



Cavitation wear of structural oxide ceramics and selected composite materials

Zbigniew Pędzich^{a,*}, Robert Jasionowski^b, Magdalena Ziąbka^a

^a AGH – University of Science and Technology, Faculty of Materials Science and Ceramics, Department of Ceramics and Refractory Materials, Mickiewicza 30, 30-059 Krakow, Poland

^b Maritime Academy, Institute of Basic Technical Sciences, Department of Shipbuilding Materials Engineering, Podgorna 51-53, 70-506 Szczecin, Poland

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Abstract

The usage of ceramic materials in the applications endangered by intensive cavitation could limit erosion phenomena. In the presented work, cavitation erosion resistance of commonly used (in structural application), oxide phases (α -alumina, tetragonal zirconia) were investigated. Additionally, the behaviour under cavitation conditions of two composite materials, based on alumina and zirconia matrices, was tested.

Significant difference in cavitation wear mechanisms for alumina and tetragonal zirconia materials was observed. Alumina was degraded by removing the whole grains from the large surface subjected to cavitation. Degradation of zirconia proceeded locally, along ribbon-like paths of removed grains. Cavitation wear of composites was strongly dependent on the residual stress state in the material. Alumina/zirconia composite with compressive stresses in the matrix showed a significant improvement of cavitation resistance. The zirconia/tungsten carbide composite with relatively high level of tensile stresses in the matrix was the worst of all investigated materials.

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1. Introduction

Cavitation is a phenomenon caused by the repeated nucleation, growth, and violent collapse of clouds of bubbles within the liquid. Microstreams of liquid developed during the implosion of cavitation bubbles as well as the action of pressure waves from disappearing bubbles are the main causes of destruction on swilled surfaces leading to a loss of material, i.e. to cavitation erosion. On the surface of the material exposed to the acting of liquid, the cavitation phenomenon induces local destruction of the surface layer as a consequence of the resultant effect of liquid micro-stream blows with high hydrodynamic parameters as well as pressure waves. Many researchers consider that due to the nature of loading, destruction of material surface can be compared to the fatigue process.^{1–3} This means that materials with larger resistance to cavitation erosion are the first of

all characterized by high hardness and micro-hardness as well as fine-grained one-phase microstructure having internal compressive stresses.^{4–6} Among metallic materials the progress in cavitation resistance could be achieved by application of intermetallic phases.^{7,8} Also ceramic materials could be perspective for such applications. The problem of the devastation of fluid-flow machinery components is very complex. It consists of processes of erosion and corrosion. The usage of ceramic materials in applications endangered by intensive cavitation could limit corrosion phenomena. The number of works devoted to the investigation of resistance to cavitation erosion of ceramics materials is not large^{9–13} and they concern the properties of pure phases, such as alumina, zirconia, silicon nitride or some types of glass. As a result, the mentioned works gave some useful data suggesting which phases could be more resistant than the other and how the microstructure of sinters could influence the susceptibility to cavitation wear of ceramic phases.

In the presented work, cavitation erosion resistance of commonly used, in structural applications, oxide phases (α -alumina, tetragonal zirconia) were investigated. Additionally,

* Corresponding author. Tel.: +48 693772169.

E-mail address: pedzich@agh.edu.pl (Z. Pędzich).

Table 1
Selected properties of investigated ceramic materials.

Material	Relative density, % of theo.	Vicker's hardness, HV ₅ (GPa)	Young modulus, <i>E</i> (GPa)	Fracture toughness, <i>K</i> _{IC} (MPa m ^{0.5})	Bending strength, <i>σ</i> (MPa)	The mean grain size in sinters (μm)
Al ₂ O ₃	99.3	17.0 ± 1.2	379 ± 6	3.6 ± 0.3	600 ± 120	Al ₂ O ₃ 2.5
Al ₂ O ₃ /ZrO ₂	98.5	17.0 ± 0.4	361 ± 5	5.1 ± 0.5	800 ± 120	Al ₂ O ₃ 1.10 ZrO ₂ 0.30
ZrO ₂	99.5	14.0 ± 0.5	209 ± 5	5.0 ± 0.5	1150 ± 55	ZrO ₂ 0.35
ZrO ₂ /WC	99.7	17.0 ± 0.9	232 ± 6	8.0 ± 1.0	1100 ± 130	ZrO ₂ 0.27 WC 0.47

the behaviour under cavitation conditions of two ceramic composite materials based on alumina and zirconia matrices was tested.

