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Design Modifications of the Rotary Biomass Burner for Application in Wood Gasification, Pyrolysis, and Flue Gas Condensation Processes

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ABSTRACT

This paper presents technical modifications and an analysis of the operation of a rotary pellet burner in the context of its use in wood gasification boilers and low-emission, low-power condensing boilers fueled by biomass. The burner design allows for a four-zone combustion process, including: fuel drying, pyrolysis, combustion, and reduction of harmful compounds.
The burner combustion chamber is equipped with a three-zone air distribution system, encompassing primary, secondary, and post-combustion zones. The design modifications included redesigning the combustion chamber by reducing the number and spacing of aeration holes in the primary zone.
The aim of this modification was to achieve more favorable conditions for pyrolytic fuel combustion. This design solution allows for the intensification of convection and radiation processes in the combustion chamber, which promotes pyrolysis and improves combustion process stability.
The effect of these modifications is increased combustion gas combustion efficiency. The rotating combustion chamber allows for mechanical air shutoff in areas not involved in the pellet combustion process, which allows for stable, low oxygen content in the exhaust gases, especially when the burner is operated at loads below rated power. The entire burner structure is sealed, preventing ambient air from entering the combustion chamber. Furthermore, the burner is adapted for use in a wood gasification boiler by incorporating an airtight aeration chamber sealing system, which blocks air flow into the combustion chamber through the burner during the gasification process.

Keywords: biomass, pellet, low-power boiler, pellet burner.

OBJECTIVES

For research purposes, the burner was equipped with a dedicated adapter that enabled the installation of a thermocouple for precise measurement of the bed temperature inside the combustion chamber during operation.

