

PhD thesis review

Title: Experimental examination and development of innovative Eco-friendly insulation materials for highly-efficient solar thermal collectors

Reviewer: Dr. Georgina Tóth-Nagy

The research presents a novel approach to addressing challenges in solar water heating systems (SWHS) by proposing a multi-criteria decision-making (MCDM) model. It introduces eco-friendly insulation materials such as rice husk, stubble fiber, and coco-peat, contributing to its originality. By applying the Analytic Hierarchy Process (AHP) and Additive Ratio Assessment (ARAS) model, the study offers a systematic method for evaluating SWHS design alternatives. Additionally, it explores the impact of alternative insulating materials on heat transfer, providing practical value and aligning with sustainability goals. The study's robustness is enhanced through sensitivity analysis and validation against other MCDM techniques, bolstering its credibility for real-world applications.

The dissertation investigates how to improve the thermal performance of solar water heating systems (SWHS). The introduction clearly outlines the research context, motivations, and objectives. It emphasizes the importance of SWHS for sustainable energy solutions and economic development. The research questions are explicitly stated, focusing on the impact of two innovative approaches:

- Delta-shaped obstacles within the SWHS collector.
- Eco-friendly thermal insulating materials (rice husk, etc.).

These questions aim to understand how these features affect heat loss and overall SWHS efficiency. The introduction effectively highlights the originality of the study by mentioning these innovative approaches. It also establishes the significance of the research by linking energy availability to economic growth and underlining the advantages of solar energy. Overall, the introduction provides a strong foundation for the dissertation by effectively communicating the research context, objectives, and the importance of the chosen approaches

This literature review comprehensively examines advancements in solar water heating systems (SWHS). It covers diverse aspects like materials (PCMs, turbulators), designs, and methodologies. The review incorporates recent studies (2023) from various locations, ensuring its relevance and up-to-dateness. It explores a broad range of efficiency-enhancing approaches, including PCMs, turbulators, nanofluids, insulation materials, and various designs. This diversity strengthens the review's comprehensiveness. Real-world implications are highlighted by incorporating experimental findings, grounding theoretical discussions in practicality. The review effectively addresses key SWH challenges like cold-environment performance, economic limitations, and efficient energy storage, making the research more relevant.

However, there is always room for improvement. The review identifies research gaps regarding delta obstacles and eco-friendly insulation's impact on heat transfer. Evaluating methodological strengths and limitations, potential biases, and the generalizability of findings provide a more nuanced understanding.

The research methodology outlined in Chapter 3 provides a detailed account of the experimental setup and procedures for investigating the solar water heating system (SWHS) with delta obstacles. The research focuses on improving thermal efficiency, and delta obstacles are introduced as a potential solution. The chapter provides a detailed explanation of these obstacles, their influence on laminar boundary layers, and their ability to potentially increase thermal conductivity. The justification for choosing delta obstacles seems well-supported. The methodology employs decision-making techniques (CRITIC-COPRAS, AHP-ARAS) to evaluate and select the optimal SWHS design. The chapter describes the validation of the experimental setup and uncertainty analysis, including the comparison of experimental and predicted values using Kline and McClintock's method. The inclusion of eco-friendly insulating materials is relevant for addressing heat loss. The design considers various factors influencing SWHS performance, aiming to isolate the impact of delta obstacles. The chapter enhances the study's overall reliability by including uncertainty intervals and experimental errors for various measurements. Additionally, the detailed descriptions of procedures, measurements, and decision-making techniques contribute to a more robust methodology.

