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EVALUATION OF DRYING KINETICS OF SLURRED CERAMIC RAW MATERIALS

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Abstract: One of the most popular applied methods during the production of ceramics is convective drying by mixing raw materials and a certain proportion of water to achieve homogeneity. In this study, drying characteristics of slurred raw materials have been evaluated according to different heat transfer mechanisms in a convective dryer. This experimental study was performed by using three different molds to understand the effects of heat and mass transfers from i) only one surface where the bottom surface was isolated, ii) two surfaces where one side of the mold was covered with an stainless steel plate to enhance heat transfer, iii) two surfaces. All experiments were conducted with two different thickness values for all three molds to determine the drying time of raw materials. The experimental results were compared to some thin-layer drying models from the literature. Midilli et. al. model was found the best relevant drying model. Also, effective moisture diffusion coefficients were found for different heat transfer mechanisms according to Crank's model (Crank, 1975).
Keywords: Convective drying, Slurred raw material, Heat transfer, Mass transfer, Effective moisture diffusion coefficient.

ÇAMUR HALİNDEKİ SERAMİK HAMMADDELERİNİN KURUTMA KİNETİĞİNİN İNCELENMESİ

Özet: Seramik üretimi sırasında uygulanan en önemli metotlardan birisi hammadde ile suyun belli oranda karıştırıldıktan sonra yapılan konvektif kurutmadır. Bu çalışmada çamur halindeki seramik hammaddesi konvektif bir kurutucuda farklı ısı transfer mekanizmalarına göre incelendi. Deneysel çalışmada, ısı ve kütle transferinin etkilerini anlamak için i) alt yüzeyi yalıtımlı, tek yüzeyden ısı ve kütle transferine izin veren, ii) ısı transferini arttırmak için kalıbın alt yüzeyinin paslanmaz çelik saçtan yapıldığı iki yüzeyden ısı transferine izin veren, iii) her iki yüzeyden taşınımla ısı transferine izin veren olmak üzere üç farklı kalıp kullanıldı. Bütün deneyler, ham maddelerin kuruma zamanını belirlemek için üç kalıp için de iki farklı kalınlık değerlerinde yapıldı. Deneysel sonuçlar literatürden alınan birkaç ince katman kuruma modelleri ile karşılaştırıldı. Midilli vd. modeli en uygun kurutma modeli olarak belirlendi. Aynı zamanda, efektif su buharı difüzyon katsayıları Crank Modeli' ne göre farklı ısı transfer mekanizmaları için hesaplandı (Crank, 1975).
Anahtar Kelimeler: Konvektif kurutma, Çamur halindeki hammadde, Isı transferi, Kütle transferi, Etkin su buharı difüzyon katsayısı

NOMENCLATURE

a, b, c	drying coefficients
D	the effective moisture coefficient [m^2/s]
DR	drying rate [$g/cm^2.min$],
k	drying constants [min^{-1}],
L	half thickness of the samples [m]
m	weight [kg],
M	moisture content [kg_{water}/kg_{dry}],
MR	dimensionless moisture content,
n	constant,
R	dimension to be measured,
R^2	determination of regression,
t	time(min),
w	errors,

Subscripts

1, 2	constants
a	total weight in samples
d	dried weight of samples
eq	equilibrium moisture content,
o	inital moisture content,
r	relative humidity,
t	time(min),
T_a	ambient temperature
T_i	temperature before test section
T_o	temperature after test section
w	moisture weight in samples
v	velocity

INTRODUCTION

Ceramic industry has been getting importance with increasing human comfort demands all around the world. Ceramics are widely used for both building materials i.e. tiles, as well as ornaments, i.e. plate, vase, bowl and etc. Ceramic production processes have several stages. One of the main and important stages is drying. Drying process starts upon the mixture of raw materials and water to obtain homogeneity. Drying, also known as an energy-intensive process, can be applied several times during the entire ceramic production. This process is also playing a crucial role in industrial applications. It has been determined that energy used in drying process has been ranging from 7 to 15% of the nation's industrial energy consumption for most industrialized countries (Keey, 1992; Dincer and Dost, 1996).

