REVIEW

by Prof. Dimitar Andonov Dichev, DSc, on the dissertation work of MSc Eng. Docho Svetlozarov Dimitrov on the topic: “Research of dynamic processes in the control of pneumatic motors using pulse-width modulation” for awarding the educational and scientific degree "Doctor" in the professional direction "5.1 Mechanical Engineering" and scientific specialty “Hydraulic and Pneumatic Drive Systems”
Scientific supervisor: Assoc. Prof. Hristo Nedev Hristov, PhD
Technical University-Gabrovo

1. Presented materials

MSc Eng. Docho Svetlozarov Dimitrov is enrolled as a full-time PhD student in the Department of Energy Engineering, Faculty of Mechanical Engineering and Instrumentation, at the Technical University of Gabrovo.

For the preparation of the present review, all documents required for the defense procedure were provided, including the dissertation thesis, the dissertation abstract, copies of five publications related to the dissertation, a curriculum vitae, a copy of the Master's degree diploma, and other supporting documents.

2. Relevance of the problem developed in the dissertation work

Pneumatic drive systems are widely used in modern industry due to their simple design, high reliability, low cost, and ability to perform high-speed operating cycles. They are employed in automated production lines, robotic systems, transport and handling equipment, as well as in various positioning and control systems.

With the continuing development of industrial automation, the requirements for accuracy, dynamic performance, and energy efficiency of electro-pneumatic systems are constantly increasing. This gives rise to a number of scientific and engineering challenges related to the improvement of control methods and the development of adequate mathematical models capable of providing a more accurate description of the dynamic processes involved.

Particular interest is focused on electro-pneumatic systems employing high-speed 2/2-way solenoid valves controlled by pulse-width modulation (PWM). These solutions are regarded as a cost-effective alternative to proportional and servo valves; however, they also lead to complex dynamic phenomena associated with valve transient operation, the compressibility of the working medium, and the nonlinear nature of pneumatic processes. These factors have a significant influence on positioning accuracy, system stability, and energy efficiency.

Despite the considerable number of publications in the field of pneumatic drive systems, a number of issues related to the modeling and analysis of dynamic processes in PWM-

controlled high-speed solenoid valves remain insufficiently investigated. This creates a need for more comprehensive theoretical and experimental studies aimed at the development and validation of mathematical models capable of providing a more precise description of the behavior of such systems.

In this context, the investigation of dynamic processes in pulse-width modulation control of pneumatic actuators represents an important scientific and applied research problem with significant relevance both to the advancement of electro-pneumatic system theory and to their practical implementation in modern automated manufacturing. Therefore, the topic of the dissertation may be assessed as timely, relevant, and significant.

3. Degree of Awareness of the State of the Problem and Creative Interpretation of the Literature

The dissertation presents a comprehensive review of the existing solutions and scientific research in the field of electro-pneumatic control and positioning systems. The main approaches to the control of pneumatic drive systems employing proportional valves, servo valves, and high-speed solenoid valves are examined, together with the existing methods of pulse-width modulation (PWM) control.

Particular attention is devoted to the mathematical modeling of pneumatic systems, studies on the dynamic characteristics of pneumatic cylinders and solenoid valves, as well as various control approaches, including PID controllers and fuzzy logic systems. Existing models of the flow characteristics of pneumatic valves and their applicability to the modeling of real electro-pneumatic systems are also analyzed.

The presented literature review demonstrates that the doctoral candidate possesses a good knowledge of the current state of the problem in the considered scientific field. The literature has not been used merely for descriptive purposes; rather, it has been critically analyzed with the aim of identifying unresolved and insufficiently investigated issues, which have served as a basis for formulating the objectives and tasks of the dissertation research.

A positive impression is created by the author's effort to establish the relationship between existing theoretical concepts, the mathematical models employed, and their practical application in the development of electro-pneumatic systems controlled by pulse-width modulation. The conducted analysis provides the necessary scientific foundation for the subsequent development of mathematical models and the experimental investigations presented in the following chapters of the dissertation.

Overall, it may be concluded that the dissertation is based on a sufficiently broad and up-to-date literature foundation. The conducted analysis demonstrates a good understanding of the state of the problem and an ability to creatively interpret the available scientific information.

4. Correspondence of the chosen research methodology with the set goal and tasks of the dissertation work

The dissertation clearly formulates the aim and objectives of the research, which are focused on the investigation of dynamic processes in electro-pneumatic systems employing high-speed solenoid valves controlled by pulse-width modulation (PWM).

