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REVIEW

of the doctoral dissertation by Reddy Babu Siddareddy, MSc Eng.

entitled "Transient engine simulations using the stochastic reactor model for driving cycle performance studies"

1. Formal basis for the review

The basis for the preparation and issue of the present review is Resolution No. 239/2025 of the Discipline Council for Environmental Engineering, Mining and Power Engineering at the Silesian University of Technology in Gliwice dated 23 October 2025 (reference number RDISGE.0211.239.2025) on the appointment of reviewers for the doctoral dissertation of Mr Reddy Babu Siddareddy, MSc, Eng., entitled as above.

2. Subject and assessment of the scientific significance of the dissertation

The development of the automotive industry over the last few decades, like many other areas of the economy and social life as a whole, has been strongly influenced by environmental protection considerations and the minimisation of its negative impacts on public health and quality of life. Such activities are of particular importance in the economic area of the European Union. Among the most undesirable effects generated by road transport in this area, the first to be mentioned is the emission of harmful exhaust components resulting from the operation of vehicles, the vast majority of which are still powered by internal combustion engines. Despite the rapid development of electromobility, many analyses and observations indicate that the combustion engine will remain the primary source of power in road transport for many decades to come, especially in heavy-duty transport, the power source for commercial vehicles and machines used to perform various types of engineering and special tasks, dual-purpose vehicles and in the area of critical tasks.

The above-mentioned conditions were properly recognised by the Author of the doctoral dissertation and prompted him to undertake specific research. This dissertation by Mr Reddy Babu Siddareddy, MSc, entitled "Transient engine simulations using the stochastic reactor model for driving cycle performance studies", was completed under the scientific supervision of Prof. Wojciech Adamczyk, PhD, Eng., and with the substantive and methodological support of the assistant supervisor, Dr Michał Pasternak, PhD, Eng., covers the area of advanced simulation research on internal combustion engines. A characteristic feature of the operating conditions of internal combustion engines in traction drives is the variability of load and rotational speed across their entire range of operating parameters. **This makes it all the more important for the Author to adopt as a specific objective and scope of work the development and validation of a mathematical model and a set of tools for simulating transient engine operation, mainly for the purpose of mapping driving tests, and in combination with chemical reaction kinetics models, also for predicting harmful exhaust emissions. In particular, the developed programming architecture allows for its integration into various simulation platforms and its use for autonomous simulation and real-time modelling and the construction of so-called digital twins.**

It can therefore be concluded that the doctoral dissertation presented by Mr. Eng. Reddy Babu Siddareddy fits into the interesting and current areas of cognitive and applied research in technical sciences in the field of motor vehicle

drive systems, in particular research on improving the energy efficiency and emissions of internal combustion engines in transient operating conditions.

3. Characteristics of the dissertation and assessment of the methodological aspects – editorial comments

3.1. Subject matter and structure of the dissertation

The doctoral dissertation under review contains a study section based on an analysis of available source material related to the subject matter of the dissertation, as well as an experimental-validation part, the aim of which was to develop and experimentally verify a unified toolchain based on a zero-dimensional stochastic model of the combustion process (SRM) integrated with the apparatus of so-called tabulated chemistry and the formation of combustion products. The argumentation and expected cognitive, and mainly application-related, effect of choosing and developing this particular topic and method of work implementation was to achieve a computational compromise between a very accurate and detailed representation of the physical and chemical modelling of the engine's working cycle and a reduction in computation time, which in practical application would create the possibility of modelling processes in real time in order to improve the energy and environmental efficiency of existing engines, including in transient conditions, and testing twin model and real objects in WLTC approval driving cycles for compliance with exhaust emission standards, thereby shortening the product development cycle.

The work is written in English, generally using correct syntax and technical and industry terminology, in a manner that allows for proper reception and understanding of the content, especially for readers familiar with contemporary automotive issues. The abundance and frequency of abbreviations and symbols, without citing their full terminological and semantic meaning, is noteworthy, which was probably due to the Author's desire to convey the widest possible range of accepted theses, data used, research conducted, results obtained, conclusions, etc., within the acceptable volume of the work. The list of abbreviations and symbols used at the end of the work, together with their descriptions, partially compensates for this inconvenience for the reader.

