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Energy savings through the use of refractory masonry with a lower thermal conductivity

Abstract

Main problem: recently, much attention has been paid to energy saving in production, especially when it comes to industrial units that burn fuel. There are several ways to maximize the use of the heat released during the combustion process, for example, to reduce the temperature of the flue gases at the outlet of the unit, by maximizing its use, both in the technological process itself and by installing additional heat-receiving units, for example, air heaters or other heaters. Another way to save money is to reduce heat losses through the lining of these high-temperature units. Metallurgical units that consume a large amount of energy and fuel require an analysis of their consumption, and ways to save their consumption based on the results of the analysis.

Purpose: this article considers the possibility of replacing the existing inner insulation layer of the second and third sections of a high-temperature unit - a metallurgical furnace, with a new one with better technical and economic indicators.

Methods: the possibility of replacing the existing inner insulation layer of the second and third sections of the high-temperature unit with a new one, with the best technical and economic indicators, was considered. The calculation of heat losses by thermal conductivity through the side surfaces and the roof with new insulation was performed, and the economic efficiency of the proposed solution was proved.

Results and their significance: replacing the existing inner layer of insulation - refractory concrete PHLOCAST M30 (thermal conductivity coefficient from 1,4 to 1,45) with the proposed CERALIT GUN HK 70070 (thermal conductivity coefficient from 1,03 to 1,12) will reduce heat loss to the environment, and thus to reduce fuel consumption for the furnace.

Key words: methodical furnace, heat, heat loss, energy saving, flue gases, thermal conductivity coefficient, inner insulation layer, heat transfer coefficient, lining thickness.

Introduction

In heating furnaces, open heating of metal is carried out by high-temperature products of combustion of gaseous or liquid fuels. These furnaces are characterized mainly by the countercurrent movement of the heated metal and combustion products, as well as the presence at the beginning of the furnace (from the side of the metal loading) of a developed unheated methodical zone, as a result of which they are often called methodical furnaces. Calculated furnace - countercurrent type with one row of incoming workpieces. The workpieces introduced by the pusher, going in a countercurrent flow with combustion products, first enter the recuperative zone, where the top layer of scale is removed by the exhaust gas. After that, the blanks pass to the proper preheating and subsequently to the heating zone, where they are brought to the final required temperature, then to the holding zone, where the heat is dissipated to the entire amount of the product [1].

Materials and methods

As a result of the inspection of the inner surface of the lining of a high-temperature unit - a batch furnace, significant cracks were found in the side walls of the second and third sections, which indicates the destruction of its integrity and increasing heat losses to the environment, and as a result, an increase in fuel consumption and economic costs.

The considered heating furnace consists of:

– a working space containing a vault, side walls and a hearth;

– a pusher designed to push the workpieces through the furnace;

– a recuperator for heating the blast air going for gas combustion in the furnace (air heating is carried out by utilizing the heat of the flue gases from the furnace);

– combustion devices for burning fuel.

Results

Thus, the data obtained in the calculation of one of the zones of the furnace indicate that when replacing refractories with new ones with a lower thermal conductivity, they show a decrease in heat loss from 3.2 to 3.08 %, thus using this refractory in the third section, you can also get a reduction heat loss, and as a result – fuel economy.

Discussion

The calculated furnace is countercurrent type with one row of incoming billets (the dimensions of which are: thickness 0,125 m, width 0,125 m and length 11 m). This furnace is characterized by the presence at the beginning of the furnace (on the metal loading side) of a developed unheated methodical zone, as a result of which they are often called methodical furnaces. Here there is a change in the temperature of the combustion products from 970 to 1090 ^{0}C; the second section is the first welding zone with an increase in the temperature of the combustion products from 1090 to 1250 ^{0}C; the third section is the second welding zone with a temperature of combustion products of 1250 ^{0}C. The scheme of the furnace is shown in Figure 1. The heating furnace works as follows: billets are stacked in rows and pushed by a pusher into the butt on the refractory lining of the hearth of the furnace, while the billets pass through the above indicated zones.

