A COMPARATIVE ANALYSIS OF THE METHODS USED FOR TESTING THE CAVITATION EROSION RESISTANCE ON THE VIBRATORY DEVICES

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The measurement of cavitation erosion resistance of materials on vibratory devices can be applied in two testing configurations: "direct method"- with the sample attached to the sonotrode and "indirect method" – with the sample fixed on a device with an offset distance between the sonotrode and the sample. Based on the testing experience of CCHAPT Resita, the authors make a comparative analysis of the main advantages and disadvantages of the two methods. The next criteria are regarded: the cavitation erosion rate, the influence of the sample characteristics on the frequency of the vibratory system and the durability of the vibratory device components.

Keywords: cavitation erosion, vibratory devices, direct method, indirect method

1. Introduction

Cavitation is a phenomenon that occurs in a significant number of hydroturbines. One of its main effects is the erosion of the material from the surfaces exposed to cavitation bubbles. In order to study the resistance of the materials to cavitation erosion, can be performed investigations in laboratory conditions. The most used laboratory tests are made on vibratory devices, cavitating liquid jet systems and Venturi systems.

The vibratory method, described in ASTM G-32 standard [1], uses a vibratory device to generate oscillations with small amplitude and high frequency (A=50 μm, f=20 kHz,), on the surface of a sample immersed into liquid (usually distilled water). The standard configuration of a vibratory system is presented in figure 1-a. The ultrasonic generator (1) sends signal to a piezoelectric transducer (2). The transducer converts the signal in mechanical oscillations. The amplitude of oscillations is amplified by the booster (3) and the sonotrode (4). At the end of the sonotrode is clamped the sample (5) immersed in liquid (6). The oscillations

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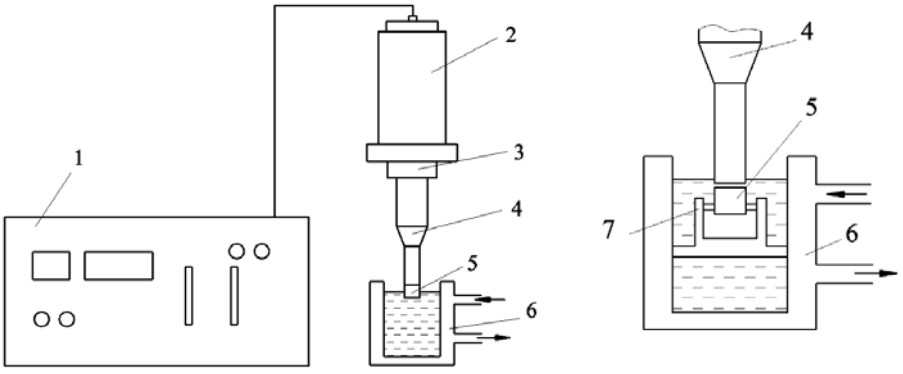
of the sample and the sonotrode generate the cavitation bubbles. The collapse of the bubbles on the sample surface causes the cavitation erosion.

In the last years several laboratories [2,3,4] used a modified method of testing (Fig. 1b): the sample is fixed in a device (7) with an offset distance between the end surface of the sonotrode and the surface of the sample. This distance is usually set between 0.5 mm and 1.0 mm. The shape and the dimensions of the sonotrode used for this alternative method differ from the sonotrode used at the standard method. The cavitation bubbles are generated by the oscillation of the sonotrode. This alternative method is referred in the scientific literature as *indirect method* of cavitation erosion on vibratory devices and the original method, described above (sample attached to sonotrode) is referred as the *direct method*.

The use of the laboratory tests for the prediction of cavitation erosion resistance is justified mainly to compare the behavior of the materials, one to each other [5,6,7]. In this context the use of two alternative methods in the vibratory devices leads to difficulties in the comparative analysis of the results. This paper, based on the measurements made in the Center for Research in Hydraulics, Automation and Thermal Processes (CCHAPT) from "Eftimie Murgu" University of Resita [8,9], indicates the limitations, the advantages and the disadvantages of the two methods and make a correlation of the values of cavitation erosion rates.



a) b)

Fig. 1. The vibratory equipment used for cavitation erosion tests: a) set-up used for direct method; b) detail on the offset between sonotrode and sample at the indirect method

2. Comparative analysis

In the Center for Research in Hydraulics, Automation and Thermal Processes the tests are performed using a 2kW generator and a vibratory equipment with piezoelectric transducer. The temperature of the water from the water bowl is monitored by a digital thermometer. The mass of the samples is measured using a digital balance with high precision (0.01mg).

The tests performed mainly on stainless steels on direct and indirect method revealed advantages and limitations for each method. At the direct method the following remarks can be made:

- The method ensure short testing times, usually 180 minutes for a sample with medium cavitation erosion resistance;
- The dimensions of the sample and the density of the material influence the frequency of the system; The sonotrode must by designed related to sample material density;
- The presence of discontinuities (material defects, cracks – Fig. 2) on the sample led to the impossibility of tuning the system in frequency;
- At the samples with thermal sprayed coatings the oscillations leads to the detachment of the overlays (Fig. 3). Future research will be made to establish if the difference between density of the base material and the density of the coatings generates this behavior;
- The clamping system between the sample and the sonotrode (thread) influence the frequency of the system; The clamping is influenced by the thread quality and the contact between sample and sonotrode; For this reason is difficult be establish a torque for the grip of the sample;
- The thread between sonotrode and sample is subjected to fatigue; This phenomenon is emphasized and can lead to sonotrode failure (Fig. 4), if the system is working on the limit of domain of frequency;
- Material particles detached from the thread in the clamping process of the sample influence the mass measurements, making difficult the analysis of the results.