2. Experimental

Cavitation wear investigations were conducted for four ceramic sinters. Two of them are the widely used oxide materials: α -alumina and tetragonal zirconia. For the sinters fabrication commercial powders were utilized: Al₂O₃ – TM-DAR produced by Taimicron Inc., Japan (the mean crystallite size of 130 nm), and yttria stabilized ZrO₂ powder 3Y-TZ by Tosoh, Japan (the mean crystallite size of 20 nm). Two other materials were manufactured on the basis of the mentioned oxides by addition of 10 vol.% of dispersed particles of the second phase. In the case of alumina matrix composite the zirconia particles were introduced. In the case of zirconia matrix composite, 10 vol.% of tungsten carbide particles Baildonit (Poland) of the mean crystallite size of 800 nm were added into 3Y-TZ powder. The mentioned materials were previously investigated^{14,15} and they showed good mechanical properties, especially in abrasive wear applications in dry and also wet environments. Composite powders were prepared by rotation–vibration wet milling of constituent powders for 1 h in the environment of ethyl alcohol. Composite powders after separation from milling media (5 mm zirconia balls) were dried and granulated.

The materials for investigations are marked in this work as follows: **A**, **Z**, **AZ** and **ZW** for alumina, zirconia, alumina/zirconia composite and zirconia/carbide composite, respectively.

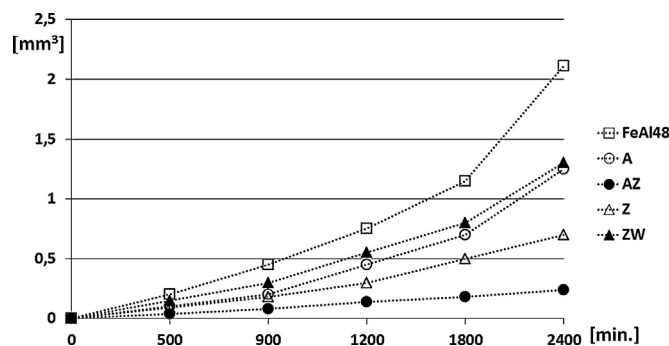


Fig. 1. Volumetric wear of investigated materials during stream impact test.

Alumina, zirconia and alumina/zirconia composite were fabricated in a quite simply way. They were uniaxially pressed under 50 MPa, consequently isostatically re-pressed under 300 MPa and then pressurelessly sintered at 1500 (for **A**) or 1550 °C (for

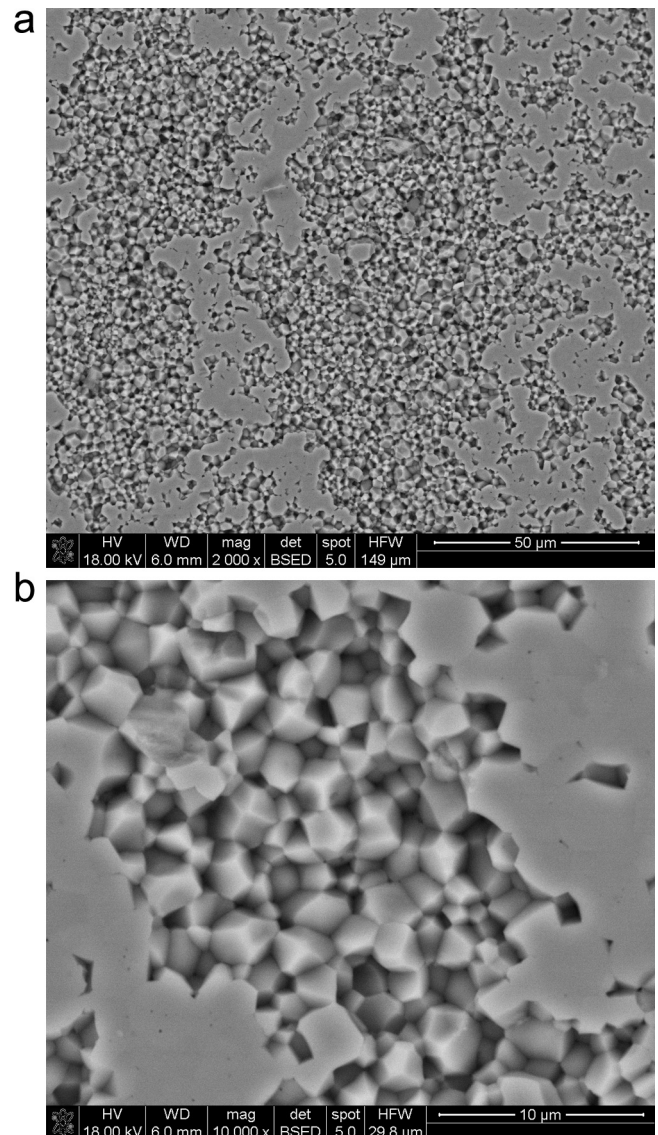


Fig. 2. Typical SEM images of alumina (**A**) sample surface after the cavitation test (a, b – different magnifications of the same area).

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