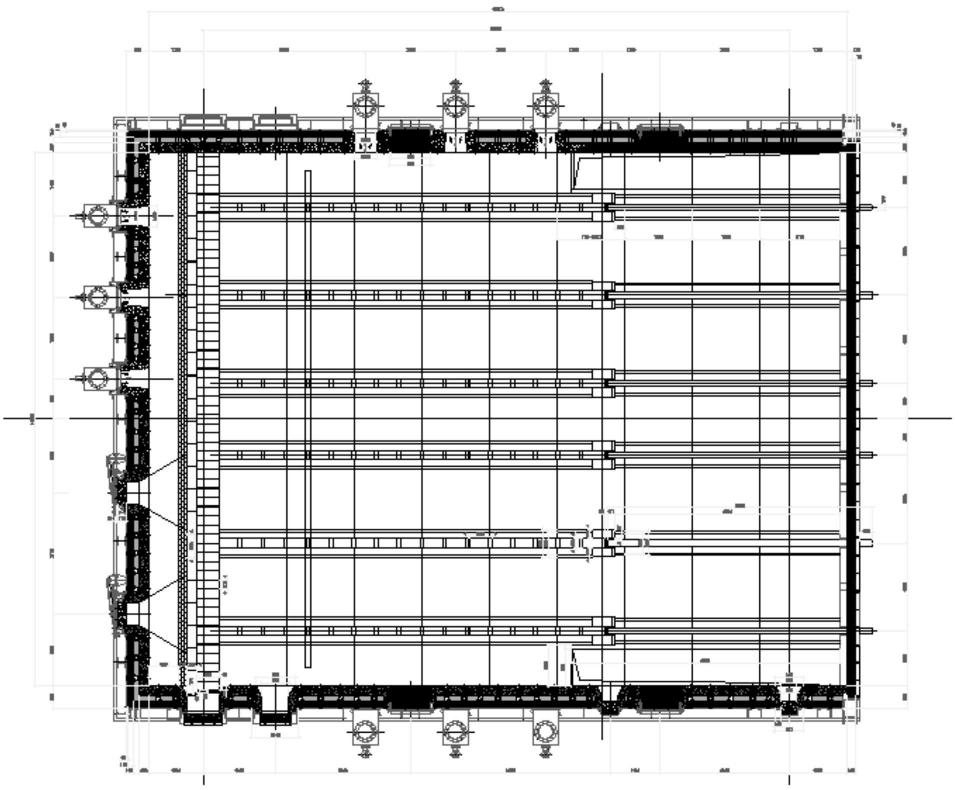

Figure 1 – Methodical oven

As a result of the inspection of the inner surface of the furnace lining, significant cracks were found in the side walls of the second and third sections, which indicates the destruction of its integrity and increasing losses to the environment (Figure 2).

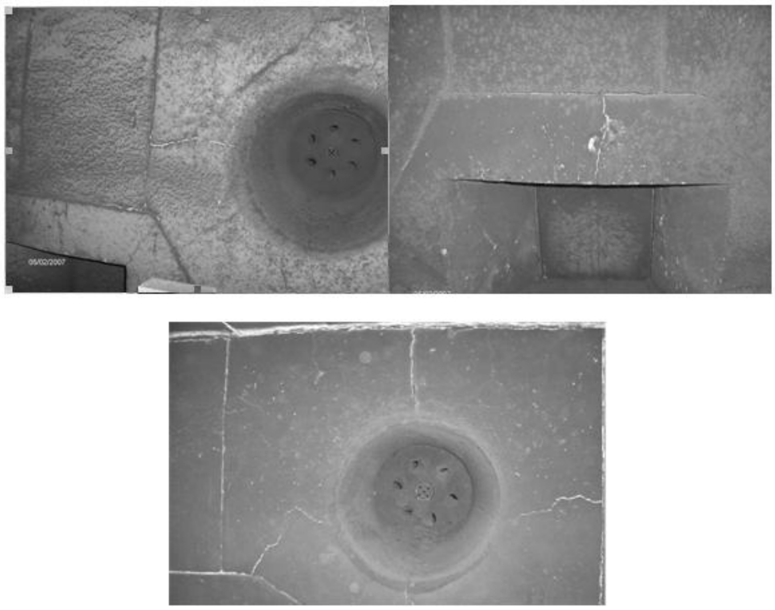

Figure 2 – Photographic data of the inspection of the inner surface of the lining of the heating furnace

After analyzing various insulating materials, it was decided to use the Ceralit insulating material, which is used for the working layer of the lining of the side walls and the roof in the heating zone, the end wall from the unloading side of the furnace. It has a lower thermal conductivity and cost compared to the existing one; we leave the layer thickness the same: the side walls of the second section and the side surfaces, and the facade in front of the burners of the third section -230 mm; arch of the second and third sections -200 mm. The main indicators of Ceralit are shown in Table 1.

