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EQUILIBRIUM MOISTURE MODEL OF CERAMIC GREEN BODY DURING DRYING

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The drying stage of ceramic green body is crucial in the production process, and the equilibrium moisture content achieved by green body drying is very important for the green body firing stage. Based on the modified Oswin equilibrium moisture model, the influence of hot air temperature and relative humidity on the equilibrium moisture content of SiO_2 and Al_2O_3 ceramic composite green body drying was studied through hot air drying experiments, and according to the experimental data, the equilibrium moisture content data was fitted by the least squares method to determine the equilibrium moisture content model.

Keywords: powder metallurgy; SiO_2 Al_2O_3; ceramic green body; drying process; equilibrium moisture content model

INTRODUCTION

The chemical composition of sanitary ceramic green body mainly includes SiO_2 and Al_2O_3, which is a composite material, SiO_2 accounts for 51,26 % and Al_2O_3 accounts for 31,49 %, which is the raw material of the ceramic industry and the co-solvent of the metallurgical industry [1]. This ceramic composite material has both the corrosion resistance of ceramic materials and overcomes the brittleness of ceramic materials.

Before the firing stage, the green body is dried, which can reduce the shrinkage of the green body and improve the production quality of the product. The equilibrium moisture content indicates that the moisture content of the green body in a certain air environment reaches an equilibrium value, which is an important parameter of the drying process, is the basis for establishing the green body drying model, and determines the final moisture content that can be achieved by the ceramic green body drying process.It is generally believed that the equilibrium moisture content of green body drying is related to ambient temperature, relative humidity and green body material, etc., if only the green body drying of the same material is studied, it can be considered that its equilibrium moisture content is only related to air temperature and relative humidity [2,3]. Therefore, scholars at home and abroad have established a model of the change trend of equilibrium moisture content with air temperature and relative humidity through experiments. Among them, the modified Oswin equilibrium moisture model is one of the most commonly used models [4,5], which provides a theoretical basis for the value of the equilibrium moisture content when establishing the drying model of ceramic green body and the requirements for the moisture content of the green body firing stage.

$$M_e = \mathrm{a}\exp\left(-\frac{\mathrm{b}}{T}\right)\left(\frac{RH}{1-RH}\right)^{\mathrm{c}} \tag{1}$$

Where: RH is the relative humidity of the air / %; T is the air temperature / °C; a, b, c are the coefficients to be determined in the equilibrium moisture model. The equilibrium moisture content of the ceramic body is crucial to the firing stage of the green body, which directly affects the production quality of ceramic products. In order to study the influence of hot air temperature and relative humidity on the equilibrium moisture content of the drying process of ceramic green body in actual environment, a hot air drying experiment was carried out on ceramic green body to determine the equilibrium moisture content model. In this paper, the prepared ceramic green body was used as the experimental sample, and the hot air drying experiment was carried out on the green body sample under different hot air temperature and different relative humidity drying conditions.

Experimental materials and equipment

A composite material prepared by powder metallurgy for ceramic green body samples used in the experiment. The sample size of ceramic green body test is 150 mm × 150 mm × 20 mm. The prepared ceramic green body sample was placed in a closed environment at 20 °C and stood for 1 h, in order to keep the green body temperature and initial moisture content unchanged and reduce the error of drying experimental results. Before the start of the experiment, the prepared ceramic green body samples should be placed in a closed environment at 20 °C and allowed to stand for 1 h.

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The experimental equipment used in the ceramic green body drying laboratory includes electric heating blast drying box, constant temperature and humidity drying box, and high-precision electronic scale, as shown in Figure 1 - 3.

