УДК 66.011

AHMET CIHAN, DINÇER AKAL, KAMIL KAHVECI

Mechanical Engineering Department, Trakya University, Turkey

DRYING KINETICS OF BRICK IN A CONVECTIVE HOT AIR DRYER

Експериментально досліджено характеристики сушіння цегли. За цими даними було обчислено коефіцієнти дифузії та побудовано діаграми сушіння.

Экспериментально исследованы характеристики сушки кирпича. По этим данным были вычислены коэффициенты диффузии и построены диаграммы сушки.

In this study, drying characteristics of brick have been investigated experimentally. Evaluating experimental results under these circumstances diffusion coefficients and drying diagrams were determined.

D – diffusion coefficient;
L – length;
m – mass;
T – temperature;
t – time;
x – moisture ratio;
ρ –density.

Subscripts
b – brick;
d – dryw;
w – moisture;
0 – initial.

Introduction

Brick is supposed to be base item of the construction sector in developing countries. Brick production is one of the highly energy consumed production method and 85-90% of used energy during its production is consumed for its baking and drying processes. Usage of appropriate drying method in the brick production highly affects cost, brick durability and production time. The performance of the drying process depends on many parameters such as condition of the drying air, dimensions of the kiln, speed of the drying line and number of the bricks to be dried. Generally, tunnel type of kilns is used for brick drying. This type of kiln works according to principles of the cross flow heat exchanger and temperature of the each zone of the kiln is measured and controlled. Bricks are get moved to opposite direction of the air flow. Brick pass is controlled through the regions of the kiln with definite temperature in defined period. The advantage of this system over the others occurs due to controlled drying systems. The kiln was continuously checked by measuring and controlling the temperature, flow rate, humidity and pressure then required modifications were done if necessary.

There are some studies concerning investigation and improvement of brick drying in the literature. Prasersan [1] observed experimentally that time and energy are saved when smaller and low loaded capacity kilns with high temperature are used. Suresh et al. [2] used turbulent air in their experiment and concluded that drying process realizes in short time and with low cost when turbulent air flow is used. Palekar et al. [3] pointed out that bricks are dried fast in vertical kilns.

In this study, drying behavior of the brick which is dried in the tunnel type kiln was investigated experimentally. Effects of drying conditions on the behavior of the drying of the brick were determined. In addition, effective diffusion coefficient of the brick in experimental conditions was calculated.

Materials and Methods

Schematic view of the tunnel type of the kiln used in this study is shown in Figure 1. Experimental measurements were taken in the kilns of the Kale Brick Factory in Turkey. Inlet temperature of the drying air was 154°C. Drying air is obtained by mixture of fresh air and air coming from bakery kiln. This mixed air is flown into kiln by a fan from the side of the kiln in which bricks being dried exit. The reason of the opposite movement of the brick and air is to prevent high temperature difference. Thus, crack formation

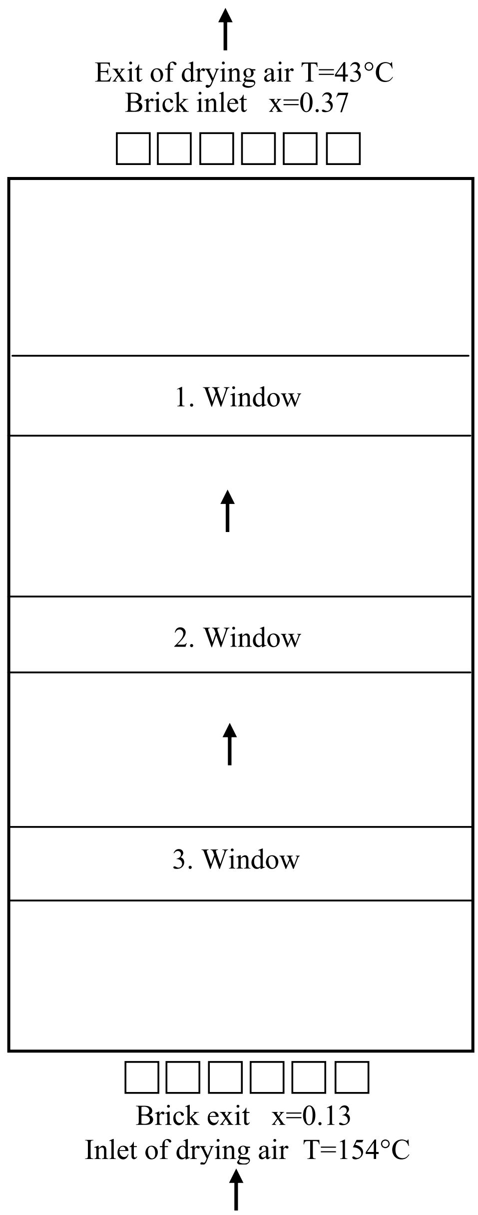

Figure 1. Schematic view of the brick drying kiln.

