Functionalization Of Casting Mould By Microwave Drying

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In Japan, application of microwave to drying operation is restricted for the case of appearing a new quality in the dried material in addition to remarkable reduction of overall drying time. This study concerns a microwave effect on physical property of the dried material. Present mould in the casting process shows homogeneous feature and may have mechanically moderate and uniform strength. The authors investigated in the previous study an effect of microwave on overall drying time and mechanical strength of the model mould which is made of glass particle layer wetted lightly with dilute gelatin binder solution. In this study, the authors tried to make an inhomogeneous mould with hard surface and fragile body through combined convective and microwave drying. As a result, cross-sectional profiles of binder and strength of the model mould changed remarkably uniform to no uniform at the initial moisture content φ_0 (volume ratio of binder solution to void in the mould) was nearly 0.15, thus the obtained mould may be functional.

1. Introduction

In casting process, mould is often formed through drying of sand layer wetted lightly with dilute binder solution. Overall drying time becomes longer in case of thick layer because of lower value of effective thermal conductivity of the layer (Imakoma et al., 2005). In this case, thermal generation with microwave in the wet layer may be effective for decreasing overall drying time. Roles of microwave during drying are acceleration of moisture transfer and water evaporation caused by the temperature increase in wet material. Combined convective and microwave drying may one of the most potential methods for drying of thick porous materials (Turner and Jolly, 1991) (Turner, 1994) (Roques et al., 1994) (Lu et al., 2003) (Roques et al., 1992) (Banafonte et al., 2002a). Besides the mould should be not only strong enough in case of handling but also easily broken in case of removing the mould from casting, and the thermal generation of microwave causes increase of mechanical strength of the mould (Yamaguchi, 2006) .

In this study, the authors focus on gelatin as a binder and perform combined convective and microwave drying with a packed bed sample of glass particle wetted lightly with dilute gelatin solution. Drying rate, surface temperature, and cross-sectional profiles of the gelatin and an impact-resistant energy of the dried sample are measured.

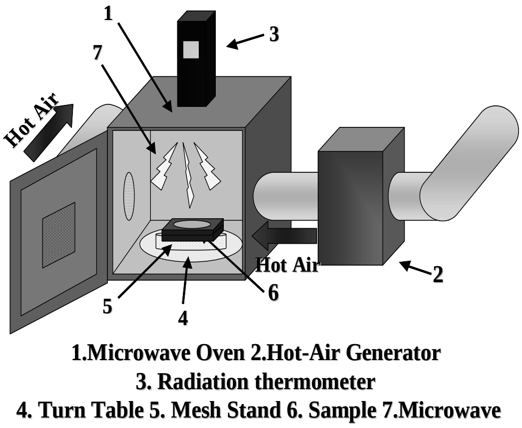


Fig.1 Drying apparatus

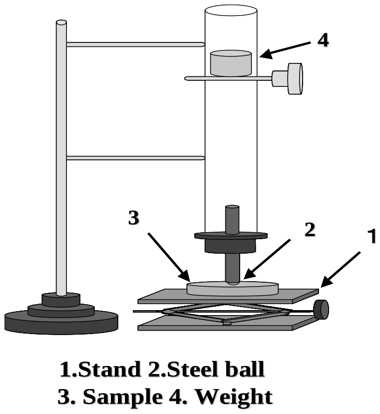


Fig.2 Dupont –type impact tester

2. Experimental

2-1 Sample preparation

Glass particle (diameter 60-120μm) and aqueous gelatin solution (C_0 =0.050, 0.033, 0.031, 0.029, 0.025, 0.022, 0.020 kg-gelatin/kg-water), colored red were well mixed together. The mixture was packed in a sample holder (70-mm inner diameter and 18-mm depth) made of polystyrene to use as an experimental sample. Initial moisture content (φ_0 = 0.10 0.15, 0.16, 0.175, 0.20, 0.22, 0.25 volume ratio of solution to void in the layer) with corresponding gelatin concentration was set in order to keeping gelatin mass within each sample constant.

2-2 Drying experiment

Figure.1 shows a diagram of the drying equipment. Drying experiment was performed by a commercial microwave oven (1500W max.) with a circulation part of hot air. Hot air temperature and microwave output were 323K and 100W. Microwave power absorbed to the both sample and microwave oven made of stainless steel was 30-40% of the output, and large part of the power was absorbed to the oven wall with rough surface. A radiation thermometer was attached on the oven ceiling to measure the surface temperature of the sample during drying. Mass change of sample was measured every 3 minutes with electronic balance.

