STRUCTURE AND MECHANICAL PROPERTIES OF 
(ZrO$_2$+3%MgO) – CaSiO$_3$ COMPOSITES

Duangsupa C.

Scientific adviser: Kulkov S.N.
National Research Tomsk Polytechnic University, Tomsk

Introduction

Zirconia has been developed into a highly sophisticated advanced ceramic material that is utilized in many important applications via the exploitation of its superior mechanical and unique functional properties. Zirconium dioxide is one of the types of ceramics that is most commonly applied. It is a polymorph that occurs in three forms, monoclinic (m), cubic (c) and tetragonal (t). Pure Zirconia at room temperature is monoclinic and stable till 1170°C, above this temperature it transforms itself into tetragonal and then further into cubic phase at 2370°C. The development of zirconia as an engineering material was demonstrated by Garvie et al, who showed how to make the best of t-m phase transformation of Partially Stabilized Zirconia (PSZ) [1], improving mechanical strength and toughness of zirconia ceramics. Zirconia holds a unique place amongst oxide ceramics due to its excellent mechanical properties. The pure zirconia cannot be used in the manufacture of parts without the addition of stabilizers [2]. Addition of several oxides such as magnesium oxide (MgO), yttrium oxide (Y$_2$O$_3$), calcium oxide (CaO), and cerium oxide (Ce$_2$O$_3$) can stabilize the high temperature cubic and tetragonal phase in zirconia, so the occurrence of monoclinic phase zirconia can be repressed [1-5]. Wollastonite (Calcium silicate; CaSiO$_3$) have been studied as bioactive materials for orthopaedic applications and used to improve the mechanical properties of the biopolymers because of its good bioactivity and biocompatibility and is used mainly in resins and plastics as filler material, as well as in other industrial products, such as ceramics, coating, frictional products, refractory, construction, elastomeric, metallurgy, paint, and bio-material, because host of favorable properties such as low shrinkage, low loss of ignition, good strength, high aspect ratio, lack of volatile constituents, body permeability, fluxing characteristics, whiteness, coupled with its low thermal coefficient of expansion and acicular shape renders wollastonite, which provides strength and improved performance [3-9]. The purpose of this study is structure and mechanical property of (ZrO$_2$-3%MgO)-CaSiO$_3$ composites by whisker content (1, 5, 10 and 25 vol. %) at different temperatures, 1000, 1100, 1200, 1300, 1400, 1500, and 1650°C. The main objectives of this research is investigate mechanical properties of (ZrO$_2$-3%MgO)-CaSiO$_3$ composites; Density, Stress, Compressive Strength, Flexural Strength, Modulus of Elasticity and Hardness.

Experimental Procedure

Many functional ceramics are based on zirconium oxide (ZrO$_2$), in this work the raw materials which were used for preparing the specimens Nano powder of zirconium dioxide, magnesia, and wollastonite (ZrO$_2$+3%MgO) - CaSiO$_3$. The obtained mixtures were washed several times in distilled water and ethanol. The mixtures were dried at 100°C. The powder compacts were prepared by pressing at 300 MPa. In order to avoid defects in the specimens, the powders were granulated before pressing. The specimens were sintered at different temperatures 1000 to 1650°C in the air atmosphere. The
diameter and mass of specimens were measured. The green density and the theoretical density were calculated. It was shown that the more wollastonite the mixture contains the less density it has. After sintering the shrinkage values of specimens, densities were measured. For all tested materials, the average grain size of the zirconia (ZrO₂) and wallastonite (CaSiO₃) grains was determined from SEM images of randomly selected areas of the polished and thermally etched specimens using the linear intercept method. For the exact measurement of this quantity, it is necessary to determine the size of the fracture surface. It is well known that the property of ceramics depends on the material combination, their mechanical properties (combination of hardness and toughness) and microstructure (grain size, porosity, phase content and distribution), experimental parameters. X-ray diffraction (XRD) experiments were carried out using a Дрон-УМ1 X-ray diffractometer which was equipped with a Ni-filtered CuKα radiation with a wavelength of λ = 0.154178 Å, a radiation source operated at a voltage of 40 kV and a current of 20 mA. The specimens were scanned diffraction angle 2θ, ranging from 15 to 120°. The step sizes and times for each step were 0.05° and 1s per step, respectively.

Results and discussion

Density

In this case the density of the specimen was measured by the Archimedes’ method. The green body density of the specimens (ZrO₂+MgO)-CaSiO₃ composites ceramics were measured to be in the range of 1.35-2.41 g/cm³ after pressed using loads of 300 MPa, the specimens were sintered at seven different temperatures 1000 to 1650°C in the air atmosphere were calculated to be in the range of 1.56-4.91 g/cm³. Specimens with 1 vol. % CaSiO₃ at 1650°C had maximum density of 4.91g/cm³. It should be noticed that the specimens with 1 vol. % CaSiO₃ had the highest values of density between 2.14 - 4.53 g/cm³ after sintering at 1000 to 1650°C accordingly.

Stress

The dependences strength, sintering temperature, the specimens with 1% of wollastonite which have been sintered at 1650°C and with 5% of wollastonite which have been sintered at 1300°C have the highest value of strength approximately 270 MPa are also given in Figure 1.

