

DAMAGE LEVEL EVALUATION OF ZIRCON SAMPLES CAUSED BY CAVITATION EROSION USING IMAGE ANALYSIS

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Abstract

This study is focused on monitoring the degradation level of zircon based ceramic materials during exposure to cavitation. In addition to conventional degradation monitoring methods, weight loss measuring, the emphasis is on monitoring the changes occurring at the surface of the sample by taking the photos and analyzing of these images. In this paper, several parameters are monitored by image analysis: the level of surface degradation, the number of pits and the average area of the pits. This method proved to be very fast and useful for a quantification of damage which could improve the prediction of the material lifetime.

Keywords: zircon based material, cavitation, image analysis

1. INTRODUCTION

Zircon is widely used for the synthesis of ceramic materials due to its properties high melting temperature, low coefficient of thermal expansion, excellent mechanical properties, high resistance to thermal shock, not wetted with liquid metal, minimal gas production when in contact with liquid metal [1-4]. Zircon based ceramics are usually applied in the foundry for making molds for casting, manufacturing ceramic shells, ceramic cores in investment casting, refractory coatings based on zircon for casting of high temperature materials, filler based on zircon providing the best resistance of liquid metal penetration with the aim of obtaining high quality surface of castings [1-5]. Bearing in mind the properties and the usual possible application of zircon based ceramics, it can be assumed that zircon will show good resistance in extreme condition such as subjecting to the cavitation erosion. This approach is useful for the assessment of possible future application of zircon based materials in conditions of cavitation exposure.

2. EXPERIMENTAL

After synthesis and characterization, zircon based ceramics samples were subjected to the vigorous exploitation conditions of cavitation erosion. Since the surface of the sample showed degradation during the testing, monitoring of occurred damages and degradation was carried out not only by a conventional method of measuring the mass loss but also by image analyses of the degraded sample surface due to better understand material degradation induced by the cavitation.

2.1 Material

An initial mineral raw material used for the synthesis of zircon based ceramic was high purity zircon (99.99 wt.% ZrSiO₄), processed and purified zircon sand. Synthesis of the zircon based samples was carried out by pressing zircon based powder with a grain size < 25 μm into the

plates with a cylindrical shape (tablets) and diameter of $2 \cdot 10^{-2}$ m. Pressure device Leitz with a pressure of 106 Pa was applied. Afterwards, the zircon samples were sintered at the temperature of 1200 °C according to the sintering regime. X-ray diffraction analysis and microstructure of sintered zircon sample were done by the X-ray diffractometer PHILIPS, model PW-1710 and SEM JOEL JSM-6390LV microscope, respectively. Phase composition and microstructure of prepared zircon based sample are shown in Figure 1.

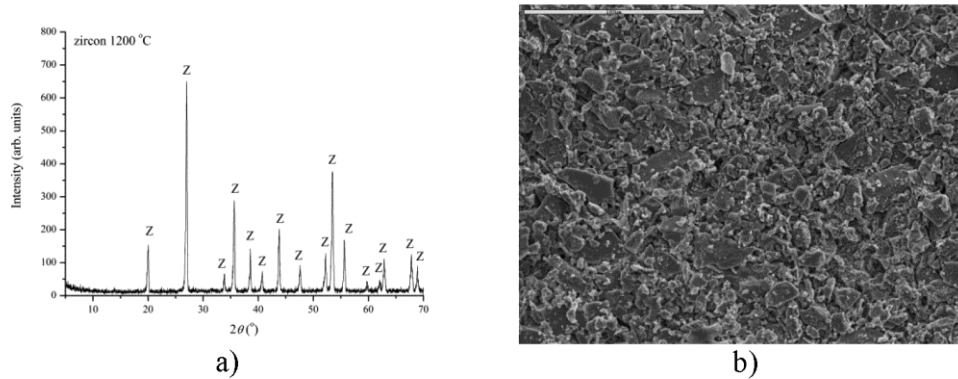


Figure 1 - Phase composition (a) and microstructure (b) of sintered zircon based sample [6]

