

Identification of character of flow realized in low power heating boilers

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Abstract. An analysis of a heat transfer process during exhaust gas flow through two boiler draughts connected in the reversing chamber is presented. The article shows the main differences in the exhaust gas flow through the boiler construction when heating boiler works with different levels of heating power. The aim of the proposed research is defining a character of a flow and a heat transfer process depending on the horizontal and vertical position of boiler draughts.

1 Introduction

Fuel combustion is very often used in eastern Europe for heating purposes. In recent years a significant development of boiler constructions is noticed. Mentioned development is connected with the limitation of harmful compounds included in flue gas and increasing of efficiency of thermal conversion of combusted fuel. More and more often combustion of fossil fuels is being replaced by renewable resources which biomass belongs to.

Literature survey showed that the topic of the heat transfer process in boilers is analyzed but most papers deal with big constructions intended for power engineering. Authors of papers [1, 2] propose a numerical model which allows for analysis of dynamic parameters of the heat transfer process in boilers intended for the steam production. Also, article [3] presents the results of numerical modeling for two identical constructions of the coal-fired boiler based on the temperature and the heat flux distribution.

The subject of low power heating boilers is also taken into account in scientific research. Researchers from the University of Vigo [4] experimentally analyzed a 24 kW fixed bed stove until work in different configurations. They analyzed in detail the efficiency of the heating boiler as a function of combustion parameters such as the mass flow of fuel, stoichiometric ratio and the secondary air fraction.

2 Modeling

The proposed analysis is connected with a character of a flue gas flow through the smoke tubes construction of a heat exchanger connected in a reversing chamber. This type of heat exchanger is popularly used in low power heating boilers. Figure 1 presents a geometrical model of the analyzed construction of heat exchanger. Mentioned geometry is part of a heating boiler located

after a combustion chamber. The area marked by a blue are filled by a flue gas comes from the combustion process of solid fuel. Area of geometrical model limited by the black edge is filled by cooling water. It is assumed, that flue gas comes from biomass combustion. Parameters of flue gas, which are necessary for the heat transfer model was analytically calculated basing on the chemical composition of the flue gas as a function of the temperature in the desirable range.

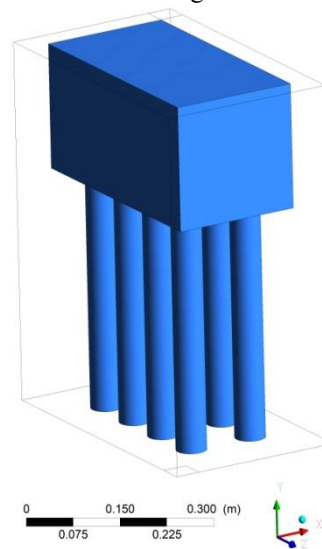


Fig. 1 Geometrical model of the domain used in numerical analysis

3.1 Mesh

Numerical analysis was realized on the structural grid prepared in the Numeca IGG software. This software allows for the preparation of high-quality hexagonal grids. The mesh is composed of 488 blocks, which are consisted of almost 4.25 million elements. Figure 2 shows the two most important parameters connected

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with the quality of the grid used in numerical calculations. Preparation of the grid as a structural mesh allowed to obtain very high quality.

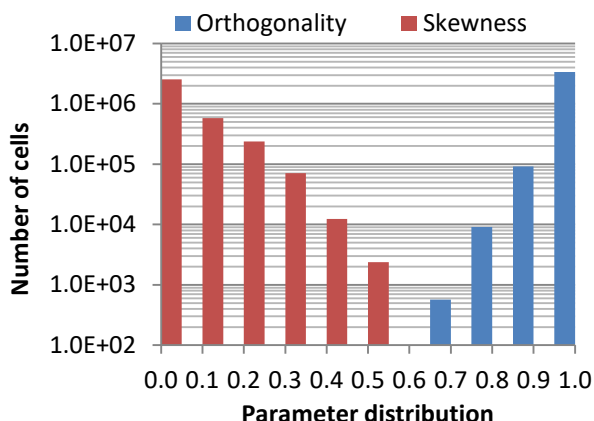


Fig. 2 Quality of mesh used in numerical calculations

Prepared grid is composed of elements, which allows obtaining the y^+ [5] parameter near 1. Elements located close to each other maximally vary in his size by a 20 percent.

3.2 Boundary conditions

Numerical simulations were prepared in the ANSYS Fluent software in version 2019 R1. Utilization of a grid with high quality allows applying the $k-\omega$ SST model of turbulence [6]. The character of flow through the domain was analyzed for two levels of mass flow for working mediums taking part in a heat transfer process. Values of the mass flow used in the prepared analysis were signed by \dot{m}_1 and \dot{m}_2 and are shown in table 1.

Table 1. Mass flow of working mediums in analyzed cases.

	\dot{m}_1 (kg/s)	\dot{m}_2 (kg/s)
Flue gas	0.0092	0.0028
Water	0.3	0.09

Modeling of a horizontal and vertical configuration of heating boiler draughts requires for defining of the gravitational acceleration in two configurations. In the horizontal configuration, gravity is defined according to the negative Y-axis. Vertical configuration requires to define gravity force according to the negative X-axis.

