**REVIEW**

**of the official reviewer for dissertation work**

**Magzhan Orynbasar on the theme «Energy and ecological efficiency of plasma-coal burners: numerical simulation and experiment» presented for the degree of Doctor of Philosophy (PhD) in the specialty «8D07106».**

| № | Criteria | Eligibility (one of the options must be checked) | Justification of the position of the official reviewer |
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| 1. | The topic of the thesis (as of the date of its approval) corresponds to the directions of development of science and/or state programs | 1.1 Compliance with priority areas of science development or government programs: | |
| | | 1) The thesis was completed within the framework of a project or target program financed from the state budget (indicate the name and number of the project or program)<br>2) The thesis was completed within the framework of another state program (indicate the name of the program)<br>3) The dissertation corresponds to the priority direction of the development of science, approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (indicate the direction) | The dissertation work was completed in accordance with the approved research plan of the Ministry of Science and Higher Education of the Republic of Kazakhstan, as well as within the framework of grant funding for scientific research on the topics: «Obtaining energy gas and neutral inorganic material by plasma gasification of carbon-containing waste, including polyethylene terephthalate» (AP19674754, 2023-2025); «Development and testing of technologies for new functional materials using plasma-chemical, mechanochemical and self-propagating high-temperature synthesis processes» (BR18574084, 2023-2025); «Ecological and energy efficiency of plasma technology: numerical modeling and experiment» (AP22687016, 2024-2026) |
| 2. | Importance for science | The work makes/~~does not make~~ a significant contribution to science, and its importance is well disclosed/~~not disclosed~~ | The research focuses on the environmental and energy efficiency of plasma-coal burners used for ignition and combustion stabilization of |

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| | | | pulverized coal at thermal power plants. It addresses the challenges associated with burning low-grade, high-ash Ekibastuz coal, which is widely used in Kazakhstan. The study combines numerical modeling and experimental investigations to analyze electrothermochemical fuel preparation and partial gasification processes in a plasma-coal burner. Special attention is given to determining optimal operating parameters under realistic industrial conditions.<br>Overall, the work makes a **moderately significant contribution to science**. While plasma ignition and combustion stabilization are well-established research areas, the study advances them within a specific and narrowly defined context. Its novelty lies in adapting and validating these technologies for local coal characteristics and regulatory requirements of Kazakhstan. This targeted approach enhances the practical relevance of existing scientific knowledge rather than introducing a fundamentally new concept. |
| 3. | The principle of independence | Self-reliance level:<br>1) High;<br>**2) <u>Medium</u>;**<br>3) Low;<br>4) No independence | Due to the limited methodology description, it is hard to determine the level of self-reliance. However, the detailed description given for the modeling part of the dissertation indicates a sufficient level of self-reliance (medium). |
| 4. | The principle of inner unity | 4.1 Justification of the relevance of the thesis: | Justified. The dissertation is set in a |

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| | | 1) **Justified**;<br>2) Partially justified;<br>3) Not justified. | clearly presented context of energy production, energy safety, and environmental protection. These issues are of high relevance not only locally and temporally, but also persistently and worldwide. The research on plasma-assisted combustion of low-rank hard coal fits perfectly within this framework. |
| | | 4.2 The content of the thesis reflects the topic of the thesis:<br>1) Reflects;<br>2) **Partially reflects;**<br>3) Does not reflect | The content of the thesis partially reflects the stated topic. The dissertation provides a relevant literature review on plasma-assisted combustion and presents known models and methods used to simulate the process. However, the energy and ecological efficiency of plasma-coal burners are not defined clearly or comprehensively and are addressed rather superficially. As a result, the obtained findings do not fully reflect the scope implied by the thesis topic or the energy and environmental context outlined in the introduction. |
| | | 4.3. The purpose and objectives correspond to the topic of the thesis:<br>1) correspond;<br>2) partially correspond;<br>3) do not correspond | The aim of the dissertation in enclosed in three tasks:<br>1. To perform thermodynamic and kinetic modeling of the products formed during the electrothermochemical preparation of low-rank, high-ash fuel for combustion, using the TERRA and PlasmaKinTherm software packages, in order to obtain a highly reactive dual-component fuel at the outlet of the plasma-coal burner; |