After the drying experiment, the sample was dried in vacuum (24 hour or more at 373K). The sample was cut horizontally into fore equal pieces. All of them was heated to 973 K and only the dried gelatin was burned out during the heating. Cross-sectional profile of the gelatin content of each sample was obtained from the mass change.

2-3 Experiment of impact-resistant energy

Figure.2 shows a diagram of the Dupont –type impact tester. Damage on the sample surface by the potential energy of the weight can be estimated quantitatively using the tester. The experiment was performed to estimate an impact-resistant energy of drying surface and cross sectional surface of the dried sample. A damage hole by the impact was formed by dropping the weight normal to the rod with tiny steel ball that is placed on the sample surface. Diameter of the hole was measured by using magnifier and ruler to determine the volume of the hole. The impact energy was estimated from the potential energy of the weigth divided by this volume.

3. Results and Discussion

3-1 Drying curve

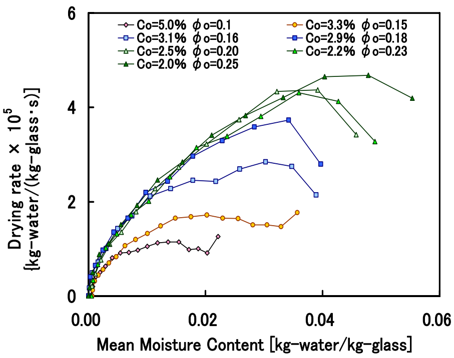


Fig.3 Drying rate curve

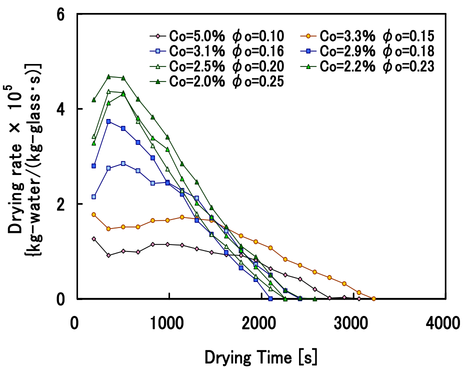


Fig.4 Drying rate vs. drying time

Figures.3,4 show relationship of drying rate of the combined drying with mean moisture content and with drying time, respectively. Drying rate was calculated by the mass change of wet sample. As a result, the drying rate and the overall drying time remarkably changed at the initial moisture content that is nearly equal to 0.15. There are two reasons to explain this result. The one is that microwave is mainly absorbed to water, and the other is that the water in the material is classified into the funicular water at higher moisture content and the pendular water at lower content. In the case $\varphi_0 < 0.15$, water in the sample is occpied with the pendular one and it evaporates on the spot and moves as the vapor with diffusion. In the case$\varphi_0 > 0.15$, however, water in the sample is occupied with the funicular one and it moves as the liquid with viscous flow caused by the capillary pressure gradient. Therefore in the case $\varphi_0 > 0.15$, the drying rate became faster and the overall drying time became shorter than the case of $\varphi_0 < 0.15$.

3-2 Surface temperature

Figure.5 shows change of surface temperature of the sample with mean moisture content during the combined drying. Regardless of initial moisture content, the temperature increases at first and keeps constant with decreasing the mean moisture content.

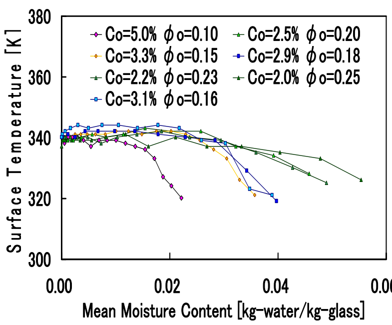


Fig.5 Surface temperature

3-3 Profile of gelatine

Figure.6 shows cross-sectional profile of the gelatin content within each dried sample (φ_0 = 0.10, 0.15, 0.20) with dimensionless distance from the drying surface.

In the case $\varphi_0 = 0.10$, profile of the gelatin content was flat and the value was near 0.0015 kg-gelatin/kg-glass. In the case $\varphi_0 = 0.15$, the gelatin content showed minimum at the middle part and the value was 0.0010 kg-gelatin/kg-glass. In the case φ_0 = 0.20, the gelatin content decreased monotonously from the drying surface and the value near the surface was 0.0030 kg-gelatin/kg-glass.

The profiles of gelatin content depend on the water movement in the sample. The solid gelatin remains at the place of water evaporation. The pendular water evaporates on the spot and the funicular water moves as the liquid to the drying plane. In the case $\varphi_0 > 0.15$, samples are occupied with the funicular water and the profiles of the gelatin content were not flat.

