Topology-optimization of an actuator in motion

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***Abstract*—Density based topology optimization is performed for moving bodies in an magnetic field. For this purpose, the nonlinear partial differential equation for the magnetostatic case is extended by the motional electromotive force term. The implementations are applied to an electromagnetic actuator in motion.**

***Index Terms*—Eddy currents, nonlinear electromagnetism, non-conforming grids, topology optimization**

I. Introduction

A density based topology optimization (TO) approach for the nonlinear magnetostatic case is presented in [1]. Optimization with a harmonic excitation was considered in [2]. Both approaches neglect the motional electromotive force (EMF) term. In contrast, moving mesh technique is applied in [3] to consider the motional EMF term in an indirect way. We enlarged the magnetostatic partial differential equation (PDE) by the motional EMF term and consider it in a material distribution based TO.

II. Physical equations and optimization

Based on Maxwell's equations the PDE to describe electromagnetic phenomena is defined by

$$\nabla \times \nu \nabla \times \boldsymbol{A} = \boldsymbol{J}_{\mathrm{i}} + \gamma \left(\boldsymbol{v} \times \nabla \times \boldsymbol{A} \right). \tag{1}$$

Here, a constant electromagnetic field was assumed. Moreover, ν is the magnetic reluctivity, $\boldsymbol{A}$ is the magnetic vector potential, $\boldsymbol{J}_{\mathrm{i}}$ is the impressed current density, γ is the electric conductivity and $\boldsymbol{v}$ the velocity of a conductive moving body [4]. Furthermore, an iterative procedure solves the algebraic system of equations obtained by applying the finite element method following

$$\boldsymbol{K}(\underline{A}_k)\underline{S} = \underline{f} - \boldsymbol{K}(\underline{A}_k)\underline{A}_k. \tag{2}$$

There, $\boldsymbol{K}$ defines the global stiffness matrix, $\underline{A}_k$ is the vector of unknowns, $\underline{S}$ denotes the Frechét derivative and $\underline{f}$ is the right hand side (RHS) vector. For optimization, a material distribution approach as introduced in [1] is used. There, the magnetostatic case is considered. We expand the approach to include the motional EMF term. For this purpose, an element wise design variable is introduced via the magnetic reluctivity. It is defined by $\rho_e = 1$ for solid material and $\rho_e = 0$ for air.

III. Numerical results

The approach was used to optimize the magnetic force of an electromagnetic actuator as presented in Fig. 1 (full material state, black and grey contour). It consists of a yoke which carries multiple coils. A magnetic field is generated in the yoke by the current driven coils. It is closed over the anchor. Besides, the yoke moves with an assumed constant velocity. We are interested into a force maximization between anchor and yoke. Hence, our objective function is defined by

$$\max \left(\boldsymbol{B}^2\right) \text{ subject to } \boldsymbol{K}\left(\underline{\rho}\right)\underline{A} = \underline{f}. \tag{3}$$

Here, the global stiffness matrix depends on the vector $\underline{\rho}$ which contains the element design variables ρ_e. The sensitivity is computed by the adjoint approach. It uses the converged system matrix $\boldsymbol{K}$ from (2). Due to the application of non-conforming grid technique, we achieve meshes with high quality. They strongly reduce instabilities arising from the motional EMF term. The optimization domain is defined by the yoke. A first result is presented in Fig. 1 (grey domain, optimized yoke). A detailed discussion will be provided in the full paper.

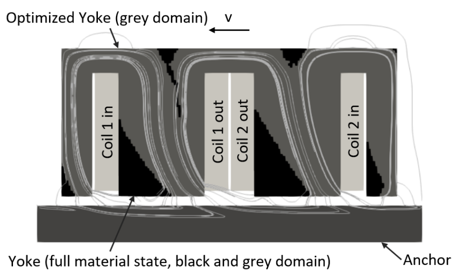

Fig. 1. TO of an electromagnetic actuator in motion.

IV. Conclusion

We apply the density based TO approach for the magnetostatic case considering the motional EMF term. Instabilities caused by the motional EMF term were solved by the use of non-conform grids. The implementations were applied on an electromagnetic actuator.

References

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