4. Results

Figures 3 and 4 present a velocity distribution for flue gas. Figure 4 presents velocity distribution for vertical and horizontal configuration of the heating boiler when a \dot{m}_1 stream of flue gas is transported. The same magnitude is visible in figure 5 for \dot{m}_2 stream of exhaust gas in the domain.

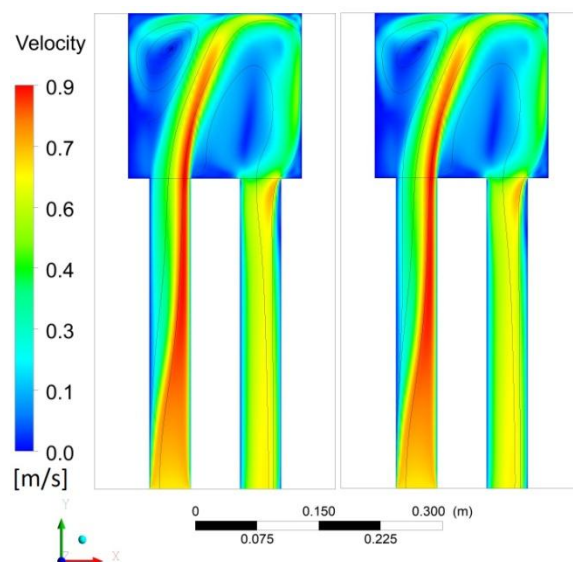


Fig. 3 Velocity distribution for lower mass flow (\dot{m}_2) of the flue gas for a) vertical, b) horizontal configuration

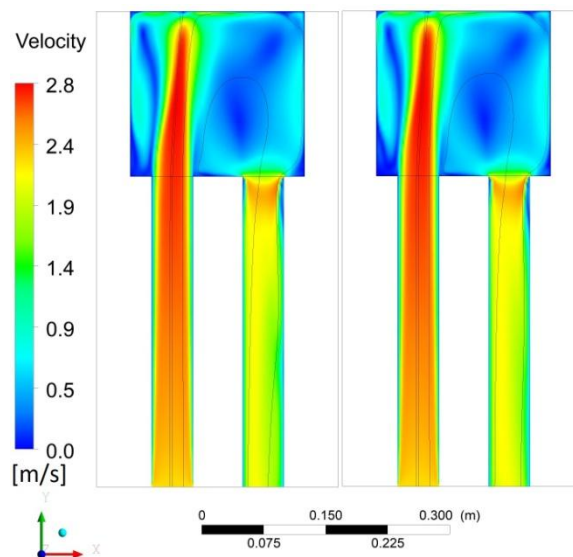


Fig. 4 Velocity distribution for higher mass flow (\dot{m}_1) of the flue gas for a) vertical, b) horizontal configuration

Distribution of velocity, obtained for horizontal and vertical configurations are very close to each other. Differences in obtained values between the horizontal and vertical configuration of the heat exchanger are lower than 0.5 percent and can be treated as a result of inaccuracy of a numerical simulation. Significant differences were noticed when through the heat exchanger a different mass flow of working mediums was provided.

In this situation, a higher stream of flue gas is flowing near the right side of the first draught. It is connected with the creation of well visible eddies inside a reversing chamber. Creation of eddies caused increasing of flue gas flow near to the right wall, which is located closer to the outlet. It caused, that velocity of flow is transferred into potential energy of pressure according to the research dealing with reversed flows [7]. In both of analyzed cases, where streams of flue gas

were the different character of flow through the second draught into the outlet is similar. The obtained velocity profile in this area is homogenous.

5 Summary

Localization of smoke tubes in a horizontal or vertical configuration does not provide visible changes in a character of flue gas flow. Influence of different direction of a gravity vector does not have a big impact on heat transfer realized in the heating boiler. Obtained results show that analyzed construction of the heat exchanger achieves the different character of flow when it works with different heating power. Increasing of mass flow of working factors flowing through the heat exchanger cause limitation of the turbulent intensity of the stream.

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References

1. Rahmani, S. Trabelsi, Am. J. Chem. Eng., **2**(5), 65-70 (2014)
2. X. Zhang, J. Yuan, Z. Chen, Z. Tian, J. Wang, Appl. Therm. Eng., **135**, 368-378 (2018)
3. J.H. Yang, J.E. A Kim, J. Hong, M. Kim, C. Ryu, Y.J. Kim, H.Y. Park, S.H. Baek, Fuel, **144**, 145-156 (2015)
4. J.C. Morán, J.L. Tabarés, E. Granada, J. Porteiro, L.M. González, Part A Recover. Util. Environ. Eff., **28**(12), 1135-1148 (2006)
5. M. Ariff, S.M. Salim, S. C. Cheong, *Seventh International Conference on CFD in the Minerals and Process Industries*, Melbourne, 1-6 (2009)
6. H.K. Versteeg, W. Malalasekera, *An Introduction to Computational Fluid Dynamics Second Edition*, Pearson Education Limited, Harlow (2007)
7. R. Kłosowiak, J. Bartoszewicz, R. Urbaniak, *23rd International Conference: Engineering Mechanics.*, Svratka, 466–469 (2017)