The entire study contains 118 pages of text in US Letter/A4 format, plus a title page, a one-page summary and a table of contents. The work includes 86 drawings and photographs and 20 tables - the illustrative material is mostly legible and of good graphic quality. The dissertation is divided into five main chapters, including a chapter containing an introduction to the topic of the work and a summary. The chapters, which constitute the substantive core of the work, are expanded with several subchapters and closed with the most important conclusions. A list of references is provided at the end of the dissertation. **The bibliography contains 106 numbered items, several of which are listed twice (items 26 and 101, items 27 and 44, items 35 and 38, and items 37 and 68), which actually gives 102 items cited in the dissertation.** Several of these are co-authored works by the doctoral student, resulting from the research conducted for this dissertation and constituting the editorial core of selected sections of the work - they include 6 items from the main bibliography and 4 additional items, including conference materials.

Chapter 1, "*Introduction*," provides a general introduction to the subject matter of the dissertation, presents the scientific background, justifies the Author's motivation for choosing the main topic of the work, and outlines the research plan. The Author identifies the primary scientific and practical goal of the dissertation as filling the gap between highly accurate and detailed physical modelling of combustion in piston engines and the practical application of effective real-time modelling and simulation of engine operating and control processes in transient states. This gives rise to the concept of developing and validating an integrated toolchain comprising the implementation of a zero-dimensional stochastic combustion model (SRM) with tabulated combustion chemistry, together with a Model-in-the-Loop (MiL) and Hardware-in-the-Loop (HiL) platform to open, industrial FMI/FMU programming standards for use in simulation studies of transient operating conditions in WLTC driving cycles. The Author points out the potential and justifies the choice of a zero-dimensional combustion model in terms of calculation speed, which is critical in the light of the assumed objective of the work.

Chapter 2, entitled "*Literature review*", provides a synthetic overview of internal combustion engine modelling tools and systems based on application examples described in the literature. Models with varying degrees of detail in the representation of physical phenomena are presented, i.e. zero-dimensional, quasi-dimensional, one-

dimensional and three-dimensional models with full CFD flow-geometric analysis. In this chapter, the author positions the stochastic reactive model (SRM) as a compromise, zero-dimensional physical model capable of representing key combustion mechanisms (turbulence, charge stratification) at an acceptable cost and computation time. The possibility of using modern FMI/FMU programming platform standards in simulation processes of complex systems in the context of automotive applications is also indicated here. The chapter concludes with a discussion of MiL and HiL real-time concurrent operational platforms, presenting their capabilities in the development of control and virtual calibration of real and digital objects. Data processing models based on artificial neural network learning are also described, although they do not constitute the main application focus of the work.

The content of the chapter, whose purpose in any scientific work of this type is to present the state of knowledge and technology as comprehensively as possible, should be considered sufficient and adequate for the subject of the dissertation. It concisely shows the evolution of simulation tools and justifies the need for a compromise between the accuracy of physical phenomenon mapping, computational cost and the possibility of real-time operation.

Chapter 3, entitled "*Methods and tools*", forms the methodological core of the dissertation. The Author formally describes the structure of the SRM combustion model, the mixing, fuel injection, charge exchange and turbulence models used, flame propagation, heat transfer processes, the idea of tabulated combustion chemistry, and computational implementation, together with the specifics of their application to simulate the operation of compression ignition and spark ignition engines. It should be recognised that operating with so many computational structures, combined with their mutual integration and integration with the FMU data exchange platform enabling their use in MiL/HiL simulation environments, despite the limited presentation, demonstrates the Author's excellent knowledge of the theoretical foundations and structure of mathematical models of engine working processes and engineering programming tools.

An important indication resulting from Chapter 3 is the use of the SRM stochastic combustion model, previously applied mainly in modelling steady states and tabulated combustion chemistry using the combustion progress variable (CPV), which the Author justifies by the need to reduce the cost of calculations. It was pointed out that full chemical kinetics would prevent real-time operation, which is a rational and well-argued methodological compromise. However, the reader may feel somewhat unsatisfied by the lack of a broader justification for the choice of empirical model parameters and their impact on the quality of the simulation results, which could undoubtedly strengthen the methodological credibility of the work in the context of its application objective.

Chapter 4, entitled "*Results and discussion*", which summarises the Author's achievements, contains a set of data representing the results of the simulation and validation of the model(s). The Author begins with the validation of an integrated simulation platform in MiL/HiL simulation mode for a vehicle with a spark ignition engine performing the WLTC driving cycle. Here, a high convergence of the cumulative emission indicators of exhaust components and the maximum combustion pressure values was confirmed.

