REVIEW

of the dissertation submitted for the award of the educational and scientific degree "Doctor"

Author of the dissertation: M.Eng. Daniel Zdravkov Ivanov
Title of the dissertation: *Investigation of the Braking Performance of a Vehicle with Internal Combustion Engine*
Field of study: 5.1. Mechanical Engineering
Doctoral program: Internal Combustion Engines
Reviewer: Assoc. Prof. Dr. Yaroslav Borisov Argirov, TU–Varna

1.Relevance of the research problem from a scientific and applied science perspective. Degree and scope of the relevance of the problem and the specific tasks addressed in the dissertation.

With the advancement of the automotive industry and the implementation of new technologies such as electric and autonomous vehicles, braking systems must meet new requirements and challenges. Research in the field of braking systems plays a crucial role in the improvement and integration of both traditional and novel technologies. These studies provide the basis for understanding the interaction between different systems and for developing optimal solutions that meet contemporary safety, efficiency, and reliability standards.

Braking systems contribute significantly to both vehicle safety and environmental sustainability. The improvement of braking deceleration is a key aspect that not only enhances braking efficiency but also helps reduce emissions and component wear—factors essential for sustainable development.

The foundation for developing automated systems that support drivers through early warnings and autonomous influence on the braking system is built upon extensive data collected from experimental studies of actual braking parameters and phases. This information is critical for understanding braking dynamics and developing effective algorithms for automatic control.

The availability and relevance of data on braking process functioning and phases are fundamental for the development and optimization of automated safety and control systems. They ensure a higher level of safety, efficiency, and sustainability of transport technologies while supporting the achievement of greater intelligence in the automotive industry.

The main objective and tasks outlined in the dissertation, along with the means and methods employed for their resolution, are both contemporary and relevant.

2.Does the doctoral candidate demonstrate awareness of the problem and a creative evaluation of the literature?

The list of literary sources includes 116 titles, presented in both Cyrillic and Latin alphabets. The analysis of the presented work reveals in-depth knowledge and high professionalism in the field of dynamic vehicle characteristics research methods. Particular attention is paid to the investigation of braking torque dynamics, which demonstrates

excellent understanding and a creative approach in analyzing the causes of fluctuations in vehicle deceleration characteristics.

The critical analysis carried out shows that the doctoral candidate has conducted thorough and detailed research on braking system processes and methods for determining vehicle acceleration parameters. He demonstrates solid knowledge of the topic addressed in the dissertation, thus confirming his high competence and serious approach to research.

3.Is the chosen methodology capable of answering the research questions and objectives of the dissertation?

The developed high-frequency synchronous data acquisition system, combined with the use of sensitive sensors, has enabled the acquisition of accurate values for dynamically occurring processes. The constructed experimental setup, along with the methods for preliminary and subsequent data processing, further supports the reliability of the study. Moreover, the implemented method for identifying braking phases and related parameters represents an adequate and effective approach to achieving the dissertation's aims and objectives.

4.Brief analytical characterization and evaluation of the reliability of the material on which the contributions of the dissertation are based.

The dissertation comprises 172 pages and includes an introduction, five chapters, a conclusion, and a bibliography. In the introduction, the doctoral candidate presents the research topic, highlights its relevance and development stage, and formulates the research objectives and tasks.

The first chapter analyzes the kinematic and dynamic processes involved in vehicle braking. Particular attention is given to the origin and causes of vibrations in braking systems using disc brake calipers. Phenomena related to technological deviations in geometry and assembly clearances are discussed, leading to pressure fluctuations in the hydraulic fluid during disc rotation, which affect the braking torque characteristics. Specific thermal deformations trigger high-frequency vibrations in braking system structures during extreme braking. Wheel slip control shows a certain inertia and generates low-frequency oscillations. It is noted that hybrid and electric vehicles produce additional braking torque via the electric motors in generator mode, allowing for higher deceleration values.

To achieve the main objectives and tasks, a system for registering fast processes was created. It is emphasized that the technical characteristics of the displacement sensor must be continuously monitored and, if necessary, recalibrated according to the described methodology. Measurement results are structured into databases for subsequent processing.

The methods for preliminary and subsequent processing of experimental data are presented. An innovative segmented smoothing approach is used, allowing different sections of the process to be treated with bands of varying width, thus preventing data loss in regions where acceleration changes significantly in a short time.

A method has been developed for identifying the phases of extreme braking using experimental data analysis. The method relies on the analysis of the longitudinal acceleration function and its derivatives. A reliable criterion for identifying the phase boundaries is

formulated. The distances of these boundaries show good correspondence with the intersections of the regression lines of the acceleration data.

An experimental study was conducted on the braking of two vehicles with different drive systems. The vehicle with a manual transmission brakes with the clutch disengaged, thus lacking additional braking torque from engine operation in forced idle mode. The hybrid vehicle with automatic transmission maintains a continuous connection between the engine and driving wheels, and, together with generator-mode electric motor operation, contributes to supporting the braking system.

