REVIEW

by Prof. Dr. Eng. Velizara Pencheva
Department of Transport, "Angel Kanchev" University of Ruse
of the dissertation for awarding the educational and scientific degree "Doctor"
Topic: *Investigation of the Braking Characteristics of an Internal Combustion Engine Vehicle*
Author: MEng. Daniel Zdravkov Ivanov
Field of Higher Education: 5. Technical Sciences
Professional Field: 5.1. Mechanical Engineering
Doctoral Program: Internal Combustion Engines

The review is prepared pursuant to Order No. 305/20.05.2025 of the Rector of the Technical University of Varna and complies with the requirements for structuring a review of a dissertation for the award of a doctoral degree according to the current Regulations for Admission, Training of Doctoral Students, and Acquisition of Educational and Scientific Degree "Doctor" and Scientific Degree "Doctor of Sciences" at the Technical University of Varna.

1. RELEVANCE OF THE PROBLEM DEVELOPED IN THE DISSERTATION IN SCIENTIFIC AND APPLIED TERMS. LEVEL AND SCOPE OF RELEVANCE OF THE PROBLEM AND THE SPECIFIC TASKS DEVELOPED IN THE DISSERTATION

Research into braking deceleration is of critical importance for the development of safe, efficient, and sustainable transport vehicles. With the introduction of new technologies in the automotive industry—such as electric and autonomous vehicles—the need for in-depth knowledge and optimization of braking systems is increasing. Research in this area contributes to improving their efficiency and integrating innovative solutions.

Furthermore, braking systems have a direct impact on the environmental footprint of vehicles. Optimizing braking deceleration can lead to more efficient energy use, reduced wear on components, and lower emissions, which is crucial for sustainable development and environmental protection.

From a safety perspective, braking deceleration plays a key role. Understanding the structure of the braking process and the factors that influence it is critical for reducing road traffic accidents and enhancing the safety of all road users—drivers, passengers, and pedestrians.

The data obtained through experimental studies on the real parameters and phases of braking serve as a basis for the development of automated driver assistance systems. These provide early warnings and autonomous intervention in the braking system. The availability of current and accurate information on the performance of modern braking systems is a necessary condition for optimizing the management of safety systems and transport technologies.

All of the above highlights the high degree of relevance of the main goal and tasks set in the dissertation, as well as the significance of the approaches and methods used to achieve them.

2. LEVEL OF UNDERSTANDING OF THE RESEARCH PROBLEM AND CRITICAL REFLECTION ON THE LITERATURE REVIEW BY THE DOCTORAL CANDIDATE

The list of references includes 116 titles, of which 11 are in Cyrillic and 105 in Latin script. The dissertation text demonstrates a high level of understanding of the methods for investigating the dynamic characteristics of a vehicle. The analysis of the braking torque characteristics shows good knowledge and the ability for a creative approach when studying the causes of oscillations in the characteristics of vehicle deceleration. The candidate's deep

knowledge of the current state of the issue is further supported by the scientific publications based on the dissertation, one of which has been published in a journal that is referenced and indexed in a world-renowned scientific database.

The critical analysis performed shows that the doctoral candidate has thoroughly studied the processes in braking systems, the methods for determining vehicle acceleration parameters, and possesses solid theoretical preparation and practical orientation in the examined subject area.

3. THE SELECTED RESEARCH METHODOLOGY ENSURES THE ACHIEVEMENT OF THE SET AIM AND OBJECTIVES OF THE DISSERTATION

The developed high-frequency synchronous data recording system, as well as the use of highly sensitive sensors, made it possible to capture the values of dynamically developing processes within very limited time ranges. The created experimental setup, the applied methods for preliminary and subsequent processing of experimental data, and the developed method for determining the braking phases and their parameters represent a comprehensive and well-founded approach for achieving the main goal and specific tasks outlined in the dissertation.

4. BRIEF ANALYTICAL CHARACTERISTICS OF THE NATURE AND ASSESSMENT OF THE RELIABILITY OF THE MATERIAL ON WHICH THE CONTRIBUTIONS OF THE DISSERTATION ARE BASED

The dissertation comprises 172 pages and is structured into an introduction, five chapters, a conclusion, and a list of references.

In the introduction, the doctoral candidate presents the research topic, outlines its relevance and current state of development, and defines the research objectives and tasks.

Chapter I examines the dynamic processes during vehicle braking, with an emphasis on emergency braking and the operation of disc brakes. The braking process involves the conversion of kinetic energy into heat, and components such as discs and pads are studied. Issues like residual braking torque and torque fluctuations due to thermal and hydraulic factors are also discussed. Finally, energy recuperation in hybrid and electric vehicles is considered, highlighting its role in improving braking efficiency and reducing brake wear.