Compressive strength

The compressive strength measurements were performed with Instron testing Machine 1185 with a loading rate of 0.20mm/min and loading of 1000 kg. Constitutes an excellent study on the 99% (ZrO₂+3%MgO)-1%CaSiO₃ at temperature 1650°C has highest value of compressive strength 136±15 MPa.
IV Всероссийская научно-практическая конференция «Научная инициатива иностранных студентов и аспирантов российских вузов»

**Flexural strength**

The flexural strength measurements were done on an Instron Testing Machine 1185 with a loading rate of 0.10mm/min and loading of 200 kg. The specimens 4 piece were cut, ground and polished into rectangular bars with a dimension approximately 6mm wide x 6mm high x 50mm long for three-point bend strength test measurements. The specimen of 99% (ZrO₂ +3%MgO)-1%CaSiO₃; 1650°C had maximum of flexural strength 55±11MPa and specimen of 95% (ZrO₂+3%MgO)-5%CaSiO₃; 1300°C had maximum of flexural strength 53±6 MPa

**Young’s Modulus**

Young’s modulus is a property that is directly related to the bonding forces between atoms. We also showed that it varies as a function of temperature. Young’s modulus (E) is a measure of the resistance to small changes in the separation of adjacent atoms (modulus is Latin for “a small measure”). It is the same for both tension and compression. Young’s modulus is related to the interatomic bonding forces and, as you might expect, its magnitude depends on the slope of the force–distance curve at r₀. Young’s Modulus of composites materials, the specimen of 99% (ZrO₂+3%MgO)-1%CaSiO₃; 1650°C had maximum of Young’s Modulus 600±44 MPa and specimen of 95% (ZrO₂+3%MgO) - 5%CaSiO₃; 1300°C had maximum of Young’s Modulus 560±67MPa. In real composites ceramics we have to consider the fact that we often have more than one phase present.

**Hardness Vickers**

The methodology used for the determination of hardness was in accordance with ASTM C 1327-99. Thirty Vickers impressions had been carried through in the surfaces of each one of the samples, which already were polished, using an applied load of 10 kg (98.1 N) during ten seconds. The experimental results of hardness Vickers of (ZrO₂ +3%MgO) - CaSiO₃ composite material are between 290 to 670 MPa.

**Conclusions**

In this case the specimens were sintered at seven different temperatures 1000 to 1650°C in the furnace. The experimental results of mechanical properties of (ZrO₂+3%MgO)-CaSiO₃ composites material with typical the Three point bending of 55±10 MPa, stress intensity factors exceeding of 273 MPa, compressive strength of 136±15 and Young’s Modulus, (E) of 600±44 MPa, it were considered that the actual composition of 99%(ZrO₂+3%MgO)-1%CaSiO₃ and 95% (ZrO₂+3%MgO)-5%CaSiO₃ at the temperatures 1650 and 1300°C by sequent. The structures of grain size have an average 1-2 μm. Phase corresponding to each exothermic peak of ceramics composites.

**Reference:**

SEISMIC ANALYSIS CONSIDERATIONS FOR UPLIFTED STORAGETANKS

Kangarloo K., Bashgah P. J.

Scientific adviser: Tryshin C.I.

State University of Civil Engineering (MSUCE), Moscow

Abstract

The objectives of this paper are to highlight the principal effects of base uplifting on the seismic response of ground supported cylindrical steel tanks that are unanchored at their Base. In practice, however, complete anchorage is not economical or may not be warranted for certain class of tanks; as a result, many existing tanks are unanchored and may uplift during ground shaking. Base uplifting completely changes the dynamic characteristics such as the stiffness and energy dissipation capacity of the system. The dynamic response of the system also becomes highly non-linear. Studies of the performance of uplifting tanks during past earthquakes have revealed that such systems are prone to extensive damage due to: (i) buckling of the tank wall, caused by large compressive stresses; (ii) rupture at the plate-shell junction, caused by excessive plastic yielding; and (iii) failure of the piping connections to the wall that are incapable of absorbing large base uplifts.

Keywords: Uplift, overturning, sloshing, cylindrical vertical steel tanks, seismic loading, simulation, elephant-foot, natural period, hydrodynamic pressure.

1-Introduction

Steel ground-based tanks consist essentially of a steel shell that resists the outward liquid pressure, a thin flat bottom plate that prevents the liquid from leaking out, and a thin roof plate that protects the content from the atmosphere. Circular vertical tanks are more numerous than any other type because they are efficient in resisting the liquid hydrostatic pressure by membrane stresses, simple in design, and easy in construction. It is common to classify such tanks in two categories depending on the support condition: anchored and unanchored tanks. It is common, particularly for large size tanks, to support the shell on a ring wall foundation without anchor bolts and to support the bottom plate on a compacted soil though, sometimes, ring walls are omitted.

For anchored tanks, the tank wall is effectively fixed to a foundation which is sufficiently heavy to prevent uplift in the event of an earthquake. This means that the anchor bolts must be able to transmit the earthquake induced vertical tension in the tank wall to the foundation. In practice, anchoring a tank requires a large number of anchor bolts and suitable attachments welded onto the tank wall, so that the tension forces in the anchor bolts can be distributed evenly in the tank wall. Poorly designed attachments, or an