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Calibration Tests of a Sonotrode and Cavitation Erosion Research through Indirect Cavitation Method for a Steel

This paper content the describe of cavitation erosion stand, especially the ultrasonic generator; the calibration tests of a oxidable steel sonotrode and the experimental results for a specimen also from oxidable steel material tested at cavitation erosion through the indirect cavitation method.

Keywords: *ultrasonic generator, sonotrode, indirect cavitation, steel*

1. Introduction

The cavitation phenomenon is present in almost all areas of industry and modern technique, where are moving liquid [1].

Cavitation erosion is determined by the transmission to solid surface of the forces generated by repeated implosion of vapors bubbles formed in the areas where the pressure of the liquid has fallen below a certain value [2].

Research equipments of the cavitation erosion can be classified as [3]:

- Tunnel type equipments;
- Magnetostriction equipments;
- Ultrasonic equipments;
- Spirt or jet equipments;
- Other types of equipments.

The purpose of this work is to present the calibration tests of a oxidable steel sonotrode with a stand or ultrasonic equipment of cavitation erosion research. The material used for this purpose is also a oxidable steel researched by the indirect cavitation method.

2. Stand description

The stand consists of the following components:

- Ultrasonic generator DG-2000-2 [4], which allows setting, display and monitoring of all parameters from the front panel;
- Converter supported via a support and the ultrasonic generator is connected to the converter through a 6HF cable;
- Mechanical transformer, which is intended to amplify the value of amplitude in the sonotrode;
- Sonotrode of oxidable steel;
- Specimen from oxidable steel;
- liquid vessel in which it is immersed the test specimen;
- Digital thermometer for measuring and checking the temperature throughout the cavitation test.

Ultrasonic generator shall be presented in detail in Figure 1, and the panels are as follows [4]:

1. Mains power/timer panel;
2. Status panel;
3. US-power/amplitude panel;
4. Frequency panel;
5. Tuning panel;
6. Load panel.

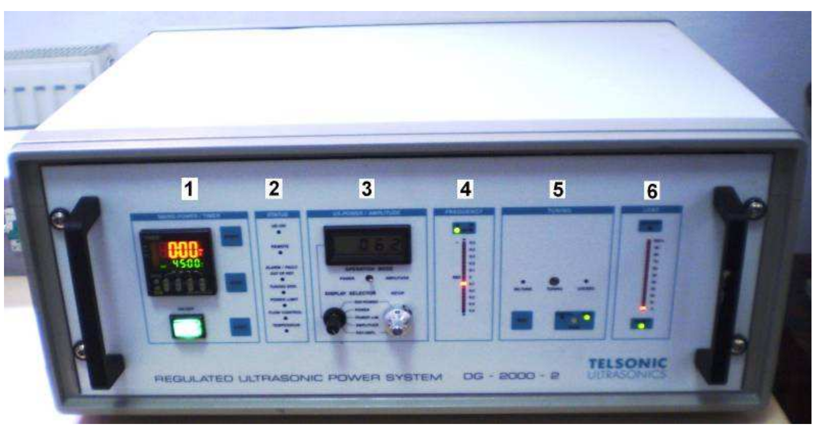

Figure 1. The generator in detail

The cavitation stand works in the following parameters:

- frequency: 20000 ± 500 Hz;
- amplitude peak to peak: 50 μm;
- the test temperature: 25 ± 2°C.

3. The calibration tests of the sonotrode

Whit the SolidWorks program [5] has schematic designed the sonotrode and made it of oxidable steel material.

For implementation of the sonotrode calibration through a specialized program [6] it have made attempts to capture the frequency in the area of 20000 ± 500 Hz, the field of operation of the ultrasonic generator.

The results of the calibration are contained in table 1 and also they are presented in graph form as in Figure 2.

Table 1.

Test Nr.	Sonotrode length [mm]	Frequency [Hz]
1	157.4	19232.2
2	157.2	19274.9
3	156.6	19372.6
4	156.1	19476.3
5	155.4	19567.9
6	155	19635
7	154.6	19708.3
8	154.2	19775.4

