INFLUENCE OF PROCESSING WATER ON CERAMIC SUSPENSION VISCOSITY

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ABSTRACT

Water is fundamental in ceramic processing. The processing waters – potable, recycling, natural – are very different regarding its chemical-physical characteristics, affecting the rheological behaviour of ceramic suspensions. As the Brazilian porcelain tiles are produced via wet milling process in Brazil, their rheology has held as important role in quality control and productivity. In this work the rheological behaviour of industrial porcelain paste is determined in function of the processing water. Two clay minerals were characterizes by chemical, mineralogical and particle size analyses and the processing waters by electrical conductivity. The rheological behaviours of the slurries were determined by viscosity and flow analysis. The results show a great influence of the type of clay mineral and processing water in the ceramic processing. The clay and the recycling water were the raw materials that most affected the deflocculation and the flow curves of the porcelain paste studied.

1. INTRODUCTION

The determination of rheological characteristics such as viscosity and thixotropy of clay-water suspensions plays an important role in the application of clays^[1]. These flow properties vary significantly due to the aggregation of clay particles under varying conditions of temperature and electrolytes. In many applications, especially in ceramic slurries, it becomes necessary to add certain additives, particularly deflocculants on the clay particles to adjust the flow behaviour^[2,3].

Also, controlling the rheological properties of clay based slurries is often indispensable in industrial processes^[3]. Liquidity at high solid contents is highly desired in many practical applications like ceramics processing by spray drying. Whereas the cations are responsible for coagulation of the negatively charged clay mineral particles, several multivalent anions counterbalance the coagulating power of the cations. It is well known that certain compounds have a pronounced liquefying effect on clay-water mixtures^[4]. In ceramics engineering deflocculants like water glass, humic acids, polyanions and phosphates are common agents for increasing the weight of ceramic masses. Many liquefying agents are polymeric compounds but simple inorganic anions like orthophosphate and oligomeric phosphates such as sodium tripolyphosphate and even sodium silicates also cause pronounced liquefying, particularly with kaolin slurries^[5]. The effect of silicates on the flow behaviour of ceramic pastes was reported in some papers^[6/7].

Raw materials for technical applications are often mixtures of different clay minerals. The deflocculation of commercially used clays depended on the composition of the major phases^[8]. An increasing amount of swelling clay minerals prevented liquefaction of clays by common additives. Many research works have been carried out on the rheological and colloidal properties of clay suspensions. These publications are concerned with the effects of factors such as concentration, pH^[6], nature of exchangeable cations^[5] and particle size^[9], additives like salts^[5,10], polymers and surfactants^[10].

In the present work the rheological behaviour of industrial porcelain paste is determined in function of the processing water. The study consists in the variation of the processing water and the analysis of the flow and viscosity behaviour of two clay mineral slurries.

2. MATERIALS AND METHODS

Two clay minerals used in a porcelain tile composition were studied regarding the slurry rheology. The clay minerals were characterized by chemical analysis (X-ray fluorescence, molten sample), phase (mineralogical) analysis (X-ray diffraction, CuK α , 0° to 75°, 0.05°/s, JCPDS) and particle size distribution by laser diffraction. Also, three processing waters were studied: the electrical conductivity of deionized water, potable water and recycling water were determined (pHmeter, standard electrode). After chemical-physical characterization, the clay minerals were dried (80°C, 14h), mixed and ground via wet milling in laboratory jar mills (400g, 400ml of water, 10min milling time). After milling the density and residue of the slurries were controlled according the standard procedure (1.6g/cm³ and 3.0% wt in a 200 Tyler mesh).

The viscosity tests were carried out with a rotational viscosimeter with concentric cylinders geometry (DIN 53019, 20°C to 23°C, 20rpm). The velocity gradient used was 40s⁻¹, compatible with ceramic mixing processes. The deflocculant (sodium silicate) was gradually added (0.1ml each aliquot) until the viscosity curve obtained became constant, then the flow

curves were determined by the measuring of the viscosity over 5rpm, 10rpm, 20rpm and 50rpm strain gradients. The viscosity and flow curves were taken for both clay minerals.

3. **RESULTS AND DISCUSSION**

The chemical analysis of the clay minerals is shown in table 1. Analyzing the results the clay is formed by kaolinite, illite and muscovite, being a plastic raw material, and is contaminated with quartz. The kaolin is formed by kaolinite and is contaminated by quartz and anatase.

	SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	LOI
clay	52.6	32.1	0.3	0.8	<0.1	0.4	2.2	<0.1	11.0
kaolin	60.3	23.8	2.4	1.1	-	0.4	0.7	-	10.5

Table 1. Chemical analysis of the raw materials (w/w %)

The clay presents an average particle size of 8.9μ m and 90% of the particles under 23μ m and the kaolin presents an average particle size of 9.3μ m and 90% of the particles under 21μ m. As both raw materials present the same average particle size and the same particle size distribution, the particle size does not affect the rheology of this particular system. The electrical conductivity of the processing water is shown in table 2. The potable water presents the greatest conductivity among the processing waters, being the one that most affect the rheology of the porcelain tile paste.

