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 «Thermal Power Engineering».

№	Criteria	Eligibility (one of the options must be checked)	Justification of the position of the official reviewer
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) 2) The thesis was completed within the framework of another state program (indicate the name of the program) 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 topic of the dissertation corresponds to national scientific priorities in the field of energy efficiency, ecological modernization of thermal power generation, and clean coal technologies. The dissertation was carried out within the framework of state-funded research projects AP19674754, BR18574084, and AP22687016 of the Ministry of Science and Higher Education of the Republic of Kazakhstan, which confirms its compliance with priority scientific development programs of the Republic of Kazakhstan. The research direction is consistent with the strategic needs of the energy sector, including modernization of thermal power plants, reduction of harmful emissions, and improvement of environmental safety.
2.	Importance for science	The work makes/does not make a significant contribution to science, and its importance is well disclosed/not disclosed	The dissertation introduces new scientific results in the field of plasma-assisted ignition and partial gasification of low-grade coal, addressing an important technological gap faced by pulverized-coal thermal power plants operating with high-ash and low-volatile fuels. For the first time, a combined numerical–experimental validation of the formation of a highly reactive dual-component fuel (HRDF) in a plasma-coal burner was performed, confirming the production of synthesis gas ($CO + H_2$) and quantifying its composition at the burner outlet (up to 37.1% in total). The dissertation also determined the optimal thermophysical operating regime—average mass temperature of ~1880 K, plasmatron power of 60 kW, and burner geometry (3 m length, 0.15 m diameter)—

			ensuring efficient electrothermochemical preparation (ETCPF) and rapid ignition of coal without the use of auxiliary liquid fuels. Methodologically, the work is distinguished by the combined utilization of thermodynamic modeling (TERRA) and kinetic modeling (PlasmaKinTherm) followed by bench-scale experiments, providing cross-validated data for both equilibrium and non-equilibrium stages of fuel preparation and ignition. The agreement between model predictions and experimental measurements reinforces the reliability of the results and provides a framework for scaling the process to industrial burners and boiler systems. From the standpoint of combustion science, the results contribute to a mechanistic understanding of plasma-induced devolatilization, coke fragmentation, and partial gasification kinetics under high heating rates (~10^3–10^4 K/s), which are unattainable in conventional burner environments and have not been previously quantified for high-ash CIS-type coals. The obtained findings expand the research frontier in thermal power engineering by demonstrating that low-grade coal, typically considered an energetically and environmentally challenging fuel, can be converted into a reactive, gas-rich intermediate suitable for clean and stable combustion. The practical implementation potential is demonstrated by the reference to industrial boiler deployment (TPE-215 at Gusinoozersk GRES), indicating both technological maturity and relevance for modernization of existing coal power infrastructure . The importance and originality of the research problem are clearly formulated in the introduction, contextualized within global trends of declining coal quality, rising environmental requirements, and the need to reduce dependency on fuel-oil ignition systems. The results have undergone scientific appraisal through publications in international peer-reviewed journals and conference proceedings, confirming both scientific credibility and dissemination effectiveness.
3.	The principle of independence	Self-reliance level: 1) <u>High</u>; 2) Medium;	The dissertation demonstrates a high level of independent scientific work. The author personally conducted numerical research using two complementary computational tools: the TERRA

		3) Low; 4) No independence	thermodynamic modeling package and the PlasmaKinTherm kinetic code, both of which require a solid understanding of reaction thermochemistry, multi-component gas equilibria, and transient ignition kinetics. In parallel with the modeling activities, the author participated directly in full-scale experimental investigations of plasma-assisted ignition and partial gasification of pulverized coal, including the operation of a laboratory plasma-coal burner, adjustment of plasmatron operating regimes, and acquisition of diagnostic data for temperature, gas composition, and ignition stability. This combination of numerical and experimental competencies is not typical of doctoral work limited to a single methodological domain and reflects a multidisciplinary research capability. The formulation of research objectives and hypotheses, together with their decomposition into solvable tasks, demonstrates clear methodological literacy. The author provides cohesive interpretation of simulation results, correlates them with experimental observations, and extracts physically meaningful trends relevant to ignition kinetics and plasma–fuel conversion mechanisms. The conclusions drawn in the dissertation are not descriptive, but analytically substantiated, grounded in quantitative modeling outcomes, and verified experimentally. This indicates that the author is not only capable of performing technical tasks, but also of synthesizing data, critically evaluating discrepancies, and formulating generalizable scientific statements. Overall, the character of the work confirms a well-developed independent research capability and methodological maturity, as expected from doctoral-level research in thermal power engineering and plasma technologies.
4.	The principle of inner unity	4.1 Justification of the relevance of the thesis: 1) Justified; 2) Partially justified; 3) Not justified.	The relevance of the scientific work is clearly substantiated. The author convincingly explains the importance of improving ignition and combustion processes for low-grade coal in thermal power engineering, as well as the environmental and technological motivation for plasma-assisted combustion modernization.
		4.2 The content of the thesis reflects the topic	The content of the dissertation fully corresponds to the declared

