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Technical Upgrading and Thermal Performance of Heating Furnace of the Pipe Rolling Workshop

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Abstract

The report is focused on the design and thermal performance of the continuous furnace for heating of pipe billets before piercing operating at 'ChPRP' PJSC. The problems arising during operation of the thermal generating unit have been analyzed. To evaluate the efficiency of existing heating system, the heat balance of the continuous furnace has been drawn up. During analysis of the results of calculated studies, disadvantages of existing furnace systems and assemblies have been revealed. In order to improve the quality of metal heating, it is proposed to install the through-type furnace heated by means of regenerative burners, as well as provided with the metal transportation system, ensuring more uniform heating, both along the length and thickness of billets, in place of the existing furnace. When implementing the proposed activities, a significant economic benefit is expected, which is confirmed by the heat balance of the through-type furnace given in the article. Besides, to visualize the distribution of temperature and gas-dynamic flows within the operating space of the proposed through-type furnace, the computer simulation for evaluation of the uniformity of metal heating has been performed.

Keywords: continuous furnace, regenerative burner, energy saving, through-type furnace, heat balance

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1. Introduction

High capacity of rolling and pipe rolling mills as well as good quality of finished products are possible only where there are powerful heating furnaces that properly heat metal with minimal oxidation and decarburization. These are met when using annular furnaces that consist of the rotating hearth and the stationary part, which is the annular channel covered by the crown. Generally, the annular furnaces are used for heating of billets when rolling of pipes, wheels and tires of railway rolling stock. The purpose of heating is to obtain a structure that provides specified physical and operating

properties, or to impart plasticity to these materials that is necessary for subsequent machining [1–13].

Currently, the continuous furnace for heating of pipe billets for piercing is in operation in the pipe rolling workshop No. 1 of 'ChPRP' PJSC. The continuous furnace has a structure of the monolithic inclined hearth and ingots arranged in two rows. The continuous furnace with countercurrent moving of heated billets and combustion products in the operating space has three heated areas.

During the operation of this furnace, the following problems have been revealed: high specific fuel consumption, high temperatures of exterior surfaces of the crown and walls, low heating rate of the billet, large volume of air ingress in the furnace operating space. Moreover, the design of gas burners does not provide for the possibility to regulate gas supply in a wide range of loads, and the heat energy of waste gases is hardly used.

The heat losses tests on the continuous furnace, carried out in order to determinate the dynamics of heating of billets of 'Uralenergochermet' JSC, have revealed that the furnace operates with a low efficiency due to failures in operation of the mill and the state of the furnace lining [14]. The heat balance of the existing furnace design, calculated on the basis of the thermal characteristics of its operation during heating of the reference billet, is given in Table 1.

Based on the items of the heat balance, presented in Table 1, it is expedient to draw the following conclusions:

Table 1: Heat balance of the existing continuous furnace.

No.	Heat input	kW	%	No.	Heat consumption	kW	%
1	Chemical heat of fuel	17 513	95.58	1	Heat for metal heating	4 679	25.54
2	Physical heat of air	287	1.56	2	Heat of outgoing combustion products	9 218	50.31
3	Heat of metal oxidation	523	2.86	3	Heat losses due to radiation through open windows	1 028	5.60
	Total of input	18 324	100	4	Heat losses due to lining	2 867	15.65
				5	Heat losses with scale	163	0.89
				6	Undeterminable losses	386	2.01
					Total of consumption	18 324	100

1. The furnace heating system in the existing state could not operate effectively; therefore its updating is required.
2. The dampers existing on the furnace (at loading, unloading) do not provide the required tightness of the operating space, which leads to increased air ingress into the operating space, and, as a result, to increase of metal loss. Besides, ingress of ambient air requires maintaining unreasonably high temperatures in the operating space that also increases metal loss.
3. The studies of metal heating, performed by the employees of 'Uralenergochermet' JSC, have shown that metal at the end of the welding zone is already ready for drawing that means that in the soaking zone it practically receives no heat, but only is additionally oxidized.
4. The external surfaces of the furnace walls have very high temperatures reaching up to 600°C (data provided by 'Uralenergochermet' JSC).
5. The billets are nonuniformly heated along the furnace width.
6. During forced outages, it is not possible to reduce scale formation by changing the temperature conditions.

When developing the design of a new through-type furnace, it was necessary to develop solutions that would allow to:

1. reduce the specific fuel consumption;
2. improve the quality of heating of the billet, ensure the uniformity of its heating along the cross section;
3. reduce losses due to scale formation;
4. automate the heating control system;
5. modernize the system of metal transportation into the furnace;
6. reduce temperature of the external surfaces of the crown, walls, etc.

In order to achieve aforementioned objectives, it has been proposed to install a through-type pusher furnace with metal transportation on movable carriages in place of the existing continuous furnace (Figure 1).

