REVIEW

By Prof. Eng. Angel Kostadinov Terziev, Ph.D

Technical University of Sofia

of a dissertation for the acquisition of an educational and scientific degree "Doctor"

Topic: **"EFFICIENCY OF THE COMBUSTION PROCESS WHEN BURNING PELLETS AND WASTE RAW MATERIALS IN BOILERS"**

Author: Nevena Milcheva Mileva

Scientific field: 5.Technical sciences

Professional field: 5.4.Energetics

Doctoral program: Thermal Engineering

1. **Actuality of the problem developed in the dissertation in scientific and scientifically applied terms. Degree and scale of the actuality of the problem and the specific tasks developed in the dissertation.**

One of the goals of the Green Deal is to increase energy and resource efficiency while reducing environmental impact in all areas of engineering science and practice. One approach to achieving this is to improve the efficiency of combustion processes and the rational use of available natural resources. Recent studies indicate that the amount of utilized waste biomass, including that from forest clearing, does not exceed 30%, which requires serious and in-depth analysis in this direction.

Direct combustion of waste biomass in boilers is a well-known technology, but in the last two decades the focus has shifted to the secondary recovery of energy from biomass through processes such as gasification, pyrolysis, and others that produce combustible gas. This gas can then be burned in gas turbines or combined heat and power units. These technologies provide a higher level of energy recovery from biomass as a waste product, while reducing the negative impact on the environment.

The above makes the topic of the dissertation extremely relevant. The main objective is to improve the efficiency of the combustion process when burning various fuels derived from waste biomass, including mixtures of different waste materials. Based on this, an analysis of the impact of the specific characteristics of the combustion process on the

design features of heat generators will be conducted. Suggestions are also made for the additional use of waste heat as part of the main process.

2. **Does the PhD student know the state of the problem and does she creatively evaluate the literary material?**

The presented materials show that the number of analyzed literature sources amounts to 141 titles, of which 8 are web-based sources. Of the analyzed sources, 36 are in Cyrillic. More than 58% of all literature sources are from after 2015, which shows that the doctoral candidate is well acquainted with contemporary research and technologies used in energy production from waste biomass.

The main sections of the dissertation are well balanced. The dissertation consists of six chapters, including an introduction, a literature review on the current state of the researched topic, experimental and numerical studies, application of the research results in a real combined energy production system, conclusions and recommendations for practical applications.

The critical analysis carried out shows that the doctoral candidate has thoroughly studied the specifics of waste biomass combustion, including methods for determining the calorific value of mono-component and multi-component fuels. She has demonstrated a deep understanding of the topic under study and has clearly defined the objectives and tasks to be addressed during the development of the dissertation.

3. **Can the chosen research methodology provide an answer to the goals and objectives of the dissertation?**

I consider the chosen approach to determine the thermal-technical characteristics of the studied types of waste biomass, as well as the experimental and numerical studies conducted to determine the efficiency of the combustion process, to be appropriate.

4. Brief analytical description of the nature and assessment of the reliability of the material on which the contributions of the dissertation are built

The presented doctoral dissertation consists of 178 pages and includes an introduction, six chapters, a conclusion with findings and recommendations for practical application, as well as a list of references.

The introductory part of the dissertation analyzes the state and importance of biomass as a primary and secondary resource for combined energy production.

In Chapter 1 (Literature Review), the doctoral candidate conducts a critical analysis of the existing methods and tools for utilizing the energy of waste biomass, including mixtures of various materials for the production of electricity and thermal energy. The primary focus is on the characteristics of biomass as a fuel, with particular emphasis on derivatives from several types of waste materials – a mixture of wood and sunflower husks in different ratios. The role of thermal analysis is highlighted as essential for characterizing the thermal-technical properties of biomass, and the candidate defines the relevant limitations of conducting thermal studies.

Chapter 2 presents the methodology that will be used to address the tasks defined in the dissertation. The methodology for studying the energy properties of pellets is well described. The methods of thermal analysis used (differential thermal analysis, differential scanning calorimetry, and thermogravimetry) are applied to analyze the thermal-technical properties of the studied materials.

Chapter 3 provides an analysis of the energy characteristics of the pellets. The study of the pellets focuses on their calorific value, moisture content and ash content. This stage of the work is extremely important as it clarifies the nature of the moisture evaporation process, the energy required for ignition, and the dynamics of the combustion process. The analysis shows that when pellets from various wood sources are mixed in different proportions, the thermal-technical properties of the materials differ significantly. This highlights the importance of repeated experimental studies.

Numerical studies of combustion processes in a domestic boiler are presented in Chapter 4 of the Ph. D work. The mathematical modeling of the combustion processes is accurate and the turbulent model used to solve the system of equations is appropriate.

