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„STUDY OF THERMAL-FLOW PROCESSES IN A SCREW ASH COOLER COOPERATING WITH CFB BOILER"

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Summary:

All over the world currently works are in progress to improve the efficiency of power units. Also in Poland, research is being carried out to reduce heat losses in power plants and heat and power plants. The subject of this doctoral dissertation is a part of this area of activities, because it presents studies relevant to possibility of using waste heat from screw bottom ash coolers of a fluidized bed boiler. The inspiration for the conducted research was the possibility of cooperation with the Turów Power Plant and the measurements on the real object. In Turów Power Plant there are two types of ash coolers: double cooler, consisting of two symmetrical screws surrounded by a case and a single cooler, made of a single screw and a case.

The goal of the thesis was to take thermal-flow measurements of both types of screw coolers and to examine whether and for what parameters of coolers performance, exists the possibility of recovering waste heat which is received from bottom ash by cooling water flowing in coolers. Moreover, the aim of the thesis was to develop a mathematical model that will allow the control of a single screw cooler in order to maximize the use of its capabilities as a heat exchanger and, in this way, increase the efficiency of the power unit.

In order to achieve the thesis objectives, a series of measurements of thermal-flow parameters of ash coolers of both types installed in the Turów Power Plant on power units number 1 and 4 (i.e. the inlet and outlet temperature of cooling water and slag and volumetric flow rates of water) were performed. Based on the obtained data, the heat fluxes received by the cooling water were calculated.

The analysis of the values of cooling water temperatures at the outlet from the coolers showed that there is a possibility of recovering waste heat for the percent rotation speeds of screws equal to 60 % and (80-90) %. Depending on the type of cooler installed, on the unit number 1, the complete, possible for further use, heat flux was maximally equal to 1,3 MW, and for single coolers on unit 4 - about 400 kW. The recovered heat can be used for the plant's own needs, e.g. sanitary purposes.

The next stage of the thesis was to develop a mathematical model. For the calculations, it was necessary to know the thermal conductivity of bottom ash, which value was not explicitly specified in the literature. In order to determine the λ_{pop} parameter of the tested ash, a laboratory stand was built. The value of thermal conduction coefficient of bottom ash increases with the temperature from 0,56 W / (m · K) for the temperature range (100-200) °C to 1,16 W / (m · K) for the temperature range (600-700) °C.

Using the results of experimental research, a mathematical model of a single screw cooler was developed. The model is based on Fourier equations, therefore the heat transfer coefficients for cooling water, slag and steel, from which the cooler walls are made, are determined. It was also necessary to determine the amount of filling of the screw's cross-section with ash in order to determine the value of the slag mass flow rate. The developed model makes it possible to determine changes of the temperature of cooling water and ash along the length of the screw cooler. Moreover, it allows to determine final cooling water and ash temperatures for initial parameters (inlet values of temperature and volumetric flow rates of cooling water, ash temperature, and screw rotational speed).

Validation of the mathematical model was conducted basing on the measurement data obtained on the real object. The relative error between the obtained results of numerical calculations and measurements for individual percent rotational speeds of the screw is below 9%, what indicates very good agreement of the model with the tested cooler. The mathematical model of a single ash cooler, based on the Fourier equations, can be used to manage a set of coolers for their maximum use as heat exchangers and to analyze the operation of various single coolers after considering and changing the geometrical dimensions of coolers operating in any given power plant.

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