Analysis of thermodynamic efficiency of the fuel preparation systems with an intermediate hopper at thermal power plants

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Annotation. The thermal and thermodynamic calculation of closed and open loop individual systems of coal preparation at TPP with different types of mills reveals the possibilities of increasing the efficiency of the technological scheme by utilizing the heat removed from the system and thus increasing the thermodynamic efficiency.

Coal as a fuel and its processing at thermal power plants

The main advantages of using solid fuel as one of the main energy carriers are its wide distribution, convenience and simplicity of storage, and low cost. The availability of coal reserves in the world are enough to last at average 230 years, in Russia - more than 500 years [1].

However, solid fuels require complex and expensive preparation for combustion. Despite a large number of scientific developments aimed at increasing the efficiency of particular elements of fuel preparing systems, the evaluation of their performance is mainly carried out experimentally or as a result of industrial tests [2].

Types of coal preparation systems

The systems of fuel (coal) dust preparation are divided into two types: central and individual [3].

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Central systems of dust preparation are intended for preparing and supplying fuel for several boilers of the power plant. The central system of dust preparation can operate independently.

Individual systems of dust preparation are designed for preparation and supply of dust for one boiler. At power plants in Russia individual systems with an intermediate dust hopper prevail. Such systems are equipped with ball mills or hammer mills, which is explained by the peculiarity of the coals burned in Russia (high content of ash and moisture). In these systems, the presence of the hopper contributes to a more stable operation of the boiler irrespective of the dust preparation system, since dust is supplied from the intermediate hopper.

In other countries roller mills have been widely used [4].

Individual coal preparation system

The individual coal preparation system at TPP consists of several main stages (the scheme is shown in Fig. 1) [5].
Coal enters the territory of the power plant usually in railway cars, after unloading of which with the help of car dumpers, it can be supplied either directly to the fuel supply line or conveyed to the warehouse. In winter pre-heating of the fuel in the defrosting construction (overall housing) is provided. The grinding of fuel to the size of pieces of about 25 mm each is carried out in crushers of coarse or fine crushing.

Prepared this way, coal enters the pulverizing system of the boiler room, which is a drying and grinding unit consisting of a mill, separator, cyclone and mill fan. Hot air, flue gases or a mixture of both may be used as a drying agent. Dust preparation systems may have closed loop or open loop modification, i.e. the spent drying agent can be fed into the furnace of the boiler or, after cleaning, discharged into the atmosphere. Coal dust from the intermediate hopper is transported by means of the feeder into the mixer, where hot air blows through the hot blast fan. The mixture of hot air and coal dust then is supplied to the furnace of the boiler. The hot air from the hot blast fan is the primary air necessary for burning of the fuel.

**Analysis of fuel preparation systems efficiency**

In conveyed research individual dust preparation systems with an intermediate dust hopper equipped with ball mill, roller mill and hammer mill with drying of fuel by air and combustion products were considered.

Calculations were carried out to identify the possibility of improving the presented technological scheme in order to minimize energy costs for the process of solid fuel preparation for combustion. Such approach to the evaluation of system efficiency makes it possible to compare different types of systems [6].

**Approach to system efficiency analysis**

The analysis of the operation of the solid fuel preparation system was carried out with determination of thermodynamic parameters of the system; in particular the exergy of the flows supplied to the system and taken from it was evaluated. The evaluation of the thermodynamic efficiency of the system was carried out in several stages.
1) On the basis of the heat balance of the fuel preparation system, the thermal characteristics of the incoming and outgoing flows of the installation were determined.

2) The aerodynamic calculation of the dust preparation system was carried out, as a result of which the resistances of each of the elements of the system and of the whole system were determined.

3) The thermodynamic characteristics of the incoming and outgoing flows of the dust preparation system were determined.

4) The values of internal losses of exergy in the elements of systems were determined.

5) The total exergic efficiency of the fuel supply system and dust preparation system were determined.

Exergic efficiency of the system was defined as the ratio of the useful technical effect of the system to the spent. In this case, only the production of coal dust of the required humidity and temperature may be considered the useful technical effect. The formula below represents the calculation of the exergic efficiency of the fuel preparation system,

$$
\eta_e = \frac{E''_{me}}{E'_{n} + E'_a + L'_1 + E'_{x,n} + \Sigma L'r_{ml} + E'_{ca} + L'_2 + E'_{r,a} + L'_3},
$$

$E'_{n}$ – exergy of the steam supplied to the air preheater; $E'_a$ – exergy of the air; $L'_1$ – power of fans of the defrosting device; $E'_{ca}$ – exergy of drying agent; $\Sigma L'r_{ml}$ – power of fuel supply mechanisms; $L'_2$ – power of the mill and mill fan; $E'_{x,n}$ – exergy of coal dust at the outlet of the drying and grinding plant; $E_{rt}$ – exergy of the heat flow spent on fuel heating and evaporation of moisture; $E'_{r,a}$ – exergy of hot air supplied to the mixer; $E'_{mix}$ – exergy of the dust-air mixture at the outlet of the mixer; $L'_3$ – power of the hot blast fan.

**Exergic efficiency calculation results**

The results of calculations of exergic efficiency calculations for fuel preparation system equipped with ball mill, roller mill and hammer mill with drying of fuel by air and combustion products are presented in Table 1.

| Table 1. The results of exergic efficiency calculations for different types of fuel preparation system |
|-------------------------------------------------------------------------------------------------------------|
| Type of dust preparation system | Exergic efficiency of the system, % |
|---------------------------------------------------------------|---------------------------------|
| Individual system of dust preparation, equipped with ball mill: | under depletion | 19,9 |
| - open loop modification with drying by air: | under pressure | 19,5 |
| - open loop modification with drying by combustion products: | under pressure | 11,6 |
| - closed loop modification with drying by air: | under pressure | 31,4 |
| closed loop modification with drying by combustion products: | under pressure | 42,2 |
| Individual system of dust preparation, equipped with roller mill: | under depletion | 18,3 |
| - open loop modification with drying by air: | under pressure | 16,7 |
| Individual system of dust preparation, equipped with hammer mill: | under pressure | 22 |
| - open loop modification with drying by air: | under pressure | 22 |
Conclusion
The results of calculations show that the system for preparation of fuel for combustion is imperfect. It can be seen that systems operating under depletion have an exergy efficiency higher than systems operating under pressure. Fuel preparation systems equipped with hammer mill have the highest efficiency, which is explained by the small consumption of the drying agent and the small specific grinding capacity of the mills.

One of the ways to increase the efficiency of the system is the utilization of the heat of the flows outgoing from the system. A significant amount of heat is lost with the condensate and heated air drained from the defrosting device, with a drying agent spent in the dust preparation system, which could be used to preheat the fuel.

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