VISCOSITY OF CERAMIC SUSPENSIONS AS A FUNCTION OF SOLIDS VOLUME CONCENTRATION

Agenor De Noni Jr.(*)(**); **Daniel E. Garcia**(**), **y Dachamir Hotza**(*)(**)

(*)hotza@materiais.ufsc.br
Graduation Program in Materials Science and Engineering (PGMAT),
Federal University of Santa Catarina (UFSC),
P.O. Box 476, 88040-900 Florianópolis, SC, Brazil
(**)hotza@enq.ufsc.br
Department of Chemical Engineering (EQA),
Federal University of Santa Catarina (UFSC)

ABSTRACT

In this work the variation of the viscosity of a suspension of ceramic powders as a function of solids concentration and shear rate was studied. Considering viscosity as being a macroscopic consequence of internal attrition of the particles in suspension, which come from mechanical and electromagnetic interactions, a model of viscosity as function of solids concentration, through easily measurable parameters, was developed, taking in account that in systems with particle diameters higher than 1 μm the variation in viscosity is affected mainly by the attrition originating from mechanical forces. An approach for the problem is a bidimensional balance of forces acting on particles in suspension presented by Hong. Assuming that the particles are big enough (bigger

than colloidal size), so that the particle-particle interactions can be neglected; the forces of hydrostatic and hydrodynamic thrust and the gravitational force can be cancelled out, the linear velocity equals the angular velocity on the surface of the particles; and the particles do not adsorb water. After those considerations only the rotational restrictive M_r and translational F_d forces are considered and it is possible to establish a relation between them. To correlate those assumptions with viscosity, a mathematical model proposed by Rodrigues Neto was used, which includes viscosity as a function of mean free path λ by Fullman. A modified model for the viscosity could be written as a function of solids volume fraction [eq. 1], which is correlated with internal restrictive forces [eq. 2].

$$\eta_r = 1 + b\left(\frac{\phi_\beta}{1-\phi_\beta}\right)^n \qquad \text{[Eq. 1]}$$

$$\eta_r = 1 + b\left(\frac{M_r}{F_d \cdot \lambda}\right)^n \qquad \text{[Eq. 2]}$$

Where: b and n are adjustable parameters; ϕ_β is the solids volume fraction;

To test the proposed model, suspensions were prepared of alumina (Alcoa, calcined, 98.45% α-alumina, average size 1.20 μm, 3.65 g/cm^3) and kaolin (Brasil Minas, industrial mineral, 97.78% kaolinite, average size 3.73 μm, 2.48 g/cm^3). The solids volume concentration was varied from 2 to 24%. The experimental measurements were accomplished in a CSL rotational rheometer of T. A. Instruments with geometry of double concentric cylinders at 25°C. No additives were used for dispersing the powders in water.

The model fitted the experimental results satisfactorily in the tested intervals, as shown in Figure 1. The coefficients b and n were calculated by least squares regression. When compared with other models the proposed model presented a very good correlation for alumina (R = 0.9989) and kaolin (R = 0.9926). From the regression fit of the curves, the constant n for alumina and kaolin was 2.8, very close to 3. According to Rodrigues Neto[7], such a value can be associated with the cubic aspect of the particles. The values for the constant b were characteristic for each material, being possibly associated with the form of particles or particle agglomerate; shear rate; electromagnetic interactions between the phases; and temperature of the system.

When the relative viscosity is plotted for different shear rates, viscosity is found to increase with higher solids volume concentrations, Figure 2, as observed also by Liu and Chou[9]. Moreover, in the range of concentrations analysed, the tendency of the flow curves is to reach a limit value of relative apparent viscosity at higher shear rates.

