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Experience of Using Volumetric-Regenerative Method of Fuel Combustion in Soaking-Pit Furnaces

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An example of implementation of volumetric-regenerative method of fuel combustion in a soaking-pit furnace is presented. The principles of overhaul and creation of new fuel combustion method are considered. Results of five-year-operation of overhauled soaking-pit furnace are shown.

Keywords: VOLUMETRIC-REGENERATIVE METHOD OF FUEL COMBUSTION, SOAKING-PIT FURNACE, FUEL ECONOMY, BURNING LOSS, AIR HEATING, OPERATION

Introduction

At present, cost of power resources is continuously rising in Ukraine as well as all over the world. In some cases, a share of fuel cost in the finished product cost price reaches 50 % in metallurgy as one of the main energy resource consumer of the country.

At the same time, entrance of metallurgy products to the world markets becomes more difficult due to sharply improved competition and severe requirements to quality and price of rolled metal. Therefore, enhancement of fuel and other resources efficiency parameters in heating devices under condition of high quality of final product is an urgent problem [1].

Heating furnaces in rolling use gas fuel. Even when the plant utilizes its own resources in these furnaces (regenerative producer gas, coke or blast furnace gases), gas cost is re-counted in relation to energy value, and its price depends on the natural gas price.

Application of current volumetric-regenerative method of fuel combustion in heating furnaces provides fuel economy by means of deep waste-heat recovery, high quality of metal heating and low level of harmful atmospheric emissions (first of all, nitrogen oxides). The principle of this fuel combustion method is based on the regulated mixing of fuel and air in a furnace body. Uniformly distributed fuel combustion, the absence of large high-temperature combustion sources, reverse motion of furnace gases create conditions for uniform heating of the load [2-3].

Results and Discussion

Statement of the problem related to soaking-pit furnace reconstruction. At present, one of the most widespread heaters in rolling are recuperative soaking-pit furnaces with heating from the centre of furnace hearth created by "Stalproekt". These furnaces provide stable high-duty operation of rolling mills, are simple and flexible in running, have a high capacity for metal and are heated by low-calorie fuel [4]. But these recuperative soaking-pit furnaces have also a number of essential drawbacks as following: low-temperature air heating, non-uniform heating of ingots from the top to bottom and as a result fuel penalty for metal heating. These disadvantages have a set of objective reasons.

Waste-heat of regenerative soaking-pit furnaces with heating from the centre of furnace hearth is recovered in tile recuperators for air heating and in metallic recuperators for gas fuel heating. Now, recuperators for gas heating are disassembled almost in all recuperative soaking-pit furnaces of this kind. It is because of hazard of their burnout, explosion of fuel-air mix and low overall performance of these heat regenerators.

Ceramic tubular recuperators applied for air heating are non-hermetic. While in service, leakage of recuperators grows and air leak is 50% and more in the second half of furnace campaign. As a result, heat power of soaking-pit furnaces decreases in two and more times during operating period between overhauls, air heating decreases to 450-500 °C as compared to designed value of this parameter 850 °C during period between overhauls, ratio fuel-air is difficult to control. Amount of air boosted by fan exceeds stoichiometric value in 2.0-2.5 times, which also leads to excess energy consumption. In the overhaul of recuperative soaking-pit furnaces (one time in 2-2.5 years), expensive recuperators need to be replaced.

Modeling and analysis of current recuperative soaking-pit furnace operation shows that burner and motion pattern of furnace gases in the current pits do not provide uniform heating of ingots. There are stagnation zones in the pit, temperature in the bottom working space is 40-50 °C lower than in the top.

Non-uniform temperature distribution from top to bottom of working space and ingots should be eliminated by extending metal soaking in the furnace at high temperatures. It leads to excess fuel energy consumption and increases waste of metal. Stratification of temperature throughout the height of furnace chamber forces to raise temperature to 1360-1390 °C under the pit cover for liquid slag running off , which has a negative effect on durability of refractory walls and cover of recuperative soaking-pit furnaces.

The majority of recuperative pits operate more than 50 years and their construction has almost not changed during the operating period at iron & steel works of CIS countries. So, construction of recuperative soaking-pit furnaces by "Stalproekt" with heating from the centre of furnace hearth is obsolete, tile recuperators do not meet the current requirements and should be substituted with more effective regenerative heat exchangers.

Regenerative heating systems also applied in soaking-pit furnaces have no specified above drawbacks. Large sizes of masonry regenerators and complicated system of gas flow motion are considered to cause their inconvenient operation. Traditional masonry regenerators and recuperators fail while in service, their permeability essentially decreases, which leads to overhaul or complete substitution of these heat recovery devices. Regenerative heating system with high-alumina (corundum) regenerators has no such disadvantages [5].

Volumetric-regenerative method of fuel combustion in a soaking-pit furnace. Heating system of soaking-pit furnace 11-1 was reconstructed with the purpose to implement volumetric-regenerative method of fuel combustion for elimination of current drawbacks of recuperative soaking-pit furnaces of blooming department No. 1 at the integrated works "Krivorizhstal".

In 2001-2002, researchers from Department of Heat Engineering & Ecology of Metallurgical Furnaces of National Metallurgical Academy of Ukraine worked out a project of soaking-pit furnace reconstruction. Design principles ensuring volumetric-regenerative method of fuel combustion were implemented in the project [4].