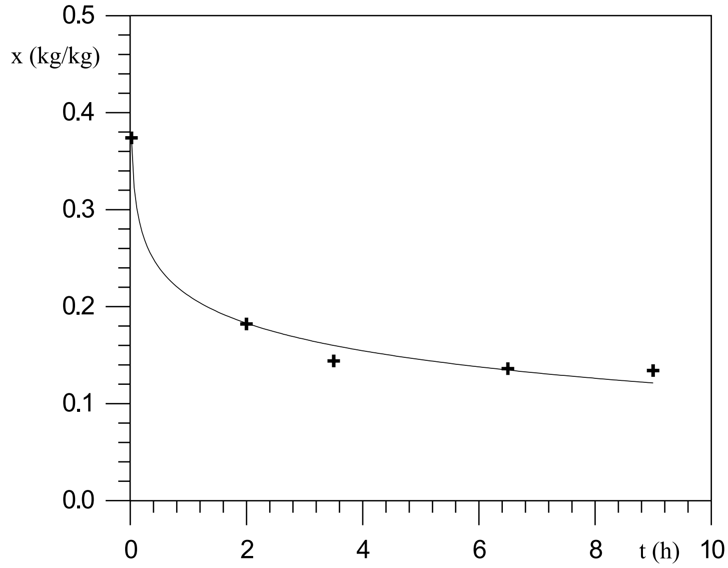

Figure 2. Variation of the moisture ratio of brick with drying time.

and brittle behavior of the brick are not permitted. There are 6 canals in the kiln used in the experiments and bricks were put into these canals. Brick samples used in the experiment are in the dimensions of about 290mm×190mm×135mm. The weight of the brick samples before entering the kiln was varied between 6.212 – 6.252 kg. The speed of the line which carries the bricks from inlet to exit was 6.33 m/h. Total length of the kiln is 57 m and there are 3 windows along the canal to take measurements. The weight of the bricks dropped to 4.254 – 4.566 kg after drying. The drying experiments took 9 hours and the weight of the samples and time required for drying were determined by measuring the temperature of the drying air at the inlet, exit and 3 windows in the kiln.

Results and Discussion

In this study, drying of brick with forced convection of hot air has been investigated experimentally by making measurements in working conditions. Moisture ratio is defined as;

$$x = \frac{mm_d}{m_d}, \qquad (1)$$

where m is the mass of the brick before drying and m_d is the mass of dried brick.

Brick is porous and nonhigroscobic item and diffusion coefficient is defined in [4] as;

$$D = 7{,}35 \cdot 10^3 \frac{T + 273}{273} \frac{\rho_w}{0{,}35\rho_b}, \qquad (2)$$

where T is temperature of drying air, ρ_b is density of the brick, ρ_w is amount of moisture in unit volume.

Moisture ratios obtained from the measurements during the drying period are given Table 1. Drying process was carried out using 6 bricks to minimize the error of measurements, the values given in Table 1 is mean values of these 6 bricks. Drying diagrams of the bricks are plotted by using experimental humidity rates and given in Figure 2 and 3. Variation of the moisture

Table 1.

m_d=4.538 kg, m_0=6.234 kg				
Location of Measurement	***L*** **(m)**	***T*** **(°C)**	***t*** **(h)**	***x*** **(kg/kg)**
Inlet of the kiln	0.0	42.5	0.0	0.374
1. Window	12.5	51.6	2.0	0.182
2. Window	25.0	54.1	3.5	0.144
3. Window	41.0	85.0	6.5	0.136
Exit of the kiln	57.0	154.1	9.0	0.134

Table 2.

ρ_b=1800 kg/m^3, ρ_w=672 kg/m^3				
Location of Measurement	***L*** **(m)**	***T*** **(°C)**	***t*** **(h)**	$D \cdot 10^{-8}$ **(m²/h)**
Inlet of the kiln	0.0	42.5	0.0	3.000
1. Window	12.5	51.6	2.0	3.932
2. Window	25.0	54.1	3.5	4.229
3. Window	41.0	85.0	6.5	9.969
Exit of the kiln	57.0	154.1	9.0	53.307