		of the thesis: 1) Reflects; 2) Partially reflects; 3) Does not reflect	topic. The work consistently reviews literature, outlines thermodynamic and kinetic modeling approaches, presents experimental studies, and analyzes obtained results within the framework of plasma-coal burner technology.
		4.3. The purpose and objectives correspond to the topic of the thesis: 1) correspond; 2) partially correspond; 3) do not correspond	The aim and research objectives are formulated clearly and align with the topic, focusing on the assessment of energy and ecological efficiency of plasma-coal burners at pulverized-coal thermal power plants. The tasks support the main research question and are coherently structured.
		4.4 All sections and provisions of the thesis are logically interconnected: 1) completely interconnected; 2) the interconnection is partial; 3) there is no interconnection	All sections of the dissertation demonstrate consistent logical structure—from the formulation of the problem, through numerical and experimental methodologies, to final conclusions. There are no incoherent or redundant sections.
		4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions: 1) there is a critical analysis; 2) partial analysis; 3) the analysis does not represent one's own opinions, but quotes from other authors	The dissertation undertakes a critical and well-reasoned comparison between plasma-assisted ignition with electrothermochemical preparation of low-grade coal and conventional ignition strategies such as fuel-oil co-firing commonly used at pulverized-coal thermal power plants. This analysis is not merely descriptive but examines the functional distinctions between the two approaches in terms of ignition stability, combustion dynamics, formation of highly reactive gas-phase intermediates, and sensitivity to fuel quality. In particular, the author highlights that plasma-assisted preparation enables the in-situ formation of synthesis gas ($CO + H_2$) and coke residue, significantly enhancing flame reactivity and reducing dependence on high-volatility auxiliary fuels. This is supported by the author's own modeling and experimental results, demonstrating syngas concentrations of industrial relevance and confirming the feasibility of replacing liquid fuel ignition systems for high-ash coals. Importantly, the evaluation extends to environmental and operational performance metrics. The author discusses the potential reduction of harmful emissions due to better burnout, decreased fuel oil consumption, and the inherent absence of sulfur- and nitrogen-bearing species in the electrical plasma energy input. The

			comparative assessment integrates numerical simulations, experimental burner data, and operational considerations associated with thermal power plant infrastructure, rather than relying solely on literature citations. As such, the comparison exhibits personal scientific reasoning, analytical autonomy, and the ability to contextualize research findings within broader technological and environmental frameworks relevant to modern thermal power engineering.
5.	Scientific novelty principle	5.1 Are the scientific results and provisions new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The dissertation presents new scientific results in the field of plasma-assisted ignition and partial gasification of low-grade coal, encompassing both thermodynamic and kinetic modeling outcomes as well as experimentally verified characteristics of dual-component fuel formation. The author demonstrates, through equilibrium thermodynamic calculations, the feasibility of converting high-ash coal into a mixture of combustible gases and residual carbonaceous solids under plasmatron-assisted heating, quantifying syngas composition, gasification degree, and specific energy consumption. Complementary kinetic modeling further elucidates transient devolatilization, heating rates, fragmentation processes, and ignition delays for pulverized coal particles exposed to plasma jets, providing insight into reaction pathways and time scales not accessible through equilibrium analysis alone. The scientific contribution is reinforced by experimental verification, in which the author validates several key predictions — including syngas formation, concentration ratios of CO and H_2, ignition behavior, and calorific value of the resulting highly reactive dual-component fuel (HRDF). These results collectively confirm that ETCPF (electrothermochemical fuel preparation) can significantly enhance coal reactivity at the burner outlet, enabling stable ignition without auxiliary liquid fuels. Taken together, the modeling–experiment synthesis provides not only a demonstration of feasibility, but also novel quantitative data that expand the scientific understanding of plasma–fuel interaction mechanisms, reaction kinetics, and partial gasification phenomena under burner-relevant conditions.

