University of Belgrade
Technical Faculty in Bor and
Mining and Metallurgy Institute Bor

49th International October Conference on Mining and Metallurgy

PROCEEDINGS

Editors:
Nada Štrbac
Ivana Marković
Ljubiša Balanović

Bor Lake, Serbia
October 18-21, 2017

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49th INTERNATIONAL OCTOBER CONFERNCE

on Mining and Metallurgy

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Technical Editor:

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University of Belgrade, Technical Faculty in Bor

Publisher: University of Belgrade, Technical Faculty in Bor

For the publisher: Dean Prof. dr Nada Štrbac

Circulation: 200 copies

Printed by "Happy trend DOO", Zaječar, 2017

ISBN 978-86-6305-066-2

CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

622(082)
669(082)

INTERNATIONAL October Conference on Mining and Metallurgy (49 ; 2017 ; Bor Lake)
Proceedings / 49th International October Conference on Mining and Metallurgy - IOC 2017, Bor Lake, Serbia, October 18-21, 2017; [organized by] University of Belgrade, Technical Faculty Bor and Mining and Metallurgy Institute Bor; editors Nada Štrbac, Ivana Marković, Ljubiša Balanović. - Bor : University of Belgrade, Technical Faculty, 2017 (Zaječar : Happy trend). - XXIII, 664 str. : ilustr. ; 25 cm

Tiraž 200. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-6305-066-2

a) Рударство - Зборници b) Металургија - Зборници

COBISS.SR-ID 246349324

Bor Lake, Serbia, October 18-21, 2017

Conference is financially supported by
The Ministry of Education, Science and
Technological Development of the
Republic of Serbia

SCIENTIFIC COMMITTEE

ORGANIZING COMMITTEE

PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the 49^{th} International October Conference on Mining and Metallurgy (IOC 2017) held at Bor Lake, Serbia, 18 – 21 October 2017.

The IOC 2017 has been organized by the University of Belgrade, Technical Faculty in Bor, in cooperation with Mining and Metallurgy Institute Bor. It is devoted to presenting recent research results and advances in the fields of geology, mining, metallurgy, materials science, technology, environmental protection, and related engineering topics. The primary goal of IOC is to bring together academics, researchers, and industry engineers to exchange their experiences, expertise and ideas, and also to consider possibilities for collaborative research.

This year's conference is dedicated to the memory of Professor Dragana Zivkovic who was one of our most loyal and active Committee members. The 4^{th} International Student Conference on Technical Sciences (ISC 2017) will take place within the frame of IOC 2017. ISC provides a unique opportunity for the students from both the country and the region to promote scientific research and discuss future directions of research with the experts and specialists.

These proceedings include 153 papers from authors coming from universities, research institutes and industries in 30 countries: Austria, Bosnia and Herzegovina, Bulgaria, China, Croatia, Czech Republic, France, Germany, Hungary, India, Iran, Italy, Japan, Jordan, Kazakhstan, Libya, Macedonia, México, Montenegro, Norway, Poland, Romania, Russia, Slovakia, Slovenia, South Africa, Spain, Turkey, USA and Serbia.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged. The support of the sponsors and their willingness and ability to cooperate has been of great importance for the success of IOC 2017. The Organizing Committee would like to extend their appreciation and gratitude to all the sponsors and friends of the Conference for their donations and support.

We would like to thank all the authors who have contributed to these proceedings, and also to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to IOC 2017. Sincere thanks to all the people who have contributed to the successful organization of IOC 2017.

We look forward to welcoming you to the 50^{th} International October Conference on Mining and Metallurgy (IOC 2018), which will be held in October 2018.

On behalf of the 49^{th} IOC Organizing Committee,

Assistant Professor Ivana Marković, PhD

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

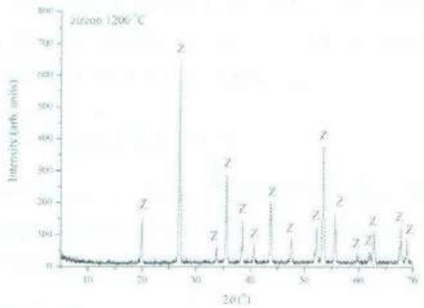
Zircon is widely used for the synthesis of ceramic materials due to its properties high melting temperature, low coefficient of thermal expansion, excellent mechanical properties, high resistance to thermal shock, not wetted with liquid metal, minimal gas production when in contact with liquid metal [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 possibile future application of zircon based materials in conditions of cavitation exposure.