In the next test, a compression ignition engine model was simulated. During the model calibration phase, the operating conditions at the operating points of the stationary test were implemented. The model configured in this way was then used to simulate engine operation according to the WLTP driving test. In this case, too, the instantaneous parameters and cumulative exhaust emissions show satisfactory agreement, in particular the values and trends of CO₂ and NO_x emissions. CO, HC and PM emissions, on the other hand, were within the lower limits of the measurement uncertainty ranges. The results obtained therefore confirm the physical correctness of the implemented SRM model, its numerical stability and the continuity of the predicted simulated values.

Subsequent simulations are aimed more at demonstrating the simulation capabilities of the developed toolchain in specific engine applications and integration with other models. We therefore have an attempt to simulate a cold start of a CNG gas engine in a modified WLTP test when fuelled with different fuels with different calorific values and reactivity (enriched with hydrogen) and for different ambient temperatures. The effect of changes in the air

excess ratio was also analysed. In this case, too, the model calibration stage was performed for fixed engine operating conditions. In the fourth test, test conditions specific to off-road vehicle engines were adopted.

Next, the capabilities of the developed toolchain for simulating a dual-fuel engine – powered by ammonia and fatty acid methyl esters (biodiesel) – equipped with a selective catalytic reduction (SCR) system for nitrogen oxides were demonstrated. The final stage of the work was to compare the quality and results of the SRM model simulation with self-calibrating models using artificial neural networks.

In summarizing this concluding chapter of the dissertation, it is important to emphasize the extensive scope and the complementary nature of the research conducted, which remains consistent with both the scientific and utilitarian objectives. Furthermore, the simulation results reflect the experimental data with satisfactory accuracy, allowing for a justified extrapolation of their informative content.

In **Chapter 5**, entitled "*Summary*", the Author presents a synthesis of the achievements in the field of simulation tool design, their implementation in integrated programming environments, and the simulation results obtained against the background of experimental data. The final conclusions are consistent with the results presented and maintain an appropriate interpretative balance.

The structure of the work is therefore logically correct, thematically coherent and complementary in its content. The Author consistently develops the relatively unique topic, starting with an analysis of the current state of knowledge and technology, identifying potential areas for research and development and possible gaps in knowledge in the analysed field, and justifying the adopted objective of the work and the proposed design of the simulation tool chain. Then, through simulation and experimental research, recording and analysis of results, he validates the developed tools and formulates substantively correct conclusions. The formal description and illustrative material included in the dissertation concerning the subject of the analysis and the results obtained (tables, graphs) are mostly legible, which allows for their correct interpretation. In terms of methodology, the dissertation is therefore a scientific work that meets the requirements of research work, including doctoral dissertations in the field of engineering and technology.

3.2. Editorial and detailed comments

As mentioned above, the dissertation has been edited with exceptional care, using generally correct syntax and linguistic norms and terminology, which allows for a full understanding of the content, both in general technical and specialist terms. There are no significant editorial comments to be made, apart from a few observations and errors that have been noticed (overuse of full stops at the end of phrases, e.g. titles of figures, tables, "gluing" of words), which, however, in no way detract from the substantive value and highly positive reception of the work. They do not require any particular discussion, only correction in the event that the content of the work is used as source material, e.g. for subsequent publications.

4. Substantive assessment of the dissertation and comments for discussion

The doctoral dissertation should be assessed very positively in terms of its substantive content. First of all, the choice of a current and at the same time unique research topic in the light of the present state of development of internal combustion engine technology, where transient engine operating conditions still pose a significant measurement and research challenge, but also a challenge in terms of durability and operation, deserves to be emphasised. Hence, the cognitive effects obtained in the dissertation are significant, both from the point of view of improving the quality of existing technical solutions and in terms of the possibility of developing modern, environmentally friendly combustion engine power sources.

