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Static and Dynamic Simulation of an Electromagnetic Valve Actuator Using COMSOL Multiphysics

Abstract In this paper an electromagnetic solenoid actuator (EMVA) consisting of an upper and lower electromagnet, a linear moving armature and two preloaded springs is considered as a potential approach in Variable Valve Actuation (VVA) Systems for Internal Combustion Engines. The analysis of the upper electromagnet has been performed using finite element (FEM) simulation. Thereby an axially symmetrical 2D FEM model in COMSOL Multiphysics has been used taking into account all nonlinear effects. The calculated static characteristics are implemented in a SIMULINK model to simulate the dynamics of the EMVA.

Introduction

In recent years, one of the main focuses within the automotive industry was improving fuel economy and reducing exhaust emissions. In order to achieve this purpose variable engine valve actuation systems are considered. Notice that in conventional engines the valve's open and closing timings are fixed relatively to the engine crank angle and cannot be adjusted to engine load and speed.

There are several ways to implement variable valve trains. Mechanical approaches such as the Valvetronic and Vanos-System by BMW and the VETEC-System by Honda make use of an adjustable camshaft. However, most research projects focus on an electromagnetic valve actuator (EMVA).

EMVA Principle of Operation

The EMVA is a solenoid consisting of an upper and lower electromagnet, a linear moving armature and two preloaded springs (see Fig. 1). Mechanically this actuator is a resonant oscillating device with inherent damping in which energy is alternating between potential energy stored in the springs the kinetic energy of the moving armature. The two basic tasks of the electromagnets are to hold the armature in either the open or the closed position and to return energy that is dissipated during motion due to friction and work against the pressure of the exhaust gas.

FEM Simulation

In the following simulation only the upper electromagnet is considered. Thereby an axially symmetrical 2D FEM model in COMSOL Multiphysics is used.

The nonlinear B H curve in Fig. 6 has been used for all steel parts. This curve can be expressed as $B = a \cdot \operatorname{asinh}(b \cdot H)$ with $a = 0{,}27\ \mathrm{T}$ and $b = 0{,}045\,\frac{\mathrm{m}}{\mathrm{A}}$. The use of this analytical expression instead of a lookup table leads to a faster convergence of the simulation in COMSOL.

The results of the flux linkage and static force characteristics are depicted in Fig. 2 and Fig. 3.

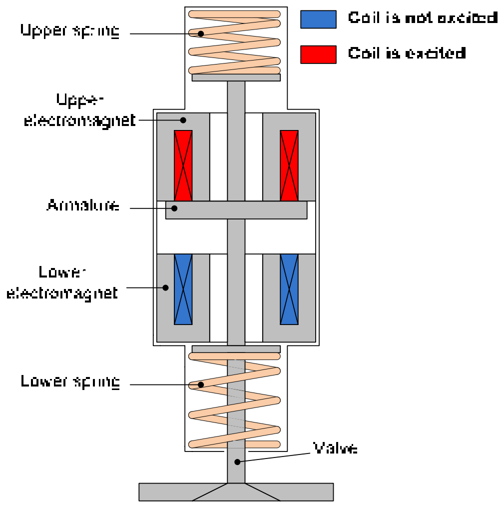

Figure 1. EMVA

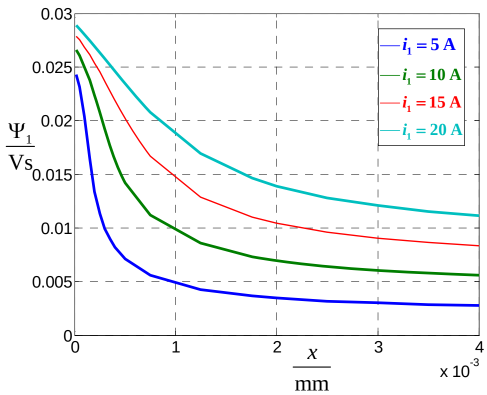

Figure 2. Flux linkage

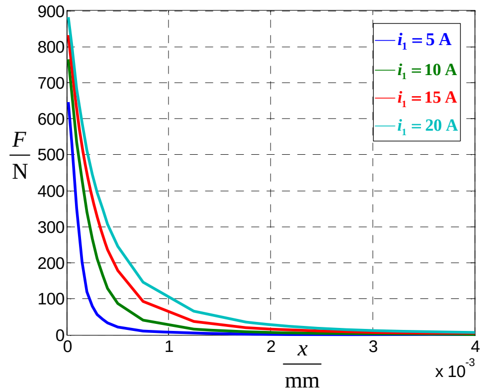

Figure 3. Electromagnetic force

Summary

An electromagnetic valve actuator (EMVA) has been designed and presented. Its static characteristics are calculated using an axially symmetrical 2D FEM model in COMSOL Multiphysics. Thereby the nonlinear magnetic behaviour of all steel parts has been considered. Based on these FEM results a Simulink model can be created to simulate the dynamics of the EMVA (see Paper).

Dipl.-Ing. Riheb Wislati[1], **Prof. Dr.-Ing.** Helmut Haase [1]
[1] Institute of the Basics of Electrical Engineering and Measurement Science, Leibniz Universität Hannover, Hannover, Germany
Contact: Tel: +49-511-762-4679, Email: wislati@geml.uni-hannover.de