ANALYSIS OF HEAT TRANSFER IN THE FURNACE OF THE P-67 BOILER P-67 FURNACE AND IMPROVEMENT OF ITS DESIGN

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The results of experimental study of heat transfer in the furnace of the P-67 boiler (under the Russian trademark) burning Kansk-Achinsk coal are presented. Means of improving the design of the furnace device are proposed.

The industrial experiment on burning of Kansk-Achinsk coals in the furnace chamber of the P-67 boiler of the Berezovsk Hydroelectric Power Plant-1 has shown that there are difficulties associated with providing its reliable operation because of the slagging of deflecting walls and steam superheater [1]. Developing designs aimed at providing no-slag operating conditions of heating surfaces requires heat transfer in the furnace of this boiler unit to be analyzed in detail.

The present article deals with the experimental results on radiation heat transfer indices in the furnace of the P-67 boiler, which together with the gas flow and fuel combustion data obtained by the present authors and other researchers [2, 3], as well as with regard to the operational experience of furnace devices of identical designs, have enabled us to propose measures on how to improve the furnace design in order to enhance heat transfer, push up the flow stability, decrease nitrogen oxide generation, etc.

In experiments, hand in hand with the indications of standard facilities the fields of temperatures, incident radiation flux density, and other characteristics of furnace processes were measured. The complete absorption radiometer RAPP-3 (under the Russian trademark) designed at the Institute of Thermophysics of the Ukrainian Academy of Science [4] was used to measure the incident radiation flux density on the trays of deflecting wall surfaces.

During experiment, the boiler operation was characterized by instability of a number of parameters. Thus, to the end of October 23, 1989 at boiler load $N = 600$ MW the air excess coefficient α''_{fur} in the furnace increased from 1.23 to 1.56 and the recirculating gas fraction r, from 0.15 to 0.18. The boiler load was $N = 656$ MW at $\alpha''_{\text{fur}} = 1.02$ and $r = 0.13$ on October 24, 1989. Two recirculation gas smoke exhausters and seven mills (the fifth mill was disconnected) worked during measurement days.

Figure 1, displaying the incident radiation flux density around the periphery of the furnace chamber shows that there is a great difference in the values of q_{in} recorded in the central and angular hatches, 140-180 kW/m^2; this difference is kept along the furnace height. For the mentioned performance parameters the rear deflecting wall is less loaded, while the right side one is more loaded where the maximum values of the quantity q_{in} are fixed: 293 kW/m^2 (October 23, 1989) and 314 kW/m^2 (October 24, 1989). Apparently, this takes place because of the accepted operation circuit of mills.

As would be expected, the maximum incident radiation flux density distribution over the furnace chamber height is near the upper boundary of the active combustion zone. It should be noted that during the first day of experiments the deflecting wall surfaces of heating were pure under operating conditions, then during the second day the slag-ash deposits grew intensively, and the incident radiation flux density on the same trays increased by 30-40 kW/m^2 under the identical performance parameters.

Analysis of the obtained results points to a high-temperature gas concentration at the furnace chamber center around the sufficiently "cold" periphery. This considerably reduces the heat transfer intensity ($\psi = 0.27$-0.3) and is the cause of the slagging centers to appear. Studies of aerodynamic flows [5] revealed that this occurred due to the unstable aerodynamics of a flame, in particular, due to the insufficient vortex tangential motion of gases. The latter was attributed

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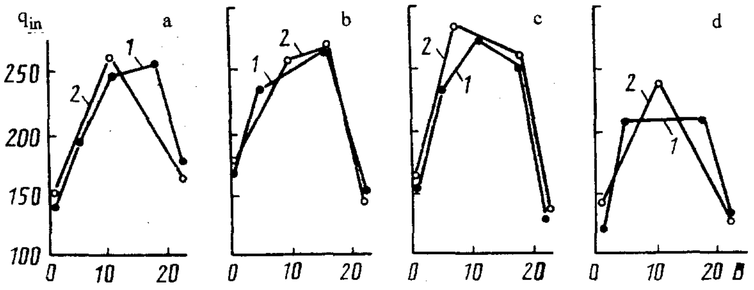

Fig. 1. Distribution of the incident radiation flux density q_{in}, kW/m^2, over the deflecting wall width B, m (a) left side; b) frontal; c) right side; d) rear) at the levels of 45.05 m (1) and 33.8 m (2).

to the fact that for large combustion chamber sizes (23.2 × 23.2 m) the fuel-air jets slightly interacted with one another and deviated from the assigned trajectories, moving into the rarefied region between the burner rows.