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| | | | 2. To conduct experimental studies of plasma ignition and combustion stabilization (PICS) processes within the burner volume;<br>3. To determine the optimal parameters ensuring the efficient progress of plasma ignition and partial gasification processes of pulverized coal fuel within the volume of the plasma-coal burner.<br>All of these tasks aim to fulfill the thesis purpose - assessing the environmental and energy efficiency of using a plasma-coal burner at a pulverized coal thermal power plant - and correspond to the stated topic. |
| | | 4.4 All sections and provisions of the thesis are logically interconnected:<br>1) completely interconnected;<br>**2) the interconnection is partial;**<br>3) there is no interconnection | In general, the main sections and provisions of the thesis are logically connected; however, some parts of the work appear out of context, and certain fragments are repeated. For instance, information on Ekibastuz coal reserves is provided on page 19 and repeated again on page 21. The model assumptions are presented on page 45, then repeated on page 65, and briefly mentioned again on page 73. On page 25, there is information on carbon capture and storage (CCS) presented as a separate paragraph that is neither developed further nor followed by a clear contextual link. Similarly, page 29 includes information on incorporating polyurethane foam, which lacks a |

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| | | | broader context and does not reference any supporting sources. On page 48, a paragraph intended to review studies on turbulent reacting two-phase flows instead briefly describes the phases of coal particle devolatilization and char burnout.<br>The thesis is divided into only three chapters, which results in some subchapters not aligning well with the main chapter themes. For example, within the chapter titled "Existing Technologies for Burning and Gasification of Thermal Coals," there are broad subchapters such as "Mathematical Modeling of Plasma Ignition of Thermal Coals" and "Statement of the Problem of Numerical and Experimental Investigation of a Plasma-Coal Burner," which would be more appropriate as a separate chapter. Furthermore, the experimental part of the work is placed within the chapter titled "Kinetic Modeling of the Processes of Heating and Ignition of Thermal Coals in a Plasma-Coal Burner," which does not accurately reflect its content. Introducing a separate chapter dedicated to experimental results would significantly improve the structural clarity of the thesis. |
| | | 4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions:<br>1) there is a critical analysis;<br>2) **partial analysis;** | The proposed solution of substituting oil or gas burners with plasma-based systems is discussed in the introduction using general statements. While these arguments appear reasonable, the |

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| | | 3) the analysis does not represent one's own opinions, but quotes from other authors | comparison would benefit from well-referenced data or calculation-based estimates, for example in terms of emissions, costs, and energy consumption. |
| 5. | Scientific novelty principle | 5.1 Are the scientific results and provisions new?<br>1) completely new;<br>**2) partially new (25-75% are new);**<br>3) not new (less than 25% are new) | As stated in point 2: While plasma ignition and combustion stabilization are well-established research areas, the study advances them within a specific and narrowly defined context. Its novelty lies in adapting and validating these technologies for the local coal characteristics and regulatory requirements of Kazakhstan. This targeted approach enhances the practical relevance of existing scientific knowledge rather than introducing a fundamentally new concept. |
| | | 5.2 Are the dissertation findings new?<br>1) completely new;<br>**2) partially new (25-75% are new);**<br>3) not new (less than 25% are new) | As stated in point 2 and 5.1: WWhile plasma ignition and combustion stabilization are well-established research areas, the study advances them within a specific and narrowly defined context. Its novelty lies in adapting and validating these technologies for the local coal characteristics and regulatory requirements of Kazakhstan. This targeted approach enhances the practical relevance of existing scientific knowledge rather than introducing a fundamentally new concept. |
| | | 5.3 Technical, technological, economic or management decisions are new and reasonable:<br>1) completely new;<br>**2) partially new (25-75% are new);** | The choice of the investigated parameters and the application of a plasma burner for a specific Ekibastuz coal may be new, but the technology |