Generally, ceramic production processes have been relied on methods like sun drying, although material science has significantly advanced on ceramics during the last few decades (Mujumdar, 2006). Musielak and Mierzwa stated that drying is the one of the important stages for the quality of product (Musielak and Mierzwa, 2009). Drying has two simultaneous processes; heat and mass transfer. Drying of ceramics is affected by a number of internal and external heat and mass transfer parameters. Drying temperature, velocity and relative humidity of the drying medium (air) are generally known as external parameters. Internal parameters can be considered as density, permeability, porosity, and thermo-physical properties of the material dried. In this regard, understanding heat and mass transfer of the product will help to improve drying process parameters hence the quality (Kaya et al., 2008).

Majority of published studies on drying have been concentrated on drying of vegetables, fruits, woods, papers and etc. (Ceylan et al., 2005), and studies on drying of ceramics are rather limited. Drying is a complex process and this process has not been precisely understood yet. Due to this reason, determining of drying characters of products has been based on empirical or semi-empirical mathematical models. These mathematical models have been used by many researches working on drying. Some of them are shown in Table 1.

Table 1. Some of mathematical models used for determining drying kinetics of products

No	Models	Equations	References
1	Page	$MR=\exp(-kt^n)$	(Aktaş et al., 2009)
2	Henderson and Pabis	$MR=a\exp(-kt)$	(Henderson and Pabis, 1961)
3	Logarithmic	$MR=a\exp(-kt)+c$	(Aktaş et al., 2009; Sacilik et al., 2006)
4	Two term Model	$MR=a_1\exp(-k_1t)+a_2\exp(-k_2t)$	(Sacilik et al., 2006; Midilli et al. 2002)
5	Midilli et al.	$MR=a\exp(-kt^n)+bt$	(Midilli et al. 2002)

These models have been successfully used to determine the drying characteristics of some products. a, b, c, n, a_1 and a_2 are drying coefficients; k, k_1 and k_2 are the drying constant (min^{-1}) and t is the time (min).

Some studies on ceramic drying are as follows in the literature. Effects of drying temperature and relative humidity were examined on water based alumina suspensions by Briscoe et al. (Briscoe et al., 1998). Chemki and Zagrouba experimentally determined moisture diffusion coefficient from drying curve of clay (Chemki and Zagrouba, 2005). Drying of clay slabs were carried out by Sander et al. in a convective dryer. Also, experimental results were compared with mathematical models getting from literature (Sander et al., 2003). Silva et al. examined drying of clay experimentally. Also, they analytically solved two dimensional-diffusion models for prediction moisture loss (Silva et al., 2013). Kowalski et al. suggested a model to determine for heat and mass transfer during kaolin materials drying (Kowalski et al., 2007). Drying of clays was carried out Itaya et al. on microwave dryer. (Itaya et al., 2007). Mihoubi et al. came up with a model for heat and mass transfer on clay drying (Mihoubi et al., 2004).

There is no literature specific to be air – drying kinetics of slurred raw materials including high density quartz. In the present work, drying characteristics of slurred raw materials were evaluated for different heat transfer mechanisms in a convective dryer. Based on the prepared molds, the drying characteristic of the slurred raw materials was experimentally investigated depending on the effect of heat and mass transfer from i) only one surface where the bottom surface was isolated, ii) two surfaces where one side of the mold was covered with an stainless steel plate to enhance heat transfer, iii) two surfaces. All experiments were conducted with two different thickness values for all three molds to determine the drying time of raw materials. Drying curves obtained from experimental results were carried out in terms of regression with some mathematical models from the literature. The obtained experimental results indicated that internal resistance according to presence of falling drying period controls drying time. Therefore, results can be interpreted using Fick's diffusion equation developed by Crank (Crank, 1975).

MATERIAL AND METHODS

An experimental apparatus was prepared for this study, which is illustrated in Figure 1. This apparatus basically consists of centrifugal fan, fan speed control unit, flow regulator, a humidifier unit, an electric heater, pressure transmitter, pitot tube, an electronic controller, sensors for temperature and humidity, data logger and a computer.

