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Research on Performance Analysis of Art Ceramics Based on Different Composition Contents

Xiumei Wu

Zhejiang University of Finance and Economics, Hangzhou 310000, China

553560638@qq.com

Abstract. Objective: To analyze the mechanical properties of ceramics and the effect of wear resistance after adding different amounts of ZrO_2 in Al_2O_3 ceramic materials, so as to obtain the optimum amount of ZrO_2 in Al_2O_3 ceramics. METHODS: Al_2O_3 ceramics were prepared by hot pressing bantering. The first group used 99.6 vol% Al_2O_3, the second group used 15 vol% ZrO_2 in Al_2O_3, and the third group used 25 vol% ZrO_2 in Al_2O_3. In order to meet the memo-mechanical theory of materials and fully consider the phase transition characteristics of ZrO_2, a mechanical structure model between the two is established. RESULTS: After the addition of refined zircon crystals to the alumina material, the compactness of the ceramic material was significantly improved. The mechanical properties of the ceramic materials produced in the three experiments showed a linear relationship of stress-strain curves. The fracture toughness of the first group of ceramics is $5._38$ MPa·$m^{0.5}$, and the fracture toughness of the second group of ceramics is 8.37 MPa·$m^{0.5}$, which is about 50% higher than the fracture toughness of the previous set of experiments; the third group of experimental sites the fracture toughness of the obtained ceramic material was 10.53 MPa·$m^{0.5}$. Conclusion: Further explanation, accompanied by an increase in the increase in ZrO_2. The elastic modulus of ceramics decreases and the fracture toughness increases. This trend is in good agreement with the experimental results. The wear form without increasing the ZrO_2 material layer is mainly abrasive wear, and the wear of the ZrO_2 material layer is mainly adhesive wear.

1. Introduction

Ceramic materials are one of the earliest materials for human applications. It is a natural or synthetic powdery compound, which is formed or interred at a high temperature, and is composed of a multipurpose solid material composed of a metal element and a non-metallic inorganic compound. Ceramic materials have many advantages such as high temperature resistance, corrosion resistance, wear resistance, high strength, high hardness, and oxidation resistance. In recent years, they have gradually expanded from traditional application industries to a wider range of applications such as aerospace, biomedical, automotive, and construction. However, alumina ceramic materials are inherently a brittle material. Due to their structure and bond properties, there are few slip systems, dislocation generation and movement difficulties, resulting in low toughness and severely limited their application and development.

ZrO_2 toughened Al_2O_3 ceramics is the earliest developed Al_2O_3 ceramic matrix composite. Crack toughening and residual stress toughening caused by ZrO_2's own intensity transformation can significantly improve its toughness, which is one of the most effective and toughening methods for toughening Al_2O_3 ceramics [1]. When ZrO_2 is cooled from high temperature to room temperature, it undergoes the isomeric transformation of cubic phase (c-ZrO_2) →tetrathlon phase (t-ZrO_2) →clinical phase (m-ZrO_2), where t phase to m the phase change produces a volume expansion of 3 vol% to 5 vol% and a shear strain of 7% to 8%. In this paper, the structured and mechanical properties at 99.5 vol% Al_2O_3, ZrO_2 (15 vol%)/Al_2O_3 and ZrO_2 (25 vol%)/Al_2O_3 ceramics prepared by hot pressing bantering were studied. A microscopic constitutive model of toughened ceramic materials was established.

2. Materials and Method

2.1. Raw materials

ZrO_2/Al_2O_3 ceramic materials were provided by Sino pharm Chemical Reagent Co., Ltd. The first set of experiments did not add ZrO_2. The latter two types of toughened ceramics were composed of 15 vol% and 25 vol% of ZrO_2, Al_2O_3 and a small amount of stabilizer Al_2O_3. Interred at high temperature. The first set of experiments without the toughening phase was interred from an Al_2O_3 powder material with a density of 4 g/cm^3. The second group of interred ZrO_2 (15 vol%) / Al_2O_3 density was 4.3 g / cm^3, and the third group of ZrO_2 (25 vol%) / Al_2O_3 density was 4.5 g / cm^3.