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| | | 3) not new (less than 25% are new) | itself is not novel. |
| 6. | The validity of the main findings | All main conclusions are/~~are not~~ based on scientifically significant evidence or well-grounded (for qualitative research and areas of training in the arts and humanities) | The main conclusions of the work are based on well-developed models using appropriate tools, namely the TERRA and PlasmaKinTherm software packages, which have a long-standing record of successful applications in the literature. The results, both modeling and experimental, on which the conclusions are based appear unambiguous and are rooted in well-known and verified methods. The experimental results show good agreement with the proposed models, thereby strengthening the reliability of the findings. |
| 7. | The main provisions for the defense | It is necessary to answer the following questions for each provision separately:<br>7.1 Is the provition proven?<br>1) proven;<br>2) rather proven;<br>3) rather not proven;<br>4) not proven<br>7.2 Is it trivial?<br>1) yes;<br>2) no<br>7.3 Is it new?<br>1) yes;<br>2) no<br>7.4 Application level:<br>1) narrow;<br>2) medium;<br>3) wide<br>7.5 Is it proven in the article? | The dissertation work presents three statements for defence:<br>1. Electrothermochemical preparation of pulverized low-grade Ekibastuz coal for combustion enables the production of a highly reactive dual-component fuel (comprising combustible gases and coke residue) with elevated concentrations of CO (26.5%) and H2 (15.2%), ensuring rapid ignition at the outlet of the plasma-coal burner<br><br>7.1: proven<br>7.2: no<br>7.3: yes<br>7.4: medium<br>7.5: Yes, in articles: |

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| | | 1) yes;<br>2) no | Messerle V.E., Mossé A.L., Orynbasar M.N., Ustimenko A.B. Plasma ignition of solid fuel: Mathematical simulation and experiment // Journal of Engineering Physics and Thermophysics. - 2024. - Vol. 97. - No. 3. - P. 116–125<br>and<br>Orynbasar M., Messerle V., Ustimenko A. Modeling and experiments on plasma ignition of Ekibastuz coal in the form of dust // Combustion and Plasma Chemistry. - 2024. - Vol. 22. - No. 3. - P. 179–186<br><br>2. The highly reactive dual-component fuel obtained at the outlet of the experimental setup, with a specific calorific value of 12,550 kJ/kg, ensures stable and intensive ignition when mixed with secondary air<br><br>7.1: rather proven<br>7.2: no<br>7.3: yes<br>7.4: medium<br>7.5: Yes, in articles:<br>Messerle V.E., Mossé A.L., Orynbasar M.N., Ustimenko A.B. Plasma ignition of solid fuel: Mathematical simulation and experiment // Journal of Engineering Physics and |

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| | | | Thermophysics. - 2024. - Vol. 97. - No. 3. - P. 116–125<br>and<br>Orynbasar M., Messerle V., Ustimenko A. Modeling and experiments on plasma ignition of Ekibastuz coal in the form of dust // Combustion and Plasma Chemistry. - 2024. - Vol. 22. - No. 3. - P. 179–186<br><br>3. The optimal parameters of the plasma-coal burner are an average mass temperature of 1880 K, pressure of 0.1 MPa, plasmatron power of 60 kW with its length of 3 m and diameter of 0.15 m<br><br>7.1: rather proven<br>7.2: no<br>7.3: yes<br>7.4: medium<br>7.5: Yes, in articles:<br>Messerle V.E., Mossé A.L., Orynbasar M.N., Ustimenko A.B. Plasma ignition of solid fuel: Mathematical simulation and experiment // Journal of Engineering Physics and Thermophysics. - 2024. - Vol. 97. - No. 3. - P. 116–125<br>and<br>Orynbasar M., Messerle V., Ustimenko A. Modeling and |

