A STUDY TO OPTIMIZE THE DRYING PROCESS OF BODIES

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1. INTRODUCTION

The drying of ceramic bodies is an important step in the production of tiles, bricks, porcelains, sanitary ware. After any forming process of pieces [pressing, slip casting, tape casting and so on], the bodies are still wet, with an excess water content ranging from 6% - 12%. Therefore, it is mandatory to remove the water before firing, to avoid breakage of materials.

In the case of cast products the drying process is critical owing to the high water content in the pieces. Problems are encountered both using the traditional technology of casting the slurries into gypsum moulds, and performing most modern processes, such as casting the pieces into resin moulds by medium/high pressures [0.4–2.0 N/mm^2] and tape casting [or tape forming] process, which is an innovative technology to produce tiles with large thickness [a typical lay out is represented in figure 1].

The drying process can be conducted in several ways (convection, radiation, microwaves, etc.), but, in the factory, it is commonly performed in big tunnel dryers by convection, using the exhaust heat of firing kilns. The process is based on air recycling, making use of water vapour at temperatures below 160°C.

The drying speed is a function of the staying power in the bulk of the products overcome by heat. This process causes a decrease in water viscosity μ and surface tension s and speeds up the water displacement. The advantage of the method is that vapour is not forced to move through a gas, but into the bulk lowering the subsequent gradient of humidity, and reducing stress due to shrinkage [1].

In ceramic production, where large masses of materials are processed, a rapid dryer is generally used for tiles, and for products obtained by casting, a continuous dryer (tunnel). In the latter case, the pieces are placed on the same vessels used to carry the materials after casting. For all types of ceramic productions it is mandatory to avoid prolonged handling of the green pieces. In a first step, the dryer is saturated by hot, wet (> 85%) air. In these conditions, evaporation is very low near the surfaces and the heat can diffuse in the bulk of the pieces, helping water diffusion from the bulk up to the surfaces [2].

In all the production processes, drying is essentially based on heat convection, where the most critical factors are temperature, relative humidity and air speed, together with the thickness of the products.

In this study, the problems of the drying process were approached by investigation of sanitary ware, where the sizes of the pieces are large and the results can be easily transferred in the tape casting technology.

2. EXPERIMENTAL

Materials - Several specimens 15 x 15 cm were formed in the laboratory, according to standard procedures: the powders were obtained milling raw materials in a laboratory ball mill [water added: 40%], with reduction to a medium grain size [<= 65μm] The powders were then subjected to slip casting, using gypsum moulds, after a rheological control of viscosity. The samples were dried in air for 2 h and then subjected to the drying tests by means of a ventilated laboratory oven.

The samples formulations were obtained by industrial practice.

Methods - To show the evolution of drying process in a ceramic body, it is useful to use diagrams where the weight loss (%) values, which are correlated to the humidity, are traced as a function of shrinkage (%) at a given temperature (Bigot diagrams). The process is conducted until attaining equilibrium (constant weight). When the system reaches equilibrium, the corresponding humidity value is called "critical humidity" and is very important in the drying process, as it shows a value that permits, for lower humidity contents, a faster thermal gradient without producing dangerous stresses and fracture lines.

It is possible to obtain a further refinement of the diagrams by plotting the Bigot-Bourry curves, where shrinkage and weight loss of the materials are shown as a function of time. These diagrams also permitted evaluating the shrinkage speed, which is a parameter defined as the ratio [Δ shrinkage %/Δ time]: in all the cases where this ratio was not linear, the greater slope value was chosen.

The measures were carried out, by means of samples residence in the ventilated oven, both using a constant temperature (30°, 40°, 60°, 70°C), drying the samples up to constant weight, and using dual temperatures curves, at 30°-70°C and at 40°-60°C, respectively.

In the two-step experiments, the time of residence in the oven was fixed at 45' for the lower temperature, and at 45' for the higher temperature, according to the industrial parameters. Every 15', the samples were removed from the oven, shortly subjected to the measurements (weight and sizes) and quickly put again.

For every thermal cycle, 6 specimens were tested and the final data have been collected by calculating the mean values of the 4 central data.

The experimental data are summarized in the figures 2 - 4, while, in the table 1, are reported the values of the shrinkage speed.

THERMAL CYCLE	MEAN SHRINKAGE SPEED [%/MIN]	
30°C	0.025	
40°C	0.045	
60°C	0.067	
70°C	0.082	
30° - 70°C cycle	0.020 [First step at 30°C]	0.055 [Second step at 70°C]
40° - 60°C cycle	0.039 [First step at 40°C]	0.065 [Second step at 70°C]

Table 1. Shrinkage speed values for samples dried in oven.