Figure 1 Electric heating blast drying oven

Figure 2 Constant temperature and humidity drying oven

Figure 3 High-precision electronic balances

Experimental methods

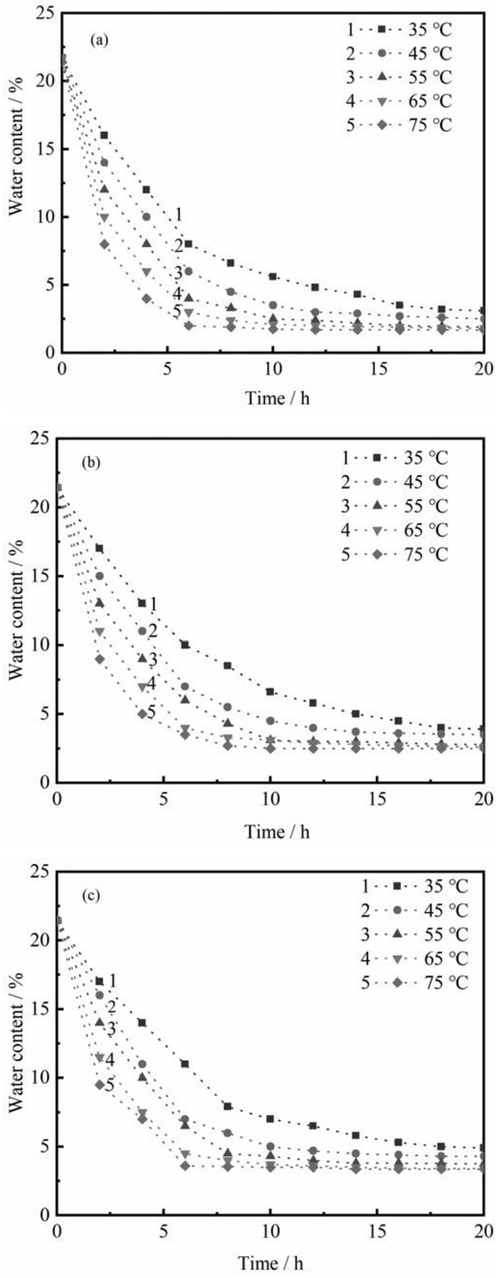
In order to explore the relationship between equilibrium moisture content and hot air temperature and relative humidity of ceramic green body drying, drying experiments were carried out on ceramic green body. In this experiment, the hot air drying experiment of the green body was set up when the hot air temperature was 35, 45, 55, 65 and 75 °C, and the relative humidity of the hot air was 5 %, 25 %, 45 %, 65 % and 85 %, respectively.

The experimental steps are as follows: after the green body samples are taken out of the confined space, they are weighed immediately to measure the initial weight of the samples; The hot air temperature of the constant temperature and humidity drying oven was set to 35, 45, 55, 65 and 75 °C, and the relative humidity of the hot air was set to 5 %, 25 %, 45 %, 65 % and 85 %, respectively. Each group was dried for 20h until the green body weight change was less than 1 g, and the sample could be considered to have reached the equilibrium moisture content, and the mass was measured at this time. Take out the sample and put it into a drying box set to 100 °C to continue drying for 10 h, during which the difference between the two weighing before and after is not more than 0,2 %, and the absolute dry quality is measured; According to the measured mass of the green body, the equilibrium moisture content of the green body under different working conditions is calculated.

Results and analysis

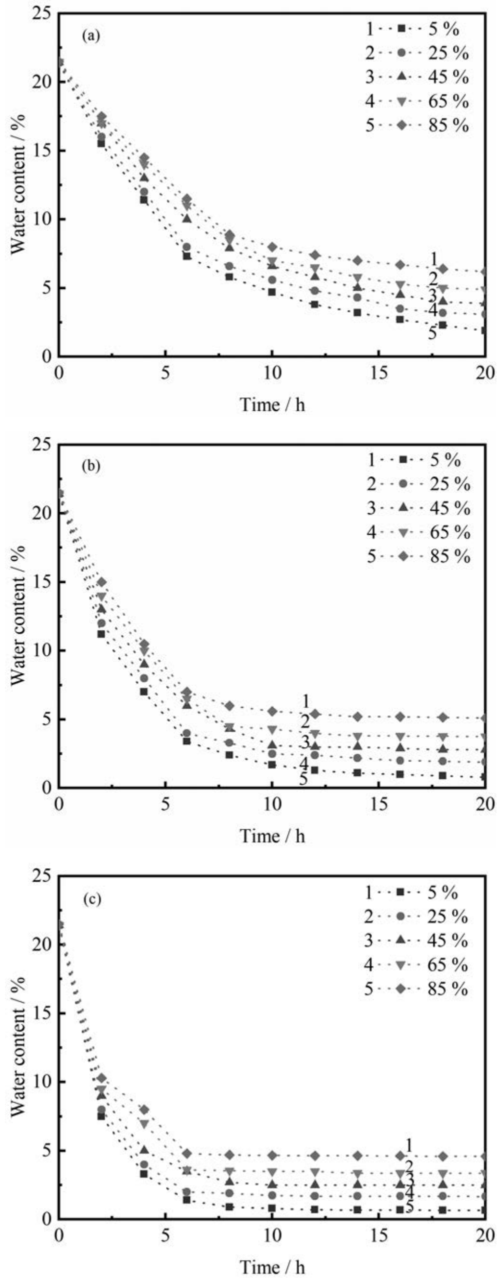
In order to explore the relationship between the equilibrium moisture content and the hot air temperature and relative humidity of the drying process of the ceramic green body, the drying experiments were carried out on the ceramic green body, and the result curves of the dry base moisture content of the green body with drying time were obtained under the drying conditions of 35, 45, 55, 65 and 75 °C and the relative humidity of hot air were 5 %, 25 %, 45 %, 65 % and 85 %, respectively. Figure 4 shows the curve of the dry base moisture content of the green body with drying time at different hot air temperatures when the relative humidity of hot air is 25 %, 45 % and 65 %, respectively. It can be seen from the figure that the dry base moisture content of the green body decreases with the drying time, and the higher the hot air temperature, the faster the dry base moisture content of the green body decreases, and the time required for the green body to dry to the equilibrium moisture content is shorter, when the hot air temperature is 75 °C, the time it takes for the moisture content in the green body to reach equilibrium is the shortest; When the relative humidity of the hot air is 25 % and the temperature of the hot air is 75 °C, the time required for the moisture content to reach equilibrium is the shortest, and the moisture content in the green body has reached equilibrium when it is dried to 6 h, and the equilibrium moisture content of the green body is the lowest, and the equilibrium moisture content reaches less than 2 %.