2. EXPERIMENTAL

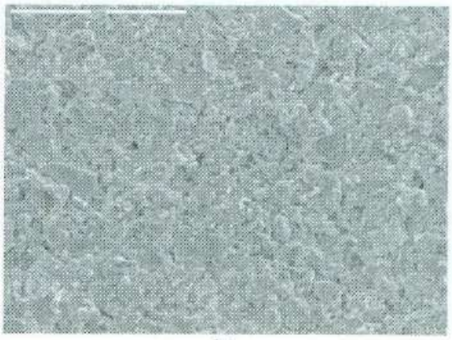
After synthesis and characterization, zircon based ceramics samples were subjected to the vigorous exploitation conditions of cavitation erosion. Since the surface of the sample showed degradation during the testing, monitoring of occurred damages and degradation was carried out not only by a conventional 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 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.



a)



b)

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.

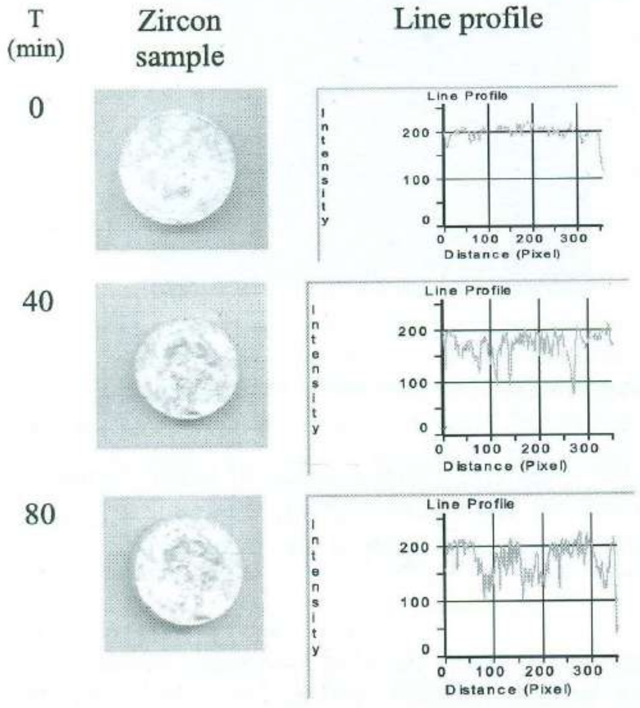


Figure 2 – Appearance and line profiles of the samples surface before and after 40 minutes of the testing

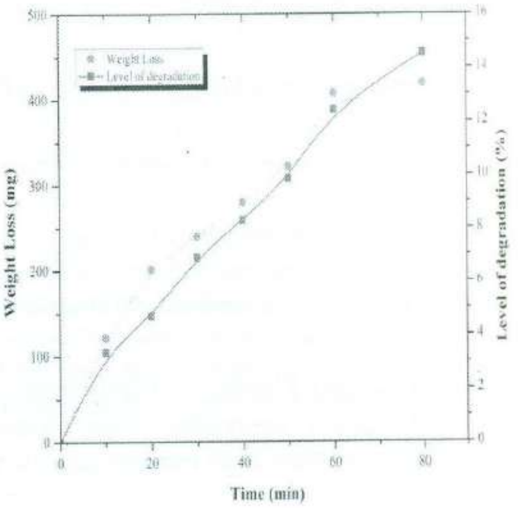


Figure 3 – Weight loss and level of degradation during the testing

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.

ACKNOWLEDGEMENTS

This research has been financed by Ministry of Education, Science and Technological Development of the Republic of Serbia as part of the projects TR 33007, III 45012, TR 35002 and OI 172060.

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