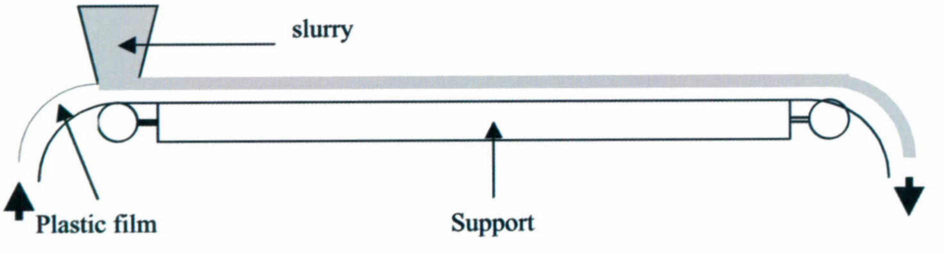

Figure 1. Scheme of tape-casting process

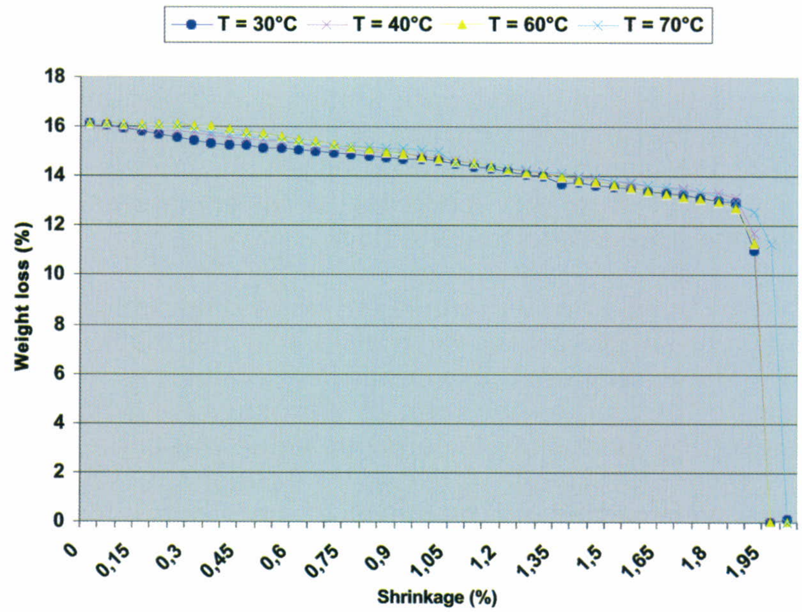

Figure 2. Bigot curves at different constant temperatures

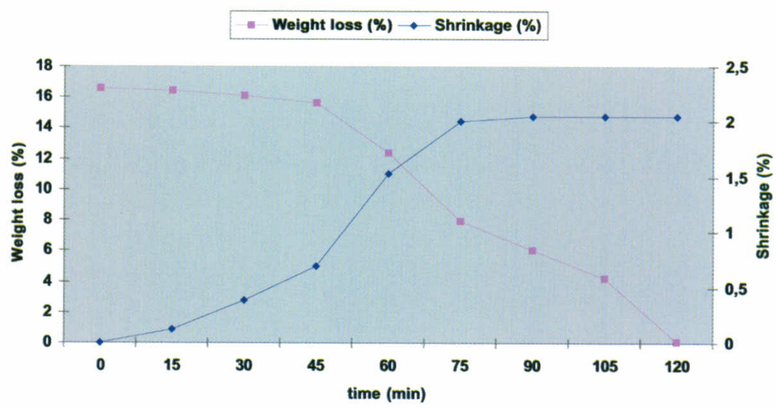

Figure 3. bigot-Bourry 30°-70°

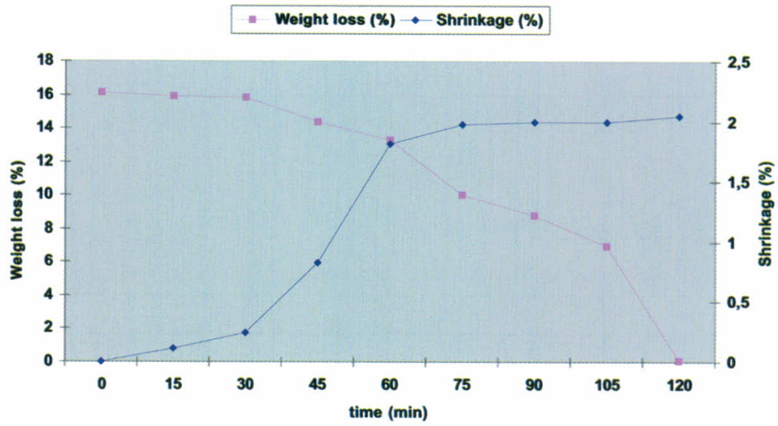

Figure 3. bigot-Bourry 40°-60°

3. RESULTS AND CONCLUSIONS

The drying of a ceramic material is a highly variable process, which requires accurate industrial controls of critical parameters such as relative humidity, drying speed and air temperature.

The results collected after different drying cycles showed a dispersion of data, with a mean deviation of about 7%, which can be considered satisfactory.

The Bigot-Bourry curves, carried out on samples dried both at a single temperature (30°, 40°, 60°, 70°C) and after a two-step thermal curve (30°-70°C and 40°-60°C), suggested the following considerations:

- The observations of tests conducted at a single constant temperature, showed that the Bigot curves were quite similar for all the samples in any thermal condition; on the contrary, the shrinkage speeds were different depending on the thermal cycle, as reported in table 1;

- The 40°-60°C thermal cycle exhibits a greater shrinkage speed with respect to the 30°-70°C cycle: the slope value observed at 40°C is near twice the value observed at 30°C [0.039 vs. 0.020]. This fact shows that the 30°-70°C cycle is more reliable for avoiding drying problems [breakages, deformations and so on];

- The slopes of the lines at 60°C and at 70°C are higher for the one-step cycles. This phenomenon shows that in the two-step cycles the shrinkage happens mostly in the first times and blocks some relative flows among the particles with subsequent reduction of the shrinkage speed.

REFERENCES

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