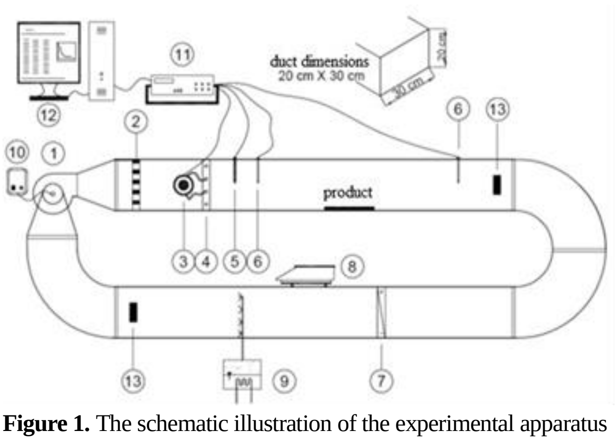
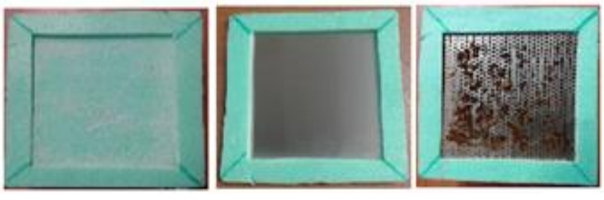


Figure 1. The schematic illustration of the experimental apparatus (1. Centrifugal fan, 2. Flow regulator, 3. Pressure transmitter, 4. Stationary tube, 5. Relative humidity sensor, 6. RTD, 7. Electrical heater, 8. Scale, 9. Relative humidity adjuster, 10. Speed control switch, 11. Datalogger, 12. Computer, 13. Cover).

The experimental apparatus was used to provide desired drying condition. The inner rectangular-sectioned channel of the experimental apparatus is 20 cm x 30 cm. Channel was insulated with 5 cm thick rock wool in order to prevent heat loss during drying.

Raw materials were provided by İznik Çini Foundation. Raw material was put in a mixing vessel by measuring its weigh first. Then, water was added about 30% of the raw material weigh in the mixing vessel and they were stirred up about ten minutes with a metal stick. Molds were prepared as 100x100x10 mm and 100x100x5 mm as shown in Figure 2, which was made from XPS materials.



(i) (ii) (iii)

Figure 2. The molds made from XPS insulation material for experimental studies.

There are 3 types of molds. The mold seen in Figure 2(i) only represents variation of drying characteristics depending on both surface heat and mass transfers from only 1 side. This mold was used to determine mass transfer ratio in consideration of heat transfer effect from upside with convection, as the other side was insulated.

The mold seen in Figure 2(ii) was used to determine drying characteristics of raw materials depending on heat transfer from two surfaces and mass transfer from only one surface. The bottom surface of mold in Figure 2(ii) was prepared with 0.5 mm stainless steel. Variations of moisture transfer were carried out, when the bottom of the mold exposed to conduction heat transfer and the upside of the mold exposed to convection heat transfer. Mass transfer only occurred from upper surface.

The mold seen in Figure 2(iii) was used to determine the drying characteristics of raw material both heat and mass transfer from 2 surfaces. The bottom surface of this mold was prepared by perforated steel. Due to high viscosity of the raw material, it did not flow down from holes on the mold. Duct height was 20 cm. The molds were placed on to a platform as shown in Figure 3 the height of the platform was 10 cm to supply about equal air flow rate to both sides of the molds. It was convection heat transfer both from the bottom and upside of the mold. Also, mass transfer occurred from both sides.

The drying experiment was carried out at 50 °C air temperature and thicknesses were 1.0 cm and 0.5 cm. Average relative humidity changed to %30±1.5. Relative humidity was adjusted with glasses filled water. These glasses were settled in dryer.

Drying air having high temperature and low relative humidity takes moisture on the surface of the product and continues through the duct. When drying air having moisture by air heater, it losses some moisture and this circulation continues this way during drying process.

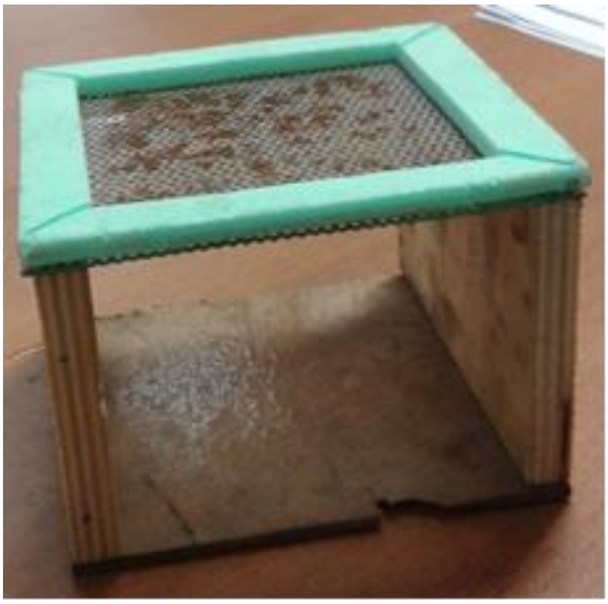


Figure 3. The mold and platform to determine drying characteristic of raw materials.

