

Abstract of the doctoral dissertation

Development of computational methods for improvement of solenoid valves used in automotive industry

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The main topic of the dissertation is to improve the functionality of the solenoid valve. In the work, an analytical model of the valve and appropriate numerical tools were proposed to estimate the value of the transverse magnetic force acting on the valve core located non-centrally in the sleeve. The model takes into account the hydraulic forces and heat induced as a result of PWM control. The developed models and tools were used to analyze and evaluate certain modifications of the valve. These modifications, of a structural and geometric nature, were proposed to improve the functionality of the valve and increase its resultant axial force. Most of the described results have been published in scientific journals. The presented work extends the previously published results with several new aspects and provides computational evidence to confirm the main thesis of the work.

The first chapter of the paper presents a review of the literature on mathematical modelling of solenoid valves used in industrial applications. The presentation is followed by a description of own contribution to valve modelling and the obtained calculation results, as well as a presentation of the thematic relationship of the published articles. The second chapter describes several examples of technical applications using solenoid valves and their operating principles.

The third chapter is devoted to deriving the mathematical model used in the work. The obtained model in the form of a system of equations expressed in analytical form takes into account the force of dry and viscous friction as well as the electromagnetic force setting the valve core in motion.

The derived model is used in chapter four to obtain computational results. These include the forces acting on the valve core, the thickness of the magnetic gaps and the density of the magnetic flux. The chapter closes with a description of the optimization potential that can be obtained by changing the characteristic geometric values of the valve, which are the diameter of the core and the thickness of the transverse magnetic gap.

The effect of the proposed geometric modifications of the valve on the temperature distribution in the core is described in chapter five. Cases in which the core temperature rises due to inductive heat resulting from modulation of the width of the control pulses are analyzed.

The sixth chapter presents the derivation and description of the numerical model used in the work. The resulting system of differential equations is discretized and solved by the Finite

Difference Method. The chapter contains a description of the implementation of the model, criteria for the convergence of numerical errors as well as the analysis of the independence of the calculation grid and validation of the obtained results.

The numerical model is used in Chapter Seven to optimize the cross-section geometry of the valve core. The geometric modification formula was taken from the author's patent solution. The result of the optimization is an increase in the resultant axial force of the valve obtained by the introduction of narrow gaps on the circumferential surface of the valve core.

Chapter eight is devoted to the summary and conclusions. A description of own contribution to the development of computational methods and modeling of solenoid valves was also presented. In addition, the possibilities of expanding the issue under consideration have been described.

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