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Ultrasound-assisted extrusion of construction ceramic samples

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ABSTRACT

The conditions for a decrease in friction during ceramic brick production between a mixture and an extruder die under the influence of 20–30 kHz ultrasound applied to the die are calculated. An optimum design of a die used to mold 30 mm diameter cylindrical samples with a resonance in this frequency range is selected using computer modeling. From the results, a titanium die is fabricated and tested on a Verdes–050 (Spain) laboratory extruder using an ultrasonic magnetostrictive transducer with a power of 1.5 kW (Inlab-Ultrazvuk, Russia). A 12% reduction in extrusion pressure, a 20% acceleration of molding and a positive influence on the properties of the ceramics were found. The surface of the ceramic samples was covered by craters with diameters of approximately 10 µm due to the boiling of water, and the porosity of the main body of the samples decreased. This technique prevents the undesirable rapid drying of the surface when the samples exit the die and stabilizes the strength of the fired samples. The color remained unchanged, the water absorption decreased, the density, strength and resistance to frost increased. Ultrasonic extrusion increased the accuracy of the strength tests of construction ceramics, indicating the prospect of ultrasonic die development for industrial extruders for bricks, facing tiles and roof tiles.

1. Introduction

Ceramic materials are widely used in construction applications. These materials include bricks, facing tiles and roof tiles. Strict requirements for color, strength, water absorption, heat conductivity, and frost resistance, among other qualities, are imposed on these materials. Therefore, developing technology for the industrial production of such products is challenging. Previous in vitro production and testing of tiny laboratory ceramic samples has been performed. The properties of the final product depend on the composition of the ceramic mixture and on the rolling, molding, drying and firing conditions of the raw product. Therefore, the laboratory must be able to precisely reproduce most factory conditions for the successful scaling of laboratory technology.

As a rule, the reproduction of the rolling, drying and firing conditions is very well. But the extrusive molding cannot be repeated accurately, and it is the source of problems. Inconsistencies are caused by the unpredictability of the emergence of residual internal tension in the ceramic column and the difficulty of objective control both for the factory extruder and in the laboratory. That is, it is possible to obtain a ceramic sample with insufficient strength from a satisfactory clay mixture because of the internal defects and tension created when molding a raw material. However, it is impossible to evaluate the contribution of these factors on the sample's strength using the results of mechanical tests. This circumstance does not allow objective judgment of the strength of the ceramic material per se. The quality of the initial clay mixture and action of the included modifying additives affect the final product; therefore, the technological parameters must be optimized. Such optimization consumes a substantial amount of labor.

Therefore, the laboratory extruder must be equipped with a special die to reduce the role of the internal defects and tension arising in the sample during molding. First, the extruder must provide minimum friction between the ceramic mixture and die walls. Second, the extruder must form cylindrical samples to avoid the angular mechanical tension that occurs in traditional rectangular samples. Third, the extruder must influence all of the depths of the ceramic mixture using an intensive judder to compact clay particles and remove mechanical tension.

It is known that in a ceramic mixture, a multilateral impact is caused by powerful ultrasound during the dry pressing of technical ceramics in closed compression molds [1]. Ultrasonic extrusion is

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