

**A NEW TYPE OF ALUMINA TOUGHENED ZIRCONIA – MODERN MATERIAL FOR
STRUCTURAL APPLICATIONS IN MACHINERY INDUSTRY**

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Permanent development of ceramics technologies is a necessary condition for the continuous improvement of many branches of industry. Each type of ceramic product demand a specific technology and has an optimal field of application. Alumina-toughened zirconia (ATZ) materials are relatively well recognized and commercialized due to their low manufacturing costs and good properties, which, in some applications, are much better than the properties of monophasic tetragonal zirconia or alumina products. A very good example are knee or hip-joint ceramics endoprosthesis, but the mentioned ATZ materials have a significantly wider field of application in the machinery industry. Mentioned composites are very often used as an efficient material for parts of machinery subjected to sliding, rolling, or any other movement usually correlated with mechanical loading and the potential abrasive acting of the environmental elements. The applications of ATZ materials are not only limited to room temperature, as ATZ materials can withstand elevated temperatures (a few hundred Celsius degrees). Many previous studies have elaborated the different aspects of ATZ composite processing, microstructures, and correlations with their final properties. Usually, attention has been focused on the zirconia/alumina ratio, phase composition, and sintering conditions (or methods). The important issue is also residual stress state caused by coefficients of thermal expansion mismatch of both alumina and zirconia phases. In alumina/zirconia materials, the zirconia phase is always under tension and alumina under compression. Values of these stresses depends on individual phase content and grains size and shape. They also could be introduced to the composite system by additional processes, e.g., ion exchange. However, composite powder processing and, consequently, sintering procedure could also significantly influence the final phase composition, microstructure and residual stress state. The aim of the presented paper was to use a zirconia matrix in the ATZ composite as a specific material with a fine microstructure and high tendency to the tetragonal to monoclinic phase transformation, which could assure a high level of mechanical and tribological properties.

An alumina-toughened zirconia (ATZ) material, fabricated using a procedure consisting of the common sintering of two different zirconia powders, was tested using the ball-on-disc method in a temperature range between 20 and 400 °C. Tetragonal zirconia balls were used as a counterpart. Three different types of microstructure were designed, one consisting in separated alumina inclusions in zirconia matrix (BC), the second one containing alumina inclusion in the amount close to the percolation point (BC10A) and another one which was a combination of two continuous phases, penetrating the whole volume of the composite (BC20A) (Fig. 1).

It was detected that at elevated temperatures all materials showed distinct decrease of measured wear rate. Composite with a low alumina content showed minimal wear rate at 300 °C and composites with higher amount of alumina were the most wear resistant at 400 °C. There are some evidences that this minimal wear rate is connected with a pseudoplastic behavior of a layer formed between co-operating elements of tribological pair (Fig. 2 and 3).

Additionally, it was stated that mentioned ATZ composites show extremely high fracture toughness (K_{Ic} higher than 10 MPam^{1/2}) and bending strength on the level of 1000 MPa. It is worth to notice that investigations of subcritical cracking susceptibility performed using Constant Stress Rate Test applied to biaxial bending procedure, proved that these materials are fully resistant for slow crack propagation phenomenon (Fig. 4).

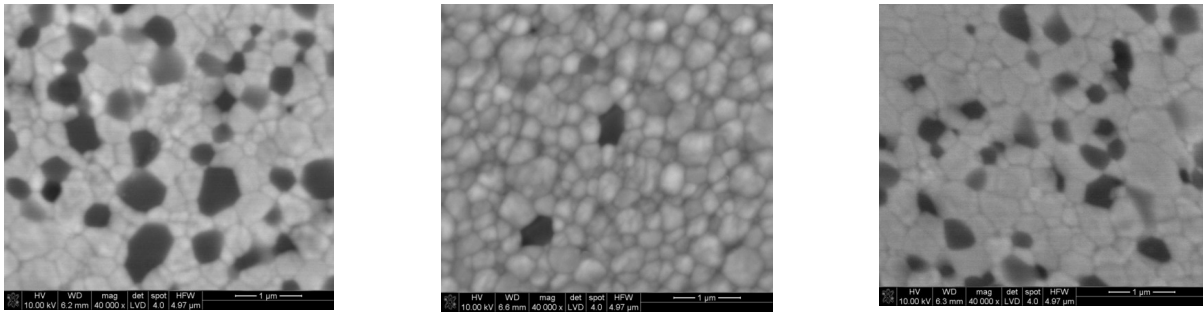


Fig. 1. Microstructures of polished and thermally etched surfaces of investigated composites (left – BC; middle – BC10A; right – BC20A).