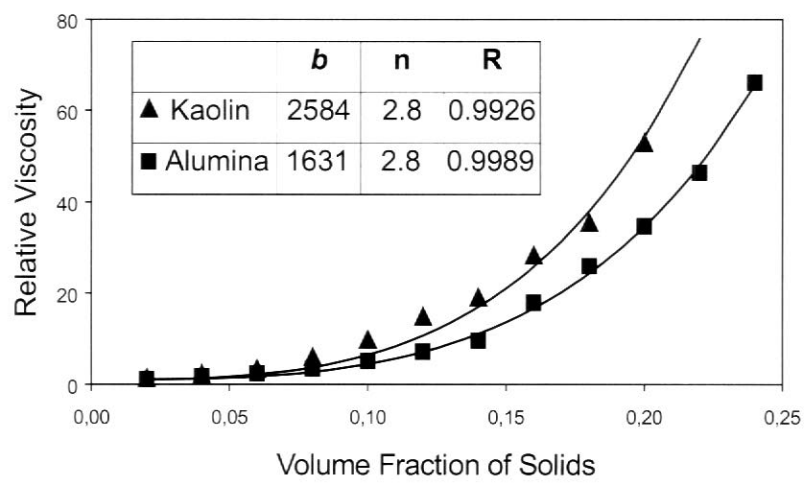

Figure 1. Viscosity experimental data for alumina and kaolin suspensions compared with the proposed model fit.

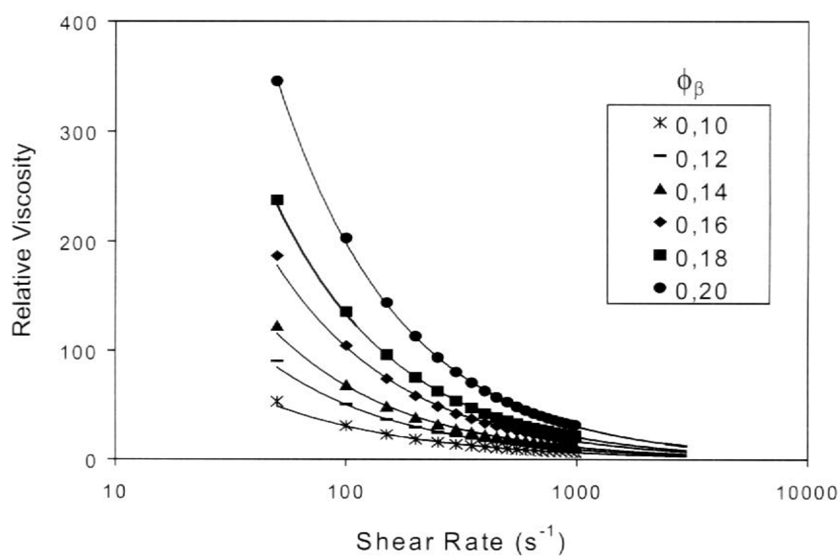

Figure 2. Relative viscosity of alumina suspension as a function of shear rate for different solids volume concentrations ϕ_β.

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REFERENCES

[1] A. EINSTEIN: Investigations on the theory of Brownian movement (Methuen, 1926; Dover, 1956).

[2] R. L. FULLMA: J. Metals Vol. 5 (1953), p. 447.

[3] R. RUTGERS: Rheol. Acta Vol. 2 (1962), p. 305.

[4] J. REED: Principles of ceramics processing, 2nd ed.(Wiley, New York, 1995).

[5] M. MOONEY, J. COLLOID. Sci. Vol. 6 (1951), p. 162.

[6] I. M. KRIEGER AND T. J. DOUGHERTY: Trans. Soc. Rheol. Vol. 3 (1959), p. 137..

[7] J. B. RODRIGUES NETO: Deflocculation mechanisms of colloidal clay suspensions, Ph. D. Thesis on Materials Science and Engineering (in Portuguese), (UFSC, Florianópolis, 1999).

[8] C. W. HONG: J. AM. CERAM. Soc. Vol. 80, No. 10 (1997), p. 2517.

[9] F.-J. LIU, K.-S. CHOU, Ceram. Int. Vol. 26 (2000), p. 159.