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THERMAL PROTECTION INSULATION IN THE LINING OF THE ROTARY KILNS

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Abstract: *The work considers the main part of cement clinker in Ukraine is fired in furnaces, the thermal efficiency of which does not exceed 55-60%, therefore the task of increasing the efficiency of using such units is extremely urgent, since an increase in these indicators even by several percent gives a great economic effect. A fragment of the lining consists of a steel sheet modeling the casing and shaped periclase-chromite refractories with cells filled with mullite-silica wool. The stand is designed to simulate the operating modes of the lining of the rotary kiln body during operation.*

Keywords: *rotary kilns, thermal insulation, lining, building materials, production of cement clinker.*

Introduction

Tubular furnaces are widely used in the oil refining, chemical and gas industries, where the furnace performs the technological functions of a thermal apparatus. However, the most widespread of these units are in the building materials industry, where they are the main thermal plants for the production of cement clinker, expanded clay, lime, perlite and other materials. However, rotary kilns, which are the main consumers of fuel, have a fairly low thermal efficiency. Thus, the main part of cement clinker in Ukraine is fired in furnaces whose thermal efficiency does not exceed 55-60%, so the task of improving the efficiency of such units is extremely important, as increasing these indicators by even a few percent gives a significant economic effect [1, 2].

The purpose of the work. One of the main factors determining the thermal efficiency of the rotary kiln is the value of the thermal resistance of the lining, as in the used rotary kilns heat loss through the body into the environment is very significant and reaches 20-25% of total combustion heat [3]. The lack of durable heat-resistant material with good thermal insulation properties largely determined the direction of work on creating a lining with high thermal resistance by introducing additional fibrous thermal insulation material, which is achieved by changing the shape of the refractory (Fig. 1). For example, such insulation can be mulite silica wool with inorganic additives, which can be used at temperatures up to 1600 ºC. In this case, a cell filled with heat-insulating material is formed between the refractory and the furnace body.

The greatest efficiency in reducing the heat loss of the furnace to the environment and the lining weight is achieved by installing shaped refractories in the high temperature zone of the furnace, which provides greater heat transfer to the material and reducing the mass of the heating apparatus [2, 3].

Figure 1 shows a constructive solution where the refractory brick rests on the body with a leg formed by a cell [4]. At the mechanical and thermal loadings which arise during work, the resulted form gives the chance, it is better to keep mechanical stability of a refractory brick and to provide high thermal efficiency. In this case, a cell having the shape of a triangle is considered.

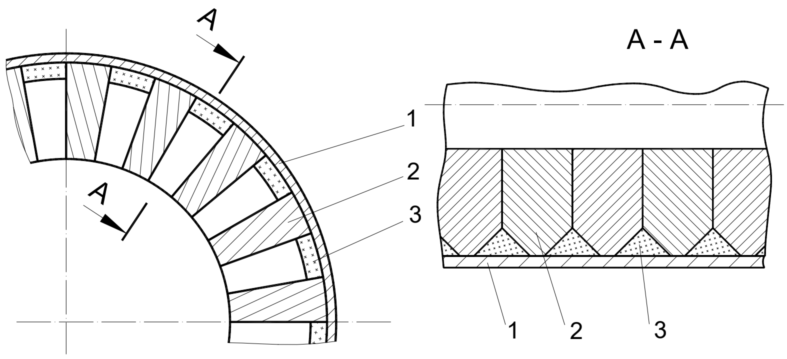


Fig. 1 - Furnace lining with shaped refractories.

1 - furnace body; 2 - refractory;

3 - cell with additional thermal insulation.

This work is devoted to the experimental study of the distribution of temperature fields in the lining fragment in the presence of shaped refractory and thermal insulation material.

The aim of the work is to study the possibilities of installing a lining with a shaped refractory, taking into account the thermal efficiency and structural reliability due to the magnitude of the resulting thermomechanical stresses.

Carrying out of experimental researches is connected with necessity of reception of values of temperatures and the subsequent estimation of correctness of mathematical model and a technique of calculation of temperatures in refractories. The data for determination of temperatures in refractories and thermal insulation by means of the developed experimental installation are specified.