Temperature was supplied by an electrical heater adjusted via a dimmer. Also, temperature was determined by two RTD type thermo elements. One of them was put before the test zone and the other one was after. Temperature values were kept in the range of ±1 °C by means of a good insulation and the mass of stainless steel on experimental apparatus after desired regime conditions. Drying conditions in the test zone were followed by means of computer program and required situations were interfered to dimmer with small adjustments for temperatures.

Relative humidity in duct was supplied by means of glasses, which were full with water and their upper side open. Desired relative humidity value was kept in the range of ± %1 by covers, which have 10x5 cm2. To supply desired relative humidity values, spaces were created by acting the covers.

Velocity in test section was controlled with voltage regulator connected to centrifugal fan. Also, relative humidity was determined through moisture sensor placed before the test section. Velocity was measured with a pitot tube. Obtained value from stationary tube was transferred to computer. Also, velocity was measured randomly with manual anemometer to control velocity in the test section.

The weight reductions of samples were measured by taking out samples quickly and using a digital balance with 0.01g sensitivity in every 15 minutes during the drying process. The experiments were repeated twice in order to control experiment sensibility. The average of the moisture ratio for each value was taken at every half hour in order to draw the drying curves. Desired regime conditions were provided after 1 to 1.5 hours. Samples were located on a tray and were enclosed in drying setup when drying conditions achieved steady-state.

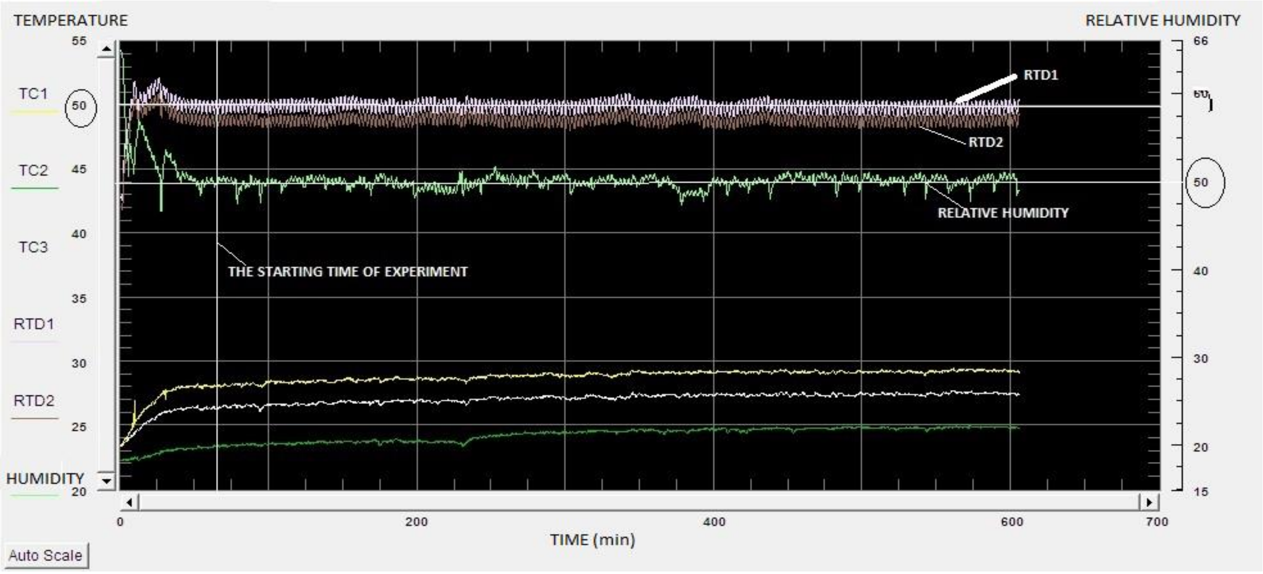


Figure 4. Momentarily screen image for computer program.