Chapter II involves the use of displacement sensors that provide high measurement accuracy through rectangular pulses reflecting vehicle movement. The sensor is connected to the road via an elastic wheel and pneumatic tire, with pressure and tread condition monitored to maintain accuracy.

The study includes two vehicles with different drive systems: a Toyota Avensis II 1.8 with a conventional drivetrain and a Toyota Corolla Cross 1.8 with a hybrid drivetrain. The aim is to evaluate their impact on the braking process.

Chapter III presents methodologies for processing sensor data that measure the positions of the clutch, brake, and accelerator pedals, aiming to identify the phases of the vehicle braking process. Algorithms are proposed for modifying data arrays by filtering insignificant values and structuring signals into synchronized vectors.

A procedure is described for identifying the boundaries of time intervals related to the driver's reaction and the technical response of the vehicle. Numerical methods are used, including function approximations and median values, with the help of the MathCAD environment.

A method is proposed for determining the main phases of the braking process, including: driver reaction time, brake system activation time, and active braking time.

Chapter IV focuses on the braking process of a Toyota Corolla Cross Hybrid. Experimental research determines the parameters of various phases—driver's physical reaction time, brake system reaction time, and the period of increasing braking deceleration. Data are collected through high-frequency sampling (500 kHz) and precision sensors, including a specially developed sensor complex on the brake pedal.

The physical reaction phase covers the time from releasing the accelerator pedal to the beginning of pressing the brake pedal. Its average duration is about 0.402 seconds, during which the vehicle travels approximately 5.86 meters, with acceleration shifting from positive to negative.

The next phase—the brake system response—includes the time needed to activate hydraulic pressure and mechanical processes within the braking mechanism. This phase lasts 0.117 seconds, with an average negative acceleration of -1.012 m/s².

In the final examined phase—braking deceleration buildup—there is a progressive increase in negative acceleration due to the formation of significant braking torque and an increase in the coefficient of friction.

The analysis results confirm the high efficiency of the braking system and the emergency braking assistance system, enabling precise evaluation and modeling of the braking process under real-world conditions.

Chapter V explores the application of harmonic (frequency) analysis to investigate the braking phases using acceleration data processing. Fourier transform methods are employed to convert time signals into the frequency domain, thus identifying harmonic components within the braking process. The analysis reveals oscillations in acceleration caused by specific harmonics, whose frequency and amplitude vary depending on the initial vehicle speed.

At different braking speeds (42.8 km/h, 52.3 km/h, and 59.5 km/h), it is found that with increased initial speed, harmonic frequencies rise, while amplitude differences diminish. This leads to a marked change in acceleration behavior and an intensification of oscillatory processes. Lower-order harmonics (1st–2nd) are associated with the operation of the ABS system, which regulates pressure via electromagnetic valves. At higher speeds, the ABS activates more frequently, increasing the actuation frequency.

The results confirm that the harmonic approach is an effective diagnostic tool for dynamic braking processes, enabling the detection of structural and functional changes in brake system behavior under various conditions.

The dissertation concludes with a summary and final conclusions based on the conducted research and obtained results.

5. SCIENTIFIC, APPLIED SCIENTIFIC, AND PRACTICAL CONTRIBUTIONS OF THE DISSERTATION

The dissertation develops and applies effective methods, tools, and approaches with direct practical relevance. The obtained results and the conclusions drawn include contributions that can be divided into two main categories—applied scientific and practical contributions, as follows:

Demonstrating essential new aspects of existing scientific problems using new tools:

- An innovative method has been developed for identifying the phases of the emergency braking process based on experimental data. The method uses high-order derivatives and regression lines for precise identification of the individual periods within the braking process.
- A methodology has been developed for preliminary smoothing of the durations of elementary displacement periods and for correcting instrumental interruptions using confidence intervals. This ensures higher accuracy and reliability in the analysis of experimental data.
- An improved method for partial smoothing of experimental data has been developed, applicable to processes with variable dynamics of the measured quantity. The proposed approach ensures the continuity of the function throughout the general dynamic range, avoiding discontinuities in the vector of smoothed data. Significant contributions to the accuracy of results include: appropriate selection of material model parameters, adequate

representation of the design specifics of the real part, and use of a suitable finite element mesh with varying density in different zones.

