Development of New Sensors for the Temperature Control of a Working Body

Anton Aleksandrovich Sinitsyn, Dmitry Andreevich Belyanskiy, Igor Andreevich Sukhanov

Vologda State Technical University, Razina Street, 25-2, 160029, Vologda, Russian Federation
london_690@mail.ru

Abstract: The article proposes a new proven system for control and monitoring of working process parameters at manufacture of construction of the ceramic bricks for modern enterprises, and analyzes a variety of devices for temperature measurement in raw bricks revealing the disadvantages of the existing devices and measuring complexes. To improve the high production efficiency, the competitiveness of products on the market, reduction of prime costs of the products by automation of time- and energy-consuming production technologies, the authors have proposed a method for organization of the optimal industrial control of the drying process of ceramic bricks using new temperature-sensitive sensors Celsius. A digital temperature sensor was used as a sensitive element that eliminates the calibration of primary measuring transducer. The device can be installed on the testing object by threaded junction, magnetic holder, or used to measure the temperature at the desired depth at the expense of the external primary measuring transducer. It is shown that the device is universal and efficient for the industries to control the thermodynamic parameters, which are the core of the technological process.

[Sinitsyn A.A., Belyanskiy D.A., Sukhanov I.A. **Development of New Sensors for the Temperature Control of a Working Body.** *Life Sci J* 2013;10(4):1057-1061] (ISSN:1097-8135). http://www.lifesciencesite.com. 137

Keywords: analog-digital device, temperature sensor, ceramic products, seasoning kiln.

1. Introduction

Development of the construction industry is directly related with the high demand for construction materials on the market and constantly rising requirements to the quality of products. Therefore, the desire of the heads to improve the existing production processes contributes to the development of growing competition among manufacturers. Improvement of competitiveness of products on the market, first of all, requires automation of routine and energy-consuming technological processes, reducing the primary costs [1].

One of the stages of production process of construction ceramic bricks is technological process of dewatering of a brick, which includes the measurement and adjustment of moisture, temperature, and pressure [2].

In work [3], the drying is the removal of superfluous moisture from any over-moistened substances. In the process, the water transforms from a capillary or the gyroscopic state into vapor. The evaporation occurs when the partial pressure or concentration of water vapor in the environment is less then the pressure of water vapor at the surface of drying body. The greater the deviations in pressure, the intensive drying process.

According to [4, 5], the drying of raw materials and products in the ceramic industry is one of the important technological operations. This is required for formed products for mechanical solidity and reduction of moisture, what allow the stacking of the products in the piles for subsequent firing to avoid the cracking.

Each material and the product is allocated a drying regime: intensity, the maximum temperature of material heating, parameters of the drying agent (temperature, relative moisture and velocity), and their change during drying. These parameters are individual for particular technology either production, or processing of the bricks and silicates, or manufacture of construction ceramics.

Drying of the bricks occurs in the drying chambers. The chamber dryers are loaded with the bricks, and the temperature and moisture gradually change within the whole space of the chamber according to adjusted diagram of drying of the products and production technology of construction ceramics and bricks. Often, the great reduction of the volume of the upper layers occurs during the drying process more often then at internal, that results in cracking of the sample reaching the critical value.

This critical value is the moisture, which corresponds to the minimum limit of plasticity, i.e. this is a point when the clay mass transforms from a supple to solid state during drying. Thus, the main goal of the first step of brick drying (especially at high temperature and air circulation) is to restrain the fast moisture evaporation from the surface.

Generally, the drying process in the production technology of bricks can be divided into three stages:

– shrinkage, which is proportional to the amount of the evaporated water;

- slow shrinkage;
- vapor release.

The intensive drying related with the evaporation of the shrink water is most interesting. Disregard of regimes of drying of the bricks during production can result in warping and cracking of the clay samples. The air temperature and moisture are the key factors influencing the drying of products.