2.2. Experimental methods

2.2.1. Micro structure test method. The phase composition of the sample was analyzed by XD-$_3$ X-ray diffraction. The Micro structure of the fracture of the sample was observed by S-4800 cold field emission scanning electron microscope. The extramural strength was measured by a three-point bending method, and the fracture toughness of the specimen was measured by a one-sided notched beam method [2].

2.2.2. Wear measurement method. The friction and wear test were carried out using an atmosphere-protected friction and wear tester. The sleeplessness speed range was 0.1 to 2000 r/min, and the axial test force range was 10 to 10000 N. The experimental ceramic sample is shown in Fig. 1, and has a size of 34 mm × 24 mm × 5 mm. The surface of the sample is subjected to strict grinding and polishing to ensure that the friction surface condition meets the experimental requirements [3]. For the grinding sample, a quenched 45# steel having a hardness of HRC 42 having an inner diameter of 18 mm and an outer diameter of 22 mm was selected, and the friction surface was polished. The experimental conditions were dry friction. The schematic diagram of the experimental device is shown in Figure 1.

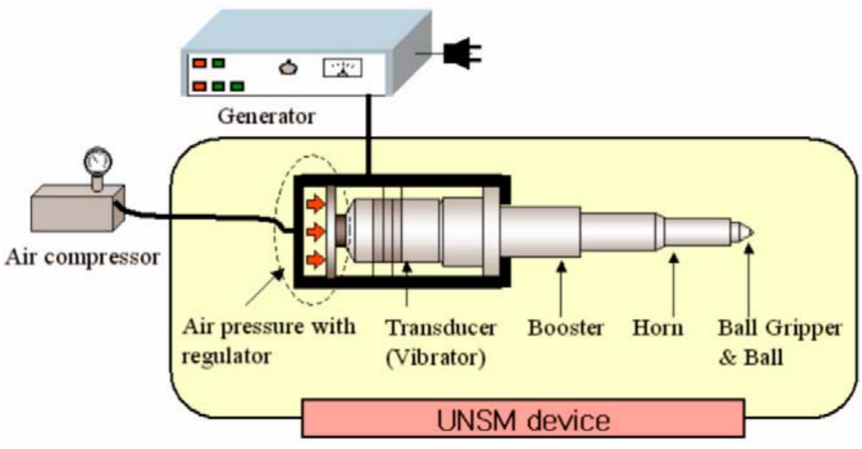

Figure 1. Schematic diagram of the friction and wear experimental device

The annular disc type sliding friction pair was selected, and the experimental time t was 4 min. The three groups were made into ceramic materials under the conditions of experimental load of 100, 150, 200, 250 N and rotating speed of 40, 80, 120, 160, 200 r/min. Perform friction and calculate the coefficient of friction. The selected load 200N remains unchanged, the speed changes (50, 100, 150, 200, 250r/min) and the speed is 100r/min, and the load changes (100, 150, 200, 250N). The mass of the ceramic sample before and after the test was weighed and the wear rate was calculated [4].

2.2.3. Mechanical properties test. In view of the mechanical properties and deformation characteristics of ceramic materials, two improvements were made in the test method: (1) Since the strain of the ceramic is very small, the axial strain of the test piece is measured by directly attaching the strain gauge to the test piece instead of The beam displacement calculation of the experimental machine is used; (2)The hardness of the ceramic test piece is much higher than the hardness of the test machine pressure plate, in order to prevent the ceramic test piece from being hardly embedded in the pressure plate during the loading process, causing damage to the pressure plate, in the test piece and the pressure plate A tungsten carbide spacer is added between them. The experimental instrument is the WDW-300 electronic universal testing machine with a maximum loading force of 300kN and a loading speed of 0.2mm/min. Dynamic strain gauge measurements use a 1/4 bridge connection [5], considering temperature compensation. The bending strength and fracture toughness of the three ceramics were measured by a three-point bending test. The experimental instrument is the RGM-3100 electronic universal testing machine with a maximum loading force of 100 kN and a loading rate of 0.2 mm/min. The dimensions of the two kinds of toughened ceramic specimens are all 40mm×5mm×10mm, and the fracture toughness test piece is processed through the incision in the middle, and the incision depth is 4mm [6].