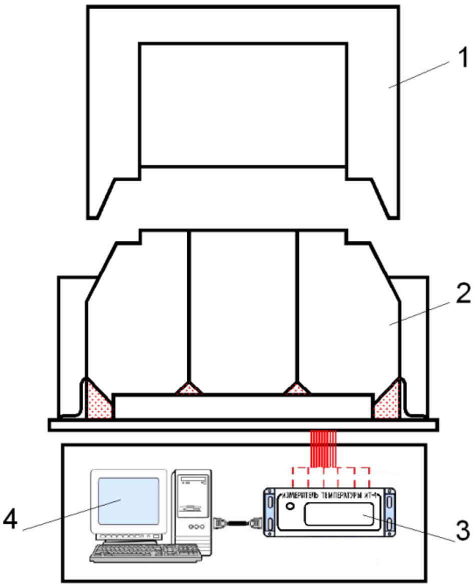
Materials and methods

Installation description

Experimental installation is a fragment of the lining of a rotary kiln with additional insulation and includes (Fig. 2):

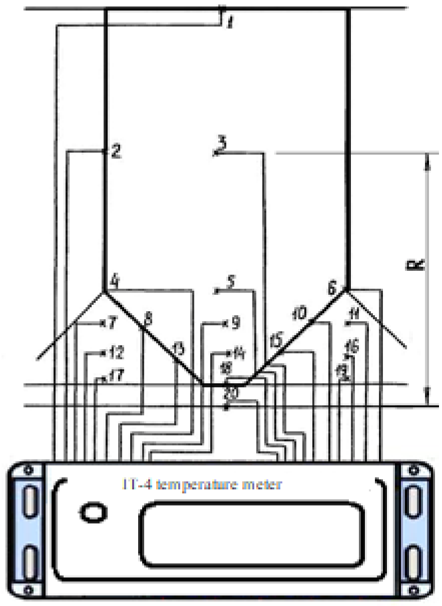
1. Heating furnace,
2. The lining element of the rotary kiln,
3. Temperature meter IT-4.
4. Computer for collecting and processing the received data.

The tests were performed in an electric heating furnace type CHO-34,5-2 / 16. During the tests, the furnace operated autonomously. Temperature control was carried out using a thermocouple installed in the oven. The temperature in the working chamber was kept constant and was 1200 ° C. Stationary heat flow through the refractories was installed 12 hours after turning on the furnace. A fragment of the lining of a rotary kiln was the main part of the experimental setup, which investigated the process of temperature distribution in cells with thermal insulation and directly in refractories. Shaped periclazochromite refractories are standard, PCC-28 brand, used for lining rotary cement kilns. Refractories are fastened together with ties, and with the help of hinged bolts are attached to a steel sheet (material ST.3) with a thickness of 14 mm, simulating the body of the furnace.



1 - furnace; 2 - a fragment of the lining; 3 - temperature meter IT-4; 4 - computer.

Fig. 2. Experimental installation



1-20 places of temperature measurement

Fig. 3. The scheme of placement of thermocouples in the refractory

The cell is enclosed with heat-insulating material - mulito-silica wool (MKRR - 130). Laying density is 300 kg / m3. To reduce the influence of external heat transfer conditions during the experiment, a prototype of refractories was placed in the center of the fragment of the lining. In addition, to exclude heat runoff from the side surfaces of the external refractories, these surfaces were covered with a layer of insulating material.

Results and discussion.

The test method was to measure the temperature in the body of the refractory. Measurements were performed using 20 thermocouples of the chromel-alumel type with a diameter of 0.5 mm made according to GOST 3044-94. Of these, 13 are installed in refractory, 6 - in mulite silica, 1 - in the case (Fig. 3). The thermocouple beads are pressed into the refractory to a depth of 3-6 mm. Thermocouple readings were taken using a connector to which a switch is connected to transmit thermocouple readings to the IT-4 temperature meter. The measurement accuracy of the IT-4 meter is 0.1%, the maximum error of the chromel-alumel thermocouple is 0.75%. From the IT-4 meter data is sent to the computer for recording and processing of the received data. After heating the furnace to 1200 ° C and entering the stationary mode, temperature measurements were carried out in the refractory, thermal insulation and metal plate (table). The interval of measurements was 4 hours.

Analysis of results

After receiving the experimental data were processed according to standard methods [5], which determined:

1. The average value of n measurement $\bar{x} = \sum x_i / n$;
2. Measurement error $\Delta x_i = \bar{x} - x_i$;
3. Squares of measurement error $(\Delta x_1)^2, (\Delta x_2)^2, \ldots, (\Delta x_n)^2$;
4. The root mean square error is the arithmetic mean $S_r = \sqrt{\sum (x_i)^2 / n(n-1)}$;
5. Student's coefficient for a given confidence probability P = 0.95 and six measurements is t = 2,446;
6. Confidence interval (measurement errors) $\Delta x = S_r \cdot t$;
7. The limits of the confidence interval taking into account the random and instrumental error $\Delta x = \sqrt{(S_r \cdot t)^2 + \delta^2}$, where δ - the error of thermocouples and temperature meter IT-4.
8. Relative error of measurement result $\varepsilon = \Delta x / x \cdot 100\%$.

