation erosion behavior of Cu and Al alloys, International Journal of Latest Research in Science and Technology, Volume 3 (2), 2014.

[9] Lupinca, C. I., Nedeloni, M.D. The Study of Bronze Behaviour During Cavitation Erosion, Indian Journal Of Applied Research, Volume 4 (5), 2014.

[10] Şerban, V. A., Răduţă, A., Ştiinţa şi ingineria materialelor (The science and the engineering of materials), Politehnica Printing House, Timişoara, 2006.

[11] http://www.floradis.com/33-bare.de.otel-27-otel.carbon.de.calitate.html

[12] Nedeloni, M.D. Cercetări privind eroziunea cavitaţională pe materiale utilizate la fabricaţia componentelor de turbine hidraulice (Research regarding the cavitation erosion on materials used to manufacture the components of hydraulic turbines), PhD Thesis, Eftimie Murgu University, Reşiţa, 2012.

[13] *** TELSONIC, Operating Instructions Cavitations Test Equipment DG 2000, www.telsonic.com, 2007.

[14] *** ASTM Standard G32-92 (1992), Standard Method of Vibratory Cavitation Erosion Test. Annual Book of ASTM Standards, Philadelphia, 1992.

[15] *** ASTM G32–10, Standard Test Method for Cavitation Erosion Using Vibratory Apparatus, ASTM International, 2010.