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PHARMACY, SCIENCE, AND TECHNOLOGY OF TÂRGU MUREȘ**

**DOCTORAL SCHOOL OF LITERATURE, HUMANITIES AND
APPLIED SCIENCES**

DOCTORAL FIELD: ENGINEERING AND MANAGEMENT

DOCTORAL THESIS

**Studies and Research on the Optimization of
Comfort Parameters in Transportation Systems**

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Ensuring and optimizing comfort in transportation systems is of real interest, as in the current military context and in the civilian vehicle manufacturing industry, comfort has become a key pillar, with direct influence on the human factor. In the military sector, optimizing these aspects contributes to health protection and operational efficiency, providing significant tactical advantages. In the civilian context, comfort has become an essential quality indicator, influencing user satisfaction and the commercial success of vehicles. Consequently, research into noise and vibrations represents a crucial field for the advancement of the automotive industry and for improving users' quality of life.

The first part of the doctoral thesis presents research guided by a novel and original approach for the foundation of doctoral work, which involves the use of statistical and mathematical techniques with the primary aim of providing an objective and quantitative perspective on comfort in transportation systems (Military Transport Systems and Civilian Transport Systems). The well-defined procedures of the current stage have provided a solid database and enabled the identification of gaps in research, supporting the research findings. The use of robust meta-analysis methodologies has led to the synthesis of existing data in the literature and the extraction of relevant conclusions.

The general objective of the research is the optimization and evaluation of comfort in transportation systems through advanced investigation of noise and vibrations in vehicles, coupled with the selection of the best available techniques, to contribute to the further mitigation of potential sound impact and vibrations on the human factor, as well as to implement a strategy leading to the improvement of the vibro-acoustic comfort level in transportation systems.

The second part of the research is dedicated to investigating noise and vibrations and addressing strategies for optimizing comfort in vehicles, generally, and in specially designed vehicles, specifically. This part has been structured according to research needs and proposed objectives across three chapters, as follows: Studies and experimental research on acoustic comfort in vehicles; Experimental research on the vibro-acoustic comfort of specially designed vehicles; Research on improving acoustic comfort - Optimizing acoustic comfort through passive noise control.

The extensive experimental studies and research on acoustic comfort in vehicles aimed to investigate and provide preliminary data on the noise levels in vehicles of various configurations and types, classified in accordance with RNTR 2, monitored both stationary and in motion across a range of engine speeds. One of the stages of this research involved presenting the main elements underpinning the analysis of noise in vehicle cabins, as well as describing the equations and principles needed to determine the characteristic parameters of sound waves (acoustic pressure, sound pressure level, acoustic power, sound intensity, etc.), with the goal of developing a theoretical algorithm for evaluating noise in vehicle cabins. The experimental determinations led to the consolidation of a substantial database of values for interior vehicle noise. Additionally, this chapter proposes and validates a methodology for noise determination and analysis, which is based on well-defined steps and grounded on a synthesis of

standards and directives adopted at both national and international levels, as well as specialized literature. The results of the experimental noise determinations provide important information and significant conclusions for the research into comfort inside vehicles, as well as on the noise levels recorded in the cabins of vehicles of various configurations. Furthermore, the consolidation of the database, its processing, and analysis provide the necessary preliminary information that underpins the investigations of vibro-acoustic comfort in specially designed vehicles, thereby serving future development activities.

The investigation of vibro-acoustic comfort in specialized vehicles involved: experimental determination and implementation of calculation algorithms for analysis based on standardized vibro-acoustic factors recorded in specialized vehicles; establishing a database with preliminary cumulative estimates for the noise level inside and outside specialized vehicles monitored in various functional situations of the engine, as well as for interior vibrations; presenting significant results for the study of vibro-acoustic comfort. The investigation of vibro-acoustic comfort in specialized vehicles was based on advanced methods of measurement, processing, and analysis. For the evaluation of vibro-acoustic comfort in specialized vehicles, complex analyses were conducted involving high-precision measurements and advanced analyses to assess noise perception by the human operator. In the first phase, the acoustic pressure level and maximum acoustic pressure level in the vehicle cabin were evaluated, as well as vibrations and RMS values at the lower ceiling of the vehicle along the X, Y, Z axes and at the seat level on the Z axis. The measurement system was managed by an application developed in DasyLab 12.0 software and specific sound level meter software B&K 2245: Noise Partner 1.8.2.0 and Enviro Noise Partner 1.8.2.0. In the second phase, FFT analysis was performed to determine the frequency distribution of noise and vibrations, in the application developed in DasyLab 12.0. The processing of measurement files was managed in Audacity 3.5.1 and Python 3.12.4 software. In the third phase, an analysis based on standardized vibro-acoustic factors was carried out, which included: noise analysis at central frequencies in 1/1 octave bands, in Noise Partner 1.8.2.0 and Enviro Noise Partner 1.8.2.0 software; comparative analysis of experimental curves of interior noise and in headsets, for the assessment of acoustic comfort (this procedure was implemented in Matlab R2024a software); analysis based on standardized vibro-acoustic factors, to study vibro-acoustic comfort (this procedure was implemented in Matlab R2024a); long-term evaluation of the impact of noise and vibrations. For processing and analyzing noise and vibration data, processing algorithms were implemented to obtain significant information about the impact on the human factor using a series of software (Audacity, Noise Partner, Enviro Noise Partner, DasyLab, Matlab, and Python). An application was also created for FFT and PDS processing and analysis in DasyLab software. These investigations include a correlative analysis of vibro-acoustic factors, implemented in software (PSSP, Matlab, and Python), divided into multiple investigations that focused on: the correlation between interior and exterior noise; the

correlation between interior noise and noise in protective headsets; the correlation between engine speed and vibration level; the correlation between vibration level and interior noise level.