Table 1 – Main Features of CERALIT GUN HK 70070

Maximum operating temperature, °C	1650
Material consumption, t/m^3	2,40
Maximum grain size, mm	7,0
Apparent density after firing at 1000 °C, g/cm^3	2,20
Open porosity after firing at 1000 °C, %	29
Reversible thermal expansion at 1000 °C, %	0,70

Saving energy resources by improving the thermal insulation properties of building envelopes is an important issue that should take into account a number of technical and economic aspects. In the general case, the optimal lining is the one in which the sum of the costs of its creation (materials, installation, etc.) and the cost of heat losses over the period of its service is minimal. It is clear that with identical resistance, the reduction of such characteristics of the materials used as cost, density, thermal conductivity is economically beneficial and helps to reduce the consumption of refractories and fuel (Table 2).

Table 2 – Refractory characteristics of the side walls of the second section

Thickness	Characteristic	Brand name	Coefficient of thermal conductivity, $W/_{m*K}$		Operating temperature, ^{0}C
			Temperature, ^{0}C	Value	
230 mm	Refractory concrete	CERALIT GUN HK 70070	at t=500	1,03	1650
			at t=800	1,04	
			at t=1200	1,12	
115 mm	Insulating bricks	BNZ 23	at t=200	0,17	1260
			at t=400	0,19	
			at t=600	0,22	
			at t=800	0,26	
			at t=1000	0,3	
115 mm	Insulating bricks	ISO 450	at t=200	0,097	900
			at t=400	0,123	
			at t=600	0,144	
40 mm	Calcium silicate boards	INISIL 1000	at t=200	0,103	1000
			at t=400	0,117	

The coefficient of heat transfer by radiation and convection from the outer surface of the masonry to the environment is calculated by the expression:

$$\alpha_{nar} = 2{,}56(t_{nar} - t_{okr})^{0,25} + \frac{4{,}65}{t_{nar} - t_{okr}}\left[\left(\frac{t_{nar}+273}{100}\right)^4 - \left(\frac{t_{okr}+273}{100}\right)^4\right] =$$

$$= 2{,}56(67-20)^{0,25} + \frac{4{,}65}{67-20}\left[\left(\frac{67+273}{100}\right)^4 - \left(\frac{20+273}{100}\right)^4\right] = 12{,}63\, W/(m^2 \cdot K).$$

The characteristic of the insulation of the arch of the second section is given in Table 3.

Table 3 – Refractory characteristic of the arch of the second section

Thickness	Characteristic	Brand name	Coefficient of thermal conductivity, $W/m*K$		Operating temperature,^{0}C
			Temperature, ^{0}C	Value	
200 mm	Poured concrete	CERALIT GUN HK 70070	at t=500	1,03	1650
			at t=800	1,04	
			at t=1200	1,12	
30 mm	Heat insulating concrete	KERLITE 130 AT	at t=500	0,49	1300
			at t=800	0,53	
70 mm	Super insulating concrete	KERLITE F 60 AT	at t=500	0,18	1050
			at t=1000	0,2	

Coefficient of heat transfer by radiation and convection from the outer surface of the masonry to the environment

$$\alpha_{nar} = 2{,}56 \cdot (t_{nar} - t_{okr})^{0,25} + \frac{4{,}65}{t_{nar} - t_{okr}} \left[\left(\frac{t_{nar} + 273}{100} \right)^4 - \left(\frac{t_{okr} + 273}{100} \right)^4 \right] =$$

$$= 2{,}56 \cdot (120 - 20)^{0,25} + \frac{4{,}65}{120 - 20} \left[\left(\frac{120 + 273}{100} \right)^4 - \left(\frac{20 + 273}{100} \right)^4 \right] = 15{,}76 \, W/(m^2 \cdot K).$$

Heat loss through the side surfaces and the facade in front of the burners is determined according to the characteristics given in Table 4.