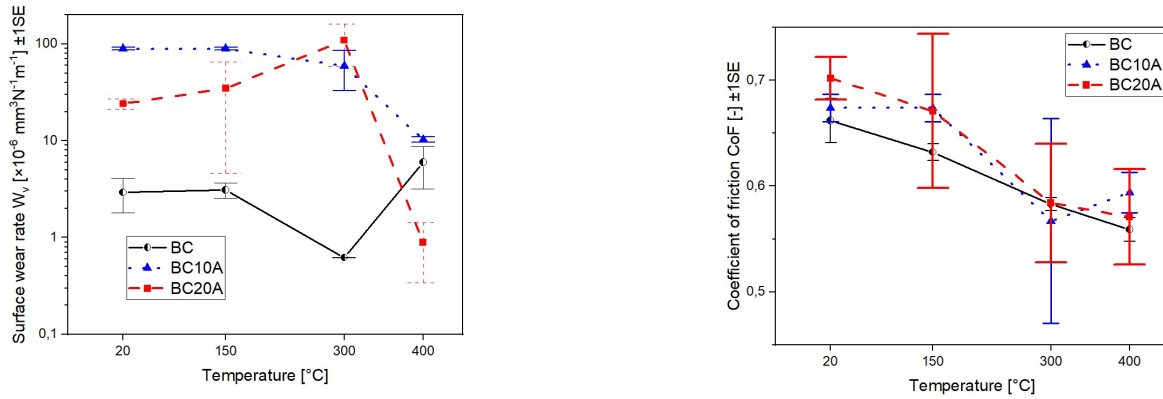


Fig. 2. Sliding wear rates W_v at different temperatures for all investigated materials (left). Coefficients of friction (CoF) vs. temperatures of tribological pairs defined by ATZ materials and zirconia ball (right).

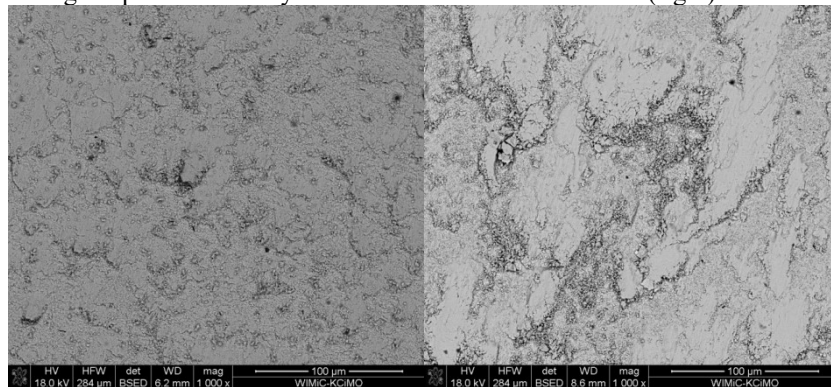


Fig. 3. SEM images of worn surface of BC material tested at 150 °C (left) and 300 °C (right).

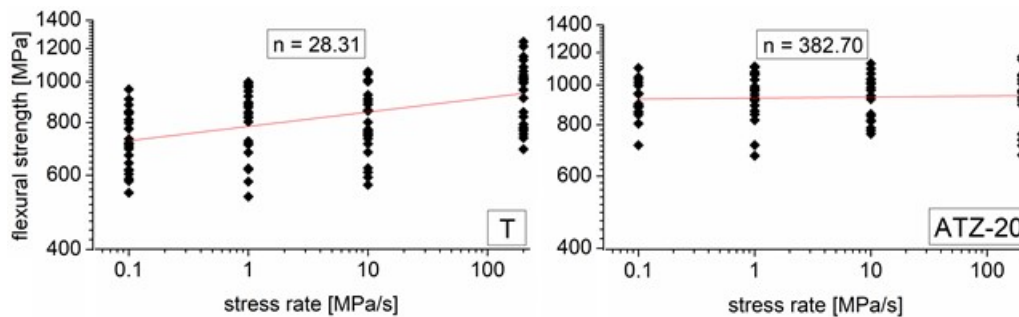


Fig. 4. Results of constant stress rate in biaxial bending test confirming the occurrence of the subcritical crack propagation phenomenon in commercial TZP ceramics (left) and lack of this phenomenon in BC20A composite (right).

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