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Research through Direct and Indirect Cavitation Method for a Aluminum Specimen

This paper aims to obtain comparative results of the cavitation erosion through direct and indirect cavitation method for a type of a soft aluminum. In the paper can be find the stand and the equipment description, the calibration test of a titanium sonotrode, the experimental results and the main conclusions.

Keywords: *sonotrode, cavitation erosion, aluminum specimen*

1. Introduction

According to data from the literature with the direct cavitation method, the sample is attached to the sonotrode tip. With the indirect cavitation method, the sample is positioned facing the sonotrode in a distance of 0.5 to 0.7 mm from the sonotrode tip surface.

The use fluid is distilled water at 25 ± 2°C at ambient pressure. To obtain accurate results it is important to run at a specified amplitude, e.g. at 50 μm and to a specified frequency, e.g. at 20000 Hz [1].

2. Stand and equipment description

This stand consists of: a ultrasonic generator, a mechanical converter, a transformer (booster), sonotrode [2], specimens of different materials, a beaker, within is a cooling bath and a digital thermometer for measuring and checking the temperature of the water.

This stand is in the laboratory for the study of materials and technology of „Eftimie Murgu" University of Reşiţa [3] and is shown in Figure 1:

Figure 1. View of the stand

For the testing of direct and indirect test method it must to be 2 different sonotrode, as shown in Figure 2 and Figure 3. For the direct test method the specimen must assemble at the end of the M12x1 external thread of sonotrode and the specimen vibrate with the sonotrode. For the indirect test method, the specimen is fixed and the sonotrode vibrate on top of it.

Figure 2. Sonotrode with M12x1 external thread used for direct method

Figure 3. Sonotrode without thread used for indirect method

The sonotrode of Figure 3 has been designed using CAD software SolidWorks [4] and in order to function by the desired parameters it must to be calibrated by a frequency in the area of 20000 ± 500 Hz.

This calibration was done using National Instruments equipment (hardware and software) for measuring its own frequency that plugs into a laptop through a USB 2.0 connection. In Figure 4 it shows the hardware part of the National Instruments equipment [5].

First the aluminum specimen is weighed to determine the starting weight. After each period of cavitation erosion, using a tweezers, the specimens are dipped in alcohol to remove any impurities, and then are dried by air jets using a compressor and finally they are weighed with a METTLER TOLEDO electronic balance, as shown in Figure 5.

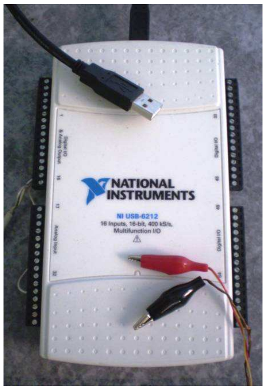

Figure 4. The hardware equipment to measure frequency

Figure 5. The METTLER TOLEDO electronic balance

This balance is replenished from an AC power source, weighs 9.1 kg, may weigh a maximum of 220 grams and its display can be set to 4 or 5 digits after the comma [6].

3. Calibration tests of a titanium sonotrode

The calibration was accomplished by reducing the length of its own frequency for classification purposes in the field of 20000 ± 500 Hz. The numerical results are presented in table 1 and the frequency measured is shown in Figure 6 and 7, but only for the first and last variant of the 10 variants of calibration.

Table 1.

Test Nr.	Sonotrode length [mm]	Frequency [Hz]	Δmm [mm]	ΔHz [Hz]
1	159	18969.7	0	0
2	158.6	19012.5	-0.4	42.8
3	157.7	19146.7	-0.9	134.2
4	157	19281	-0.7	134.3
5	156.1	19384.8	-0.9	103.8
6	155.7	19451.9	-0.4	67.1
7	155.5	19500.7	-0.2	48.8
8	155.1	19549.6	-0.4	48.9
9	154.7	19628.9	-0.4	79.3
10	154.4	19659.4	-0.3	30.5

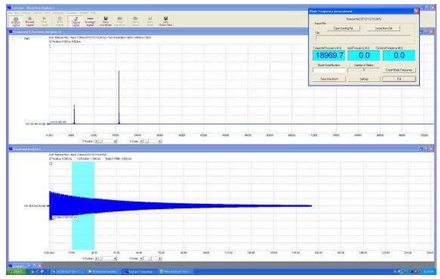

Figure 6. Value of 18969.7 Hz to a length of 159 mm

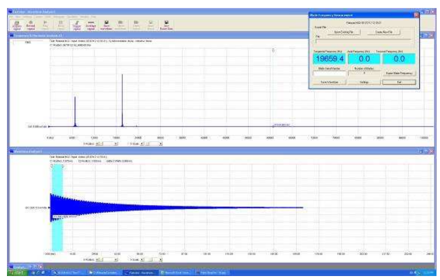

Figure 7. Value of 19659.4 Hz to a length of 154.4 mm

The graph that was drawn up by the 10 test is shown in Figure 8, and at this value of 19659.4 Hz for the titanium sontrode, the generator work correctly.

