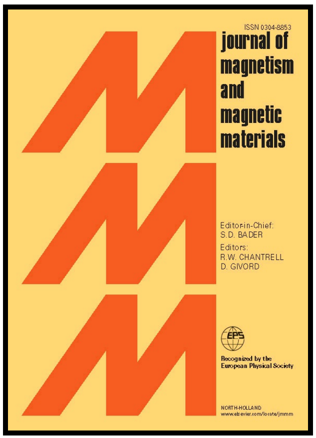

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Development of models of the magnetorheological fluid damper

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Abstract

The algorithm for analytical calculation of a power characteristic of magnetorheological (MR) dampers taking into account the rheological properties of MR fluid is considered. The nonlinear magnetorheological characteristics are represented by piecewise linear approximation to MR fluid areas with different viscosities. The extended calculated power characteristics of a MR damper are received and they coincide with actual results. The finite element model of a MR damper is developed; it allows carrying out the analysis of a MR damper taking into account the mutual influence of electromagnetic, hydrodynamic and thermal fields. The results of finite element simulation coincide with analytical solutions that allows using them for design development of a MR damper.

1. Introduction

The power characteristic is the main characteristic of hydraulic damping devices; also it is dependence of the damper resisting force on the rod conveying velocity, determined by the flow regime of working fluid. Methods for properties determination of dampers concerning classical fluids are not very applicable for a MR damper. Laminar flow of MR fluid in a MR damper gap is adopted in [1, 2]. It is connected with high viscosity of used MR fluid and stabilizing influence of an external magnetic field. Analytical methods for determination of a MR damper power characteristic are based on that MR fluid is a viscoplastic body, described by Bingham model or Herschel-Bulkley model in [3–7]. These approaches exclude the initial section of a MR fluid rheological curve, which gives incorrect results under low flow gradients. Under harmonic oscillation of the piston, the shear rates in the MR damper gap periodically varies in amount from maximum value to zero. Therefore, it is necessary to take into consideration the area with low shear rates. Thus, the development of adequate methods to evaluate the MR damper properties based on a flow regime in the working gap is actual.

In a MR damper magnetic, hydrodynamic and thermal fields exist simultaneously and they are interdependent. The disadvantage of analytical models is matching of equations to the certain type of a MR damper working area and impossibility to obtain the exact solution for complex channels. The application of finite element simulation is one of the best ways to assess properties and search for new technical solutions. Most famous works about finite element simulation of a MR damper describe a numerical calculation of electromagnetic field and exportation of the results for the hydrodynamic calculation [7–9], however, currently there are virtually no researches, concerned with the complex finite element analysis of the physical fields in the MR damper with considering of their mutual influence.

2. Materials and Methods

The approximation of a MR fluid nonlinear rheological curve by several linearized sections is used for calculation of a power characteristic. The areas with constant viscosity for each linearized section are highlighted in the profile of a MR fluid flow velocity. The justification of transition zones from one viscosity to another is carried out.

During finite element simulation the interconnections of fields (electromagnetic, hydrodynamic and thermal) are taken into account in the form of feedback in accordance with the results of the certain fields calculation. Finite element model of the MR damper is built in the COMSOL Multiphysics package in axis symmetric formulation.

Geometry of the damper for analytical and finite-element analysis is presented in fig. 1. For analytical simulation, form of the damper gap was approximated by plane slot. This assumption not leads to significant error in analysis results.

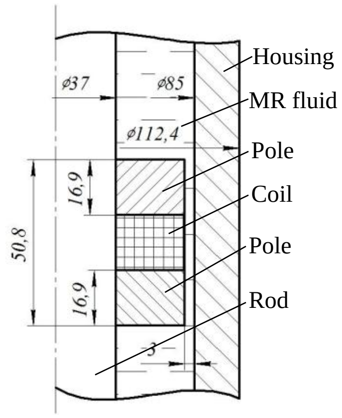

Fig. 1. Geometry of the damper.

3. Theory/Calculation

The MR fluid enforced flow in a channel in an external magnetic field is considered. The magnetic-field vector $\overline{\boldsymbol{H}}$ is perpendicular to the stream of MR fluid. The velocity field under the enforced flow of viscous fluid is parabolic type [10]. The formula for the velocity field is

$$v = [C/2\eta]\cdot(R^2 - r^2) \qquad C = \Delta p/L \qquad (1)$$

where $\Delta \mathbf{p}$ – pressure difference, **L** – channel length, **2R** – channel thickness, $\boldsymbol{\eta}$ – fluid viscosity, **r** – current coordinate.

The rheological curve is the dependence of the shear stress $\boldsymbol{\tau}$ on the shear rate $\boldsymbol{\gamma}$ of fluid layers. It has the form shown in Fig. 2 under an external magnetic field. The profile of the velocity field is shown in Fig. 3 considering two sections with their dynamic viscosities.

The shear stress in sections with viscosities $\boldsymbol{\eta_1}$ and $\boldsymbol{\eta_2}$ during the MR fluid stream is