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Review of the doctoral dissertation of M.Sc, Eng. Hamza Mumtaz

Title: „Experimental analysis of the waste hydrothermal treatment process".

This review was prepared on the basis of the Resolution of the Discipline Council of Environmental Engineering, Mining and Energy of the Silesian University of Technology of 25.09.2025 r.

1. Characteristics and structure of a doctoral dissertation

Doctoral thesis of M.Sc. Eng. Hamza Mumtaz entitled "Experimental analysis of the waste hydrothermal treatment process" was carried out at the Faculty of Environmental and Energy Engineering in Gliwice.

The thesis supervisor is Prof. Sebastian Werle, and the auxiliary supervisor: Dr Eng. Szymon Sobek. This dissertation takes the form of a series of publications. A collection of publications included in the doctoral dissertation of M.Sc. Eng. Hamza Mumtaz has 7 publications connected thematically, is an original solution to a scientific problem, and contains articles published in journals from part A of the list of scientific journals of the Ministry of Science and Higher Education. Importantly, in all 7 publications, the doctoral student M.Sc. Hamza Mumtaz is both the first author and the corresponding author.

The dissertation in the form of a publication series consists of 8 main chapters and a bibliography. It consists of 102 pages plus a list of references, a list of tables and drawings, and 7 original publications on the basis of which the thesis was written.

The reviewed doctoral dissertation opens with a chapter titled "introduction", which is a justification for undertaking the dissertation. It contains many valuable observations on the issue of plastic waste and its processing methods, including the method of oxidative liquefaction of polymers. The second chapter contains a description of the materials and methods used to analyze the oxidative liquefaction process, research methods and methods of analyzing the properties of products and by-products obtained from this process. In the third chapter, the doctoral student analyzed the valorization process through oxidative liquefaction of polymer and composite waste from wind turbine blades, and the analysis of the physical and chemical properties of the process products was also included in this chapter. The fourth chapter presents an extension of the analysis of the process of oxidative liquefaction of polymer waste, focusing on methods to improve obtaining a larger amount of final products generated during the process of oxidative liquefaction of wind turbine blade elements, improving the kinetics of this process and precise characteristics of by-products that can be recycled.

The aim of the presented doctoral dissertation in the form of a series of works was a detailed analysis of the process of oxidative liquefaction of polymers as a method of selective degradation of polymer waste, composites from wind turbine blades, personal protective equipment used in the medical sector, used photovoltaic panels and municipal waste. The main PhD project results have shown that for each waste stream, emphasize the inherent versatility and adaptability associated with HTL. PhD candidate has proven the capacity of oxidative liquefaction to recover clean, reusable fibers but also has identified the main potential problems which can occur during the re-scaling HTL process closer to industrial scale.

The doctoral student adopted the following main research thesis for the assessed doctoral dissertation: Oxidative liquefaction is a suitable method for selective degrade polymeric waste, facilitating the production of liquid chemical compounds and valuable secondary materials.

In the fifth chapter, the PhD student presented in a very accessible and transparent way a description of the comparative research and thermal-chemical valorization of polymer waste, composites from wind turbine blades compared to personal protective equipment used in the medical sector, using thermogravimetric analysis to determine the optimal

conditions for the process of oxidative liquefaction of polymers: process temperature, pressure, residence time, ratio of waste to the liquid phase, concentration of oxidizing compounds in order to obtain the highest efficiency. energy of the entire process.

Poland, problems related to the selective collection of municipal waste, its type, composition and methods of municipal waste conversion, including an analysis of the conditions for the valorization of this waste using the oxidative liquefaction method.

In chapter seven, the PhD candidate has analyzed oxidative liquefaction processes for MSW and PPES. He got the conclusion from this experimental work described in that chapter: oxidative liquefaction represents a viable method for the valorization of polymeric waste types to enhance both efficiency and sustainability.