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| | | | experiments on plasma ignition of Ekibastuz coal in the form of dust // Combustion and Plasma Chemistry. - 2024. - Vol. 22. - No. 3. - P. 179–186 |
| 8. | The principle of reliability Reliability of sources and information provided | 8.1 Choice of methodology - is justified or the methodology is described in sufficient detail<br>1) **yes**;<br>2) no | The choice of methodology is fully justified and is described sufficiently for the modeling part. The experimental part was improved to a sufficient level after revision based on the reviewer's request; prior to that, the experimental methodology lacked crucial information. The additional details brought the description of the experimental methodology to an acceptable level, although it could still benefit from further expansion. |
| | | 8.2 The results of the thesis were obtained using modern methods of scientific research and methods of processing and interpreting data using computer technologies:<br>1) **yes**;<br>2) no | Yes, the results are based on well-established, modern methods. The presented results (figures) were obtained using computer technologies, and the entire section devoted to process chemistry modeling employs advanced numerical calculations based on the TERRA and PlasmaKinTherm software packages. |
| | | 8.3 Theoretical conclusions, models, identified relationships and patterns have been proven and confirmed by experimental research (for areas of training in pedagogical sciences, the results have been proven on the basis of a pedagogical experiment):<br>1) **yes;**<br>2) no | Yes, the presented models have been validated by experimental results. |
| | | 8.4 Important statements are confirmed / **partially confirmed** / not confirmed by references to current and reliable scientific | The majority of the thesis statements are supported by references. However, several statements lack proper citation. |

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| | | literature | For example, Table 1.4, which presents a comparative analysis of oil and plasma-based burners, does not reference the data sources used. Table 3.1, presenting kinetic parameters, is also missing a reference. In addition, the statement on page 84: "Coal and heavy fuel oil co-combustion presents a range of environmental …" lacks references to support the presented claims and numerical values.<br>Moreover, most of the references used in the thesis date from the 1970s, 1980s, 1990s, and the early 2000s. These references are predominantly from post-Soviet Union countries. There is a noticeable lack of recent and internationally diverse references, which would strengthen the scientific context and relevance of the work. |
| | | 8.5 Used literature sources are **sufficient**/not sufficient for a literature review | More than 150 reference positions, mainly scientific articles, are included in the thesis, which is sufficient for a literature review. However, the point presented in Section 8.4 remains valid. |
| 9 | Practical value principle | 9.1 The thesis has theoretical value:<br>1) **yes**;<br>2) no | Yes, the numerical simulations presented in the thesis have theoretical value, as they allow a better understanding of the gasification and combustion processes occurring during plasma burner operation. |
| | | 9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice:<br>1) **yes**;<br>2) no | Yes, the findings of the work directly affected the TPE-215 boiler. |

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| | | 9.3 Are the practice suggestions new?<br>1) completely new;<br>**2) partially new (25-75% are new);**<br>3) not new (less than 25% are new) | These practical suggestions are partially novel. Similar conclusions could likely have been drawn from an extensive review of plasma-based burner implementations. However, the modeling and experimental tests designed for a narrow set of conditions, specified for a particular implementation, provide more accurate and reliable conclusions. |
| 10. | The quality of writing and design | Academic writing quality:<br>1) high;<br>2) **average**;<br>3) below average;<br>4) low. | The academic writing is average due to the presence of some statements that are out of context and recurring statements, as noted in point 4.4. Additionally, some equation references point to incorrect equations. Certain phrases are also unclear. |
| 11. | Notes on a thesis | The dissertation suffers from a poorly described methodology. This issue was raised by the reviewer in the form of an email addressed to the author of the dissertation. The following issues were raised:<br>1. Table 2.2 (p. 60) presents the characteristics of Ekibastuz coal. Please clarify the source of these data. Do they refer to the coal samples used in the experimental part of the work? Which standards and analytical methods were applied to obtain these results?<br>2. Table 3.2 (p. 74) presents the fractional composition of Ekibastuz coal. Please indicate the origin of these data. Do they correspond to the coal samples used in the experiments? Which standards and methods were applied in this analysis?<br>3. How was the power of the plasmatron determined, and how was its efficiency evaluated? (p. 80)<br>4. What type of centrifugal fan was used, and how was the air flow rate determined? (p. 80)<br>5. What type of hopper was applied, and how was its output determined? (p. 80)<br>6. On page 80, it is stated that the coal used in the experiments is characterized in Table 2.2. Were these parameters, including the highly fluctuating moisture content, determined immediately before the experiments? Was the coal prepared prior to testing, for example by grinding, drying, or homogenization?<br>7. On page 81, the torch temperature is reported to range between 870 and 3270 K. A few lines later, the HRDF flame temperature is stated to fluctuate between 1420 and 1450 K. Do these temperature ranges refer to the same object? At what location was the temperature measured? How many measurements were performed, and over what duration? | |