As shown in Figure 4, a computer program was programmed to observe the variation of drying temperature and relative humidity by means of HP VEE package program. When desired experimental conditions were made, experiments were started. For example, screen image of the program can be seen on Figure 4 for 50 ºC and 50% relative humidity.

The initial moisture content of slurred ceramic raw material was determined by using a drying oven at 105 oC for 24 h. The initial moisture content of the samples was found as 31.3%-35.4% d.b. according to Eq. 2.

$$m_a = m_w + m_d \tag{1}$$

Eq. 1 represents total weight for samples, where ma is total weight of samples, mw is moisture in samples, md is dried weight of samples

$$M = \frac{m_w}{m_d} \tag{2}$$

Dimensionless moisture ratio (MR) of during drying experiments was calculated using the following equation (Ceylan et al., 2005; Mihoubi et al., 2004).

$$MR = \frac{M(t) - M_{eq}}{M_o - M_{eq}} \tag{3}$$

where M(t) is the moisture content at any time (kg water/kg dry solid), M_o is the initial moisture content ($kg_{water}/kg_{dry\ solid}$) and M_{eq} is equilibrium moisture content of sample ($kg_{water}/kg_{dry\ solid}$). It was assumed that the equilibrium moisture content was equal to zero for the analysis (Aktaş et al., 2009). Then, Eq. 3 changes,

$$MR = \frac{M(t)}{M_o} \tag{4}$$

Also, drying rate can be found according to following Eq. 5.

$$DR = \frac{M_{t+dt} - M_t}{dt} \tag{5}$$

Drying rate was found for each 15 minutes depending on moisture loss (Aktaş et al., 2008).

Obtained drying data were fitted to five thin-layer mathematical models to determine the best model in terms of regression. The models can be seen on Table 1. The effective moisture diffusivity has significance for transport property in ceramic and other materials during drying process. Fick's second law of diffusion equation can be seen in the following equation for falling rate drying period.

$$\frac{\partial M}{\partial t} = D_{eff} \nabla^2 M \tag{6}$$

If the assumptions of moisture migration being by diffusion, constant diffusion coefficients, negligible shrinkage, and temperature during the drying process are considered, the effective diffusion coefficient can be found by Crank's model used often in the literature for the analytical solution of Fick's second law (Crank, 1975; Doymaz, 2012).

$$MR = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \exp\left(-\frac{(2n+1)\pi^2 D_{eff} t}{4L^2} \right) \tag{7}$$

Where Deff is the effective diffusivity (m2/s), and n is a positive integer, L is the half thickness of the samples. This equation Eq. (7) can be simplified by taking the first term of series solution for long term drying:

$$MR = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 D_{eff} t}{4L^2}\right) \tag{8}$$

When natural ln (MR) versus time was plotted, the effective diffusivity is typically calculated by using the slope of Eq. (8) straight line with a slope E was obtained.

$$E = \frac{\pi^2 D_{eff} t}{4L^2} \tag{9}$$

where E is the slope of straight line. The calculated the effective diffusivity values gained from different heat and mass transfer conditions are presented in Table 4.

There are many uncertainties during experimental studies because of selection of equipment, calibration, reading, observation etc. Determination of these case is important to enhance sensitivity of experimental study. That's why, uncertainty analysis for experimental measurement and results is an important tool for planning and design of experiments. Uncertainties can be calculated with Eq.10 where R is the dimension to be measured, $x_1, x_2, x_3, \ldots, x_n$ are independent variables, $w_1, w_2, \ldots, w_n$ are the errors in the independent variables and w_R is the total error (Akpınar, 2006).

$$w_R = \left[\left(\frac{\partial R}{\partial x_1}\right)^2 w_1 + \left(\frac{\partial R}{\partial x_2}\right)^2 w_2 + \left(\frac{\partial R}{\partial x_3}\right)^2 w_3 + \ldots + \left(\frac{\partial R}{\partial x_n}\right)^2 w_n \right]^{(1/2)} \quad (10)$$

Temperature, velocity, relative humidity and weight loss happened uncertainties for experimental study.