The results of the calculation are summarized in the table.

Table 1

Temperature measurements and error estimates

№	Temperature measurements							Data Processing					
	R	Experiment number (T⁰C)						$\bar{x}$	S_r	$S_r \cdot t$	δ	Δx	ε
		1	2	3	4	5	6						
	мм	T ⁰C	T ⁰C	T ⁰C	T ⁰C	T ⁰C	T ⁰C	T ⁰C	T ⁰C	T ⁰C	T ⁰C	T ⁰C	%
1	241	1193,0	1190,0	1193,0	1193,0	1192,0	1192,0	1192,8	0,703	1,72	8,95	9,11	0,76
2	153	956,0	955,0	957,0	957,0	958,0	957,0	956,3	0,614	1,50	7,17	7,33	0,77
3	157	960,0	965,0	964,0	963,0	962,0	962,0	962,8	0,600	1,47	7,22	7,37	0,77
4	71	769,0	773,0	773,0	773,0	772,0	771,0	771,8	0,654	1,60	5,79	6,01	0,78
5	71	744,0	747,0	746,0	745,0	744,0	746,0	745,3	0,494	1,21	5,59	5,72	0,77
6	68	760,0	764,0	764,0	765,0	763,0	763,0	763,3	0,557	1,36	5,73	5,89	0,77
7	54	721,0	720,0	721,0	721,0	722,0	721,0	721,0	0,258	0,63	5,41	5,44	0,76
8	51	705,0	706,0	707,0	706,0	705,0	706,0	705,8	0,307	0,75	5,29	5,35	0,76
9	51	669,0	671,0	673,0	671,0	670,0	670,0	670,6	0,557	1,36	5,03	5,21	0,78
10	50	699,0	700,0	701,0	701,0	700,0	701,0	700,3	0,333	0,82	5,25	5,32	0,76
11	51	715,0	717,0	718,0	717,0	716,0	717,0	716,6	0,421	1,03	5,38	5,47	0,76
12	32	621,0	624,0	626,0	628,0	626,0	625,0	625,6	0,557	1,36	4,69	4,89	0,78
13	32	559,0	561,0	563,0	563,0	562,0	560,0	561,6	0,494	1,21	4,21	4,38	0,78
14	32	556,0	556,0	558,0	557,0	557,0	554,0	556,3	0,557	1,36	4,17	4,39	0,79
15	30	575,0	572,0	577,0	575,0	574,0	573,0	573,8	0,477	1,17	4,30	4,46	0,78
16	30	616,0	617,0	619,0	619,0	618,0	619,0	618,0	0,516	1,26	4,64	4,80	0,78
17	16	410,0	414,0	413,0	413,0	412,0	412,0	412,5	0,428	1,05	3,09	3,27	0,79
18	13	332,0	334,0	335,0	335,0	333,0	334,0	333,8	0,477	1,17	2,50	2,76	0,83
19	17	420,0	421,0	422,0	422,0	421,0	422,0	421,3	0,333	0,82	3,16	3,26	0,77
20	2	305,0	307,0	308,0	308,0	306,0	307,0	307,0	0,365	0,89	2,30	2,47	0,80

Temperature measurements were extrapolated linearly between the values obtained at the installation points of thermocouples. The temperature distribution in the shaped refractories and cells with thermal insulation are shown in Fig.4.

The temperature distribution in the center of the refractory in Fig.5.

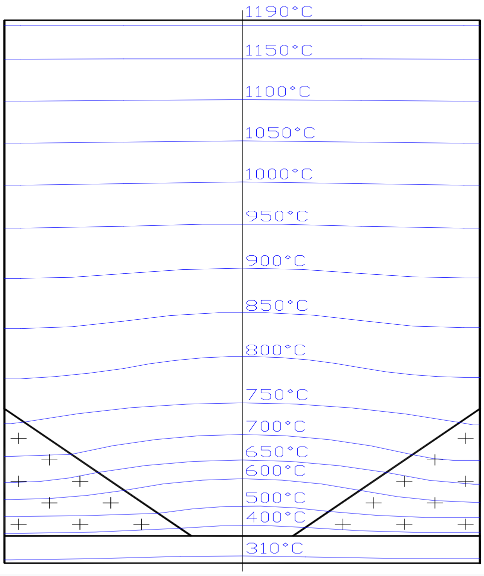


Fig. 4. Temperature distribution in prepackaged refractories and measures with thermal insulation (experimental data)