		5.2 Are the dissertation findings new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The findings concerning syngas formation, concentration levels of CO and H_2, and the identification of optimal operational parameters of the plasma-coal burner are presented for the first time specifically for high-ash coal under the electrothermochemical plasma preparation regime. The dissertation reports quantitatively that the plasma-assisted treatment of this fuel leads to the in-situ generation of a synthesis gas mixture with significant concentrations of CO and H_2, together comprising over one-third of the gaseous products at the burner outlet, as well as corresponding increases in the calorific value and reactivity of the resulting dual-component fuel. These experimentally validated data are novel for this coal type, which is widely utilized in CIS thermal power systems yet remains challenging to ignite using conventional fuel-oil-based methods due to its low volatile content and high ash fraction. Additionally, the author establishes for the first time the optimal thermophysical parameters (including average mass temperature, plasmatron power input, geometric configuration, and residence time) that enable efficient devolatilization, partial gasification, and subsequent ignition stability for Ekibastuz power plant coal. This parameterization is of practical relevance because it provides a basis for engineering design, scale-up, and integration of plasma-coal burners into existing boiler systems. The originality of these results extends beyond empirical reporting, contributing new baseline data for future modeling, techno-economic evaluation, and industrial deployment of plasma-assisted coal combustion technologies.
		5.3 Technical, technological, economic or management decisions are new and reasonable: 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The dissertation proposes new technical solutions that enable ignition and stabilization of pulverized-coal combustion without the use of auxiliary fuel oil by means of plasma-based electrothermochemical fuel preparation. This constitutes a significant advancement for the modernization of pulverized-coal thermal power plants, where ignition reliability and flame stabilization for low-grade fuels have traditionally required large quantities of expensive and environmentally unfavorable liquid

			fuels. By demonstrating that plasmatron-assisted preparation can convert low-grade, high-ash coal into a highly reactive dual-component fuel with sufficient syngas content to ensure rapid ignition and sustained combustion, the work provides a viable alternative pathway toward eliminating fuel-oil support systems, reducing operational costs, and decreasing associated emissions. From an engineering perspective, the proposed solutions address both the combustion-side and system-integration challenges associated with retrofitting plasma-coal burners into existing boiler architectures. The ability to ignite high-ash coal (used in Ekibastuz power plant) without auxiliary fuels directly supports the broader goals of the thermal power sector in CIS countries, where this coal dominates the fuel mix and where modernization is constrained by the cost and scarcity of fuel oil. The practicality of the proposed approach is strengthened by the identification of optimal operating regimes and by experimental validation under burner-scale conditions, positioning the technology as an applicable and economically relevant modernization measure rather than a purely theoretical concept. Overall, the dissertation provides not only scientific justification but also applied technological solutions with clear implications for reducing energy costs and improving energy security at coal-fired power facilities.
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 conclusions of the dissertation follow logically from the research objectives and are coherently structured in accordance with the sequence of numerical and experimental investigations. They are supported by results obtained from thermodynamic equilibrium modeling and kinetic reaction modeling using the verified software tools TERRA and PlasmaKinTherm, respectively. These tools are well established in the field for analyzing complex multi-component reacting systems and ignition kinetics, which enhances the methodological credibility of the numerical component. The conclusions are further substantiated by full-scale experimental validation of plasma-coal ignition and partial gasification processes in a burner-scale environment. The dissertation consistently demonstrates that the experimentally observed syngas formation,