Figure 5 shows the variation of the dry base moisture content of the green body with drying time at different relative humidity when the hot air temperature is 35 °C, 55 °C and 75 °C, respectively. It can be seen from the figure that the dry base moisture content of the green body decreases with the drying time, and the



(a) RH = 25 %; (b) RH = 45 %; (c) RH = 65 %

Figure 4 Curve of dry base moisture content of green body with drying time at different hot air temperatures



(a) T = 35 °C; (b) T = 55 °C; (c) T = 75 °C

Figure 5 Curve of dry base moisture content of green body with drying time under different hot air relative humidity

greater the relative humidity, the slower the dry base moisture content decreases, the higher the equilibrium moisture content, and when the relative humidity is 85 %, the equilibrium moisture content is higher.

Figure 6 shows the influence of hot air temperature on the dry equilibrium moisture content of the green body, and it can be seen from the figure that the equilibrium moisture content decreases with the increase of hot air temperature. When the hot air temperature is 75 °C and the relative humidity of the hot air is 25 % dry, the equilibrium moisture content of the green body is the lowest, and the dry base moisture content reaches equilibrium at 1,68 %.

The influence of hot air temperature on the equilibrium moisture content of green body drying is shown in Figure 7, from which it can be seen that the equilibrium moisture content increases with the increase of relative humidity, when the relative humidity is 85 % and the temperature is 35 °C, the equilibrium moisture content of green body drying is the largest, and the dry base moisture content is 6,2 % to reach equilibrium.

Based on the modified Oswin formula, the equilibrium moisture content data obtained under different hot air temperature and relative humidity conditions were fitted, and the equilibrium moisture content model of the green drying process was determined. The experimental data were fitted by least squares method by Matlab software, and the coefficients a, b and c were 0,02264, 13,1 and 0,3976, respectively, and the correla-

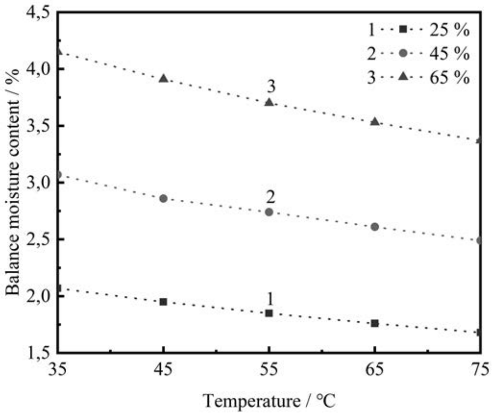


Figure 6 Effect of temperature on equilibrium moisture content

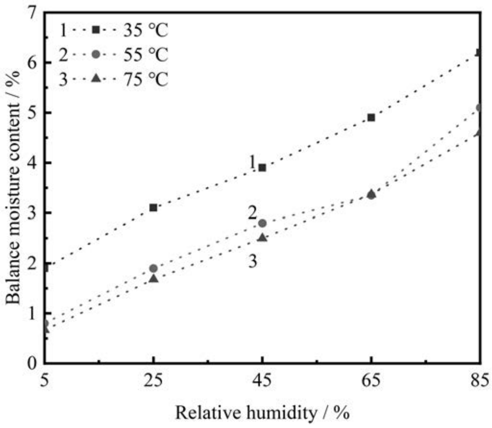


Figure 7 Effect of relative humidity on equilibrium moisture content

tion coefficient R^2 was 0,9956, indicating that the fit was good. Therefore, the modified Oswin formula, the equilibrium moisture content model, is expressed as:

$$M_e = 0{,}02264 \exp\left(\frac{13{,}1}{T}\right)\left(\frac{RH}{1 - RH}\right)^{0{,}3976} \quad (2)$$

CONCLUSION

Through the hot air drying experiment, the drying experiments of the green body were carried out under the drying conditions of 35, 45, 55, 65 and 75 °C and the relative humidity of the hot air were 5 %, 25 %, 45 %, 65 % and 85 %, respectively, and the influence of hot air temperature and hot air relative humidity on the drying moisture content and equilibrium moisture content of ceramic green body were studied. The equilibrium moisture content data obtained by the experiment were fitted, and the equilibrium moisture content model for green body drying was determined.

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Note: The responsible translator for English language is Y Y Jin-North China University of Science and Technology, China