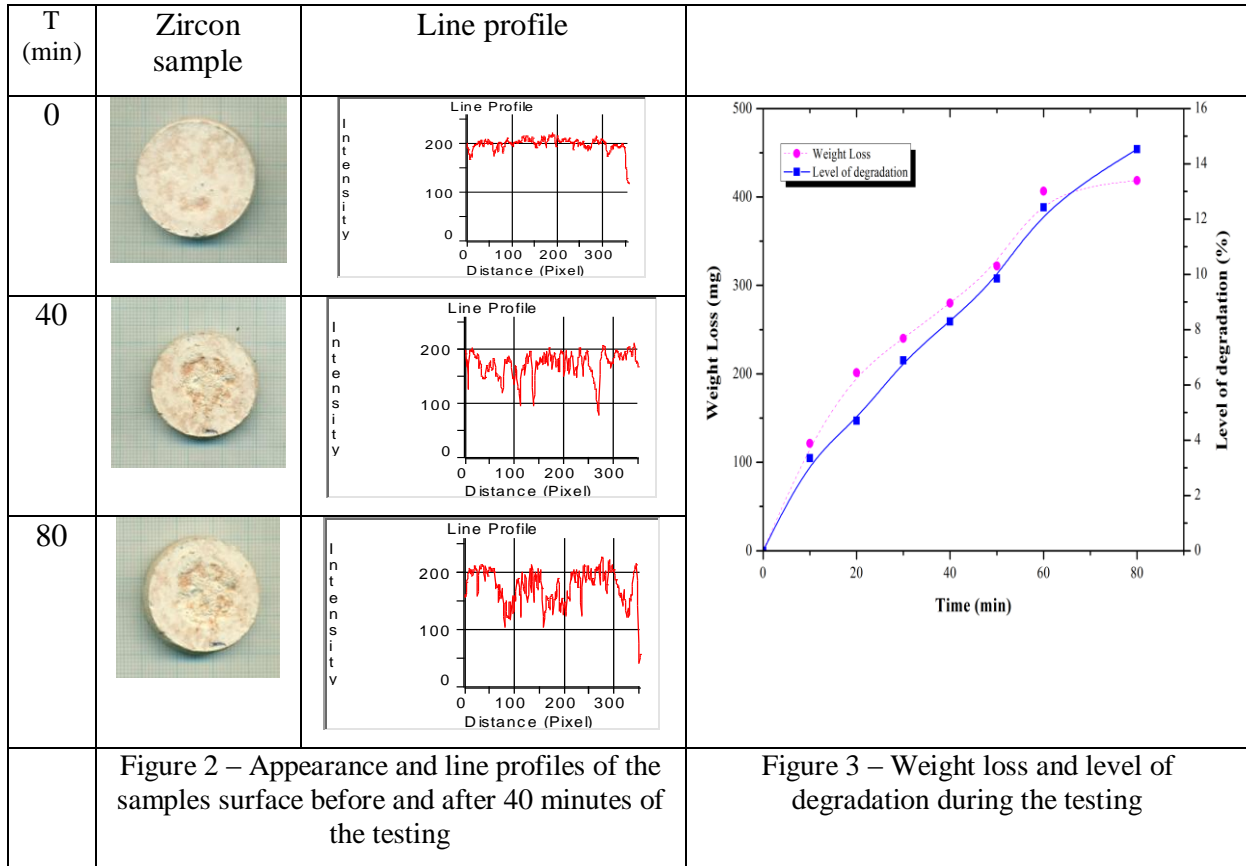
Diffraction pattern Figure 1 a) indicates that the dominant mineral phase in tested sample is zircon with clearly expressed picks characteristic for high purity zircon. Figure 2 b) shows uniform structure with high density and very little porosity (dark part of the surface).

2.2 Methods

Cavitation erosion is a phenomenon usually observed in many types of hydraulic structures and engineering installations such as ship propellers, pumps, hydraulic turbines or valves. Metallic materials are mostly used for the synthesis of the components exposed to the cavitation. However, recent studies are mainly occupied by replacement of metallic components with composite and ceramic materials to enhance the erosion resistances of different alloys and steels by deposition of protective coatings on their surfaces [6-26]. Cavitation erosion testing was performed using ultrasonic vibration method (with stationary specimen) according to standard procedure [14,15]. The usual characteristics for the frequency and peak-to-peak displacement amplitude of the horn were used, as well as characteristics of liquid are described in details in previous papers [8,9,16,24,25]. Based on the standard procedure, the specimen is weighed before and periodically during the test using analytical balance with an accuracy of ± 0.1 mg in order to obtain mass loss versus time or cumulative erosion versus time curve. Measuring the mass loss was performed after each exposure interval of 10 minutes for the test period of 80 min. As an addition to the standard laboratory procedure of material damage monitoring (mass loss), image analyses were also applied with the aim of monitoring damage occurrence and its growth during the cavitation testing. Therefore, samples were photographed using CCD camera before and during the cavitation erosion testing. Image Pro Plus program was applied in the analysis Results were given as the surface degradation level (P/P_0) during the testing time. P_0 (level of degradation before the testing) was determined according to the ideal surface (surface area without any defects). P was measured as surface area that was destructed during the cavitation testing. Besides the determination of surface degradation level during the testing, it is also possible to estimate amount and size of existing pits giving us the information and allowing us to study the complex changes occurred in the sample by monitoring formation of new pits and growth of already existing pits but also to analyze behavior of tested material and predict its durability.

3. RESULTS AND DISCUSSION

Photographs obtained by CCD camera as well as corresponding line profiles obtained using IPP program are shown in Figure 2. Level of surface degradation was determined by image analysis of the photographs and results are given in Figure 3. Total mass loss results as a function of exposure time are given in Figure 3, showing typical cumulative mass loss curve.



Based on the photos taken by CCD camera, it is clearly evident that the development of surface degradation exists, while the line profiles proved increase of the degradation. Analysis obviously indicates that the surface degradation begins almost immediately, as the first pits are formed only after 5 minutes of the testing. Based on the changes of peaks intensity, it is possible to notice that the pits occurred and grown at the center of the exposed area. By analyzing the erosion progression, it is evident that mass loss of the sintered zircon sample gradually increases almost linearly till 60 minutes. During this period, material suffers a significant deterioration and weight loss until attaining a maximum value. After 60 minutes of exposure to the cavitation, mass loss is slightly slowing down and reaching deceleration erosion period. Obtained results indicate good resistance of tested zircon sample. Level of surface degradation is linearly increasing up for almost whole period of testing.

This approach based on the assessment of resistance of zircon samples to the effects on cavitation erosion can be very useful in practice for the purpose of estimating the lifetime of the product based on zircon.

4. CONCLUSION

Monitoring the damage level on the surface of the sintered zircon samples at 1200 °C several approaches were used: changes of mass loss, measuring of surface degradation by determining area of surface degradation, line profiles.

Obtained results showed that the cavitation erosion of sintered zircon sample is characterized by occurrence of small pits, and that their number grows during the test. Results of measuring the surface level degradation reliably demonstrated the high quality of zircon samples exposed to cavitation erosion. Chosen methods of image analysis fully contributes to the characterization of zircon sample in terms of cavitation erosion and can be used for rapid and reliable selection of materials for use in this conditions.

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