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Effect of SiC particles on rehological and sintering behaviour of alumina–zircon composites

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Abstract

The effect of additions of SiC particulates on rheological and sintering behaviour of slip-cast alumina–zircon composites has been investigated. Finely divided alumina, zircon and silicon carbide powders were first processed into slips, using polyacrylite dispersant (0.5 wt.%) to create highly concentrated, stable aqueous suspensions at 40 vol.% loadings, from which test specimens which were then slip cast and dried. They were subsequently sintered in air for 2 h at 1650 °C. Rheological properties of the prepared slips were evaluated and related to the amount of added SiC. After sintering, the resultant porosities, fractional densities, crystallographic phases present, and microstructures were determined.

Keywords: A. Suspensions; A. Solid state reaction; A. Sintering; A. Slip casting; Alumina–mullite–zirconia–SiC composites

1. Introduction

Ceramic matrix composites have found increasing applications as structural components where high temperature strength, wear and corrosion resistance are required. Alumina–mullite–zirconia composites (AMZ) are the particular class among the various composites which are widely used for producing refractory parts in glass and refractory industries [1–3]. The AMZ composites have been prepared in two ways, hot-pressing and slip casting [1]. The preparation of these composites using zircon instead of zirconia has attracted the attention of the scientists since the zircon powder with a good quality is ready available from beach sand with a cheap price, thus making the development cost effective [4]. Although conventional dry preparation methods have been used to produce composites, there are few available works on the casting method of these composites. On the other hand, the colloidal processing has been realized to be useful for forming ceramic green bodies [5]. The powder mixture must be dispersed in water to achieve optimum particle packing through colloidal processing. This requires the preparation and dispersion of highly concentrated suspensions which are fundamental steps in the colloidal processing of ceramics [6]. In order to have a successful colloidal processing, polyacrylate based dispersants have been commonly used to improve and control the colloidal stability and rheological properties of concentrated ceramic suspensions. Colloidal stability of concentrated suspensions using polyelectrolytes was attributed to both electrostatic repulsion and steric stabilization mechanism. The adsorption of anionic polyelectrolytes on the powder surfaces increases the negative surface charge and produces some steric repulsion [4].

In the present work, the rheological behaviour of highly concentrated suspensions containing alumina, zircon and SiC particles in the presence of a polyelectrolyte was studied. The rheological measurements were based on the effect of dispersant content, solid loading, pH values and volume fraction of SiC particles on viscosity, shear rate and shear stress.

2. Experimental procedures

2.1. Materials

The α-alumina (MR70, Martinswerk, Germany), zircon (Zircosil, Johnson-Matthey, Italy) and SiC (Mirali Company, Iran) powders with mean particle size of 0.6, 1.4 and 4 μm, respectively, were used as the starting materials. Dolapix CE-64

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(Zschimmer and Schwarz), which is a polyelectrolyte and acts through electrosteric stabilization mechanism, was used to disperse aqueous alumina–zircon suspensions.

2.2. Suspension preparation and rheology

The mass ratio of alumina to zircon in all mixtures was 85/15. Aqueous alumina–zircon suspensions at 40 vol.% solid loading were prepared using different amounts of Dolapix (0.3–0.7 wt.% based on solid weight). Each slip was prepared by solving of the dispersant in water and subsequent pouring of mixed powders in the dissolved dispersant. The resultant slurry was stirred for 1 h and then ultrasonically agitated for 3 min.

Rheological measurements were performed to determine the stability of suspensions using viscometer Physica MCR300 of coaxial cylinders at 25 °C. Zeta potential of suspensions was determined by Zetasizer3000 HS_A (Malvern). The adjustment of pH was achieved with NaOH or HCl. The amount of dispersant adsorbed on particles surfaces was measured using titration method [7].

2.3. Sample preparation and sintering

The composite powders containing 0, 10, 20 and 30 vol.% SiC were stabilized and the resultant suspensions were consolidated through slip casting method using plaster moulds. The cast parts were healed at room temperature for 24 h, dried at 110 °C in an oven and finally sintered at 1650 °C for 2 h.