The errors depending on the measurement of temperature errors that might occur in the temperature measurement varies depending on the measurement devices used in the experiments. Errors resulting from temperature measurements at various points in the system during the experiments are;

(a_1) The error depending on sensitiveness of RTDs = ±0.06 °C,
(b_1) The error depending on fasters and points = ±0.1 °C,
(c_1) The error depending on readings for drying air temperature before drying section = ±0.25 °C,
(d1) The error depending on readings for drying air temperature after drying section = ±0.25 °C,
(e1) The error depending on readings for the ambient temperature =±0.25°C,

The total errors (w_{Ti}) before test section for temperature (T_i)

$$w_{Ti} = [(a_1)^2 + (b_1)^2 + (c_1)^2]^{1/2} \quad (11)$$

$w_{Ti} = \pm 0.275$

The total errors (w_{To}) after test section for temperature (To)

$$w_{To} = [(a_1)^2 + (b_1)^2 + (d_1)^2]^{1/2} \quad (12)$$

$w_{To} = \pm 0.275$

The total errors (w_{Ta}) for ambient temperature (T_a)

$$w_{Ta} = [(a_1)^2 + (b_1)^2 + (e_1)^2]^{1/2} \quad (13)$$

$w_{Ta} = \pm 0.275$

The errors depending on the measurement of weight loss

(a_2) The error depending on sensitiveness of precision scale = ±0.01 gr
(b_2) The error depending on readings = ±0.05 gr

$$w_w = [(a_2)^2 + (b_2)^2]^{1/2} \quad (14)$$

$w_w = 0.05$

The errors depending on the measurement of velocity

(a_3) The error depending on sensitiveness of anemometer = ±0.2 m/s
(b_3) The error depending on readings = ± 0.25 m/s

$$w_v = [(a_3)^2 + (b_3)^2]^{1/2} \quad (15)$$

$w_v = 0.32$

The errors depending on the measurement of relative humidity

(a_4) The error depending on sensitiveness of relative humidity sensor = ± 2.0 RH
(b_4) The error depending on readings = ± 0.25 RH

$$w_r = [(a_4)^2 + (b_4)^2]^{1/2} \quad (16)$$

$w_r = 2.02$

Uncertainties of the parameters can be seen on Table 2.

Table 2. Uncertainties of the parameters during drying.

Parameters creating errors	Unit	Comment
Total errors during the measurement of temperature		
w_{Ti}	°C	±0.275
w_{To}	°C	±0.275
w_{Te}	°C	±0.275
Total error during the measurement of weight loss		
w_w	gram	±0.050
Total error during the measurement of velocity		
w_v	m/s	±0.32
Total error during the measurement of relative humidity		
w_r	RH	±2.02

RESULTS

In this study, a convective drying system was designed and set up. Drying characteristics of slurred raw materials were evaluated according to different heat transfer mechanisms in a convective dryer. The drying characteristic of the mixture was experimentally investigated depending on the effect of heat and mass transfer i) only from one surface, ii) heat transfer from two surfaces mass transfer from one surface, and iii) heat and mass transfer from two surfaces by preparing different molds as shown in Figure 5.

Drying stages and variation of drying rate of slurred raw material with drying time can be seen in Figure 5 for 1.0 cm thickness, 50 ±1 °C, 2.0 m/s velocity and 30±1.0% relative humidity. Drying rate was calculated based on samples' weight loss for each 15 minute. It is obvious that drying with the insulated mold takes the longest time. Also, the constant drying period rate was observed during experimental studies. The reason of this situation has been thought that slurred materials have high porosity since raw materials only stirred with water without applying any pressure. Therefore, capillary flow easily continued towards the surface and moisture was measured constant on the surface. During the constant drying period, free moisture on the surface was taken similar rate by circulation air. Temperature of free moisture on the surface remained steady wet bulb temperature depending on drying temperature and relative humidity in the duct. This process continues until critical moisture rate starting falling drying period. When moisture in product reached to a certain value, surface temperature began increasing and surface of the product slowly begins drying from the front side to back side. Also, crack initiation was observed at this stage as seen on Figure 6.