ratio of the brick with time is given in Figure 2. Figure 3 shows variation of moisture ratio with the distance from the inlet of the kiln. The variation of the drying air which is the most important parameter in the brick drying along with length of the kiln is given in Figure 4. As seen from Figure 2-3, the big amount of the moisture in the brick is removed in the first 20 m of the kiln in first 2 hours. The moisture on the surface of the brick and very near the surface is removed quickly at the beginning of the drying process. Meanwhile, removal of the moisture in the deep part of the brick is mostly related to internal structure of the brick rather than external conditions. Because brick is porous item and movement of the moisture depends on the internal structure. Therefore moisture removal from the brick is very slow after a certain stage even if the temperature of the drying air is very high. The values of diffusion coefficients related to temperature of the measurements points are given in Table 2. As seen from Table 2, diffusion coefficients are dependent on the temperature and the higher the temperature the bigger the value of the diffusion coefficient. The temperature of the drying air is not increased to prevent the crack formation in the brick due to thermal stress. Experimentally obtained results show that the drying performance does not change much when the length of the kiln is kept shorter. The

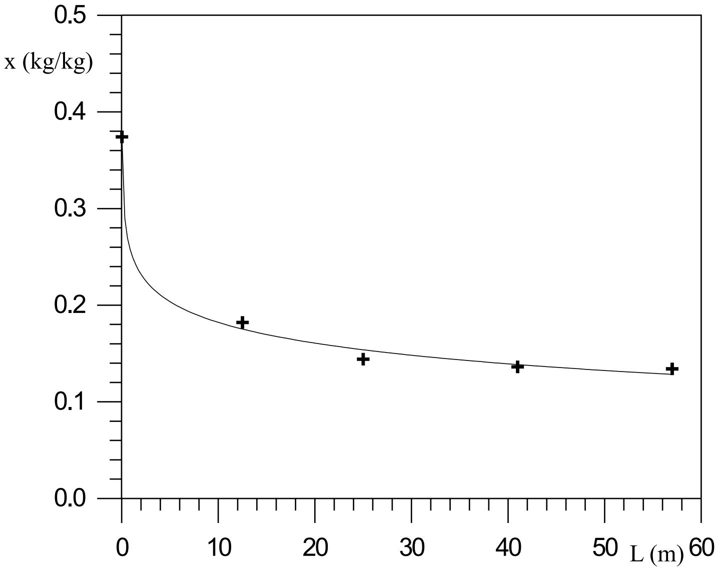

Figure 3. Variation of the moisture ratio of brick along the kiln length.

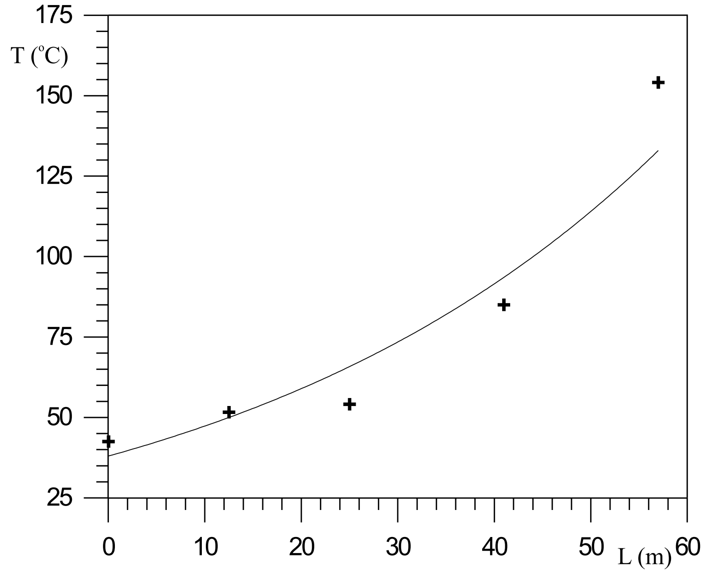

Figure 4. Variation of the air temperature along the kiln length.

big amount of the drying occurs at the first 20 meter distance of the kiln. Drying in the other part of the kiln almost does not affect the moisture ratio of the brick.

As a result, keeping the shorter kiln length or faster band speed for the temperature of the drying air which experiments done does not change the performance of the drying but it provides merit in terms of time and cost.

References

1. *Prasersan, S.,* Energy Saving in Making, 1995, Thailand.

2. *Suresh, H. N., Murugesan, K., Narayana, A. And Seetharamu, K. N.,* Drying of Porous Material Using Finite Element Method, Second International Conference on CFD in the minerals and Process Industries, 1999, CSIRO, Melbourne, Australia.

3. *Palekar, A. And Date, A. W.,* Drying of Brick, Technology Project Report, 1993, Indian Institute of Technology, Bombay, India.

4. *Mujumdar, A. S.,* Handbook of Industrial Drying, 1995, Marcel Dekker Inc.

Получено 30.08.2005 г.