The main task in processing of bricks is a selection of the optimum regime of operation of the seasoning kiln, which combines both the high quality with maximum efficient performance of brick production. Disregard of parameters of a technological regime results in production spoilage. If raw material at the beginning of the drying contains the surplus of water vapor then their pressure, may exceed the strength of raw material and result in cracking. Therefore, the temperature and moisture in the first zone the seasoning kiln must be constructed to avoid the destruction of the raw material by the pressure of the water vapor during manufacture of a ceramic bricks.

The drying cracks have appeared if the relative moisture of the heat-carrier supplied into the chamber is lower 65% during winter at the first stages of drying of raw material. Moreover, the cracks disappear at the 3-4% residual moisture of the raw material after drying. However, the sample cracks again during firing and the production of the finished bricks is lower by 20%.

To avoid the cracking on the raw bricks, the relative moisture of heat-transfer agent supplied into the dryer should be in the range 70-75% during initial stage of drying and its temperature at initial stage of drying should not exceed a temperature of raw brick by 5-7°C.

Modern production of the ceramic bricks is market-oriented characterized by competitiveness. Competitiveness of the products is higher the lower primary costs and higher quality. Optimization of the production process is one of the ways to increase competitiveness of the manufactured products [1].

Technological Process

To reduce the spoilage and minimize costs, it is recommended to establish a system of control and regulation of moisture for both supplied heat-transfer agent and finished products at each stage of drying bricks. The implementation of moisture and temperature sensors can become an effective solution. For example, the moisture and temperature sensors as a means of measurement are used to control the position of the regulation valves by the parameters such as relative moisture, temperature, and moisture content. Further, the measured signal transmits to the control units of ventilation systems (supply and recirculation of the drying agent) or valve control units of regulation and redirection of the drying agent. Thus, the problem of the optimal control of the drying process of ceramic bricks is extremely important. This requires the determination of temperature and moisture changes during entire technological process of drying. However, the space of a seasoning kiln limits any measurements using the sensors directly connected to the computer.

To solve this problem, the employees of the Department "Heat-Gas Supply and Ventilation Systems" at the Vologda State Technical University performed a complex work related to the choice of the scheme of measurements of temperature in some of the local points of raw samples of bricks, the development of temperature measuring system, as well as its implementation at the industrial enterprises.

The market of measuring equipment for temperature monitoring and the patents on the autonomous measuring devices were previously analyzed. Among the companies manufacturing these systems, Rotronic, TermoChron Revisor, and Dallas Semiconductor were selected. However, their measurement systems of thermodynamic parameters of working bodies are expensive for mass production processes and operate within the low range of temperatures.

The simplest device [6] for continuous measurement and registration of temperature of the outer surface of pipes consisting of a base, a case with lid, a cable outlet, and the sensitive element made of the core with wire thermistor has been analyzed among previous versions of equipment for autonomous experimental data collection. Temperature indicators are gradually recorded with regular intervals directly to a computer via a cable outlet, that is hardly feasible due to the high temperatures and the limited space in industrial conditions, and measuring system is unstable and short-lived.

Temperature control unit [7] with sensitive element as the temperature sensor and the sensor of external temperature, which outputs are connected with the input of the analog-digital device (ADD) has been also analyzed. Output of analog-digital converter (ADC) is connected to the input of the reprogramming block, which is an algorithm for recording of temperature data at operation threshold into the computer. However, this device requires the preliminary mathematical calculations after move from one production site to another or replacing the sensitive element, as well as the use of thermoelectric converters requiring mandatory pre-calibration before use in different temperature conditions.

Thus, the development of own system for measurement of temperature of the working body became an objective of our study. The device [8] was developed to expand the variety of technical means in this field and facilitate the implementation of this device by its fixation on the measurement object by the threaded or magnetic connection.