2.4. Physical properties and characterizations

Density and porosity of sintered samples were determined by the water adsorption method. Crystalline phases in fired samples were characterized by XRD (Siemens, D500 system) using Cu Kα radiation working with 30 kV accelerating voltage. The microstructure of sintered samples was observed by SEM (VEGA II, TESCAN company) on polished surfaces which were thermally etched at 1500 °C for 20 min.

3. Results and discussion

3.1. Effect of dispersant concentration on the rheological behaviour

Fig. 1 shows the variation of apparent viscosity as a function of dispersant content. The well-dispersed suspensions containing 0, 10, 20 and 30 vol.% SiC were prepared using 0.5 wt.% dispersant. As Fig. 1 further reveals, in the absence of SiC particles the minimum viscosity (40 mpa s) appears at 0.5 wt.% dispersant. It is observed that the viscosity of suspensions increases with decreasing the dispersant content which can be attributed to an incomplete covering of particles surfaces with polyelectrolyte. Additionally, with further decreasing in dispersant content, the net negative surface charge of all particles decreases and this means that the heterocoagulation mechanism (electrostatic attraction between two or more particles with opposite charge) would be more probable. In the absence of SiC particles, the apparent viscosity gradually increased with increasing the dispersant content higher than 0.5 wt.%. This occurs most probably because of immersing the excessive dispersant into the medium. Free electrolytes in a suspension disturb the electrostatic forces within the particles and decrease the amount of available solvent and subsequently increase the viscosity of the suspension [8]. As reported [6], the existence of free polyacrylate has a detrimental effect on the stability of a suspension with the promotion of the flocculation. The above effect extends with an increase in the molecular weight of polymer.

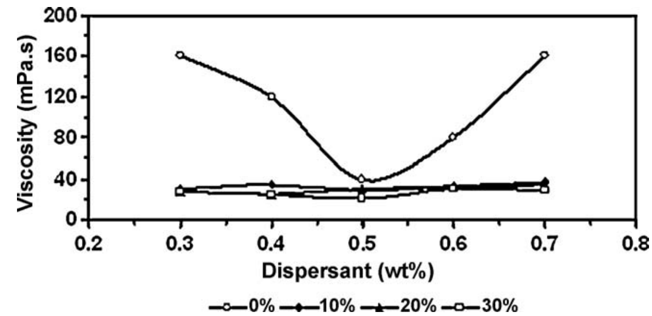

Fig. 1. Viscosity variations of alumina–zircon suspensions with and without SiC particles (vol.%) as a function of Dolapix.

3.2. Effect of pH on the rheological behaviour

Fig. 2 demonstrates the apparent viscosity of alumina–zircon suspensions with and without adding SiC particles as a function of pH. It is observed that suspensions dispersed with 0.5 wt.% dispersant indicate a low viscosity at pH 9 and as pH value goes higher the viscosity increases. As reported [9–13], the isoelectric point of alumina, zircon and SiC is at the pH around 8.5, 5.5 and 5, respectively. From these pH values, it can be postulated that the electrostatic interaction between SiC, zircon and alumina particles in suspension is attractive within the pH range 5–9. Based on the explanation mentioned above, alumina–zircon–SiC suspensions should be prepared at a high pH (pH > 9), whereas the degree of dissociation of polyacrylate in the pH 9 is higher than that in the pH 7 [14]. The

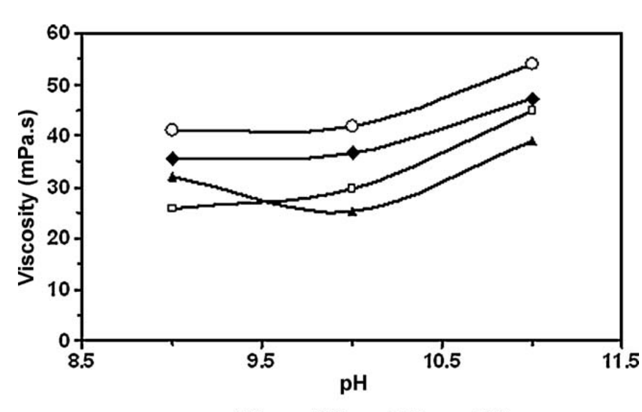

Fig. 2. Viscosity variations of alumina–zircon suspensions with and without SiC (vol.%) as a function of pH.