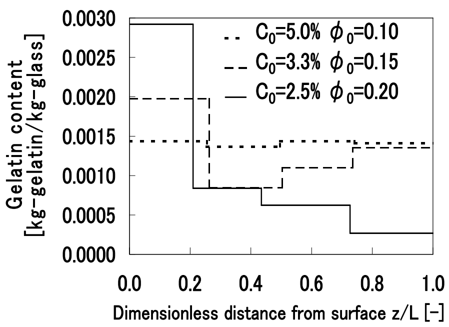
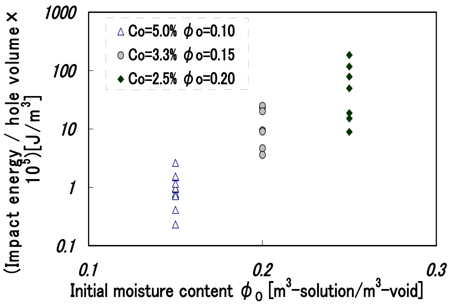


Fig.6 Profile of gelatin

3-4 Impact-resistant energy



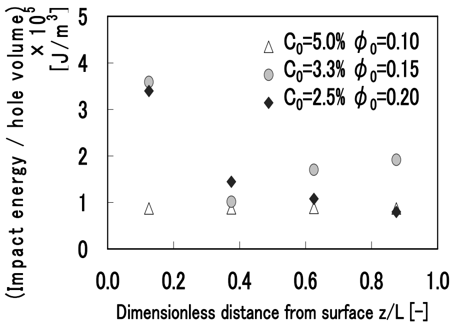


Fig.7 Surface impact-resistant energy   Fig.8 Cross sectional impact-resistant energy

Figure.7 shows the surface impact-resistant energy. The impact-resistant energy of each sample scattered and a representative value was obtained from the arithmetical mean. The value of impact-resistant energy on drying surface increased with the initial moisture content, because the gelatin was accumulated on the drying surface with increasing the initial content. Correlation coefficient *C* is defined as indicating strength and direction of a linear relationship between two random variables (x_i, y_i), and can be calculated with Eq.(1).

$$C = \frac{\sum_{i=1}^{n}(x_i - X)(y_i - Y)}{\sqrt{\sum_{i=1}^{n}(x_i - X)^2}\sqrt{\sum_{i=1}^{n}(y_i - Y)^2}} \quad (1)$$

where (X, Y) = arithmetic mean of (x_i, y_i). The correlation coefficient between the gelatin content and the impact-resistant energy was calculated in this study and the value was 0.976, where the nearest value to the drying surface was used as the gelatin content. The result showed a close correlation.

Figure.8 shows the cross sectional profiles of the representative value of the impact-resistant energy and the profiles were similar to those of the gelatin content. The energy increased with the gelatin content. The correlation coefficient between the cross sectional profiles of the gelatin content and the impact-resistant energy was calculated and the values were 0.865, 0.925, and 0.999 for φ_0 = 0.10, 0.15 and 0.20, respectively.

The result showed a good correlation. The authors succeeded to show drying conditions to obtain the two types of functional moulds that is the one is single sided hard surface and fragile body and the other is double sided hard surfaces and fragile body.

4. Conclusion

In this study, the authors focused on gelatin as a binder and performed combined convective and microwave drying with a packed bed sample of glass particle wetted lightly with dilute gelatin solution. Drying rate, surface temperature, cross-sectional gelatin and impact-resistant energy profiles were measured. Initial moisture content was changed with keeping gelatin mass within each sample constant.

In the case $\varphi_0 > 0.15$, the drying rate became faster and the overall drying time became shorter than the case $\varphi_0 < 0.15$. In the case $\varphi_0 = 0.10$, profile of gelatin was flat and the value was near 0.0015 kg-gelatin/kg-glass. This is the case of usual mould. In the case $\varphi_0 = 0.15$, the gelatin content showed minimum at the middle part of the sample and the value was 0.0010 kg-gelatin/kg-glass. In the case $\varphi_0 = 0.20$, the gelatin content decreased monotonously from the drying surface and the value near the surface was 0.0030 kg-gelatin/kg-glass.

Damage on the sample surface by the potential energy of the weight was estimated quantitatively using the Dupont –type impact tester. The impact energy was defined as the potential energy of the weigth divided by the damage volume. The impact-resistant energy on drying surface increased with the initial moisture content, because the gelatin was accumulated on the drying surface with increasing the initial content. The cross sectional profiles of the impact-resistant energy increased with the gelatin content and the profiles were similar to those of the gelatin content. The gelatin content and the impact-resistant energy were highly correlated.

The authors succeeded to show drying conditions to obtain the two types of functional moulds that is the one is single sided hard surface and fragile body and the other is double sided hard surfaces and fragile body.

5. Reference

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