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| | | 8. Please describe in more detail how the gas chromatograph was connected to the experimental setup. How was the gaseous sample introduced into the chromatograph? Please provide details of the chromatographic system, including the type of columns, detector, and analytical method, such as temperature program, analysis time, and split or splitless mode. On what basis and using which methods were qualitative and quantitative analyses performed? How many samples were analyzed? Would it be possible to include an exemplary chromatogram of the analyzed samples in the thesis?<br>9. It is stated that "the resulting solid residue is passed through a high-temperature filtration unit equipped with a replaceable filler to assess the remaining carbon content". How many samples were collected? Additionally, it is stated that "the carbon content of condensed PICS products was determined using an absorption gravimetric method". Please describe this method in detail. Were the results used to determine carbon conversion/degree of coal gasification? If not, how were this parameter determined? (p. 82)<br><br>The author responded with an extended version of the thesis addressing these issues. The additional information, although still limited, can be considered the minimum required for a reliable presentation of the experimental results. Only on the basis of this revised version did the reviewer agree to award the degree of Doctor of Philosophy.<br><br>Besides this main drawback, the dissertation suffers from the following shortcomings:<br><br>- Lack of recent, international literature relevant to the dissertation topic, which could have improved the applied models.<br>- Lack of insightful comparison of the benefits of the plasma-based burner relative to gas or oil burners, particularly in terms of ecological and economic aspects.<br>- Lack of uncertainty analysis of the experimental results and coal characteristics, as well as the absence of sensitivity analysis of the developed model. |
| 12. | Scientific level of the doctoral student's articles on the topic of research (in case of defense of the dissertation in the form of a series of articles, the official reviewers comment on the | Not appliceable |

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| | scientific level of each article of the doctoral student on the topic of research) | |
| 13. | Decision of the official reviewer (pursuant to paragraph 28 of the present Model Regulations) | The research work Magzhan Orynbasar, titled "Energy and ecological efficiency of plasma-coal burners: numerical simulation and experiment" complies with the legislation of the Committee of Scinece nad Education of the Republic of Kazakhstan for awarding the degree of Doctor of Philosophy. Magzhan Orynbasar deserves **to be awarded the academic degree of Doctor of Philosophy (PhD) in the educational program "8D07106 – Thermal Power Engineering".** |

In reviews, official reviewers indicate one of the following solutions:

**1) to award the degree of Doctor of Philosophy (PhD) or Doctor of Specialization;**

2) send the thesis for revision (except for cases of thesis defense in the form of a series of articles);

3) refuse to award the degree of Doctor of Philosophy (PhD) or Doctor of Specialization.

Copies of the reviews of the official reviewers are handed over to the doctoral student no later than 5 (five) working days before the defense of the thesis.

**Official Reviewer:**
PhD, Eng,
Assitant professor at
Wrocław Univeristy of Science and Technology (Poland)
Department of Energy Conversion Engineering
(place of work, academic title)




(signature)

Mateusz Wnukowski
(FULL NAME)