In particular, considering the specific achievements presented in the dissertation, the positive assessment includes, among others:

- an in-depth and detailed analysis of the issues related to the developing technologies of simulation of transient engine operating conditions and real-time simulation (including the construction of digital twins),

- justified determination of the objective and scope of work, and an appropriate choice of toolchain structure for further research,
- completion and implementation of advanced simulation models based on a stochastic engine working cycle model supplemented with an innovative tabulated combustion chemistry model, which allows for a significant reduction in simulation time,
- highly complex nature and complementary scope of the simulation studies performed, which were verified with experimental data, providing the Author with important cognitive and validation data,
- a synthetic presentation of the research methodology and tools used,
- clear analysis and substantive discussion of the simulation results obtained,
- accurately formulated cognitive and utilitarian conclusions and identification of areas of application for the potential use of the developed simulation tools.

The doctoral dissertation of Mr Reddy Babu Siddareddy, MSc, Eng., is therefore a valuable scientific study that undoubtedly makes a significant contribution to the development of the methodology and instrumentation of internal combustion engine research, especially in the field of transient state optimisation. The Author has successfully combined extensive theoretical knowledge with the effective implementation of simulation research, demonstrating professionalism and attention to the proper communication of information. However, the work strongly emphasises the "technical and tool-related" aspect of the achievements, and the Author's indication of the significant scientific value of the work and the novelty of the research leaves something to be desired. This carries with it the potential risk of the work being interpreted as mainly integrating advanced, but existing and known resources of knowledge and technology. Hence, certain questions naturally arise, to which the doctoral student is expected to refer during the public defence of his doctoral dissertation, namely:

- what do the uniqueness and scientific added value of the simulation tools developed by the doctoral student consist in;
- why a stochastic model of the SRM engine cycle was chosen as the core of the tool chain and not, for example, another variant of a zero-dimensional (or quasi-dimensional) model or a one-dimensional model;
- what are the main limitations of using the tabulated combustion chemistry model and how they may affect the functionality of the tool chain developed by the doctoral student;
- To what extent does the doctoral student assess the accuracy of the developed model in mapping the dynamics of rapidly changing processes in the engine operating cycle – which processes does it map better and which not so well?
- what level of computational delays relative to the clocking time of vehicle controllers in HiL mode has been observed;
- what are the actual limits of applicability/functional limitations of the developed toolchain in relation to compression ignition and spark ignition engines;

The above comments and questions are purely for discussion purposes – they may result from the reviewer's subjective assessment or the need to supplement or emphasise the essence of a given problem or issue by the Author of the work, as the most knowledgeable person on the subject and its scope.

It should also be noted that the above observations in no way affect the positive reception and generally very high assessment of the dissertation as a whole, which prompts the reviewer to submit a motion to the Discipline Council for Environmental Engineering, Mining and Power Engineering at the Silesian University of Technology to admit the dissertation to its public defence.

5. Summary of the assessment of the doctoral dissertation and final conclusions

The doctoral dissertation entitled "Transient engine simulations using the stochastic reactor model for driving cycle performance studies" by Reddy Babu Siddareddy, MSc, Eng., is in line with current trends in research and development of internal combustion engines in motor vehicles and machinery.

The doctoral dissertation is an original scientific study and presents the current level of scientific and engineering knowledge as well as an interesting methodological solution for achieving the scientific goal and demonstrating the validity of the assumptions covered by the dissertation.

The doctoral student demonstrated knowledge of complex research issues, the ability to construct advanced programming and simulation tools, the ability to conduct research experiments, analyse results and formulate conclusions correctly. This demonstrates the Author's well-established theoretical knowledge and competence to conduct independent research in the field of engineering and technical sciences, in particular in the area of engine and motor vehicle research, especially in unstable engine operating conditions.

In summary, I conclude that **the doctoral dissertation of MSc Eng. Reddy Babu Siddareddy entitled "Transient engine simulations using the stochastic reactor model for driving cycle performance studies" meets the conditions defined in the Act of 20 July 2018 Law on Higher Education and Science"(Journal of Laws of 2018, item 1668, as amended) and on this basis, I request that the dissertation be accepted and admitted for public defence before the Discipline Council for Environmental Engineering, Mining and Power Engineering at the Silesian University of Technology in Gliwice.**

At the same time, considering the high substantive level of the dissertation, its multifaceted and complementary research character, I request that the doctoral dissertation of Mr Reddy Babu Siddareddy, MSc, Eng., under the above-mentioned title, be awarded a distinction, provided that other conditions regarding the rules for awarding distinctions to doctoral dissertations adopted at the University are met.

Rzeszów, 16 February 2026

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