			temperature fields, ignition behavior, and dual-component fuel characteristics are in qualitative and quantitative agreement with the predictions derived from the modeling framework. This high level of consistency between simulated and experimental results significantly strengthens the reliability of the findings and confirms their scientific validity. Moreover, the dissertation goes beyond mere correlation by using the modeling results to predict optimal operating regimes and then verifying these predictions experimentally. This iterative validation loop indicates a mature research approach in which simulations are not only interpretative but also predictive. The agreement between numerical estimates and measured data supports the robustness of the electrothermochemical preparation concept and provides confidence that the conclusions are not accidental or case-specific, but rather grounded in reproducible physical behavior relevant to plasma-assisted coal combustion.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately: 7.1 Is the provition proven? 1) proven; 2) rather proven; 3) rather not proven; 4) not proven 7.2 Is it trivial? 1) yes; 2) no 7.3 Is it new? 1) yes; 2) no 7.4 Application level: 1) narrow; 2) medium; 3) wide 7.5 Is it proven in the article?	**7.1 Has the position been proven? — 1) proven** The provisions submitted for defense are convincingly proven. They are substantiated through a comprehensive combination of thermodynamic equilibrium modeling, kinetic ignition simulations, and full-scale experimental studies of plasma-coal ignition processes. The dissertation demonstrates not only internal consistency of results but also cross-validation between numerical predictions and empirical measurements, which significantly strengthens evidential support. The methodological triangulation (TERRA + PlasmaKinTherm + experimental bench studies) provides a sufficiently robust basis for confirming the validity of the stated provisions. **7.2 Is it trivial? — 2) no** The provisions are not trivial, as they address complex and longstanding scientific and engineering problems associated with the ignition and sustained combustion of low-grade, high-ash coals — fuels that are traditionally characterized by low volatile content, poor ignition characteristics, and high dependence on auxiliary liquid fuels. The plasma-assisted electrothermochemical preparation

		1) yes; 2) no	regime represents a non-standard approach requiring interdisciplinary knowledge in combustion kinetics, plasma physics, fuel chemistry, and thermal power engineering. The results extend beyond routine parameter optimization and provide insight into syngas formation, reaction pathways, and ignition behavior under extreme heating rates that are not accessible in conventional burners. **7.3 Is it new? — 1) yes** The novelty of the provisions is clearly expressed and well justified. The demonstrated formation of synthesis gas ($CO + H_2$) and the identification of optimal operating parameters for plasma-coal burner ignition and partial gasification of Ekibastuz coal are reported in the scientific literature for the first time. Given the industrial relevance of Ekibastuz coal in the CIS energy sector, the results fill a knowledge gap at both the scientific and technological levels and establish a new reference dataset for future studies. **7.4 Level of use (applicability): — 3) wide** The provisions demonstrate broad applicability. Potential fields of utilization include: (a) research laboratories and R&D centers investigating plasma-assisted combustion; (b) modernization projects for pulverized-coal boilers in energy sector infrastructure; (c) integration into national and industrial energy efficiency and emission reduction programs; and (d) techno-economic assessments of alternative ignition systems for coal-fired thermal power plants. The possibility of eliminating auxiliary fuel oil ignition systems provides additional economic, environmental, and logistical benefits, enhancing the industrial attractiveness of the results. **7.5 Is it proven in publications? — 1) yes** The main scientific provisions have been presented in peer-reviewed journals and international conference proceedings, including publications recommended by national quality assurance committees and indexed papers with non-zero impact factors. This confirms that the scientific community has reviewed and accepted

			the core results, providing an additional layer of external validation and certifying the scientific credibility of the conclusions.
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 1) yes; 2) no	The methodology is well-justified and described in sufficient detail, combining thermodynamic and kinetic numerical modeling with full-scale experimental validation.
		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: 1) yes; 2) no	The research uses modern modeling tools (TERRA, PlasmaKinTherm), experimental instrumentation, and computerized data processing methods.
		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): 1) yes; 2) no	Theoretical predictions regarding syngas formation and combustion stabilization were confirmed by experimental studies, supporting the validity of the models and identified dependencies.
		8.4 Important statements are confirmed / partially confirmed / not confirmed by references to current and reliable scientific literature	Key statements are supported by references to contemporary and reliable scientific literature, including publications in indexed journals and conference proceedings.
		8.5 Used literature sources are sufficient/not sufficient for a literature review	The literature base (153 sources) is up-to-date and adequate for establishing the scientific context of the research.
9	Practical value principle	9.1 The thesis has theoretical value: 1) yes; 2) no	The work deepens theoretical understanding of plasma-assisted ignition and dual-component fuel formation mechanisms in low-grade coal combustion processes.
		9.2 The thesis is of practical importance and	The research enables the modernization of pulverized-coal thermal