Braking period characteristics under various urban driving conditions were experimentally determined. The differences in drive system construction between the two vehicles revealed different acceleration behaviors. It was found that the hybrid vehicle registers higher negative acceleration values.

Acceleration characteristics show oscillatory processes with a continuous spectrum. Frequency analysis revealed that single braking events produce low-frequency oscillations. This distribution is due to the discrete control of the anti-lock braking system. Low-frequency harmonics with higher amplitudes do not affect the shorter-duration periods.

The final section contains a conclusion and general evaluation of the dissertation in relation to its goals and tasks. Scientific and applied contributions are formulated, and conclusions are drawn.

5.What are the scientific or applied science contributions of the dissertation?

The dissertation presents six scientific and applied contributions, which are categorized as follows: the demonstration of essential new aspects of existing scientific problems using new tools, the discovery and substantiation of new facts, and the confirmation of known data. The contributions are accepted as formulated:

1. A method has been developed for determining the phases of the extreme braking process using high-order derivatives and regression lines based on experimental data.
2. A methodology has been established for preliminary smoothing of elementary displacement period lengths and correction of hardware interruptions using confidence intervals.
3. A methodology for segmented smoothing of experimental data for processes with variable dynamics has been improved. The proposed approach ensures continuity in the smoothed data vector and prevents function breaks across the general dynamic range.
4. A system has been developed for precise measurement and high-frequency recording of vehicle displacement data. The system enables synchronous real-time data acquisition using a specially designed sensor and integration with external vehicle control signals.
5. The boundaries and durations of braking phases for mid-class vehicles at urban speed limits have been defined.
6. Oscillatory processes during different braking phases have been investigated, and the amplitudes and frequency spectra of significant harmonics have been determined. It was established that during single braking events at low disc temperatures, high-

amplitude low-order harmonics occur only during periods of maximum negative acceleration.

6.To what extent can the dissertation and its contributions be considered the personal work of the candidate?

I am personally acquainted with the doctoral candidate M.Eng. Daniel Ivanov and his work as a lecturer in the Department of Transport Equipment and Technologies. The dissertation developed by him convinces me that, under the guidance of his supervisor and with the support of his colleagues, he has established himself as a researcher. I believe that his acquired research experience will contribute to his future success in both teaching and scientific activities.

7.Evaluation of the publications related to the dissertation.

Four publications are presented in relation to the dissertation. One is independent, and three are co-authored with his academic advisor and other contributors. The results have been published in Bulgarian scientific journals.

8.Have the results of the dissertation already been applied in scientific or social practice?

The main results of the dissertation have been presented and discussed at scientific conferences and are known to the scientific community. The materials presented do not include data on application in scientific practice. However, the developed methodology for determining braking phases holds potential for future experimental studies on vehicles with advanced braking and driver assistance systems.

9.Recommendations for future use of the scientific and applied contributions.

The high-frequency data recording system and the optimized processing methodologies provide the opportunity to study rapidly evolving processes over short time intervals. The local smoothing method facilitates the analysis of processes with uneven dynamics while preventing the loss of important information during processing. This enables more accurate and reliable tracking of complex phenomena in the studied field.

Research on braking processes in hybrid vehicles is particularly significant. The developed system could also be applied to analyze acceleration dynamics. The obtained numerical values for the characteristics of individual phases can be used as input for theoretical studies, design work, and road accident reconstruction.

Abstract

The abstract comprises 40 pages and meets the formatting requirements of the Technical University of Varna. It is properly structured and reflects the main parts of the dissertation.

Critical notes on the dissertation, including the candidate's literature awareness.

The following remarks are made:

- Chapter 2 describes the experimental research system. It would be beneficial to include an overview of other modern measurement tools used for vehicle braking studies in the introductory part of this chapter.
- In Table 2.1, there is an error in the reported average number of pulses per 100 m when calibrating the displacement sensor. The actual value is likely 50,585 pulses.
- Some figures lack labels indicating the driving modes of the vehicles.
- The doctoral candidate is advised to expand his publication activity in other conferences and journals, especially those indexed in global scientific databases.

CONCLUSION

The reviewed dissertation addresses a relevant issue related to road safety in motor vehicle transport. Sufficient scientific publications reflecting its main sections have been produced. I consider the presented dissertation to comply with the Law on the Development of Academic Staff, its regulations, and the rules and methodological guidelines of the Technical University of Varna. I hereby give my positive evaluation of the work of M.Eng. Daniel Zdravkov Ivanov and confidently recommend that he be awarded the educational and scientific degree "Doctor" in the doctoral program "Internal Combustion Engines", area of higher education 5. Technical Sciences, field of study 5.1. Mechanical Engineering.

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Prepared by: Assoc. Prof. Dr. Eng. Yaroslav Argirov