This can be achieved by filling of the body of the device with thermal insulation, which allows the electronic parts of device to endure the high heat loads in the temperature range from - 55 to + 125 °C. All elements of device are protected from mechanical and thermal damage and all components are located inside the case. A digital temperature sensor is used as a sensitive element that eliminates the calibration of primary measuring transducer. Device can be installed on the object of examination by means of threaded connection, magnetic mounting, or used to measure the temperature at the desired depth at the expense of the external primary measuring transducer.

This complex of measures ensures high reliability of the device, extends the area of application, increases the usability and accuracy of measurements of temperature data.

A device for temperature measuring is a self-sufficient system, which measures temperature and records the results into a protected section of internal Flash data memory after selection of microcontroller settings by a user. The recording is carried out with the speed specified by user and programmable timer. The data is stored as a sequence of the results of the temperature measurements in the memory cells of the data buffer. The device allows save the temperature data with the regular interval from 1 to 255 minutes. Device is labeled by a unique laser-made 64-bit identification number of the temperature sensor. Autonomy of the device is ensured by power supply. Gas, liquids, and solid bodies can serve as environment for measurements. The temperature data can be transferred from the Flash memory to PC for further processing [8].

The device can be equipped by threaded or magnetic connection and the temperature sensor can be external that enable the temperature measuring in the depth areas of the surface of the research object.

To measure temperature, the device is fixed by the side with the temperature sensor on the measured surface. Measurement is carried out according to the program of timer with data saving in the buffer of data storage. Upon completion of the measurement, the user removes the device from the tested object followed by data extraction through USB connector.

Results and discussion

In particular case, to organize the optimal control of the drying process of the ceramic bricks, the device (Fig. 1) is embedded into the sample of a brick. The main task of this autonomous system is the recording of temperature function inside of the raw brick during passage of the sample through a tunnel drier (Fig. 3B). According to the studies [9, 10], we have planned the experiment and accomplished the measurement procedure. The results extracted from the Flash memory of the device are processed using the standard Microsoft Office software.

Fig. 1. General view of sensor (left) and type of fixation in a raw brick (right).

Convective drying of raw bricks occurs in the tunnel furnace by the heat of reverse flow of hot air (50-60°C) moving in reverse direction to the trolley. Comparing the experimental data on the change in temperature and moisture parameters of a brick with the technology of moisture removal in the devices described in the studies [9, 10], we can determine the optimal period of drying. According to the Fig. 2, we have made the several conclusions.

The temperature increase on the sensor was registered on the AB interval with the temperature of external medium until temperature of the raw brick; the BCDE interval is the alternation of the temperature after loading of raw bricks into the seasoning kiln; EF is the period of cooling of the bricks until the room temperature. According to the experimental data, the temperature inside the raw brick decreases on the CD interval due to energy exhausting of supplied heat to evaporate the moisture. The temperature increases (on the DE interval) after the brick is completely dried.

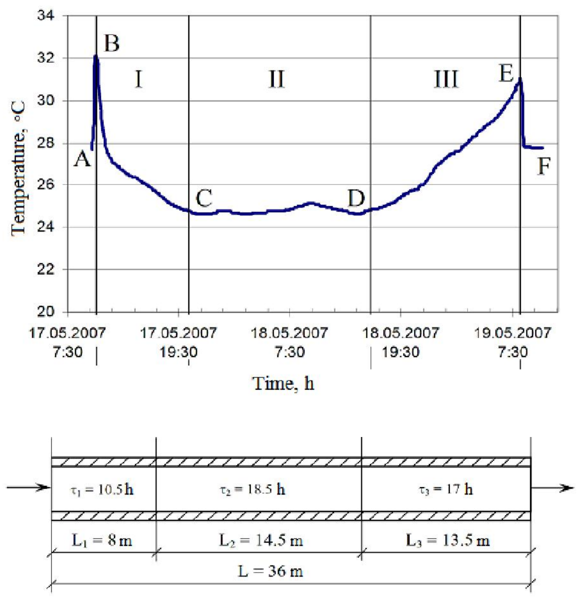

Fig. 2. Temperature changes in the raw bricks

Conclusions

The system of temperature measurement of a working body and the method for determination of the efficiency of the drying based on the temperature and moisture characteristics of raw bricks during entire technological process of Sokolstrom Ltd. (Russia) have been developed.

