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A RHEOLOGICAL MODEL FOR PARTICULATE CERAMIC SLURRIES AT LOW TEMPERATURES

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Introduction

Ceramic particulate reinforced metal- and ceramic-matrix composites are increasingly being used in a wide range of applications in the electronics packaging, automotive and aerospace industries. Wet-processing methods such as slip casting, tape casting and freeze casting [1], with slurries as the starting material offer an attractive first step in the manufacture of these composites. Slurry-based processing techniques are often preferred since they result in a more homogeneous microstructure in the final product relative to the dry-processing methods [2]. Wet-processing methods are also used to fabricate porous preforms which are subsequently infiltrated with the matrix material to form a composite, and in the manufacture of many monolithic ceramics.

An important consideration in wet-processing methods is the viscosity characterization of the particle-laden slurries, also known as slips. The viscosity in turn determines the process parameters such as pressures, flow rates and processing times. Since the slurry composition varies depending upon the processing method and the desired product properties, the viscosities also exhibit a wide variation. Furthermore, ceramic slurries, especially those with high solids volume fraction, generally exhibit shear-dependent viscosities, and are best characterized as non-Newtonian fluids [3].

While the viscosities of ceramic slips have been reported in the literature for specific compositions and temperature ranges, a generalized characterization is not available. Most of the studies in the literature on the rheology of ceramic systems have focused on polymer melts as the suspension medium [3-6], while others have investigated ceramic particles suspended in organic solvents such as ethanol, which are used in the tape casting process [7,8]. Relatively little data is available on the rheology of water-based slurries, particularly at low temperatures which are employed in processes such as freeze casting [1] and low temperature molding [9,10].

This article presents an empirical correlation for the viscosity of particulate ceramic slurries in terms of the viscosity of the suspension medium, μ_s, volume fraction of the solids in the slurry, ϕ, shear rate, $\dot{\gamma}$, and slurry temperature, T_s. The correlation was obtained from extensive rheological characterization of silicon carbide (SiC) slurry formulations, and is based on physical consistency validations. The proposed rheological model is valid over the range of shear rates between 6 and 96 sec^{-1}, solids loading up to approximately 70 percent, and slurry temperatures between 0 and 25 °C. The model predictions are shown to be in good agreement with the experimental data.

Rheology Experiments

Silicon carbide slips with solids loading in the range 63–66 percent, and slurry temperatures of 2, 12 and 22°C were prepared for experimental characterization of their viscosities. The solids content in the slurry includes silicon carbide particles and a proprietary binder. A proprietary blend of four SiC particle sizes between 220 – 1000 grit (~65μm – ~8μm) was used in the slurry formulations. The range of solids fraction was selected to simulate the typical reinforcement loadings and binder concentrations used in the manufacture of SiC preforms for electronic packaging applications. A total of nine slurry samples with the parameters shown in Table 1, were used in the experimental studies. The viscosities

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