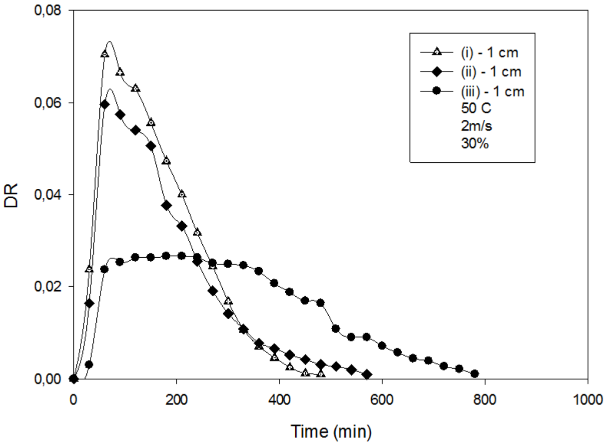


Figure 5. Drying rate of slurred raw materials.

Secondly, longer drying time was observed on the mold used to be understood effects heat transfer from two surfaces and one surface mass transfer. The smallest drying time was observed on the mold used to be understood two side heat and mass transfer. Drying time decreased of about two times, when the sides of the mold were insulated and the bottom surface was covered with perforated steel instead of instead of insulating both sides of the mold.

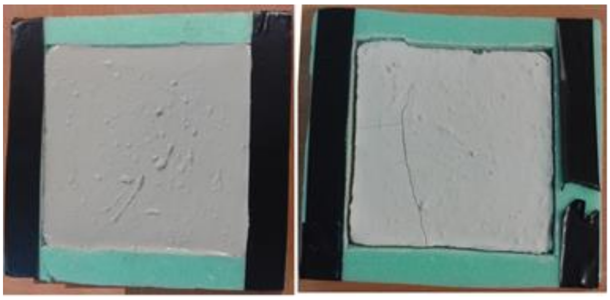


Figure 6. Initiation of cracking of the samples; a) before drying, b) after drying.

Variation of dimensionless moisture content depending on different heat and mass transfer cases can be seen on Figure 7 and Figure 8. These graphs were drawn for 1 cm and 0.5 cm thickness based on drying conditions %30±1.0 for 50±1.0 ºC and 2±0.1 m/s velocity. As expected, drying time decreased with the increasing area that was subjected to heat transfer. Drying time took approximately 7 hours for two side heat and mass transfer under same conditions. Drying time was found of about 9 hours for two side heat and one side mass transfer, and approximately 12 hours for heat and mass transfer from only one surface. When energy for drying and drying time are considered, drying with two sides heat and mass transfer conditions are quite suitable. Especially, drying of slurred raw materials can be appropriate with convective drying in terms of both drying time and energy.

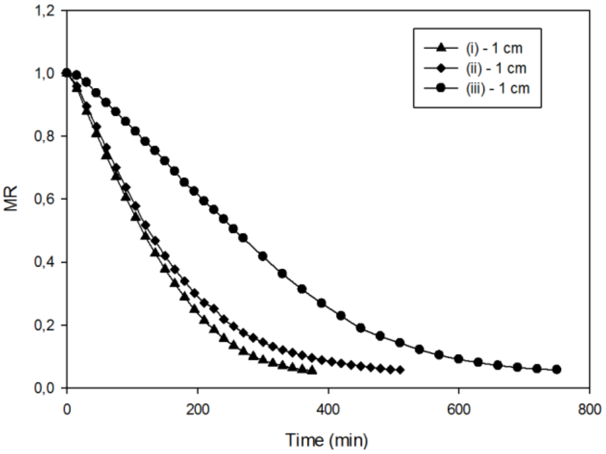


Figure 7. Variation of dimensionless moisture content with time depending on different heat and mass transfer cases for 1 cm thickness.

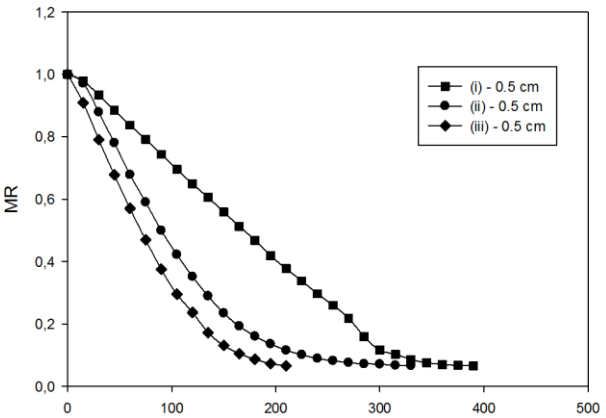


Figure 8. Variation of dimensionless moisture content with time depending on different heat and mass transfer cases for 0.5 cm thickness.