Table 1 shows the results of testing the elastic modulus and strength of glass tubes, Al_2O_3 ceramic tubes and ZrO_2 fiber tubes using notched rings. Measuring the modulus of elasticity of ordinary float glass at room temperature using the notched ring method the sum and intensity are 73.6 GPa and 73.1 MPa, respectively, which are consistent with the results of the conventional three-point bending test. The notched ring test technology was established as an international standard by ISO/TC206 in 2011 and has been advanced to the consultation stage (ISO TC206/FDIS). 18558).

3. Results analysis

3.1. Wear condition results

3.1.1. Density and hardness of three sets of experiments. As shown in the table below, the density and hardness of the three sets of ceramic materials.

Table 1. Analysis of density and hardness of three groups of materials

Group	Material composition	Density(g/cm^3)	hardness
First group	99.6vol% Al_2O_3	4.48	19.3
Second Group	Al_2O_3+15vol% ZrO_2	4.52	20.1
The third group	Al_2O_3+25vol% ZrO_2	4.57	20.5

3.1.2. Comparison of friction coefficients of three groups. The friction coefficient of the three groups of ceramics gradually decreases with the increase of load and speed. Under low load and low speed conditions, the coefficient of friction is relatively large, reaching 0.5-0.6. When the load is 250N and the speed is 200r/min, the friction coefficient is lower than 0.44. When the rotation speed and load are low, the friction between 45# steel sample and ceramic sample mainly occurs between the contact peaks on the friction surface [7]. During the friction process, the micro-convex peak of the ceramic surface is cut to the 45# steel material. And for the ceramic sample itself, the surface micro-convex peak collides with the metal material, which is easy to cause breakage, and the falling fine crystal grains remain on the friction surface to hinder the relative motion between the frictional pair members, so that the friction coefficient is large. With the increase of load and speed, plastic deformation occurs at the contact point of 45# steel sample and ceramic sample, which increases the contact area between the friction pairs and reduces the grain loss, so the friction coefficient is relatively small.

The friction and wear properties of materials in relatively high speed and high load working environments are superior to those of low speed and low load. When the load and rotation speed are low, the friction surface does not reach the temperature required for alumina and ZrO_2 particles to change from brittle to plastic. The surface of the ceramic sample does not forms a lubricating film. At this time, the wear rate is large, and the wear debris is mostly dark red. Iron oxides; as the load and speed increase, the friction surface temperature increases, and alumina and ZrO_2 form a lubricating film on the friction surface, which improves the friction and wear of the material, reduces the friction coefficient, and reduces the wear rate. Therefore, the sample wear rate decreases as the load and the number of revolutions increase. The above experiments show that the wear resistance of ZrO_2 is increased, and the wear resistance is stronger with the increase of the increase.

3.2. Analysis of mechanical properties results

3.2.1. Structural impact. The grain size of Al_2O_3 matrix in toughened ceramics is smaller than that of Al_2O_3 ceramics. On the one hand, most of the ZrO_2 grains are uniformly pinned between the grain boundaries of Al_2O_3 matrix, which limits the length of Al_2O_3 matrix grains during bantering. Large, thus refining the grains. On the other hand, when ZrO_2 particles are added to the Al_2O_3 matrix, the bulk expansion and shear deformation caused by the ZrO_2 phase transformation inhibit the growth of the original micro cracks, making the number and size of micro cracks/holes of ZrO_2/Al_2O_3 ceramics significantly less than Less than Al_2O_3 ceramics, the compactness of the ceramic material is improved. By counting the gradation of multiple scanned photographs, the number of micro cracks per unit area of the three ceramic materials is simply estimated.