Numerical studies have been performed on the combustion process of wood and sunflower pellets, as well as mixtures in different ratios. The efficiency of the boiler under different conditions of primary and secondary air supply is demonstrated. The velocity and temperature fields in the boiler under different operating conditions are presented. The degree of turbulence is analyzed to evaluate the heat transfer and the formation of specific zones in the boiler. The emission analysis shows that the improvement of the degree of combustion reduces the carbon emissions and has a corresponding positive environmental impact. The results of the numerical studies are logical and comparisons with experimental results show a satisfactory margin of error of about 5%.

Chapter 5 presents the practical application of pellet combustion in a biomass boiler. The steam produced by direct combustion is used to generate electricity in a turbine. The remaining heat energy is used in an Organic Rankine Cycle (ORC) module for additional electricity production. Despite the lower efficiency of the module, its implementation is economically viable because a significant portion of the heat energy produced cannot be used elsewhere.

Chapter 6 presents the main conclusions of the dissertation, along with recommendations for practical applications. The methodologies developed during the research for conducting experimental studies to determine the characteristics of the fuel material, as well as methods for optimizing the amount of primary and secondary air in the combustion process, provide a basis for increasing energy efficiency and mitigating harmful environmental impacts.

5. What are the scientific or scientific-applied contributions of the dissertation?

I classify the contributions of the Dissertation as both scientific applied and engineering applied. The results obtained can be successfully used in future numerical studies of combustion processes using waste biomass, as well as for optimization of combustion processes in boilers. The contributions of the thesis can be summarized as follows:

Demonstration of significant new aspects of existing scientific problems and theories using new methods:

- New thermal methods have been utilized to improve the combustion process of pellets. On this basis, it is possible to develop new types of combustion systems;
- Numerical research-based models have been created to predict the behavior of combustion processes. Significant factors influencing the combustion process have been identified;
- The proposed model for mixing fuel with primary/secondary air allows for the regulation of combustion temperature, which in turn affects the type of emissions generated.

Discovery and verification of new facts and confirmation of existing ones:

- The applied aspect of the thesis is the automation of fuel and air supply at specific ratios for domestic boilers to improve energy and resource efficiency;
- The integration of a combined energy production system equipped with an ORC module into an industrial boiler for heat generation is identified as an applied contribution.

6. Can it be assessed to what extent the dissertation work and contributions represent the personal work of the dissertation?

I know the work of M.Sc. .Eng. Nevena Mileva from her participation in scientific forums in our country. I believe that the candidate's work is her personal effort, of course, carried out under the guidance of her supervisor. I can confidently state that the two key components for the development of a doctoral thesis - pedagogical and scientific - have been fulfilled. The candidate has undoubtedly improved her qualifications both in the field of combustion processes and in the field of numerical modeling. The experience gained will certainly be beneficial for her future teaching and research activities.

7. Evaluation of the publications on the dissertation.

The Ph.D. student has submitted a list of three publications, two of which are sole authored, while the third is co-authored, including the research advisor. The publications have appeared in two peer-reviewed journals and one conference proceedings volume in the Scopus database.

8. Have the results of the dissertation already been used in scientific and social practice?

The main results of the dissertation have been presented at scientific conferences and are well known in the scientific community. The topic is highly relevant and the results will undoubtedly have an impact on engineering science and practice.

9. Recommendations for the future use of scientific and scientific-applied contributions.

The built pilot plant proves the applicability of the results of the thesis. There are opportunities for integration into a number of industrial facilities.

10. Abstract

The presented abstract is compiled according to the requirements, its content corresponds to the dissertation and correctly reflects all its main parts. Its volume is 52 pages.

11. Critical notes on the dissertation, including on the candidate's literary awareness.

The dissertation shows a well-developed and in-depth study in the field of combustion processes. The research work can be characterized as thorough and consistent. It progresses logically from the first to the last chapter of the study. It includes a comprehensive theoretical review, a well-chosen set of tools and methodologies in line with the objectives of the research, and an interpretation of the results obtained. These results are presented with precision in both tabular and graphical formats, supported by appropriate conclusions.

CONCLUSION

The presented dissertation fully meets the requirements for obtaining the educational and scientific degree "Doctor."

I highly value the positive results and contributions achieved in the dissertation, and I consider that the presented work complies with the Law on the Development of Academic Staff, the regulations for its application, and the Procedural Rules of the Technical University of Varna. Based on all of the above, I give my positive evaluation and propose to the scientific jury to award M.Eng. Nevena Milcheva Mileva the educational and scientific degree of Doctor in the field of higher education 5.Technical sciences, Professional field 5.4.Energetics, Doctoral program: Thermal Engineering.

24.02.2025
Sofia

Reviewer: .....
/Prof. Eng. Angel Terziev, PhD/