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Comparison of cavitation erosion behavior of cordierite and zircon based samples using image and morphological analyses

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ABSTRACT

In this study the resistance of cordierite and zircon to the cavitation erosion was investigated with the aim of possible spreading their application. Cavitation erosion test was applied using standard ultrasonic vibratory set up with stationary sample. Weight loss and image analysis measurements including morphological analysis of the formed pits were used for monitoring degradation during the cavitation erosion testing. The obtained results were discussed in order to compare and analyze degradation mechanism and the resistance of the investigated materials to cavitation erosion. Cordierite sample underwent less serious degradation, characterized by continual forming of new pits, while zircon degradation progressed by growth and merging of already formed pits.

1. Introduction

Cavitation erosion is the process of wear that occurs in many types of hydraulic structures causing surface degradation. This can be explained by the generation of vapor or gas pockets inside the flow of liquid. Cavitation erosion usually involves an attack on the surface by gas or vapor bubbles, creating a sudden collapse due to a change in pressure near the surface. Low pressure is generated hydrodynamically, and it is influenced by various flow parameters, such as liquid viscosity, temperature, pressure and nature of flow. This deterioration is initiated by a sudden surge of bubbles harmering the surface [1–3].

Cavitation erosion usually occurs on the surfaces of metals and nonmetals. Many published results are related to the different types of steel, coatings, as well as to the engineering ceramic materials [4–14]. This phenomenon can be observed on the contact between the flowing fluid and the material and it is conventionally monitored by weight loss measuring.

Image analysis approach was previously successfully implemented for determination of degradation level of various materials caused by different impacts [15–19].

Cavitation erosion of cordierite and zircon samples was previously interpreted by degradation level combined with thermal imaging [20,21]. The aim of this research is to understand the mechanism of degradation. For this purpose, possibilities offered by image analysis were expanded on measuring morphological parameters to perform morphology analysis. Depths of the formed pits were also measured for the same reason.

2. Materials and methods

Cordierite and zircon based samples, both sintered at 1200 °C, were prepared with the same composition as for the coatings materials previously investigated [20,21].

Cavitation erosion test was performed using ultrasonic vibration method (with stationary sample) applying water flow (5–10 ml/s), according to the standard [22]. Total duration of the cavitation tests was 80 min.

The cavitation damage was determined by monitoring weight loss and surface degradation during the experiment.

The weight loss was measured by analytical balance with an accuracy of ±0.1 mg. Before being weighted, the test samples were dried at 110 °C until the constant mass.

Image analysis was added to the standard laboratory procedure of weight loss measuring with the aim to monitor and determine surface damage. Photographs of the sample surfaces were analyzed by Image Pro Plus software program. The chosen morphological parameters of selected defects were measured using the image analysis tools to additionally quantify surface damage.

Pit depth measurements were performed using mechanical comparator "Orion" added to the microscope.

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3. Results and discussion

3.1. Weight loss

The weight loss of the samples during the cavitation erosion testing is presented in Fig. 1. The obtained results showed an increase with the testing time which was expected, as similar behavior was noticed with some other materials [19]. However, the difference between the samples was obvious, as cordierite showed lower value of weight loss during the total experiment time.

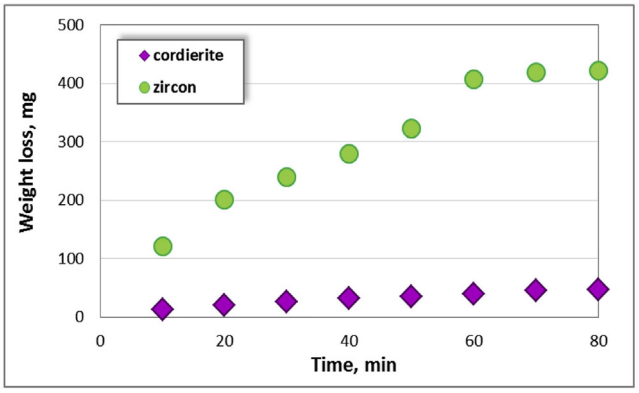

Fig. 1. Weight loss of the samples during cavitation erosion testing.

3.2. Image analysis

Images of the samples surfaces before and during cavitation erosion testing and corresponding line profiles are given in Fig. 2.

According to the given images, it is obvious that zircon underwent more serious degradation than cordierite. The shapes of the line profile curves are pointing out formation of new defects. Namely, obvious deviation from the straight line (which would indicate an ideal surface with no degradation or pits) is present here. Width of the deviation should indicate the diameter of the formed pit, and differences between intensities (y-dimension) the depth of the pit. The real dimensions cannot be measured directly from the graph intensity- distance.