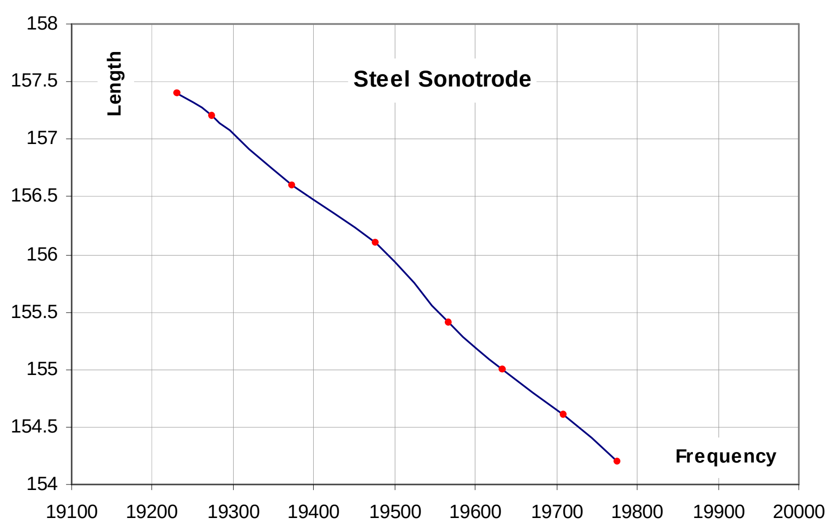

Figure 2. Calibration of the oxidable steel sonotrode

In figures 3 and 4 are presented the images recorded to capture their own frequency only for the first and last attempts of calibration.

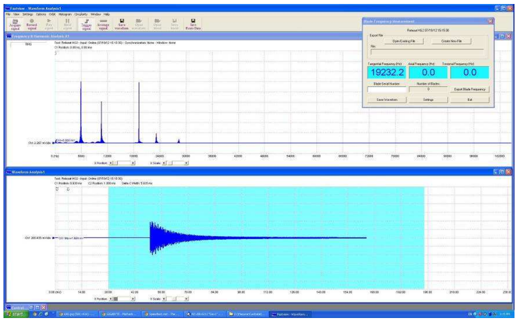

Figure 3. Value of 19232.2 Hz

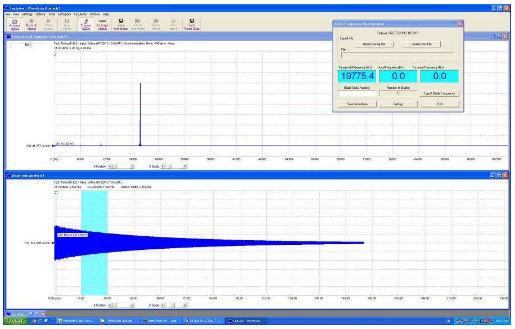

Figure 4. Value of 19775.4 Hz

As is observed for the first attempt at 157.4 mm is get the frequency of 19232.2 Hz and for the last attempt of calibration at the length of 154.2 mm is get the frequency of 19775.4 Hz, and the ultrasonic generator was worked.

3. Experimental results

With this sonotrode, using the indirect cavitation method were made attempts to cavitation erosion on a specimen of oxidable steel, that was already tested to another test, but with the direct cavitation method.

Obtained results with the indirect cavitation method are presented in table 2 and the cavitation erosion curve in time with the cumulative weight loss is shown in Figure 5.

Table 2.

Time	Phase	Specimen Mass	Eroded Mass		Erosion rate/phase	Cumulative erosion rate
			phase	cumulative		
t	Δt	m	Δm	Δmt	vef	vec
[min]	[min]	[mg]	[mg]	[mg]	[mg/min]	[mg/min]
0	0	15246.06	0	0	0	0
15	15	15243.10	2.960	2.960	0.197	0.197
30	15	15240.56	2.540	5.500	0.169	0.183
45	15	15237.28	3.280	8.780	0.219	0.195
60	15	15234.25	3.030	11.810	0.202	0.197
75	15	15231.06	3.190	15.000	0.213	0.200
90	15	15228.25	2.810	17.810	0.187	0.198
105	15	15224.73	3.520	21.330	0.235	0.203
120	15	15221.95	2.780	24.110	0.185	0.201
135	15	15218.63	3.320	27.430	0.221	0.203
150	15	15215.11	3.520	30.950	0.235	0.206
165	15	15212.35	2.760	33.710	0.184	0.204
180	15	15208.23	4.120	37.830	0.275	0.210
195	15	15204.55	3.680	41.510	0.245	0.213
210	15	15200.46	4.090	45.600	0.273	0.217
225	15	15197.03	3.430	49.030	0.229	0.218