The last, eighth chapter is a very compact summary and conclusions. The summary indicates the most important areas in which research is conducted by the doctoral student. Based on them, the PhD student formulated the following conclusions:

1. **Oxidative liquefaction as a versatile recycling technology**: The HTL process enables the breakdown of polymers, recovering the useful resources and generating valuable secondary compounds, making it a noteworthy option for waste valorization;
2. **Material-specific degradation efficiency:** The effectiveness of HTL is significantly influenced by the composition of waste material. The results highlight the necessity for customized reaction conditions based on the specific types of waste involved;
3. **Recycling of fiber-reinforced composites:** oxidative liquefaction is capable of efficiently recovering high-quality glass fibers from composite waste by selectively degrading the polymetric matrix while maintaining the integrity of the fibers;
4. **Influenced by reaction parameters on product yield:** through experimental optimization, it was determined that temperature, oxidant concentration, and waste to-liquid ratio are the key parameters significantly impacting polymer degradation and OCC formation during the HTL process;
5. **Thermal behavior of process energy dynamics:** the inverse analysis of process heating has established that HTL process exhibits partial exothermicity mainly

because of the decomposition of peroxide, with the degradation of polymers providing supplementary heat in addition to the energy supplied externally;

6. **Comparative waste stream analysis;**
7. **TSR/TPD and OCCs yield as performance indicators;**
8. **Scalability and industrial feasibility considerations:** HTL in larger industrial scale problems: energy demands; the variability of waste materials; and the management of inorganic residues;
9. **Environmental and circular economy implications;**
10. **Future research directions:** using catalysts for future HTL process.

At the end of the dissertation, the doctoral student included all 7 publications in it's original form. It is clear that at this stage of work, the PhD student has properly reviewed the content available in the literature and that the topic he has undertaken is a continuation and extension of the research described in the analyzed sources.

2. Scope of work, purposefulness of tackling the topic

Reviewed doctoral dissertation by M.Sc. Eng. Hamza Mumtaz titled "Experimental analysis of the waste hydrothermal treatment process" concerns a very important issue of environmental engineering - minimizing energy consumption in waste processing processes, intensifying the process of thermal and chemical valorization of plastic waste.

The PhD student made a very interesting choice of the topic of his PhD, the HTL process is a very important issue for many reasons. The domestic energy sector and the waste recovery and regeneration sector are key pillars of the economy, which in the era of high energy prices are more important issues for reasons of the country's energy security.

The application of HTL is very wide: it is a new solution, however, consistent with generally used practices and industrial trials used in the industry to recover by-products and produce energy from waste.

This doctoral thesis of Hamza Mumtaz, M.Sc., fits perfectly into the trend of minimizing energy consumption for the waste valorization and contains many new elements, not previously analyzed in known works in this field. Therefore, it can be

considered that this is a work whose topic and scope have been accurately selected, because it concerns an important problem of engineering and environmental protection, energy management in production processes.

In light of the research results presented by the PhD student and the conclusions formulated at the end, it can be concluded that the main goal adopted in the doctoral thesis has been achieved, and the adopted research thesis has been proven. Taking into account the current state of knowledge in the subject area of research, I consider it the original scientific achievements of the PhD student.

3. Critical remarks

Scientific and applied value of the dissertation

The presented doctoral thesis is characterized by a good logical structure, the doctoral student has maintained the correct order of chapters and the proportions between them, which allows her to easily follow the research methodology and quickly interpret the results of the work.

Comprehensively assessing the doctoral dissertation, Ms. M.Sc. Eng. Hamza Mumtaz should be told that:

1. The topic of the doctoral dissertation was correctly defined and its selection was exhaustively justified.

2. The selection of literature is well made and consistent with the scope and thematic area of the work.

3. The dissertation has a good, correct structure, the correct order of chapters, completeness of objectives, theses and justified conclusions.

4. The doctoral student correctly developed and described the research methodology.

5. The doctoral thesis is novel, technological and multi-threaded. The presented research allowed for creative development of technological issues and obtaining practical results allowing the use of the obtained results.

6. The work definitely represents an original solution to a scientific problem.

7. The high application value of the analyzed dissertation allows the implementation of practical solutions in the field of waste HTL conversion directly into industrial practice.

8. The obtained research results confirmed the theses and allow us to conclude that the aim of the work was achieved

9. The results and results obtained in the dissertation, also confirmed by scientific articles, can be considered important and important in the disciplines of environmental engineering, mining and energy.

