Calculation of Force Acting on the Armature of Electromagnetic Actuator

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Abstract **Numerical simulation of an electromagnetic actuator is performed. Distribution of magnetic field in the system is modeled by higher-order finite element method and effective implementation of Newton's method. The force acting on the armature is subsequently computed using several methods and compared with experiment.**

Keywords **nonlinear PDE, Newton's method, finite element method, FEM**

I. Introduction

The task is to model mechanical force acting on the armature of an electromagnetic actuator. In the Fig. 1, a principal arrangement of a typical device is depicted. Magnetic field generated by the direct current carryed in

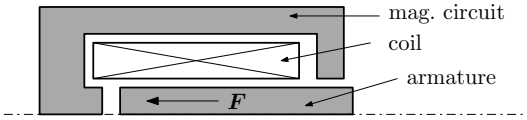

Fig. 1. Basic arrangement

the coil causes force acting on the armature, which is drawn in the axial direction inside the actuator.

II. Mathematical Model

The distribution of the magnetic field is described by equation for vector potential $\boldsymbol{A}$ in the form

$$\operatorname{curl} \frac{1}{\mu(\|\boldsymbol{B}\|)} \operatorname{curl} \boldsymbol{A} = \boldsymbol{J}_{\mathrm{ext}}, \quad \boldsymbol{B} = \operatorname{curl} \boldsymbol{A},$$

where $\mu(\|\boldsymbol{B}\|)$ stands for permeability and $\boldsymbol{J}_{\mathrm{ext}}$ is external current density. The permeability exhibits a very strong nonlinear dependence on magnetic flux density and causes convergence problems.

III. Numerical Solution

Described problem was solved by our own code Agros2D [1] and Hermes using higher-order finite element method. Strongly nonlinear problem was solved using our effective implementation of the Newton's method. Fig. 2 shows the number of iterations needed to solve the problem with residual norm 10^{-4}. Calculation time is similar for all methods of solving nonlinear PDE. Our implementation, however, requires 19 iterations only to achieve the prescribed precision.

Finally, Fig. 3 compares several methods (virtual work approach, Maxwell stress tensor and eggshell method [2]) of calculation of the force with measurement on experimental device (black dots).

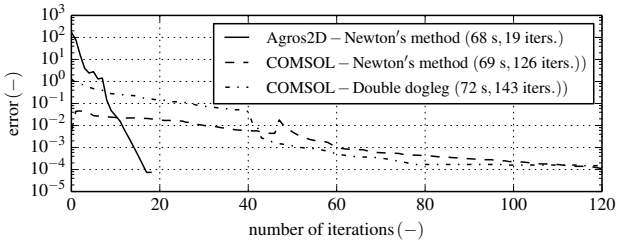

Fig. 2. Comparison of absolute norm of residual on number of iterations

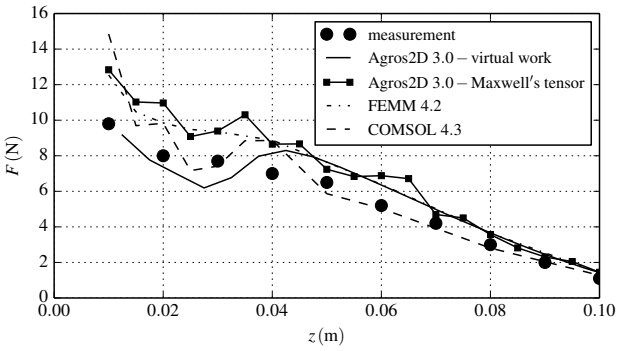

Fig. 3. Comparison of several methods for calculating the force acting on the armature of electromagnetic actuator

IV. Acknowledgements

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