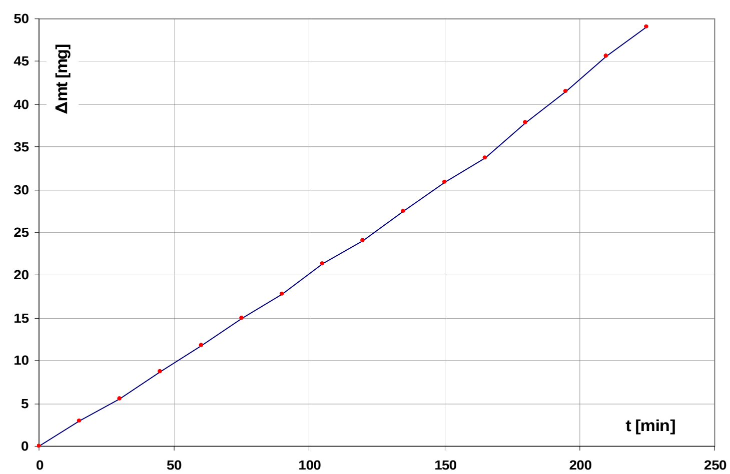

Figure 5. Cumulative erosion-time Curve for oxidable steel

In figures 6 and 7 are presented the erosion rate/time phase and the cumulative erosion rate graphs.

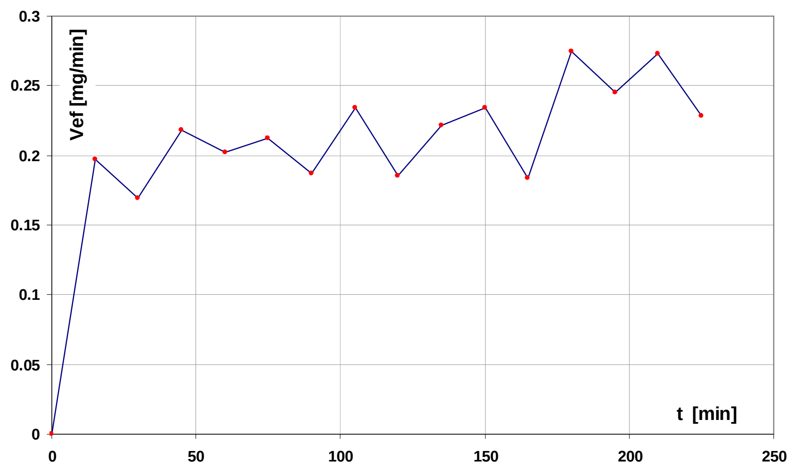

Figure 6. The variation of erosion rate/phase in time

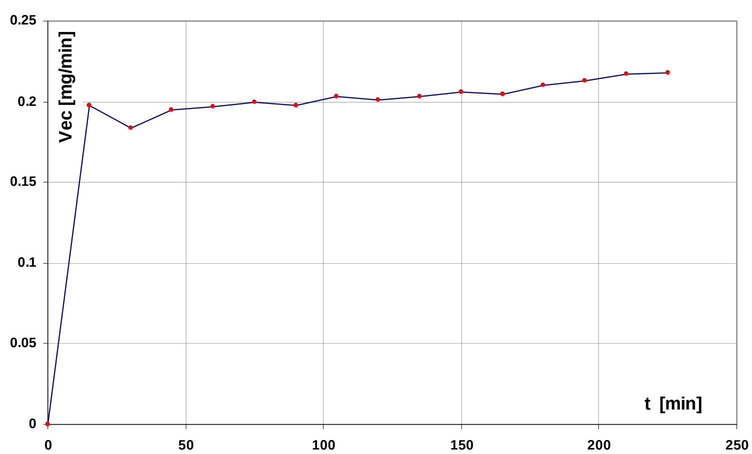

Figure 7. The variation of the cumulative erosion rate in time

Image area of eroded by cavitation test of oxidable steel after the 225 test minutes is shown in Figure 8 and in Figure 9 can see the image of the macrostructure.

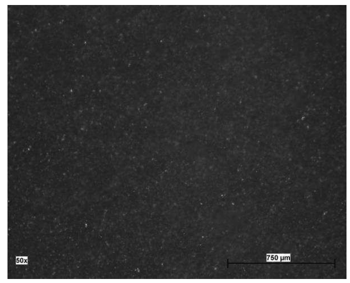

Figure 8. Eroded surface of specimen

Figure 9. Image of the macrostructure of specimen

After a time of about 100 minutes the sonotrode made of oxidable steel has the disadvantage that it heats and rusts in time and erodes by cavitation as seen in Figure 10.

a) b) c)

Figure 10. The oxidable steel sonotrode after several hours of operation: a), b) oxidation details; c) oxidation and erosion details

4. Conclusion

The initial weight of the oxidable steel specimen was 15246.06 mg and after the erosion test, the weight was 15197.03 mg, which means that it has lost a total mass of 49.030 mg.

Cumulative mass loss curve versus time is a linear one, so the specimen lost successively and continuously from her weight.

This oxidable steel is not a durable material against erosion through cavitation, compared to other steels specimens tested in the laboratory.

Acknowledgements

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