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Microscopic residual stresses on quartz particles in porcelain tile as a function of microstructure

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Abstract – In this work the microscopic residual stress of quartz particles was determined for seven composition of porcelain tile, comprised of kaolin-quartz-feldspar mixtures, prepared according to a simplex-centroid mixture design. XRD´s experiments were used to measure displacement of quartz peaks and then to calculate the microscopic residual stresses from determination of unit cell volume expansion. The results show that quartz particles in porcelain tile seldom meet the condition in that the Selsing´s equation is valid: spherical particle and infinite glass matrix. However, for high feldspar contents, even for irregular quartz particles, the microscopic residual stress close met the theoretical estimation from Selsing equation.

Porcelain tile is a high technical product for covering surfaces, specially floor in houses and buildings. Compositions are similar to those applied in triaxial porcelain, but with higher amount of clay-based minerals and other eutectic additives like talc. Sintering conditions are characterized by fast firing and low temperature compared to traditional porcelain. The final microstructure is composed by a continuous glassy phase with dispersed porous, unsolved quartz, primary and secondary mullite and residual feldspar particles[1].

Together with others mechanisms quartz particles in porcelain tile composition are related to strengthening due to thermal expansion coefficient mismatch that reinforce the microstructure. The traditional Selsing´s equation[2] can predict microscopic residual stress from some mechanical and thermal properties of a particle and glass matrix according to special boundary conditions, mainly spherical particles and infinite glass matrix.

Microscopic residual stresses of quartz particles were determined for seven compositions of porcelain tile prepared according to a simplex-centroid mixture design. XRD´s experiments were used to measure displacement of quartz peaks and then to calculate the microscopic residual stresses [3]. Final microstructure presented quartz (Q) content from 10 to 40%wt., residual albite + albite glass (A+AG) from 40 to 70% wt., and mullite + kaolin glass (M+KG) from 20 to 50%wt.

The final microstructures do not meet the boundary conditions of Selsing equation, since high concentration of irregular quartz particles is present in glass matrix. However, for high albite contents, even for irregular quartz particles, the microscopic residual stresses closely meet the theoretical estimation of Selsing's equation (i.e. σ_{rr}^{eq} = 260MPa). Micrographs are presented in Figure 1 (C3). The diagram presented in Figure 2 shows how microscopic residual stresses vary as a function of composition. The effect of surrounding or interface particles may be summarized as follows: (a) as the concentration of M+KG increases the residual stresses increase due to a lower thermal expansion coefficient than glassy matrix, presenting a maximum of σ_{rr}^{eq} = 300MPa, micrographs are presented in Fig.1(C2); (b) as concentration of quartz increases the residual stresses decrease due to the action of forces of adjacent quartz particles, resulting in approximately σ_{rr}^{eq} = 220 MPa, Fig 1(C1).

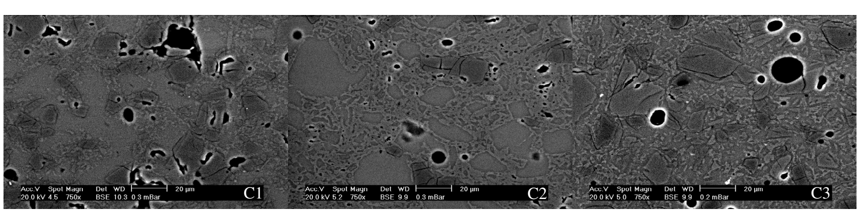

Fig.1.Microstructure of composition diagram vertices: C1(P-(Q));C2(P-(M+KG);C3(P-(A+AG)

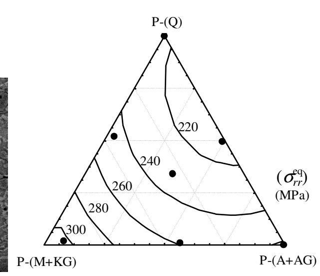

Fig.2.Microscopic residual stress (σ_{rr}^{eq})

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