To achieve the stated aim, the author applies a comprehensive research approach that includes the analysis of existing scientific publications and technical solutions in the field of

electro-pneumatic systems, the development of mathematical models of individual system components, and their integration into a comprehensive model of an electro-pneumatic positioning system. In parallel, experimental investigations have been carried out to determine the parameters of the developed models and to assess their adequacy.

The research methodology is based on a sequential progression through the stages of literature review, mathematical modeling, experimental investigation, simulation studies, and validation of the obtained results. The work employs methods for the mathematical modeling of dynamic systems, experimental methods for the investigation of pneumatic devices, as well as modern software tools for the simulation and analysis of dynamic processes.

The selected research methodology may be assessed as appropriate and consistent with the aim and objectives of the dissertation. Through its application, the author has developed mathematical models of high-speed pneumatic valves and an electro-pneumatic positioning system and has subsequently carried out their experimental testing and validation.

5. Brief analytical characteristics of the nature and assessment of the reliability of the material on which the contributions of the dissertation work are built

The dissertation is devoted to the investigation of dynamic processes in electro-pneumatic systems employing high-speed 2/2-way solenoid valves controlled by pulse-width modulation (PWM). The main focus of the research is the development of mathematical models of individual system components and an integrated model of an electro-pneumatic positioning system, as well as their experimental testing and validation.

The dissertation addresses both the theoretical aspects of pneumatic system modeling and practical issues related to the determination of the flow characteristics of high-speed valves and the investigation of the dynamic characteristics of a real electro-pneumatic system. Mathematical models have been developed for the flow characteristics of the valves, their electromagnetic and mechanical dynamics, and an electro-pneumatic positioning system incorporating the principal elements of the actual drive system.

A distinctive feature of the dissertation is the combination of mathematical modeling, simulation studies, and experimental validation of the obtained results. For this purpose, an experimental test bench was developed, enabling investigations of a real electro-pneumatic system and providing data for the identification of model parameters and the assessment of model validity.

The reliability of the obtained results is based on the use of established theoretical principles and mathematical relationships in the field of pneumatic drive systems, as well as on experimental investigations conducted under real operating conditions. Of particular importance for the validity of the conclusions is the comparison between the results obtained from mathematical modeling and the corresponding experimental data, demonstrating good agreement between the developed models and the behavior of the real system.

The presented developments are logically consistent and mutually interconnected, while the conclusions and generalizations follow naturally from the conducted theoretical and experimental investigations. This provides sufficient grounds to conclude that the employed research material and applied methods constitute a reliable basis for the formulation of the scientific and applied results and contributions of the dissertation.

6. Scientific-applied and applied contributions of the dissertation work

The contributions stated by the author are correctly formulated and reflect the main results obtained in the course of the research. For the purpose of a clearer systematization and in accordance with the generally accepted methodological categories for the classification of scientific results, I consider the contributions of the dissertation to be formulated and grouped as follows.

A. Scientific and Applied Contributions

A1. Development of New Methods, Designs, and Technologies

1. A mathematical model of the actual flow characteristic of high-speed 2/2-way solenoid pneumatic valves has been developed and verified by means of experimentally determined static characteristics.
2. A mathematical model describing the electromagnetic and mechanical dynamics of high-speed 2/2 pneumatic valves has been developed, enabling the analysis of valve opening and closing processes and the determination of their dynamic characteristics.
3. An extended mathematical model of an electro-pneumatic positioning system controlled by pulse-width modulation (PWM) has been developed, integrating the models of the principal system components.
4. Simulation models have been developed in the Matlab/Simulink environment for the investigation of transient processes and dynamic characteristics of an electro-pneumatic positioning system employing high-speed valves and PWM control.

B. Applied Contributions

B1. Development of New Designs and Technical Solutions

1. An automated measurement system with virtual instruments implemented in the LabVIEW environment has been developed for the acquisition, processing, and visualization of experimental data.
2. An experimental test bench for investigating the dynamics of a PWM-controlled electro-pneumatic positioning system has been designed and implemented.
3. An energy-efficient electronic unit for PWM control of high-speed pneumatic valves has been developed.

B2. Obtaining Confirmatory Facts

4. The influence of the control signal frequency and PWM duty cycle on the dynamic characteristics of an electro-pneumatic positioning system has been experimentally investigated.