WATER	POTABLE	RECYCLING	DEIONIZED
conductivity (mS)	5.2	74.5	1.5

Table 2	Processing	water	electrical	conductivity	(mS)
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Using deionized water the kaolin was easily deflocculated: only 0.068% w/w of sodium silicate was necessary to lower the viscosity from 640cP.s to 23cP.s, figure 1. The kaolin processed with recycling water was more difficult to deflocculate: a 0.299% w/w of sodium silicate was necessary to lower the viscosity from 6200cP.s to 18cP.s. Finally, the kaolin processed with potable water presented an intermediate behavior: a 0.092% w/w sodium silicate was necessary to lower the viscosity from 890cP.s to 20cP.s.



Figure 1. Kaolin deflocculation curves in function of processing water



Figure 2. Clay deflocculation curves in function of processing water

The clay processed with deionized water was more difficult to deflocculate: it was necessary 0.692% w/w of sodium silicate to lower the viscosity from 3900cP.s to 40cP.s, figure 2. With potable water the behaviour was similar: 0.672% w/w of sodium silicate was necessary to lower the viscosity from 2250cP.s to 40cP.s. Finally, the clay processed with recycling water was very difficult to deflocculate: 1.517% w/w sodium silicate was necessary to lower the viscosity from 1080cP.s to 50cP.s.

The kaolin flow curves show a typical shear thickening behaviour, figure 3. The recycling water causes the greatest viscosity increment with the shear rate, being a problem during milling, transport and spray-drying.



Figure 3. Kaolin flow curves in function of processing water

The shear thickening behaviour also occurs for the clay processed with potable, deionized and recycling waters, figure 4. Once again the recycling water causes the greatest viscosity increment with the shear rate, and in this case all curves are steeper than those for kaolin.



Figure 4. Clay flow curves in function of processing water

It is evident the influence of processing water and clay mineral type in the rheology behaviour of ceramic systems. The use of recycling water is necessary to avoid environmental damage and waste, so the water used must be considered a raw material, not only an additive for ceramic processing. In this way the use of recycled water must be rigorously controlled regarding its pH, conductivity and soluble salt content. The water content, viscosity and rheological behaviour of ceramic slurries are directly affected by the interaction between the type of clay mineral and water characteristics^[5,6,9,10].

4. CONCLUSIONS

Analyzing the flow and viscosity curves the clay and the recycling water are the most effective raw materials in the rheological behaviour of the studied system. Variations of slurry viscosity are the major causes of variation in granule size and distribution after spray-drying. The studied clay is formed by kaolinite, illite and muscovite as major phases, and as stated before, an increasing amount of swelling clay minerals prevents liquefaction of clays by common additives, causing difficulties in the deflocculation of commercially used clays.

The rheological behaviour of a ceramic suspension is controlled not only by the type of deflocculant used in the process, but also by water hardness and pH and characteristics of the raw materials used (type, shape, particle size). Regarding the particle size, as both clay minerals presented the same distribution curves, this property did not affected the rheology of the studied system, but the processing water strongly affected the flow behaviour of the clay slurries. The recycling water in association with the clay caused the greatest influence in the rheology of the system.

Finally, it is necessary to determine the cationic exchange capacity and zeta potential of the clay minerals and to determine the soluble ions present in the processing water to characterize the complete rheological behaviour of ceramic suspensions.

REFERENCES

- [1] Eisenstadt, G.; Sims, D. Journal of Structural Geology 27 (8) (2005) 1399-1412.
- [2] Adachi, N.; Hashiba, M.; Saturada, O. Ceramics International 30 (6) (2004) 1055-1058.
- [3] Penner, D.; Lagaly, G. Applied Clay Science 19 (2001) 131-142.
- [4] Ilstad, T.; Elverhøi, A.; Issler, D.; Marr, J.G. Marine Geology 213 (1-4) (2004) 415-438.
- [5] Marco, P.; Labanda, J.; Llorens, J. Powder Technology 148 (1) (2004) 43-47.
- [6] McFarlane, A.; Bremmell, K.; Addai-Mensah, J. Powder Technology 160 (1) (2005) 27-34.
- [7] Mpofu, P.; Addai-Mensah, J.; Ralston, J. International Journal of Mineral Processing 75 (3-4) (2005) 155-171.
- [8] Tombácz, E. and Szekeres, M. Applied Clay Science 7 (1-2) (2004) 75-94.
- [9] McFarlane, A.; Bremmell, K.; Addai-Mensah, J. Journal of Colloid and Interface Science 293 (1) (2006) 116-127.
- [10] Labanda, J.; Llorens, J. Powder Technology 155 (3) (2005) 181-186.