THE EFFECTS OF HIGH-ENERGY MILLING ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF PORCELAIN TILE

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INTRODUCTION

The authors demonstrated that high-energy (HE) milling can improve product quality by reducing particle size without increasing expenses or affecting the product composition in a prior publication. The goal of this study was to see how HEM altered porcelain tile's mechanical properties. Particle size reduction is a well-known technique for increasing triaxial ceramics' mechanical characteristics. The size of the quartz particle has a big influence on the flaw size and fracture toughness. The goal was to reduce the following effects while minimizing the overall particle size distribution: 1) reduce global energy consumption; 2) delaminate clay particles efficiently to promote plasticity; 3) reduce the size of coarser quartz particles to achieve a narrow size distribution to reduce microstructural cracks.

MATERIALS AND METHODS

This research was carried out using an industrial non-glazed porcelain tile composition. Three slurry samples were taken directly from the industrial ball milling process (CM). When two-thirds of the total milling time had completed (10% of 45 µm sieve residue - 45SR), the first one (run 1 – R1) was collected. Once the standard milling time was done, the second one (R2) was collected (3% 45SR). The third sample (named R4) was collected after the milling time had been increased in order to reach 0.5% 45SR. Sample R1 was also sent to HE to reach a 3% 45SR (R3) and 0.5% 45SR (R5) (R5). Sample R2 was then subjected to high-energy grinding to achieve a 45SR concentration of 0.05 percent (R6). Alumina balls ranging from 1.0 to 1.5 mm were employed in an attrition mill. Spray drying was used to dry the six slurry samples. The 6.5 percent moisture powders were pressed with 45 MPa to produce 80x20x6 mm pieces, which were then dried. The pieces were subjected to a maximum densification temperature fitted according to each run (1220 °C for R1; 1200 °C for R2 and R3; 1180 °C for R4 and R5; 1160 °C for R6). Heating rate of 0.83 °C/s up to 600 °C and 0.41 °C/s up to sintering temperature. After 5 minutes of holding time, two cooling rates were tested: 1) a slow rate of 0.41°C/s to avoid residual stresses, and 2) a fast rate of 13 °C/s to generate macroscopic residual stresses that mimic industrial conditions. The bending strength and macroscopic residual stress were measured. SEM was used to examine the microstructure.

RESULTS AND CONCLUSIONS

The main findings are summarized in Table 1. The results showed that utilizing HEM, a narrow particle distribution was obtained and the colloidal percentage was raised as a function. Parts manufactured with particles subjected to high-energy milling have a 5 to 15% higher mechanical strength and macroscopic residual stress. The increased flaw size, Δa, is a number that shows how the fast cooling rate used in ceramic tile production affects mechanical characteristics and microstructure[2]. When d_{99} was reduced, there were less Δa.

	Run	45SR (%)	d_{99} (µm)	$^*\sigma_f$ (MPa)	$^*\sigma_{ta}$ (MPa)	σ_s (MPa)	a_0 (µm)	Δa (µm)
CM	R1	10	59	56	59	-21	210	249
CM	R2	3	47	71	81	-26	197	127
HE	R3	3	43	72	83	-27	178	118
CM	R4	0.5	34	75	89	-26	129	51
HE	R5	0.5	27	78	95	-29	115	48
HE	R6	0.05	14	76	103	-29	77	3

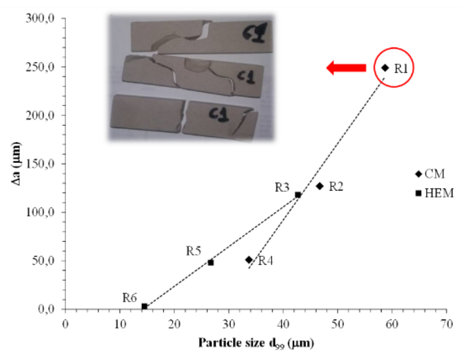

Table 1. *Results of particle size (45SR, d_{99}), bending strength (σ_f slow and σ_{ta} high cooling rate), Macroscopic residual stress (σ_s), flaw size (a_0), increased flaw size (Δa)*

To compare the impact of CM and HE on the final microstructure, Figure 1 displays representative samples. The mullite clusters were better dispersed in HE, which was the most noticeable difference compared to CM.

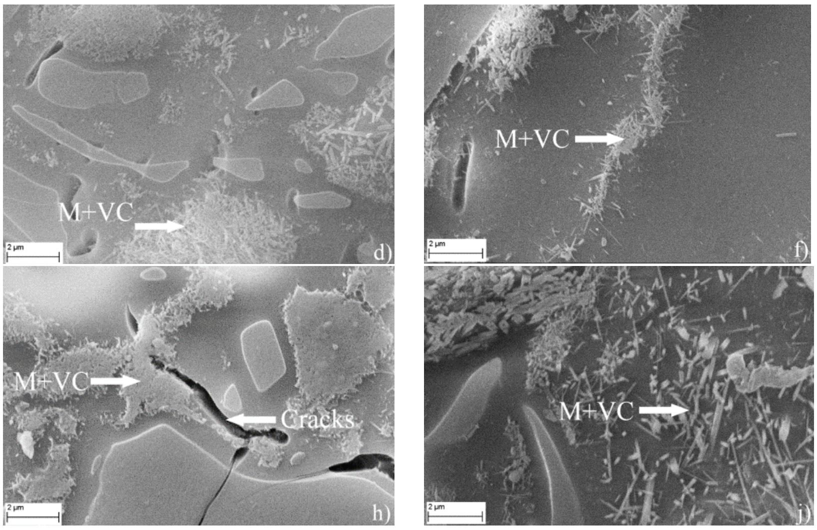

Figure 1. *Microstructure of porcelain samples processed by conventional milling: d) 3% CM R2 f) HE R3 3%HE h) 0.5%CM j) 0.5 HEM.*

It was effective to employ high-energy milling to improve the overall qualities of porcelain tile. Clay particle delamination and a narrowing of the particle size distribution were blamed for the results. This extra processing step minimizes milling time and energy consumption. Another approach could be to find a way to improve porcelain tile qualities while using the same amount of energy.

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