Use of furnace (Fig. 2) incorporating a square combustion chamber with straight-flow burners mounted on each wall in two vertical rows symmetrically relative to the combustion chamber axes and tangential to the conventional circumference is one of the ways of eliminating the revealed drawbacks of the furnace design of the P-67 boiler. In the proposed device, improving the fuel combustion reliability and decreasing the nitrogen oxide generation is provided by the fact that the vertical row burners on all the combustion chamber walls are shifted upwards relative to the burners of the previous vertical row by 0.7-3.2 of the burner height, and the air nozzles inclined to the side of their own burners and tangential to the conventional circumferences, with diameters d'_n and d''_n, are mounted in front of each burner at the angles and along the axes of the combustion chamber:

$$d'_n = 1.414 a_{\text{fur}} \sin\left[45 - \operatorname{arctg} \frac{b_{\text{b}}\ (9-n)\sin\alpha'}{0{,}25a_{\text{fur}} + b_{\text{b}}\ (9-n)\cos\alpha'}\right]; \tag{1}$$

$$d''_n = a_{\text{fur}} \sin\left[90 - \operatorname{arctg} \frac{b_{\text{b}}(9-n)\sin\alpha''}{0.25a_{\text{fur}} - b_{\text{b}}(9-n)\cos\alpha''}\right]. \tag{2}$$

The proposed step-tangential arrangement of the burners [5, 6] allows one to detect of aeromixture jets within each row in two horizontal planes. This allows eight fuel supplies over the furnace height. In this case, the jets formed by the burners of the vertical row are arranged in the upper plane. As this takes place, the lower jet expanding (expansion angle of 14-16°) and moving in the assigned direction will interact with the neighboring jet located above having the same expansion angle due to the ejection ability. The marked interaction augments not only the tangential vortex motion of furnace gases within the row but also the translational spiral motion upwards.

The twist stability of high-temperature combustion products is enhanced due to the fact that only four burner jets tangential to the conventional circumference are arranged in the horizontal planes of each row. This number is above all optimal from the viewpoint of creating stable aerodynamics, which is supported by studies made on isothermal models and in acting furnaces. It is important that as the furnace gases penetrate into the zone which the aeromixture enters, conditions are created for it to ignite intensively.

A $0.76\text{-}3.2b_{\text{burner}}$ shift over the height between the vertical neighboring burner rows is necessary to reduce the active combustion zone heat stress up to the safe one according to the slagging conditions from 0.82 to 0.55-0.64 MW/m^2, keeping the previous interrow spacing in order not to deteriorate fuel ignition and combustion processes. A wide range of limit relations is attributed not only to the entire spectrum of designs of boiler units but also to the choice of the quantity $q_{\text{r.h.}}$ when the lower limit is taken at burning of a weak-slagging fuel and the upper one at burning of a strong slaggish fuel.

The air jets formed by mounting additional nozzles on the horizontal burner axes in the middle of the furnace walls and at its angles in the burner direction tangential to the conventional circumference make an extra pulse to the vortex twist of the furnace gases. Moreover, the scheme of the air nozzles in Fig. 2 prevents slagging, since their arrangement in the middle of the walls due to the cold air supply allows the incident radiation flux density values to be decreased. Their

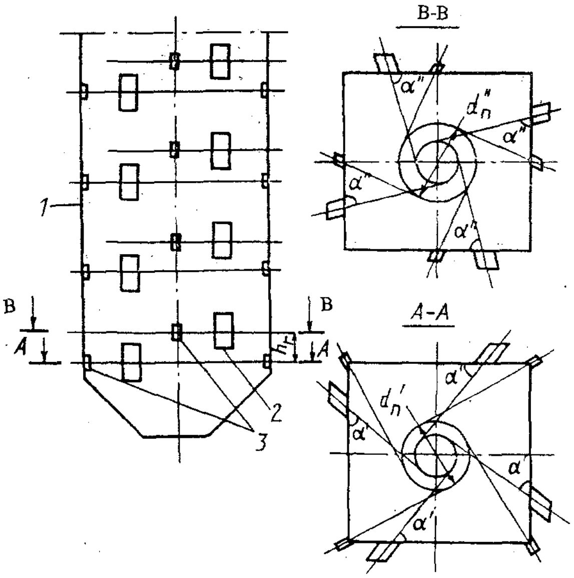

Fig. 2. Furnace design: 1) combustion chamber; 2) burners; 3) air nozzles.

maximum is observed in the central hatches of the furnace at all height levels (see Fig. 1). The annular arrangement of the nozzles will allow the stagnated flow zones to be avoided there and heat transfer to be enhanced, since this improves the medium circulation due to the furnace gas ejection to the air jet mouth.

In addition to the necessity of making the flame aerodynamics more stable and preventing slagging, the arrangement of the additional air nozzles is meant for performing step fuel burning. Formulas (1) and (2) for air nozzle orientation are obtained, starting from the geometrical features of the furnace design and relying on the processing of the data on the nitrogen oxide concentration maximum position over the entrance rectilinear burner jet section when the burner arrangement is multirow [7]. This allows the nitrogen oxide generation to be reduced, not worsening the coal ignition conditions.

Separate units of the proposed furnace, in particular, the additional air nozzles, are planned to be used in the P-67 type boilers of the Berezovsk Hydroelectric Power Plant-1.

NOTATION

N, energy unit power, MW; α''_{fur}, furnace air excess coefficient; r, gas recirculation degree; q_{in}, incident radiation flux density, kW/m^2; a, spacing between the combustion chamber walls, m; b_b, burner width, m; n, number of the burner row, starting from below; α' and α'', inclination angles of the burners located in front of and behind the combustion chamber axis; d, diameter of the conventional circumference, tangential to which the burners are directed, m; $q_{\text{r.h.}}$, heat stress of the radiant heat absorbing surface of the active combustion zone, MW/m^2; ψ, furnace-mean thermal efficiency of deflecting walls.

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