Fig. 3 presents surface degradation level (a), number of formed pits (b), total area of formed pits (c) and pit depth (d).

According to Fig. 3(a), at the beginning of the test (20 min), both samples exhibited similar degradation level (below 1%). However, for longer periods, degradation of zircon was much higher, reaching 26% at the end of the testing compared to cordierite (19%).

As can be seen from Fig. 3(b), for cordierite sample new pits formation is characteristic for the period 0–40 min. During the period 40–80 min number of pits was decreasing, indicating merging of

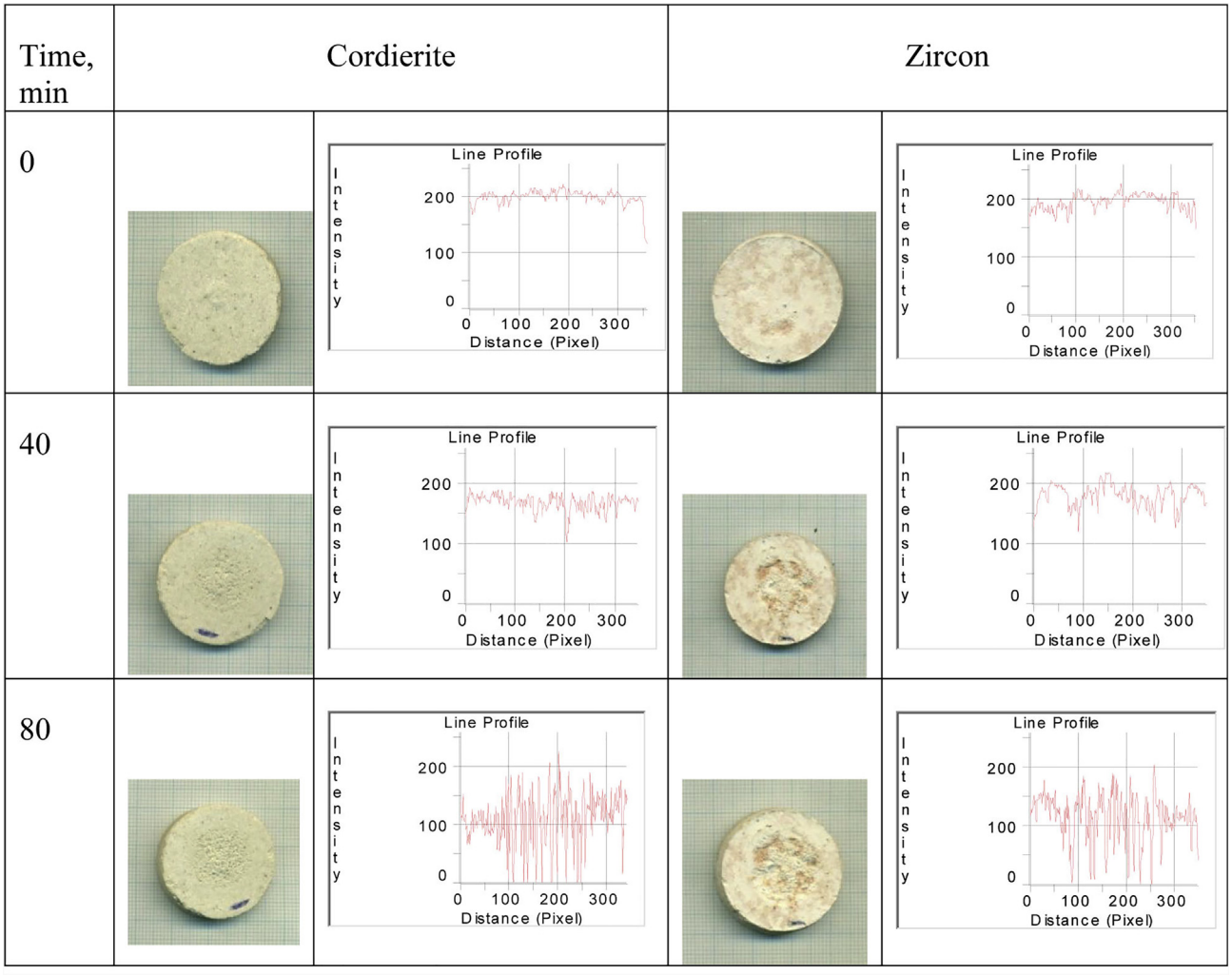

Fig. 2. Images of the samples surfaces before and during cavitation erosion testing and corresponding line profiles.