Thus, the use of the capacities of modern technologies for receiving and transmission of the data reveals the new innovative opportunities to control the production processes of the manufacture of ceramic brick.

The analysis of the existing scientific and technical achievements and assessment of the product competitiveness have revealed the several widely used devices produced by the Swiss company Rotronic and the American company Dallas Semiconductor (table 1).

The analysis of the similar devices has shown the advantages of the measuring complex Celsius comparing with other existing analogues by the maximum number of control points is 32, by temperature and by moisture, simultaneously. In industrial facilities, where the access to the sensor is very limited, there is a possibility of remote data collection using Bluetooth connection and control unit. The case of the device can be made of alloy or stainless steel and able to endure the high loads.

Patented measuring complex Celsius based on developed temperature sensors and automated control system [8] can be applied in various areas of science and industry, where the measurements using the sensors connected directly to the computer and the presence of employees are limited by space and process.

Table 1. The technical characteristics of the developed sensor compared with foreign analogues

Device characteristics	**Device type**		
	Rotronic	**iButton**	**Celsius**
Total dimensions	59 cm^3	1.5 cm^3	20 cm^3
Number of control points	from 1 until 2	1	from 1 until 32
PC connection type	USB interface for configuration and data transfer	Data registration coming from the device using specific device and software	1. USB interface for configuration and data transfer; 2. Bluetooth connection
Measuring interval	-25 until + 80 °C	-55 until +125 °C	-55 until +125 °C
Protection against dust, moisture, and dynamic impacts	Plastic case	Case is resistant to vibrations, hits, and other mechanical impacts	Case is resistant to vibrations, hits, and other mechanical impacts
Price per piece	2500-3000 RUB per sensor	600-750 RUB per sensor, 15000 RUB per specific device for reading information and software	From 5000 RUB (the price can be higher depending on amount of control points and PC connection type)

Corresponding Author:
Dr. Sinitsyn
Vologda State Technical University, Razina Street, 25-2, 160029, Vologda, Russian Federation
london_690@mail.ru

References

1. Jones, J.T., 1995. New brick plant allows for product flexibility. Ceramic Industry, 144 (4): 65-67.
2. Burkinshaw, R.F., 2004. Which instruments should surveyors use to monitor moisture condition? Structural Survey, 22 (1): 7-19.
3. Murugesan, K., K.N. Seetharamu and P.A.A. Narayana, 1996. A one dimensional analysis of convective drying of porous materials. Heat and Mass Transfer, 32(1-2): 81-88.
4. van Zanden, A.J.J. and M.H. de Wit, 2012. A procedure to measure the diffusion coefficient of water in brick as a function of the water concentration. Drying Technology, 30 (5): 526-534.
5. Suresh, H.N., P.A.A. Narayana and K.N. Seetharamu, 2001. Conjugate mixed convection heat and mass transfer in brick drying. Heat and Mass Transfer, 37 (2-3): 205-213.
6. Tsarenko, A.G., N.S. Serov, A.A. Isaev, et al., 2003. Patent RF 2215271: Temperature Sensor.
7. Leonov, S.D., A.A. Maksimchuk and Yu.V. Troitskiy, 2004. Patent RF 2405131: Device of Measurement of Temperature Interval by Thermoresistant Sensors.
8. Belyanskiy, D.A. and A.A. Sinitsyn, 2012. Patent RF 119877: Device for Temperature Control of the Working Body.
9. Murugesan, K., H.N. Suresh, K.N. Seetharamu and P.A.A. Narayana, 2001. A theoretical model of brick drying as a conjugate problem. International Journal of Heat and Mass Transfer, 44 (21): 4075-4086.
10. Lykov, A.V., 1968. A Theory of Drying. Moscow: Energiya, pp: 472.

24/10/2013