		there is a high probability of applying the results obtained in practice: 1) yes; 2) no	power plants by reducing or eliminating fuel oil during startup and stabilization, thereby improving economic and ecological performance.
		9.3 Are the practice suggestions new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The proposed plasma-coal burner operating regimes and identified optimal parameters are reported for the first time for Ekibastuz coal and offer new technical solutions applicable to industrial boilers.
10.	The quality of writing and design	Academic writing quality: 1) high; 2) average; 3) below average; 4) low.	The text of the dissertation is clearly structured, logically coherent, and written in a scientific academic style. Terminology is used correctly, the narrative is consistent, and figures, tables, and references are well-integrated into the work.
11.	Notes on a thesis	The dissertation presents significant scientific and applied results in the field of plasma-assisted ignition and partial gasification of low-grade coal. The author successfully integrates thermodynamic and kinetic numerical modeling with experimental validation, which substantially strengthens the reliability of the conclusions and demonstrates an appropriate level of methodological maturity for doctoral research in thermal power engineering and plasma fuel preparation. At the same time, several substantive remarks can be formulated that may guide future development of the research: **First**, although the selected modeling tools (TERRA and PlasmaKinTherm) are technically adequate and recognized in combustion science and plasma chemistry, the assumptions embedded in the simulation framework would benefit from more explicit articulation. Topics such as heat-loss treatment, mixing uniformity, turbulence–chemistry interactions, and the handling of non-equilibrium plasma kinetics are addressed only briefly. More detailed exposition of model boundaries, validity domains, and sources of numerical uncertainty would increase the transparency, reproducibility, and interpretability of the computational analysis. **Second**, while the comparison between numerical predictions and experimental measurements is generally convincing, quantitative error analysis remains limited. The inclusion of confidence intervals, measurement uncertainties, or statistical deviation metrics (e.g., absolute or relative error for syngas composition, temperature profiles, or ignition delay) would allow the reader to assess the degree of model–experiment agreement more rigorously and evaluate claims of predictive fidelity. **Third**, the plasma–coal interaction process involves a cascade of transient thermochemical mechanisms, including particle heating, micro-fragmentation, devolatilization, homogeneous and heterogeneous gasification	

		reactions, and mixing-controlled ignition. The dissertation provides a solid qualitative description of these mechanisms, but a deeper kinetic analysis of devolatilization pathways, radical formation, or syngas composition evolution would enhance the scientific contribution, especially given that one of the core novelties concerns the formation of a dual-component fuel with specific CO/H_2 ratios and ignition characteristics. **Fourth**, the practical relevance of eliminating auxiliary fuel oil during boiler start-up and stabilization is clearly demonstrated; however, a dedicated techno-economic assessment is absent. Even a preliminary evaluation of specific electrical energy consumption versus fuel oil savings, payback time, operational cost impact, or CO_2/NO_x emissions reduction would significantly reinforce the industrial argumentation and support technology transfer to the power sector. **Fifth**, the question of scalability remains relatively underdeveloped. The dissertation convincingly demonstrates feasibility at laboratory or pilot scale, but additional discussion of scale-up constraints—such as plasmatron durability, coal feed variability, burner–furnace aerodynamics, slagging and fouling behavior, and plant-level integration—would strengthen the link between the experimental results and potential industrial deployment scenarios. **Sixth**, the literature review could engage more systematically with contemporary international research in plasma-assisted combustion of low-grade coals, particularly from Chinese and European groups where large-scale deployment of plasma-coal burners has been most active. A deeper comparison with these efforts would help contextualize the originality and industrial relevance of the present contribution within the global research landscape. These remarks do not detract from the scientific value of the dissertation; rather, they highlight promising directions for continued research and development that could further enhance both the scientific depth and industrial applicability of plasma-assisted coal fuel preparation technologies.
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 scientific level of each article of the doctoral student on the	not applicable

	topic of research)	
13.	Decision of the official reviewer (pursuant to paragraph 28 of the present Model Regulations)	The research work by Magzhan Orynbasar titled " Energy and ecological efficiency of plasma-coal burners: numerical simulation and experiment" meets all the standards established by the Committee for Quality Assurance in Science and Higher Education of the Republic of Kazakhstan for awarding the degree of Doctor of Philosophy. Magzhan Orynbasar is deserving of being 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:

D.Sc., PhD, Eng, Professor of IMP PAN
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