Reviewed doctoral dissertation by M.Sc. Eng. Hamza Mumtaz was developed in a thoughtful and orderly manner. The assessed dissertation is written in a concise, understandable language, and the way of presenting both the author's state of knowledge regarding conversion methods using HTL and processes is unquestionable. As for the final conclusions formulated by the PhD student, they are described synthetically and do not raise any objections to me. It should be noted that reading the doctoral thesis allows us to conclude that there are some small deficiencies in several areas analyzed by the PhD student. **In my opinion, to achieve a higher quality of work, Phd student could improve his work by answering several comments:**

1. Adding an analysis of differences related to the scaling of the HTL process carried out in laboratory conditions to industrial research (e.g. with discussion in detail the review of available reactors for the HTL process operating at least on a pilot scale, describe differences in their designs, discuss the method of heat transfer to the valorized material, describe the advantages and disadvantages of individual types of reactors and describe future planned work in the field of further scaling of the HTL process);

2. Please answer the question whether it is possible to carry out the presented research on the HTL process on a laboratory scale or on a pilot scale in the near future, or does the PhD student have a plan to further research on the HTL process on a scale similar to the industrial scale.

3. Presenting a shortened SWOT analysis of the HTL process of the examined waste, taking into account problems occurring on a laboratory scale and potentially occurring technical problems (based on literature analysis and own experience).

4. What kind of catalytic upgrading and energy recovery in the HTL process Phd candidate has in mind to improve the overall efficiency and decrease energy input?

Could be possible to describe more briefly the types of catalyst that would be possible apply for HTL and further working plan in this area?

5. Could the PhD candidate mention the 3 most important advantages of the HTL process of wind turbine blends over the classical pyrolysis process?

6. If this is possible please explain how does HTL process of polymer and composite waste from wind turbine blades have been advantages over HTC process?

7. How do you see the positioning of HTL technology in the process of utilizing photovoltaic panels? What technological and economic risks do you foresee in this process for HTL technology?

8. Please present your research plans for the coming years related to HTL technology. Do you plan to work on the disposal of other types of waste, e.g. textile waste?

According to the reviewer, despite the critical remarks formulated above, it is a very good work that brings new elements to our knowledge of waste conversion methods. My comments and questions do not diminish the scientific value of the presented study. This is work with great application potential and high probability of being used to achieve higher profitability of production processes related to waste conversion.

4. Conclusions

Despite several critical remarks, the reviewed doctoral dissertation by M.Sc. Eng. Hamza Mumtaz should be assessed very positively. It is related to an extremely important area of engineering and environmental protection - thermal-chemical conversion of waste and reduction of energy consumption during their processing. The work is coherent, well-thought-out, orderly and constitutes a significant novelty in the field of environmental engineering.

The work is an original solution to a scientific problem. The doctoral student has demonstrated the ability to independently conduct scientific work by planning an experiment, formulating research theses, conducting research and drawing conclusions from the research conducted.

The prepared dissertation proves that the doctoral student knows and masters the scientific and research work well and has considerable knowledge in the field of the represented specialty. I declare that the comments formulated in this review are of an

editorial and discussion nature and do not reduce the value of the reviewed work, which meets the requirements for doctoral dissertations.

In the light of the above, I declare that the doctoral dissertation submitted for evaluation by M.Sc. Eng. Hamza Mumtaz, prepared under the supervision of Prof. Sebastian Werle, meets all the requirements for doctoral theses of the Act of July 20, 2018 - Law on Higher Education and Science (Journal of Laws of 2022, item 574, as amended). The doctoral dissertation presents the candidate's general theoretical knowledge in the disciplines of environmental engineering, mining and energy and confirms the doctoral student's knowledge, M.Sc. Hamza Mumtaz's ability to independently conduct scientific work. This doctoral dissertation is an original solution in the field of applying the results of own scientific research in the economic sphere.

In connection with the above, I am requesting the admission of M. Sc. Eng. Hamza Mumtaz to further stages of the procedure for awarding the degree of Doctor of Engineering and Technical Sciences in the discipline of Environmental Engineering, Mining, and Energy. At the same time, due to the originality of the research presented in the thesis, the high quality of the research presented, the prestige of the journals on which this doctoral thesis is based, its wide scope, as well as the importance for the development of the area related to waste utilization and energy production, **I am requesting that this doctoral thesis be distinguished.**

Podpisał Szymon Szufa