Abstrakt (English version)

This dissertation was carried out within the framework of the "Implementation Doctorate IV" program and focuses on developing a comprehensive methodology for testing and simulating the operation of electromechanical circuits in servo valves and position sensors used in aircraft applications. The primary objective was to evaluate the influence of mechanical loads and temperature variations on the performance, stability, and reliability of these transducers under real operating conditions.

An extensive review of the available literature revealed a significant research gap — the absence of multiphysics models capable of capturing the coupled electromagnetic, mechanical, and thermal phenomena that affect modern aircraft fuel system components. To address this, an integrated multiphysics model was developed, combining electromagnetism, structural mechanics, and thermal conductivity. The model was implemented using ANSYS®, FEMM®, and JMag® environments and coupled with the MATLAB/Simulink® computational toolkit. It incorporates temperature, stress, and geometry-dependent material properties obtained from experimental measurements, enabling highly accurate simulations of transducers behavior in servo drive systems.

Theoretical models were experimentally validated using dedicated test stands designed and built as part of this research. The experimental results demonstrated a high degree of agreement with the simulations, with a mean error of less than 3%. Additionally, numerical analyses were conducted to evaluate the effects of environmental factors on both the dynamic and static characteristics of torque motors used in servo valves. Based on these findings, design improvements were proposed to enhance the robustness and reliability of EMID components operating within aircraft fuel systems.

This implementation-oriented research addresses a critical demand of the aviation industry for advanced digital design methodologies. The developed simulation framework allows for precise modeling of magnetic circuits by considering the variations in ferromagnetic materials' properties induced by temperature and mechanical stress. It has been successfully applied to the design of a high-precision position transducer used in an Active Clearance Control system and can be further extended to analyze servo system performance and enable digital condition monitoring of mechatronic components in aviation.

This dissertation contributes to the advancement of engineering practices in the aerospace sector and serves as a valuable reference for specialists in mechanical and mechatronic engineering seeking to deepen their understanding of magnetic materials and their influence on the performance of servo drives and related electromechanical devices.