The research focused on improving acoustic comfort through passive noise control centered on investigating and assessing the acoustic properties of six material classes through experimental determination and both qualitative and quantitative analysis of the obtained database. This involved: identifying and establishing qualitative and quantitative characteristic parameters for assessing acoustic comfort; analyzing the database using advanced statistical methods to determine the best predictors for acoustic comfort across different material classes; identifying the performance of material classes and the frequency ranges at which they provide optimal isolation and absorption; and establishing the relationship between material parameters and acoustic comfort to develop predictive mathematical models of comfort. To achieve this objective, several methods of experimental determination were employed (such as the acoustic interferometer method - the Kundt tube) and statistical analysis (descriptive analysis, Mann-Whitney U test, three models of multiple linear regression, and the CHAID decision tree method). Among the specific conclusions obtained, the significant influence of material type and consequently the physical and acoustic properties of the material on acoustic comfort was highlighted. The investigations demonstrated that the acoustic absorption class varies depending on the material type and frequency. Metals and materials based on glass, plastic/polymers, and textiles (especially at frequencies above 1700 Hz) are more effective in sound absorption, indicating that these materials perform optimally in the mid-frequency range due to their density and molecular structure. Regarding the physical properties of the materials, it was determined that materials with greater thickness (samples 1-51 ranging from 1-100 mm) exhibited improved acoustic absorption. Additionally, the materials analyzed and structured into five categories (metals, glass-based materials, wood-based materials, polymer-based materials, and textiles) demonstrated variable efficiencies at different frequencies in terms of acoustic absorption properties, with textile and polymeric materials showing superior properties in the mid-frequency range. Also, through the three models of multiple linear regression, with the collinearity diagnostics for the best predictors of acoustic comfort, acoustic absorption class, and performance of the absorption class, the sound absorption coefficient was identified as a primary predictor for acoustic comfort and performance of the absorption class. This underscores the importance of optimizing the absorption coefficient in the development of materials to enhance acoustic properties.

The results deduced from the studies conducted make a significant, original, and timely contribution to the field of vibro-acoustic comfort in specialized vehicles as well as in the broader domain of comfort in transportation systems. The research integrated advanced measurements, analyses, and data processing for both vibrations and noise, providing a comprehensive perspective on vibro-acoustic comfort issues and offering solutions and strategies for optimizing comfort through passive

control. Based on the consistent and in-depth results obtained from the conducted research and the elaborated conclusions, I have developed a series of strategic proposals divided into distinct research directions, each having a unique impact on the vehicle industry. These categories of proposals target military units on one hand, and on the other hand, they provide a detailed technical and scientific framework for improving comfort while ensuring health protection and operational efficiency of personnel.

The potential impact of the research results contributes significantly to advancing technical knowledge and implementing innovative solutions, responding to current research needs in the field of comfort in transportation systems because:

- They propose a new and objective method that eliminates the inevitable systematic errors of qualitative research and allows for the identification of needs and gaps in research, as well as current trends; the method can be compatible and valid for any research domain.
- They contribute to the investigation, evaluation, and optimization of comfort in transportation systems (MTS and CTS), through the proposal and validation of methodologies for the experimental determination of vibro-acoustic comfort, the proposal of methods, measurement systems, and data acquisition, presenting and validating algorithms for the objective evaluation of comfort based on standardized vibro-acoustic factors.
- They provide a consistent database with standardized acoustic parameter values for a range of vehicles of various types and configurations classified in accordance with RNTR 2, monitored both stationary and in motion, across a variety of engine speeds.
- They contribute to optimizing vibro-acoustic comfort through passive noise control, both through experimental determination and through qualitative and quantitative data analysis and determination of the best predictors for comfort and the correlation between physical material factors and acoustic factors.
- They offer a reference framework for establishing measurement standards, investigating, and evaluating vibro-acoustic comfort, by presenting quality information and an integrated and multidisciplinary approach to noise and vibrations.
- They support the development of effective and innovative strategies in the field of comfort, by integrating the presented results and passive noise control strategies with new strategies for active noise and vibration control.
- They determine future research directions in the field.

In conclusion, the research conducted demonstrates the importance of an integrated approach in analyzing and optimizing acoustic comfort in vehicles and vibro-acoustic comfort in specialized vehicles. By combining advanced analyses of vibrations and noise, I have achieved significant results that contribute to improving comfort, safety, and crew performance. Future research directions aim to

expand and deepen these studies, with the goal of developing innovative and effective solutions for optimizing vehicles and ensuring a comfortable and safe operating environment, focused on performance in operational settings.

The exploitation of the scientific research results during the doctoral studies contributes to enhancing the prestige of IOSUD through the presence of published articles in the field of comfort in the scientific stream: 13 articles published as first author (8 in international databases, 1 in ISI, 1 in ISI Proceedings, and 3 in ISI pending publication), participation in five international conferences, an international mobility at the WAVES center of the University of Ghent, Belgium, and membership in a research grant team.