In 2003-2004, heating system for the standard recuperative soaking-pit furnace with central burner was reconstructed at the integrated works "Krivorizhstal" by means of tubular tile recuperators substitution with small-size regenerators with checkerworks consisting of corrundum pellets. This reconstructed soaking-pit furnace was put into operation in June 2004. As before, the pit is heated by coke-blast furnace gas with combustion heat 1950-2000 kcal/m^3. The maximum fuel rate before reconstruction was 2100-2200 m^3/h. It was possible to use 70 % of smoke gases for air heating in regenerators at such combustion heat. The other 30 % of furnace gases was enough for fuel heating in metallic recuperators, which is an additional fuel economy. The temperature of air heating in regenerators according to test data was 950-1000 °C. The maximum fuel rate in the reconstructed pit does not exceed 1500 m^3/h. Smoke temperature behind regenerators was lower 200 °C.

The feature of regenerative soaking-pit furnace heating system consists in the original idea defended by patents of Ukraine No. 42445A and 61495A [6, 7]. One burner is used in the centre of hearth bottom instead of two. This makes it possible to desist from gas reversing valves and pilot burners. There are two channels separated by a leak-free wall. Each channel is connected to a separate regenerator and serves for air supply in the burner or for smoke removal. Suggested solution has advantages featured for regenerative burners and allows deep waste-heat recovery.

The construction of gas burner nozzle and regenerative pit neck ensures more uniform heating of ingots [2]. Some technical-and-economic indexes of soaking-pit furnace 11-1 operation at JSC "ArselorMittal Kryvyy Rih" before and after reconstruction are presented in **Table 1**.

Table 1. Technical-and-economic indexes of soaking-pit furnace operation before and after reconstruction

Index	Unit	Pit type	
		recuperative	regenerative
Fuel type	-	Coke and blast-furnace mixture	
Combustion heat	MJ/m^3	8200	
Maximum consumption:	m^3/h		
- fuel		2150	1500
- air		10000	5000
Maximum heat power	MW	4.87	3.48
Mass of furnace load	t	120	
Mesh capacity in ingots	pcs	14	
Volume of heat exchanger checker	m^3	31.75	0.75
Metal heating temperature	°C	1320 (max)	
Air heating temperature	°C	to 600	to 1100
Fuel heat utilization factor	%	50	75
Waste of metal under heating	kg of scale/t	11.2	10.8
Specific fuel rate on furnace load heating:	kg equivalent		
- without considering wasted motion of furnace	fuel/t	18	12
- considering wasted motion of furnace		28.8	23.5
Turnover (average amount of charging per day)	-	3.25	3.38

Flue gas purification from dust and slag is provided in the offered heating system according to patent [7]. One reversing smoke-air valve equipped with a special device for self-cleaning of its working surfaces from dust serves to switch regenerators from smoke on air and and vice versa. Application of this valve allowed refusing a great number of reversing devices available in classical heating system.

Uniform temperature pattern in soaking-pit furnace 11-1 is confirmed experimentally by means of unit temperature measurement at various levels from top to bottom, temperature measurement of top and bottom of heated billets using mathematical and physical simulation. The results of hydrodynamic processes mathematical simulation in the reconstructed soaking-pit furnace and results of experiments on a physical model are presented in [8]. Adequacy of numerical model is checked by physical simulation on a pit model in scale 1:15 and by results of investigation of full scale object operation. Simulation showed that there was no dead-air space in the reconstructed soaking-pit furnace under volumetric-regenerative combustion of fuel. Movement pattern ensures volume combustion in the pit. Position and sizes of circulating zones of kiln gases are defined by using simulation.

<u>Results of new technique implementation</u>

The following conclusions can be drawn from results of five-year-fault-free-operation of soaking-pit furnace with ball regenerators.

1. There is no temperature drop from top to bottom of pit which is a feature of recuperative pits with heating from the centre of furnace hearth due to volumetric combustion of fuel, reverse and recirculation of gases.
2. In conjunction with temperature equalization throughout the height of chamber, slagging practice takes place during soaking of ingots at lower temperatures in the unit (1340-1350 °C) as compared to recuperative soaking-pit furnaces. Temperature equalization throughout the height of pit led also to reduced duration of ingot soaking and total heating time.
3. Duration of high-temperature period and waste of metal decreased. Reduction of oxide scale amount by 0.4 kg /t is confirmed by investigations of heat engineering laboratory of integrated works.
4. Aerodynamic drag of checker, air and exhaust ducts almost does not change while in

service.

5. Air heating temperature in ball regenerators of soaking-pit furnace exceeds 1000 °C, as a result fuel heat utilization factor increases from 0.5 to 0.75.

6. Maximum fuel rate under heating decreased from 2100 to 1500 m^3/h. Fuel economy in the reconstructed soaking-pit furnace on the average was 30 %.

Positive experience of soaking-pit furnace operation in department Blooming-1 at JSC "ArselorMittal Kryvyi Rih" (the former Integrated Works "Krivorizhstal") guided reconstruction of one more soaking-pit furnace which was accomplished by efforts of integrated works. The second regenerative soaking-pit furnace was put into operation in 2007. One more group of recuperative soaking-pit furnaces is being prepared for reconstruction. All solutions related to implementation of volumetric-regenerative method of fuel combustion were obtained at the Department of Heat Engineering & Ecology of Metallurgical Furnaces by means of mathematical and physical simulation.

Conclusions

Large-capacity chamber furnace for ingot heating with application of volumetric-regenerative method of fuel combustion ensuring high uniformity of metal heating, decrease of harmful air pollutant emissions and essential fuel economy was implemented and adopted.

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Опыт использования объёмно-регенеративного способа сжигания топлива в нагревательных колодцах прокатного производства

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Приведен пример реализации объёмно-регенеративного способа сжигания топлива в нагревательном колодце. Рассмотрены принципы реконструкции и организации нового способа сжигания топлива. Подведены результаты пятилетней эксплуатации реконструированного нагревательного колодца.