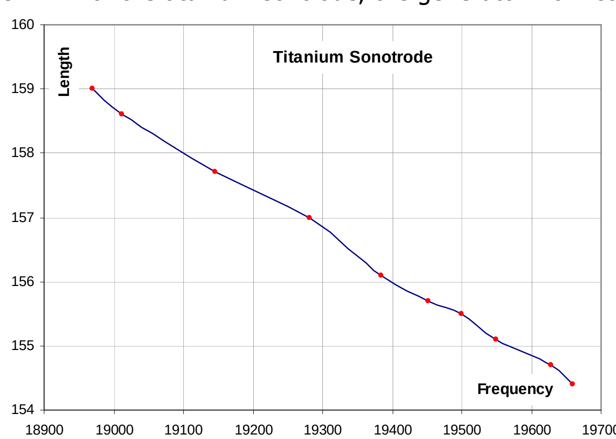

Figure 8. Graph of calibration of the titanium sonotrode

4. The tests of aluminum specimen through direct and indirect cavitation method

On experimental research of the literature shows that the materials most resistant by cavitation erosion are stainless steels materials, followed by the Al, Bz, cast iron, Pb as follows from Figure 9 [7].

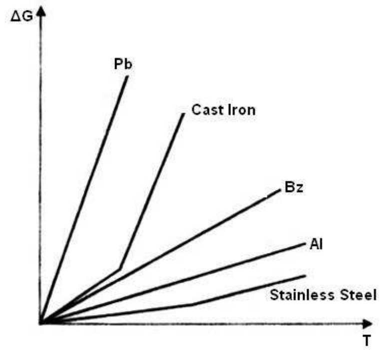

Figure 9. Material losses by cavitation

Therefore to verify which method is more efficient it was chosen a soft aluminum material, because the process of cavitation erosion is faster compared to stainless steel.

The first tests were done by direct method for a total time of 60 minutes and 90 minutes for indirect method.

The results of these tests are given in table 2 (for direct method) and table 3 (for indirect method).

Table 2.

Time	Phase	Specimen Mass	Eroded Mass		Erosion rate/phase	Cumulative erosion rate
			phase	cumulative		
t	Δt	m	Δm	Δmc	vef	vec
[min]	[min]	[mg]	[mg]	[mg]	[mg/min]	[mg/min]
0	0	4288.70	0	0	0	0
5	5	4273.52	15.18	15.18	3.0360	3.0360
15	10	4256.85	16.67	31.85	1.1113	2.1233
30	15	4227.43	29.42	61.27	0.9806	2.0423
45	15	4205.60	21.83	83.1	0.4851	1.8466
60	15	4186.54	19.06	102.16	0.3176	1.7026

Table 3.

Time	Phase	Specimen Mass	Eroded Mass		Erosion rate/phase	Cumulative erosion rate
			phase	cumulative		
t	Δt	m	Δm	Δmc	vef	vec
[min]	[min]	[mg]	[mg]	[mg]	[mg/min]	[mg/min]
0	0	4039.84	0	0	0	0
5	5	4037.73	2.11	2.11	0.4220	0.4220
15	10	4035.06	2.67	4.78	0.1780	0.3186
30	15	4027.44	7.62	12.4	0.2540	0.4133
45	15	4015.36	12.08	24.48	0.2684	0.5440
60	15	3966.37	48.99	73.47	0.8165	1.2245
90	30	3959.26	7.11	80.58	0.0790	0.8953

Graph for the 2 curves based on the cumulative mass dampened of time is shown in Figure 10, where they are highlighted the macrostructure of cavitation erosion.