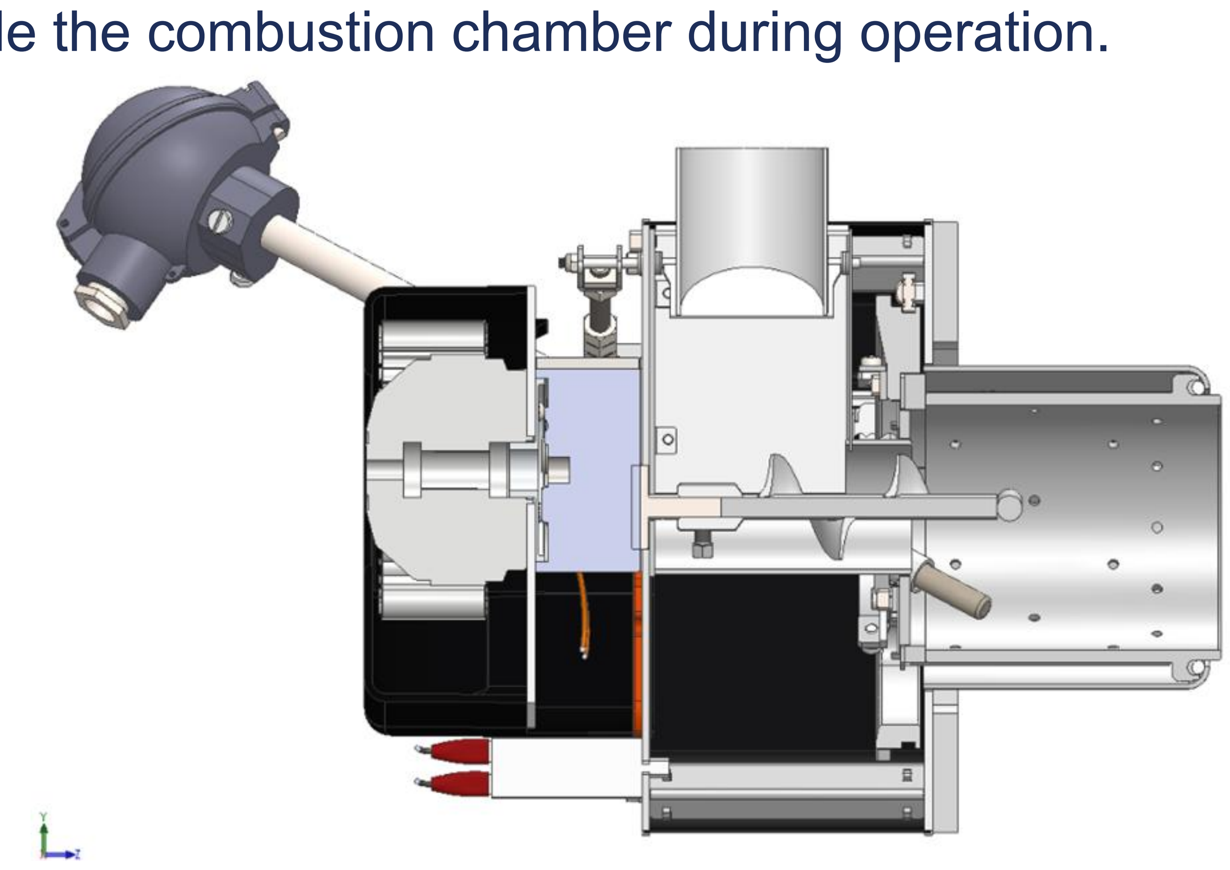

Fig. 1. View of the modernized rotary burner with a thermoelectric sensor (type S) installed to measure the temperature in the combustion chamber via an adapter.

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CONCLUSIONS

Design modifications to the rotary burner for biomass boilers have enabled its wider application in various types of heating appliances. The efficiency of the biomass gasification process in the burner and throughout the boiler directly determines the quality of the resulting wood gas and, at the same time, depends on the design solutions adopted, which influence the system's efficiency and the composition and purity of the exhaust gases emitted into the environment.
Significant differences in air distribution between wood gasification boilers and pellet boilers affect the emission levels of nitrogen oxides (NO_x) and carbon monoxide (CO). The varying temperature conditions in both boiler types determine the intensity of thermal and rapid nitrogen oxide formation, and therefore the total pollutant emissions.
Further planned research will focus on assessing the impact of flue gas recirculation on the conditions in the reduction zone and its impact on boiler efficiency and emission levels. The next stage of work will involve modeling a low-power condensing heat exchanger working in conjunction with a rotary pellet burner. The main goal of this solution is to increase the energy efficiency of biomass boilers and reduce the negative impact of their operation on the environment by recovering waste heat and reducing pollutant emissions, including dust and soot.
In the context of increasingly stringent requirements regarding the energy efficiency of heating devices and their environmental impact, the proposed design solutions represent a significant step towards improving operational parameters and generate tangible economic and ecological benefits for the end user.

REFERENCES

1. Junga R., Sobek S., Mizerna K., Drożdżol K., Kabaciński M., Moskal-Zaucha H., Wróbel-Iwaniec I., Rogowski M. 2025. Co-combustion of straw and waste rubber thermolysis char in a moving grate boiler. Renewable Energy, vol. 239, iss. 121948.
2. Ciupek B., Urbaniak R. 2018. Optimization of the Retort Burner Construction to Reduce Emission of Harmful Substances. Ciepłownictwo, Ogrzewnictwo, Wentylacja, T. 49, no 12, p. 519-524.
3. Ciupek B., Bartoszewicz J. 2019. The influence of geometry of primary air channels in standard retort burners on dust emission. MATEC Web of Conferences, vol. 254, p. 4009-1-04009-11.
4. Ciupek B., Frąckowiak A. 2024. Review of Thermal Calculation Methods for Boilers—Perspectives on Thermal Optimization for Improving Ecological Parameters. Energies, vol. 17, iss. 24, p. 6380-1-6380-15.
5. Ciupek B., Urbaniak R., Nocoń A. 2024. Emission Models for Selected Harmful Substances Emitted During Low-Temperature Combustion of Wood Pellets. Journal of Ecological Engineering, vol. 25, iss. 2, p. 267-273.
6. Ciupek B., Urbaniak R., Kinalska D., Nadolny Z. 2024. Flue Gas Recirculation System for Biomass Heating Boilers—Research and Technical Applications for Reductions in Nitrogen Oxides (NOx) Emissions. Energies, vol. 17, iss. 1, p. 259-1-259-16.

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