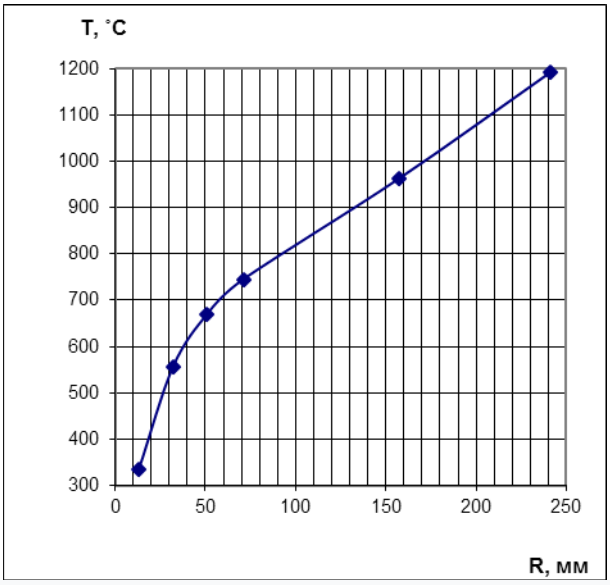


Fig. 5. Temperature distribution in the center of the refractory

Fig. 5. Temperature distribution Given the differences obtained by comparing the data, the proposed method of experimental research can be considered acceptable, and the results can be used as initial for the development of methods for calculating temperature fields in refractory refractory and thermal insulation.

Conclusions.

An experimental stand designed and manufactured for experimental studies of the heat exchange process in the fragment of the lining of a rotary kiln with additional thermal insulation has been developed and manufactured. The lining fragment consists of a steel sheet modeling the body of the drug, and shaped periclazochromite refractories with cells filled with mullitokremnezemisty cotton wool. The stand is intended for modeling of operating modes of lining of the case of the rotary furnace in the course of operation.

Experimental studies have been carried out in which the processes of heat exchange in the furnace lining are physically modeled. The experimental setup allows in the process of research to determine the degree of influence of various regime and design factors on the heat transfer process.

Experimental studies of the heat transfer process, and the creation on their basis of the calculation technique, will allow to implement in the practice of development of rotating thermal devices lining with high thermal resistance. The efficiency of such lining is higher in comparison with the existing ones, which opens wide prospects for its introduction into the production process, as it has significantly better thermal and acceptable cost indicators.

In further research it is planned to develop a mathematical model for modeling the process of heat transfer and comparing the data of numerical and field experiments.

Literature

1. Islamov M.Sh. Design and operation of industrial furnaces. - L.: Chemistry, 1986. - 280 p.

2. Shcherbina V.Yu., Shvachko DG "Improving the energy efficiency of rotating heat units." SCIENTISTS NOTES OF THE TAVRIA NATIONAL UNIVERSITY NAMED AFTER VI VERNADSKY Series: Technical Sciences 2018. Volume 29 (68). Part 2. № 4, art. 68-72. URL: http://tech.vernadskyjournals.in.ua/journals/2018/4_2018/part_2/15.pdf

3. Shcherbina V., Shvachko D., Borshchik S. Heat exchange simulation in energy zones of a rotarykiln with change of heat resistance of the body. «Technology audit and production reserves» 2019. №6 / 1 (50). pp. 36-41. DOI: https://doi.org/10.15587/2312-8372.2019.189169

4. Pat. u 64150 Ukraine, IPC7 (2006.01) F27B 7/00. Rotary furnace / Shcherbina V.Yu., Shishkovsky OV, Samilenko Yu.M., Kryvko Yu.V .; applicant and owner Shcherbina V.Yu. - № u201010558; declared 31.08.2010; publ. 10.03.2011, Bull. № 5/2011.

5. Kunkin SN, Vostrov VN, Kuznetsov PA, Ryabinin AG Mathematical methods of experimental data processing. Textbook.– St. Petersburg: St. Petersburg State Technical University Publishing House, –2002. - 68 p

Анотація: *У роботі розглядається основна частина цементного клінкеру в Україні, що випалюється в печах, теплова ефективність яких не перевищує 55-60%, тому завдання підвищення ефективності використання таких агрегатів є надзвичайно актуальним, оскільки збільшення ці показники навіть на кілька відсотків дають великий економічний ефект. Фрагмент футеровки складається із сталевого листа, що моделює кожух, і фасонних периклазохромітових вогнетривів з осередками, заповненими мулітно-силікатною ватою. Стійка призначена для імітації режимів роботи футеровки корпусу обертової печі під час роботи.*

Ключові слова: *обертові печі, теплоізоляція, футеровка, будівельні матеріали, виробництво цементного клінкеру.*

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