Table 4 – Refractory characteristic side surfaces and facade in front of the burners of the third section

Thickness	Characteristic	Brand name	Coefficient of thermal conductivity, $W/m*K$		Operating temperature,^{0}C
			Temperature, ^{0}C	Value	
230 mm	Refractory concrete	CERALIT GUN HK 70070	at t=500	1,03	1650
			at t=800	1,04	
			at t=1200	1,12	
115 mm	Insulating bricks	BNZ 23	at t=200	0,17	1260
			at t=400	0,19	
			at t=600	0,22	
			at t=800	0,26	
			at t=1000	0,3	
115 mm	Insulating bricks	ISO 450	at t=200	0,097	900
			at t=400	0,123	
			at t=600	0,144	
40 mm	Calcium silicate boards	INISIL 1000	at t=200	0,103	1000
			at t=400	0,117	

Coefficient of heat transfer by radiation and convection from the outer surface of the masonry to the environment

$$\alpha_{nar} = 2{,}56 \cdot (t_{nar} - t_{okr})^{0,25} + \frac{4{,}65}{t_{nar} - t_{okr}} \left[\left(\frac{t_{nar} + 273}{100} \right)^4 - \left(\frac{t_{okr} + 273}{100} \right)^4 \right] =$$

$$= 2{,}56 \cdot (71 - 20)^{0,25} + \frac{4{,}65}{71 - 20} \left[\left(\frac{71 + 273}{100} \right)^4 - \left(\frac{20 + 273}{100} \right)^4 \right] = 12{,}89 \, W/(m^2 \cdot K).$$

Specific heat flux through the laying of the side walls

$$q_{kl}^{bok3} = \frac{t_{vn} - t_{okr}}{\sum_i \left(\frac{\delta_i}{\lambda_i}\right) + \frac{1}{\alpha_{nar}}} = \frac{1250 - 20}{\frac{0,23}{1,116} + \frac{0,115}{0,2968} + \frac{0,115}{0,1438} + \frac{0,04}{0,103235} + \frac{1}{12,89}} = 661,9 \, W/m^2,$$

where δ_i - is the thickness of the i-th layer of masonry, m;

λ_i - coefficient of thermal conductivity of the i-th layer of masonry, $W/(m \cdot K)$, is determined depending on the material and the average temperature of the layer;

α_{nar} - the total coefficient of heat transfer by radiation and convection from the outer surface of the masonry to the environment, $W/(m^2 \cdot K)$.

Table 5 – Fireproof characteristic of the roof of the third section

Thickness	Characteristic	Brand name	Coefficient of thermal conductivity, $W/m*K$		Operating temperature, ^{0}C
			Temperature, ^{0}C	Value	
200 mm	Poured refractory	CERALIT GUN HK 70070	at t=500	1,03	1650
			at t=800	1,04	
			at t=1200	1,12	
30 mm	Heat insulating concrete	KERLITE 130 AT	at t=500	0,49	1300
			at t=800	0,53	
70 mm	Super insulating concrete	KERLITE F 60 AT	at t=500	0,18	1050
			at t=1000	0,2	

Coefficient of heat transfer by radiation and convection from the outer surface of the masonry to the environment

$$\alpha_{nar} = 2,56(t_{nar} - t_{okr})^{0,25} + \frac{4,65}{t_{nar} - t_{okr}}\left[\left(\frac{t_{nar} + 273}{100}\right)^4 - \left(\frac{t_{okr} + 273}{100}\right)^4\right] =$$

$$= 2,56(129 - 20)^{0,25} + \frac{4,65}{129 - 20}\left[\left(\frac{129 + 273}{100}\right)^4 - \left(\frac{20 + 273}{100}\right)^4\right] = 16,33 \, W/(m^2 \cdot K).$$

The heat loss through the furnace masonry in the existing version is found as:

$$Q_{kl}^{\%} = \frac{\sum Q_{kl} * 100}{M_{obs1}},$$

where $\sum Q_{kl}$ - total heat loss through the furnace masonry, $\sum Q_{kl}$=1653,685 W;

$$Q_{kl}^{\%} = \frac{1653,685 * 100}{51722,344} = 3,2\%.$$

Heat loss through the furnace masonry after replacement:

$$Q_{kl}^{\%} = \frac{\sum Q_{kl} * 100}{M_{obs1}},$$

where ∑Qkl - total heat loss through the furnace masonry, $\sum Q_{kl}$=1588,233;

$$Q_{kl}^{\%} = \frac{1588{,}233*100}{51629{,}386} = 3{,}08\%.$$

Conclusion

Since the proposed refractory concrete has a lower coefficient of thermal conductivity, the loss of thermal conductivity decreases from 3,2 % to 3,08 %, which leads to a decrease in fuel consumption burned in the furnace.