The presented scientific and applied contributions, as well as the applied contributions, are sufficient in scope and significance and satisfy the requirements for a dissertation submitted for the award of the educational and scientific degree of Doctor (PhD).

7. Assessment of the degree of personal participation of the doctoral student in the contributions

My assessment of the extent of the doctoral candidate's personal contribution is based on the materials submitted within the procedure. I am not aware of any information that would

cast doubt on the authorship of the presented results and contributions. Therefore, I accept that they have been achieved with the candidate's substantial personal involvement.

8. Evaluation of the publications on the dissertation

Five publications related to the dissertation have been presented, reflecting the principal results obtained in the course of the research. The publications are thematically consistent with the subject of the dissertation and address various aspects of the study, including the modeling, control, and experimental investigation of electro-pneumatic systems employing pulse-width modulation (PWM).

The results of the dissertation have been presented at national and international scientific conferences and forums, providing opportunities for their discussion and dissemination within the scientific community. Some of the publications are devoted to the experimental investigation of electro-pneumatic systems employing high-speed valves, while others address issues related to the application of PWM control and the analysis of the dynamic characteristics of such systems.

In my opinion, the presented publications are sufficient both in scope and content and reflect a substantial part of the scientific and applied results obtained within the framework of the dissertation research.

9. Application of the findings of the dissertation in scientific and social practice

The results of the dissertation have a clear practical orientation and address current challenges in the field of electro-pneumatic control and positioning systems. The developed mathematical models extend the possibilities for analyzing dynamic processes in systems employing high-speed solenoid valves and pulse-width modulation (PWM) control and provide a basis for their more accurate design and tuning.

The obtained results are relevant to the development of modern industrial automation systems, mechatronic devices, and positioning systems employing pneumatic drives, where high requirements are imposed on dynamic performance, energy efficiency, and control quality.

Particular practical value is provided by the developed technical means and experimental facilities for the investigation of electro-pneumatic systems with PWM control. The implemented automated tools for control, measurement, and experimental investigation create the necessary conditions for the analysis of dynamic processes, the validation of the developed mathematical models, and the assessment of the influence of various control modes on the performance of electro-pneumatic systems.

The results of the dissertation are also valuable for educational and research activities, providing a solid basis for the training of specialists and for future investigations in the fields of automation, mechatronics, and pneumatic control systems.

10. Assessment of the compliance of the abstract with the requirements for its preparation

The dissertation abstract comprises 52 pages and, in general, complies with the requirements for its preparation. It accurately reflects the content of the dissertation and presents the main results, conclusions, and contributions of the conducted research. At the same time, I believe that certain parts of the exposition could be presented in a more concise form, which would contribute to a clearer presentation of the most significant results and contributions of the dissertation.

11. Opinions, recommendations and notes

I have no substantial objections that would call into question the obtained results or the formulated scientific and applied contributions of the dissertation. The presented developments are logically consistent, well substantiated, and directed towards solving a relevant problem related to the investigation of dynamic processes in electro-pneumatic systems employing pulse-width modulation (PWM) control.

As a recommendation, greater emphasis could be placed on the practical implementation of the obtained results in specific technical systems. The developed models and experimental investigations are directly related to electro-pneumatic positioning systems, robotic and handling devices, automated production lines, transport systems, and other mechatronic applications employing high-speed pneumatic drives. A more detailed consideration of such applications would contribute to a more comprehensive presentation of the practical significance of the obtained results. In many cases, it is precisely the specific fields of application that impose new requirements on the systems under investigation and reveal additional aspects of the problem, thereby creating opportunities for the further development and improvement of scientific and engineering solutions.

12. Conclusion

In my opinion, the dissertation represents a fully accomplished research work with a pronounced practical orientation. The material is well structured and presented in a clear and coherent manner.

In conclusion, I may state that the dissertation fully complies with the requirements of the Academic Staff Development Act of the Republic of Bulgaria and the Regulations for its Implementation. In view of the above, I propose that the esteemed Scientific Jury award MSc Eng. Docho Svetlozarov Dimitrov the educational and scientific degree of Doctor in Professional Field 5.1 Mechanical Engineering and Scientific Specialty “Hydraulic and Pneumatic Drive Systems”.

04.06.2026 г.

Reviewer:

/Prof. Dimitar Dichev, DSc/