Analysis of temperature distribution in the heating boiler equipped with afterburning chamber

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Abstract. Analysis of a heat transfer process for construction of solid fuel heating boiler equipped with additional afterburning chamber is presented. Analyzed construction of the heating device is intended for house heating and preparation of hot utility water. A heat exchanger in the analyzed boiler is composed of vertical tubes divided into three boiler draughts. Afterburning chamber connects main combusting chamber of the heating boiler with second and third boiler draught. The aim of this analysis is to identify the character of heat transfer through the heating boiler.

1 Introduction

Low power heating boilers are very often used in domestic applications for heating and preparation of hot water for sanitary purposes. Heating systems based on solid fuels are very popular in Polish households. In the European Union, solid fuel consumption by a residential sector is equal to about 3-5% of the overall consumption. In Poland, about 40% of energy consumption in the residential sector comes from coal combustion [1]. Coal combustion negatively affects an air quality, which is very well visible in Poland during a heating season when a concentration of particular matter and other smog components in the air is much higher [2]. Poland has the worst air quality among all countries associated with the European Union [3]. Respiration with contaminated air causes many problems with health and increases mortality among the inhabitants of polluted areas [4].

Authors of the paper are doing research connected with the improvement of solid fuel combustion in the domestic including emission of the combustion process and efficiency of the heat transfer. An object of research is a construction of low power heating boiler with the additional afterburning chamber. This construction cooperates with an automatic coal feeder. According to [5], 80,6% of Polish households use solid fuels as a primary source of heating. About 66,9% of households use heating boilers where coal is combusted, but only 8% of households use automatic coal-fired boilers. Emission of pollutants obtained from solid fuel combustion depends on the used method of the combustion process. Nowadays production of low power heating boilers in Poland with a manual system of fuel supplying is not allowed [6]. Heating boilers supplied with automatic burners allows to achieve levels of emission complies with the present legal regulations [7]. Analyzed construction of heating boiler is presented in figure 1.

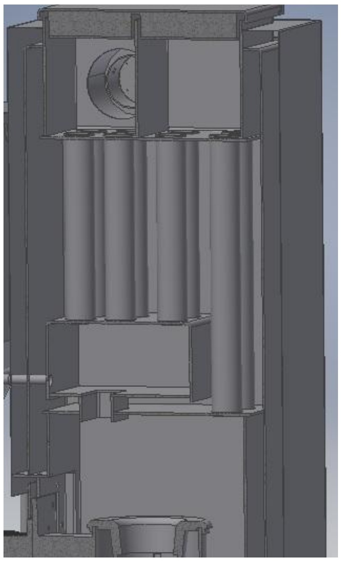

Fig. 1 Geometrical model of the domain used in numerical analysis

2 Modeling

Tested construction of the heating boiler was subjected to numerical simulations. Numerical analysis of fluid flow through the heating boiler was prepared in the Ansys Fluent software. Application of numerical analysis allows showing crucial information about the character of a flow and a heat transfer process. Numerical analysis was realized for the heating power equal to 30% of the nominal power of this heating device. Designed nominal power for this heating device is equal to 18 kW. The numerical model predicts two configurations of the amount of exhaust gas directly into the afterburning chamber. In the first case a flow of exhaust gas to the afterburning chamber is free. In the latter case flow is limited by a 50 percent.

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3.1 Mesh

Numerical analysis was prepared for a hybrid mesh obtained in the Ansys Meshing Software. The quality and sizing parameters of the used grid are shown in table 1.

Table 1. Quality of mesh used in numerical calculations

Number of elements	4.2 mln	
Orthogonal quality	min	ave
	0.14	0.83
Skewness	max	ave
	0.84	0.18

Used grid is composed of hexahedrons in parts of the structural mesh. Tetrahedrons and hexahedrons are present in non-structural parts of the mesh. Pyramids are present in inflation zone of non-structural parts of the grid. Increasing the number of cells in analyzed simulation does not provide a more accurate solution.

3.2 Models used in numerical calculations

As a working medium exhaust gas and water were used. Thermodynamic parameters required in numerical calculations for exhaust gases were defined as a function of temperature. To those parameters belongs a density, specific heat, heat conduction and kinematic viscosity. Most of the thermodynamic parameters for water used in numerical calculations were defined as constant, only a density is defined as a function of temperature.

In a numerical model, a realizable k-ε model of turbulence with enhanced wall treatment was used. Applied model of turbulence is characterized by a higher ability to capture the mean flow of the complex flow relative to the standard k-ε model. It is connected with higher accuracy of calculations, which results from the different formulation of the transport equation for the dissipation rate of the turbulent energy [8]. Mentioned model of turbulence based on the near-wall function. It allows predicting a character of flow when y+ parameter [9] is in range 5-30.

4. Results

Figure **Błąd! Nie można odnaleźć źródła odwołania.** shows the temperature distribution of exhaust gas in the heating boiler for two analyzed cases. The left side of the figure refers to the free flow to the afterburning chamber. Tight side refers to the limited flow by 50 percent between the burning chamber and the afterburning chamber.

An analysis prepared for 30 percent of the nominal power does not show significant changes in the character of flow for an unlimited and restrained stream. When a flow of exhaust gas into the afterburning chamber is limited a higher amount of flue gas is directed through first and second draughts.

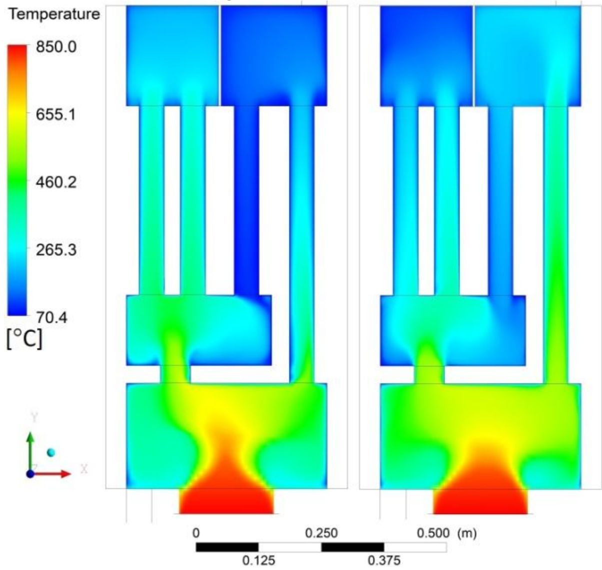

Fig. 2 Temperature distribution of flue gas for 30 percent of nominal power during left: free, right: limited, flow to the afterburning chamber

In this situation, a higher temperature of flue gas is present in this area. Increasing the temperature difference and Reynolds number caused the rising amount of heat transferred into the cooling medium. Temperature distribution in the heat-exchanger chamber and at the outlet from the heating boiler keeps on a similar level. Obtained heat flow is higher for 5.4 percent, but obtained heat flux between working mediums is still on the same level.

5 Summary

Numerical calculations prepared for a heating boiler supplied with afterburning chamber allows for showing a character of a flow of flue gas through the heating device. Limitation of the exhaust gas stream directed directly to the afterburning chamber from the combustion chamber caused increasing of heat flow delivered to the cooling water. It is connected with an extension of exhaust gas flow and increasing of Reynolds number in two first draughts of the heating device.

Implementation of regulation system responsible for controlling of amount of exhaust gas developed into afterburning chamber allows to achieve fractional influence for a pressure drop with preserving of the high efficiency of heating boiler work, depends from heat load of the heating device.

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