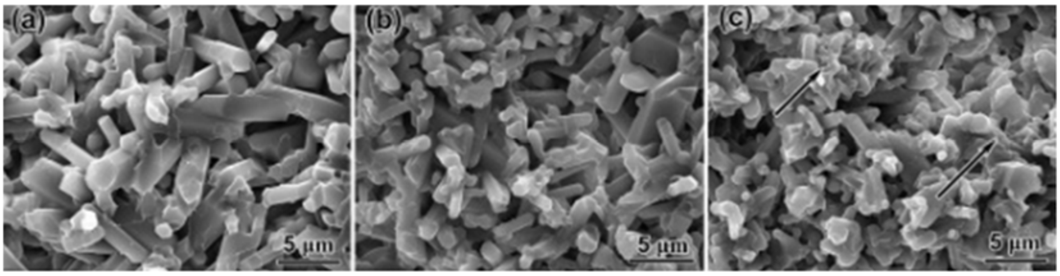

Figure 2. Micro structure of SEM photographs of three sets of ceramic materials

Table 2. Statistical results of ceramic micro cracks in three sets of experiments

Material	Number per unit area/cm^{-2}	Average size/µm	Microcrack density/µm^{-1}
99.6vol% Al_2O_3	20241.49	6.22	0.048
Al_2O_3+15vol% ZrO_2	23041.99	5.24	0.033
Al_2O_3+25vol% ZrO_2	3677.86	4.64	0.014

The related research results show that when the agglomerates exceed a certain critical size, micro defects will be caused in the ZrO_2/Al_2O_3 ceramics, which will significantly reduce the fracture toughness and strength of the ceramic [8]. Therefore, due to the influence of the processing technology, the excessive ZrO_2 content may not be able to toughen, but may reduce the mechanical properties of the material.

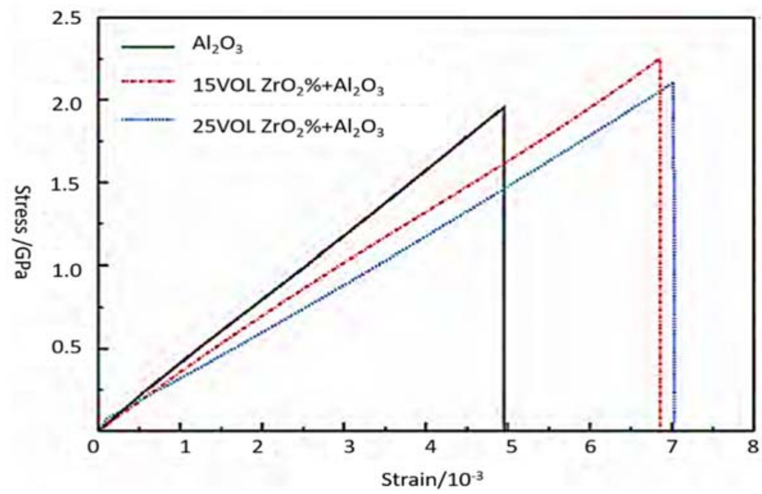

Figure 3. Stress-strain curves of ceramics in three sets of experiments

4. Conclusion

4.1. Analysis of wear and tear
(1) When the load is constant, the friction coefficient and the wear rate decrease with the increase of the rotation speed; when the rotation speed is constant, the friction coefficient and the wear rate decrease as the load increases. (2) The wear forms of the three experimental ceramic materials are mainly abrasive wear and adhesive wear. The wear form without increasing the ZrO_2 material layer is mainly abrasive wear, and the wear of the ZrO_2 material layer is mainly adhesive wear [9].

4.2. Analysis from mechanical properties
(1) The structured characteristics of ZrO_2/Al_2O_3 ceramics show that the addition of ZrO_2 refines the Al_2O_3 grains of the matrix; at the same time, the micro cracks/micro pores in the ceramic materials are reduced, so that the compactness of the material is improved. The hot-pressed ZrO_2/Al_2O_3 ceramics have good mechanical properties, and the extramural strength and fracture toughness are much higher than those of pure Al_2O_3 ceramics. The phase transformation of stress-induced ZrO_2 particles is the main physical mechanism of strengthening and toughening ZrO_2/Al_2O_3 ceramics. (2) ZrO_2/Al_2O_3 ceramic materials are typical brittle materials with high strength, high hardness and small deformation and failure. The stress-strain relationship under compression loading is approximately linear, and the specimens exhibit brittle failure modes.

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