It can be seen in Table 3. that evaluation of five mathematical models in terms of regression depend on different heat and mass transfer mechanisms. Coefficients and regression of the mathematical model for one surface heat and mass transfer case are shown in Table 3 (i). Coefficients of model for two surface heat transfer and one surface mass transfer can be seen in Table 2 (ii). Similarly, Table 2 (iii) shows coefficients of models and regression for two side heat and mass transfer.

While all models generally gives good relevant results, the best relevance is observed for Midilli et al. model (Midilli et al., 2002).

The determined values of the effective moisture diffusivity values are shown in Table 4.

Determined values were found to range between 2.026E-09 and 7.929E-10 m^2/s. The moisture diffusivity was quite affected by different heat and mass transfer conditions under same drying air conditions.

Table 3. Regression coefficients of thin-layer mathematical models.

(i)

MODEL	k	a	b	c	k_1	k_2	n	R^2
Page	0.000249	…	…	…	…	…	1.433	0.9994
Henderson and Pabis	0.003388	1.113	…	…	…	…	…	0.9797
Logarithmic	0.00226	1.304	…	-0.2367	…	…	…	0.9925
Two Term	…	-2180	2181	…	0.006388	0.006385	-	0.9991
Midilli et al.	0.0001772	0.9904	0.0002592	…	…	…	1.496	0.9995

(ii)

MODEL	k	a	b	c	k_1	k_2	n	R^2
Page	0.003043	…	…	…	…	…	1.126	0.9951
Henderson and Pabis	0.006266	1.062	…	…	…	…	…	0.9949
Logarithmic	0.006471	1.057	…	0.01122	…	…	…	0.9950
Two Term	…	1.068	0.0002223	…	0.006364	- 0.01355	…	0.9959
Midilli et al.	0.001713	1.007	0.0001114	…	…	…	1.256	0.9998

(iii)

MODEL	k	a	b	c	k_1	k_2	n	R^2
Page	0.001776	…	…	…	…	…	1.257	0.9987
Henderson and Pabis	0.00720	1.081	…	…	…	…	…	0.9911
Logarithmic	0.006281	1.116	…	-0.05596	…	…	…	0.9939
Two Term	…	-0.5842	1.582	…	0.0202	0.009093	…	0.9991
Midilli et al.	0.00144	0.9909	0.0007637	…	…	…	1.353	0.9997

Table 4. Effective moisture diffusion coefficient values.

Heat And Mass Transfer	Temperature (°C)	Thickness (cm)	Velocity (m/s)	Relative Humidity (%)	Effective Moisture Diffusion Coefficent	R^2
Heat Transfer From Two Side and Mass Transfer From One Side	50	1.0	2.0	30	3.802E-09	0.9872
Heat and Mass Transfer From Two Side	50	1.0	2.0	30	7.929E-10	0.9905
Heat Transfer From Two Side and Mass Transfer From One Side	50	0.5	2.0	30	2.026E-09	0.9874
Heat and Mass Transfer From Two Side	50	0.5	2.0	30	5.066E-10	0.9849

CONCLUSIONS

In this study, drying characters of slurred raw materials were experimentally carried out depending on different heat and mass transfer conditions by means of three different molds. Experimental results were investigated with thin-layer mathematical models. Also, diffusion coefficients were found depending on that conditions.

Generally, results are as follows:

- It is obvious based on the experimental studies that heat and mass transfer are quite important for drying process.

- It was found that drying times were about 6.5 hours for heat and mass transfers from two sides, about 8.5 hours for heat transfer from two side and mass transfer from one side, about 12.5 hours for heat and mass transfers from one surface for 10 mm thickness, 3.5 hours for heat and mass transfer from two sides, about 6 hours for heat transfer from two sides and mass transfer from one side, about 10.5 hours for heat and mass transfers from one surface for 5 mm thickness

- The experimental results show that drying time can be considerably decreased if suitable mold is used during drying process.

- It is clear that all thin-layer mathematical models gave suitable values in terms of regression. However, the best model observed was Midilli et al. (Midilli et al., 2002) model during this study.

- Effective diffusion coefficients were determined between the range of 2.026E-09 and 7.929E-10 m^2/s.

- As a result of experimental studies, it can be seen that convective drying is an appropriate process for slurred ceramic raw material in terms of drying time and energy.

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