Fig. 2. Sample with cracks on welded overlay

Fig. 3. Thermal sprayed coatings destroyed on direct vibratory tests

The indirect method was used in CCHAPT especially to materials where the direct method could not be applied (samples with cracks, samples with thermal sprayed overlays). The following remarks can be made on this method:

- The sample parameters don't influence the frequency of the system;
- The same type of sonotrode can be used for all samples;

- Due to the position of the sample in the water bowl the offset distance between the sample and the sonotrode is difficult to be measured accurate; This distance influences the intensity of the erosion;
- The testing times are larger in comparison to the direct method;
- For the materials with high erosion resistance the mass loss is very low. This leads to difficulties in mass measuring and in the analysis of the results. The typical variations of the mass loss and cavitation erosion rate (Thiruvengadam curve) are difficult to be reproduced by the measurements performed by indirect method;
- The cavitation generates erosion on the sample surface but also on the sonotrode surfaces (Fig. 5). The sonotrode surface must be periodically restored (usually by turning) but after several reconditioning the sonotrode will exit from domain of frequency due to shortening of its overall length.

At the method with fixed sample should be noted that the end diameter of the sonotrode influence the material mass loss and the diameter of the eroded area on the sample [10].

Fig. 4. Sonotrode for direct vibratory method. Detail on the failure area of the thread

Fig. 5. Sonotrode for indirect vibratory method. Detail on the cavitation eroded surface

3. Cavitation erosion rate correlation

For a comparative analysis of the cavitation erosion rates obtained for the same material, using the two variants of vibratory method, two samples (named 1A and 1B) were subjected to tests. The samples were cut from the same material (welded overlays of austenitic stainless steel with the base material from steel grade 1.4313). The austenitic steel tested is designed for repairs of the hidroturbines components damaged by cavitation erosion. Previous researches showed that this material has a high resistance to the cavitation erosion [9]. The sample 1A was tested by the direct method and the sample 1B by indirect method.

The parameters used for the tests were the same for the both setups (according to ASTM G32-10): frequency f=20 kHz, amplitude A=50 μm,

temperature of the water: 22-25 °C. The testing time for the direct method was 180 minutes, with mass measurements at each 15 minutes. For indirect method the testing time was extended to 3000 minutes with mass measurements at each 15 minutes in the first hour and at each 30 minutes for the remaining time.

The variation of cumulative eroded mass, Δm_t, is presented in figure 6. It can be observed that the loss of the mass on the indirect method is considerably smaller related to loss of the mass on direct method. The medium erosion rate is about 0.012 mg/min for sample 1A and $0.5x10^{-3}$ mg /min for sample 1B. This high difference is considered to be valid only for the materials with high cavitation erosion resistance, for others materials new tests will be made.

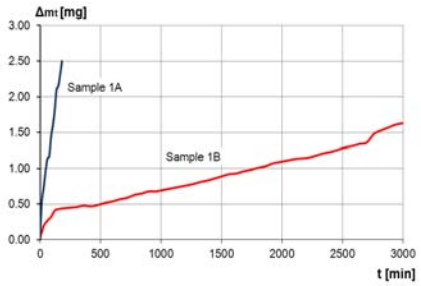
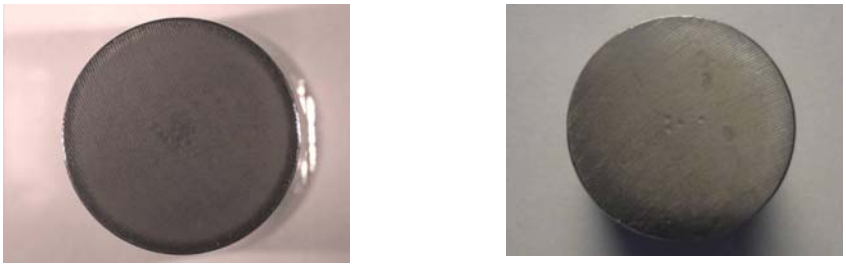


Fig. 6. Variation of cumulative mass loss for sample 1A (direct method) and 1B (indirect method)



a) b)

Fig. 7. Cavitation erosion pitting: a) sample 1A after 180 min of cavitation erosion; b) sample 1B after 3000 min of cavitation erosion

The difference in the cavitation erosion pitting between the samples tested by the two methods can be observed on the surfaces exposed to cavitation (fig. 7).

4. Conclusions

The cavitation erosion tests performed on a vibratory device in the Center for Research in Hydraulics, Automation and Thermal Processes from the "Eftimie Murgu" University of Resita, using both variants of the method (attached sample and fixed sample) led to the following main conclusions:

The method with attached sample on the sonotrode has the advantage of a high cavitation erosion rate. The main disadvantage of this method is the influence of the sample characteristics and the sample clamping on the frequency of the vibratory system;

The method with fixed sample allows the tests of large types of samples and materials but generates cavitation erosion with lower erosion rate compared to the direct method (mainly on the samples manufactured from materials with high cavitation resistance). For this reason the testing time increases at this method more than 10x related to the time from the method with attached sample.

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