The results and analysis sections provide a comprehensive examination of the performance of solar water heating systems (SWHS) using different eco-friendly insulating materials. The results are presented in clear and well-organized tables. These tables effectively showcase the experimental data for various SWHS configurations concerning performance criteria (decision matrix tables) and the final ranking with optimal values (ARAS results). Figures effectively illustrate how key factors like outlet-inlet water temperature, ambient temperature, and solar radiation change over time for different insulating materials. Additionally, figures visually compare the thermal efficiency of various insulating materials with different thicknesses. The study employs the Spearman correlation coefficient to assess the reliability of ranking results under different weight scenarios for the chosen criteria. The consistently high correlation (>0.98) across all scenarios indicates robust ranking outcomes. The chapter clearly explains the prioritization of criteria weights using AHP and the subsequent calculation of consistency parameters (λ_{max} , RI, CR) to ensure reliable weight allocation. It then outlines the decision matrix formation, normalization, and weighted normalization processes involved in the ARAS method for final SWHS alternative ranking. The robustness of the MCDM (Multi-Criteria Decision-Making) results is assessed through sensitivity analysis. This analysis considers 18 different weight variation scenarios (by $\pm 10\%$, $\pm 20\%$, and $\pm 30\%$ for each criterion weight). The study validates the proposed ARAS technique by comparing the ranking results with other established MCDM models (TOPSIS, VIKOR, COPRAS). Consistent rankings across these models, confirmed by the Spearman's correlation coefficient, strengthen the reliability and validity of the obtained ranking. In conclusion, Chapter 4 provides a detailed and systematic analysis of the SWHS performance with various insulating materials. The clear presentation of results, informative visualizations, robust ranking with sensitivity analysis, and validation through other MCDM models all contribute to the strength of this chapter.

The discussion effectively interprets the results obtained from the analysis, linking them back to the research questions and objectives. The ranking of SWHS alternatives based on performance criteria (Nusselt number - N_{udh} , collector efficiency factor - f_{dh} , thermal efficiency - η_{dh}) is clearly interpreted. The discussion explores the implications of these results, considering the sensitivity analysis and the robustness of the proposed ARAS model. Identifying the most and least sensitive alternatives to weight changes provides valuable insights into the model's behavior. The comparison of ARAS with other MCDM (TOPSIS, VIKOR, COPRAS) techniques is thoroughly discussed. Consistency in ranking across models is highlighted, and Spearman's correlation coefficient is used effectively for validation. The impact of varying weight allocations on the ranking is well-elaborated. Recognizing specific

alternatives as most susceptible to weight changes offers valuable insights. The discussion acknowledges limitations related to potential inaccuracies in MCDM approaches under changing conditions and evolving expert opinions. This transparency strengthens the study's credibility. The conclusions align with the results and discussions, summarizing the key findings and their practical implications. The identification of design A12 as the optimal configuration for enhanced SWHS performance is well-supported by the evidence presented earlier.


The thesis has a clear structure, with distinct sections such as Introduction, Literature Review, Methodology, Results, Discussion, and Conclusions. Each section is appropriately titled, aiding the reader in understanding the organization of the thesis. Ideas flow smoothly with clear and concise language throughout. The introduction effectively sets the stage for the research, and the literature review provides a strong foundation. The detailed methodology section clearly explains the research design, data collection, and analysis procedures, including equations and tables for transparency. The results are clearly presented with tables and figures, coupled with thorough analysis using appropriate statistical methods and sensitivity analysis. The discussion logically interprets results and links them back to research questions. Conclusions are well-supported by evidence and summarize key findings. The strategic use of tables, figures, and graphs enhances data visualization, with clear captions and references.

This thesis demonstrates a strong command of writing style and language, contributing to its overall quality. Complex ideas are conveyed effectively without unnecessary complexity. Well-structured sentences enhance readability. Formality and objectivity are maintained throughout, using appropriate academic language that strengthens credibility. Technical terms are used accurately, demonstrating subject-matter expertise. A balance is struck between technical details and accessibility for a broader audience. Minimal grammatical and syntax errors are observed. Varied sentence structures contribute to the writing's fluency. No significant typos or formatting inconsistencies were found, indicating a polished presentation. The writing style remains consistent across the thesis, ensuring a cohesive experience for the reader. Citation style and formatting guidelines are followed consistently. The author effectively engages the reader by clearly articulating arguments and providing sufficient context for complex topics. Citations and references are appropriately integrated, adhering to the designated style. A comprehensive reference list indicates a thorough literature review.

During the pre-defense the doctoral candidate was able to provide satisfactory answers to all my questions, and incorporated them into the final version of the thesis, so I do not have any further questions for them.

Overall, I recommend **accepting** the thesis and the doctoral candidate's work.

Date: Veszprém, 16/05/2024


Signature
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