The design of the new furnace provides for the use of panels, lined with fibrous refractories with operating temperature of 1425°C, as well as the metal transportation

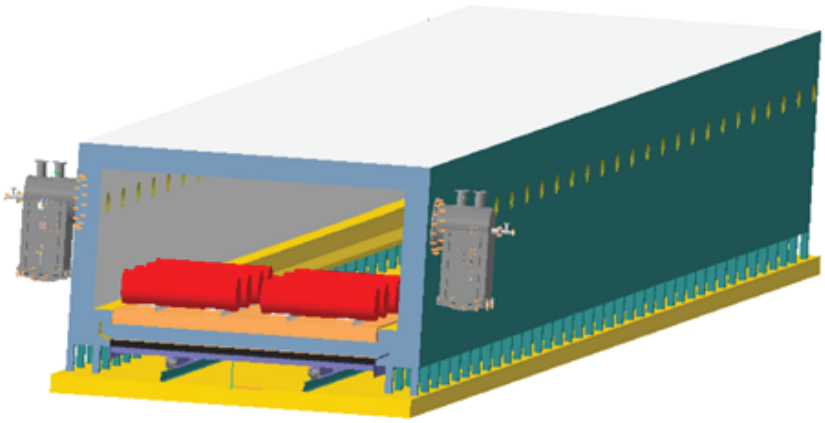

Figure 1: 3D model of heating furnace.

system consisting in moving of the billets along railways on the special carriages, on the crown and side walls of the furnace.

When operating the furnace, the main and most important problem is the loss of heat energy. Therefore, the energy saving potential in this case could be very high, and the use of this potential will reduce the costs of the enterprise. To increase the heat characteristics of the furnace operation, it has been decided to use regenerative burners.

To evaluate the energy efficiency of the proposed activities, the heat balance of the furnace after updating, given in Table 2, has been drawn up [15–20].

Table 2: Heat balance after updating of the furnace of PRW-2 of 'ChPRP' JSC.

No.	Heat input	kW	%	No.	Heat consumption	kW	%
1	Chemical heat of fuel	7558	75.4	1	Heat for metal heating	4373.2	43.6
2	Physical heat of heated air	2469.1	24.6	2	Heat of outgoing combustion products	4586	45.7
	Total of input	10027.1	100	3	Heat losses due to radiation through open windows	420.2	4.2
				4	Heat losses due to lining	647.8	6.5
					Total of consumption	10027.1	100

When implementing activities for technical upgrading, the following positive results could be obtained:

1. When the temperature of air heating increases due to the use of regenerative burners, the second item of the heat balance increases – the physical heat of heated air, which has effected on the reduction of fuel consumption.

2. When use of fibrous lining, the losses of heat conduction through the hearth, the crown and walls are significantly reduced.

3. When using non-water cooled partitions, there will be no losses with cooling water, which gives a positive effect in the thermal performance.

4. After updating of the furnace, the overall (by 18.1%) and thermal (by 31%) efficiency of the furnace are increased, as well as the specific fuel consumption (by 62.3 kg r.f./t) is reduced.

In addition, the engineering analysis (CAE, Computer Aided Engineering) of the thermal and gas-dynamic conditions inside the operating space of the renewed design of the heating furnace has been performed. In particular, the temperature fields of gaseous combustion products in the volume of the operating space and inside the billets, as well as distribution of velocities of gaseous flows in the operating space have been calculated in the ANSYS Fluent package by the computer simulation. The fragments of the results are shown in Figures 2 and 3.

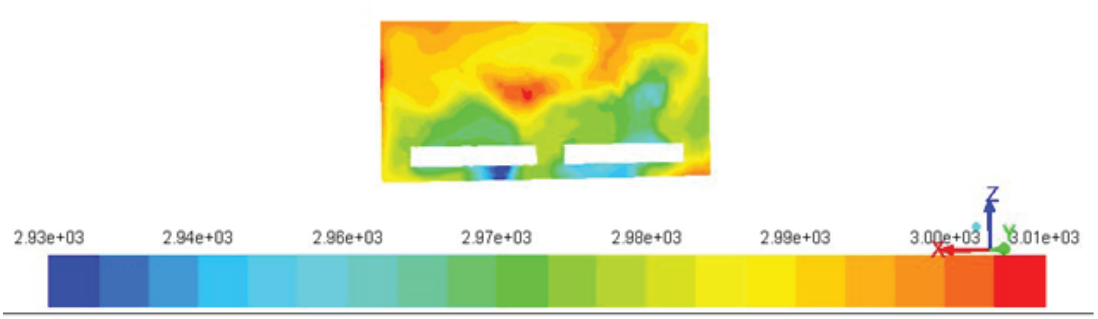

Figure 2: Distribution of temperature fields inside the operating space of through-type furnace (cross-section of the furnace operating space).

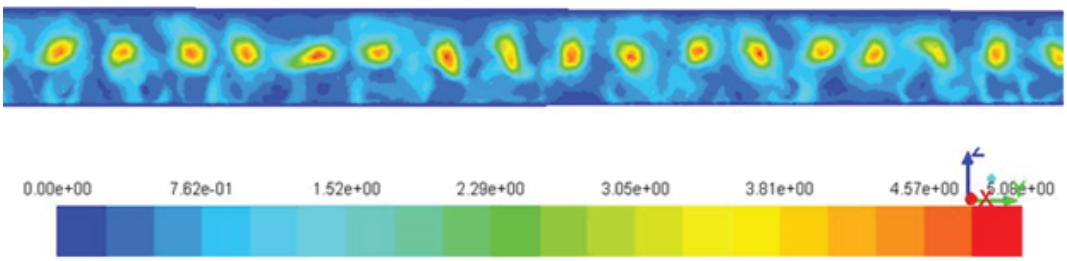

Figure 3: Distribution of velocity flows (longitudinal section of the furnace operating space).

Based on the results of the computer simulation, it could be concluded that the distribution of temperature and velocity fields within the furnace operating space is

uniform and provides the specified thermal and gas-dynamic conditions for the furnace operation.

Thus, the proposed activities as for updating of the furnace of PRW-2 of JSC 'ChPRP' will improve the technical and economic performance of its operation, in particular, reduce fuel consumption and increase the thermal efficiency.

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