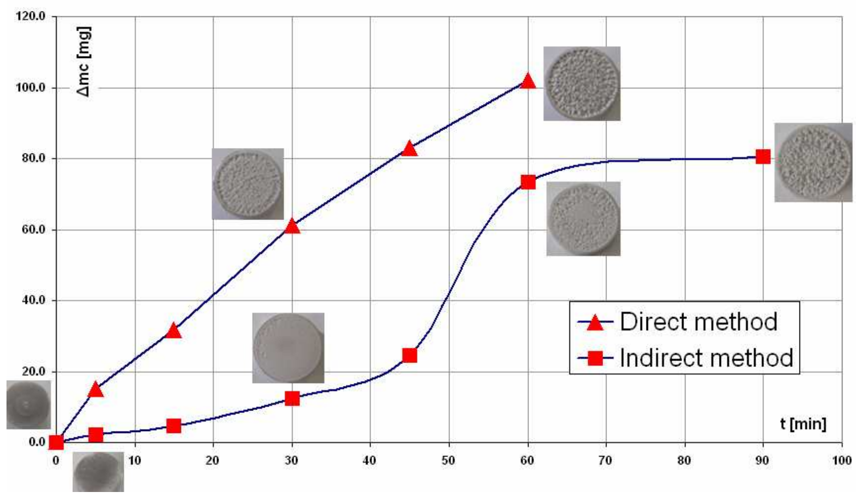

Figure 10. Comparison between the two methods of cavitation erosion

Of the graph corresponding to figure 10, results that the direct method is more efficient than the indirect method in the sense that, for the same time by direct method, it erodes cracks must faster than by the indirect method.

In figures 11 and 12 are given graphs of erosion speed/time and cumulative erosion speed.

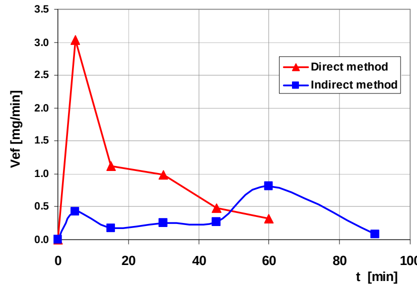

Figure 11. The variation comparison of erosion speed/phase in time by the both methods

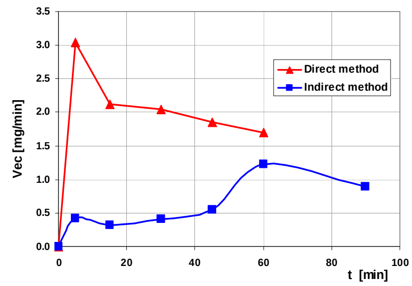

Figure 12. The variation comparison of the cumulative erosion speed in time by the both methods

In figures 13 and 14 is shown the macrostructure of the 2 aluminum specimens obtained from a stereomicroscope. In both of these situations are highlighted the damage by cavitation.

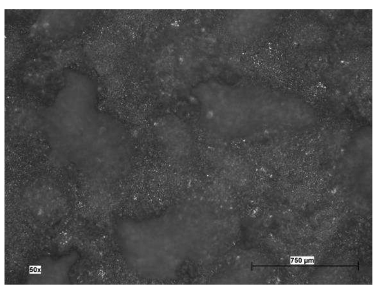

Figure 13. Aluminum test specimen testing to cavitation after 60 minutes using direct method

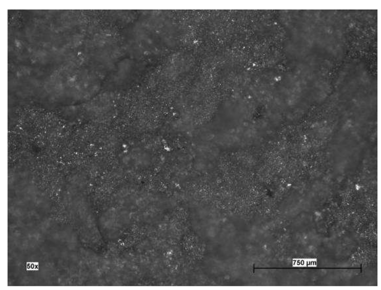

Figure 14. Aluminum test specimen testing to cavitation after 90 minutes using indirect method

5. Conclusion

By direct cavitation method for different materials must be used different sonotrode, so that the specimen-sontrode assembly to fit with its own frequency in the area of 20000 ± 500 Hz.

Also the assembly by thread is very sensitive to such high frequencies. These elements constitute disadvantages for the direct method.

At the indirect method, sonotrode is not assembled and it can be calibrated once and used for different materials. Sonotrode of titanium is the most recommended in such tests, it does not heat and does not affect the internal temperature of the ultrasonic generator.

The advantage of the direct method is given by the fact that the process of erosion is much sharper in relation to the indirect method.

The frequency value was in the area of 20000 ÷ 20500 Hz for the direct method and in the area of 19500 ÷ 20000 Hz for the indirect method.

The initial weight of the specimen with the direct method was 4288.70 mg and after the 60 minutes of cavitational attack is reached the weight of 4186.54 mg, so it lost a total of 102.16 mg.

The initial weight of the specimen with the indirect method was 4039.84 mg and after the 90 minutes of cavitational attack is reached the weight of 3959.26 mg, so it lost a total of 80.58 mg.

Acknowledgements

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