THE LIST OF SOURCES

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Жылу өткізгіштігі төмен отқа төзімді тасты қолдану арқылы энергияны үнемдеу

Соңғы уақытта өндірісте, әсіресе отын жағатын өндірістік қондырғыларға қатысты энергияны үнемдеуге, көп көңіл бөлінуде. Жану үрдісі кезінде бөлінетін жылуды максималды пайдаланудың бірнеше жолы бар, мысалы, технологиялық үрдістің өзінде де, қосымша қондырғыларды орнату арқылы оны максималды пайдалану арқылы қондырғының шығысындағы түтін газдарының температурасын төмендету, жылу қабылдау қондырғылары, мысалы, ауа жылытқыштары немесе басқа жылытқыштар. Ақшаны үнемдеудің тағы бір жолы – бұл жоғары температуралы қондырғыларды қаптау арқылы жылу шығынын азайту. Энергия мен отынның көп мөлшерін тұтынатын металлургиялық қондырғылар олардың жұмсалуын талдауды, талдау нәтижелері бойынша тұтынуды үнемдеу жолдарын талап етеді.

Бұл мақалада жоғары температуралы қондырғы – металлургиялық пештің екінші және үшінші секцияларының қолданыстағы ішкі оқшаулау қабатын техникалық-экономикалық көрсеткіштері жақсырақ жаңасына ауыстыру мүмкіндігі қарастырылады.

Жоғары температуралы қондырғының екінші және үшінші үлескілерінің қолданыстағы ішкі оқшаулау қабатын техникалық-экономикалық көрсеткіштері ең жақсы жаңасына ауыстыру мүмкіндігі қарастырылды. Бүйірлік беттер мен жаңа оқшаулаумен шатыр арқылы жылу өткізгіштік бойынша жылу шығындарын есептеу жүргізілді және ұсынылған шешімнің экономикалық тиімділігі дәлелденді.

Қолданыстағы оқшаулаудың ішкі қабатын - отқа төзімді бетонды PHLOCAST M30 (жылу өткізгіштік коэффициенті 1,4-тен 1,45-ке дейін) ұсынылған CERALIT GUN HK 70070 (жылу өткізгіштік коэффициенті 1,03-тен 1,12-ге дейін) ауыстыру қоршаған ортаға жылу шығынын азайтады, осылайша отынның шығыны мен пешке арналған тұтынуды азайтылады.

Түйінді сөздер: әдістемелік пеш, жылу, жылу жоғалту, энергияны үнемдеу, түтін газдары, жылу өткізгіштік коэффициенті, ішкі оқшаулау қабаты, жылу беру коэффициенті, төсем қалыңдығы.

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Энергосбережение за счет использования огнеупорной кладки с меньшим коэффициентом теплопроводности

В последнее время вопросам энергосбережения на производстве уделяется большое внимание, особенно, когда речь идет о промышленных агрегатах, на которых сжигается топливо. Существует несколько путей максимального использования тепла, выделенного в процессе горения, например, уменьшение температуры дымовых газов на выходе из агрегата путем максимального её использования, как в самом технологическом процессе, так и установкой дополнительных тепловоспринимающих агрегатов – воздухоподогревателей или иных подогревателей. Еще один путь экономии – это снижение потерь теплоты через обмуровку этих высокотемпературных агрегатов. Металлургические агрегаты, потребляющие большое количество энергии и топлива, требуют анализа их потребления, путей экономии их потребления по результатам анализа.

В этой статье рассмотрена возможность замены существующего внутреннего слоя изоляции второго и третьего участка высокотемпературного агрегата – металлургической печи – на новый, с лучшими технико-экономическими показателями. Выполнен расчет потерь тепла теплопроводностью через боковые поверхности и свод при новой изоляции, доказана экономическая эффективность предлагаемого решения.

Замена существующего внутреннего слоя изоляции – огнеупорного бетона PHLOCAST M30 с коэффициентом теплопроводности от 1,4 до 1,45 на предлагаемый CERALIT GUN HK 70070 с коэффициентом теплопроводности от 1,03 до 1,12 позволит снизить потери тепла в окружающую среду и расход топлива на печь.

Ключевые слова: методическая печь, теплота, потери теплоты, энергосбережение, дымовые газы, коэффициент теплопроводности, внутренний слой изоляции, коэффициент теплоотдачи, толщина футеровки.

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