Discovery and confirmation of new facts:

- A system for precise measurements and high-frequency data recording of vehicle displacements has been developed. The system uses a specially designed sensor and enables synchronous real-time recording of experimental data through integration with external signals from the vehicle's control system. This provides high accuracy and reliability in capturing dynamic processes during braking.
- The boundaries and durations of individual phases of emergency braking for mid-size vehicles moving at urban-legal speeds have been identified. The results allow for more accurate modeling of the braking process and can be used in the development and validation of active safety systems.
- Oscillatory processes during the different braking phases have been studied, and the amplitudes and frequency spectra of significant harmonics have been determined. It has been established that during single braking events and at low brake disc temperatures, high amplitudes of lower harmonics are registered only during the period of motion with maximum negative acceleration.

6. ASSESSMENT OF THE EXTENT TO WHICH THE DISSERTATION AND THE PRESENTED SCIENTIFIC CONTRIBUTIONS CAN BE CONSIDERED AS A RESULT OF THE DOCTORAL STUDENT'S INDEPENDENT RESEARCH WORK

I do not know the doctoral candidate, MEng. Daniel Ivanov, personally, but the quality of the dissertation work and the listed publications provide sufficient grounds for me to conclude that, under the guidance of his academic supervisor and with the support of colleagues from the training department, he has established himself as a competent researcher. I am convinced that the research experience he has gained will be successfully applied in both his future teaching and research activities.

7. ASSESSMENT OF THE PUBLICATIONS RELATED TO THE DISSERTATION

The doctoral candidate has submitted a list of four publications—one authored solely by him and three co-authored with his academic supervisor and other contributors. The research results have been presented at international conferences. One of the publications is indexed in Scopus, with five citations identified.

8. UTILIZATION OF THE DISSERTATION RESULTS IN SCIENTIFIC AND SOCIAL PRACTICE

The main results of the dissertation have been presented at international scientific conferences and have received recognition in the scientific community. Although no specific data on practical applications in science are included in the presented materials, the nature of the research and the applied methods demonstrate significant potential for citation and use in future scientific investigations.

9. RECOMMENDATIONS FOR FUTURE UTILIZATION OF THE SCIENTIFIC AND APPLIED CONTRIBUTIONS

The developed system for high-frequency synchronous data recording and the adapted methodologies for pre- and post-processing of experimental data enable the study of dynamically changing processes over extremely short time intervals. The approach for partial data smoothing allows for the analysis of processes with varying dynamics in different periods, without loss of information during digital processing.

The conducted research and obtained experimental results provide a wealth of data that can be used to derive conclusions about the characteristics of individual phases of emergency

braking and various driving modes and conditions. The developed methodologies can also be applied in studies of other transport vehicles, including acceleration regimes with gear shifting.

10. ABSTRACT

The abstract of the dissertation has been prepared in accordance with established academic standards. Its content fully reflects the structure, logic, and key results of the dissertation research. It clearly presents the goals and objectives of the study, the applied methods, the main scientific contributions, as well as conclusions and recommendations. The 40-page length is within the acceptable range and allows for a complete and well-reasoned presentation of the dissertation. The style and language of the exposition are clear, precise, and academically sound.

11. CRITICAL REMARKS ON THE DISSERTATION, INCLUDING THE CANDIDATE'S AWARENESS OF THE SCIENTIFIC LITERATURE

The following remarks are made regarding the dissertation:

1. Some conclusions drawn from the conducted research could be further refined.
2. The presented publications are all reported at scientific forums held only at "Angel Kanchev" University of Ruse. It is recommended that in future work, the doctoral candidate publishes the results of his scientific activities in other reputable journals and presents them at international scientific conferences. This will contribute to the wider dissemination of his scientific contributions and expand opportunities for collaboration with the international scientific community.

CONCLUSION

The dissertation submitted for review, along with the significance of the doctoral candidate's publications on the topic, provides sufficient grounds for me to conclude that the educational component of the doctoral program has been fulfilled. Based on the results and the contributions presented in the dissertation, I consider that the work meets the requirements of the Law on the Development of Academic Staff, the Regulations for its implementation, and the current Regulations for Admission, Training of Doctoral Students, and Awarding of the Educational and Scientific Degree "Doctor" and the Scientific Degree "Doctor of Sciences" at the Technical University of Varna.

All of the above allows me to give a positive evaluation of the work of MEng Daniel Zdravkov Ivanov and to recommend that he be awarded the educational and scientific degree "Doctor" in the doctoral program "Internal Combustion Engines," professional field 5.1 Mechanical Engineering, in the area of higher education 5. Technical Sciences.

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