# Applicability of Magnetic Hysteresis Models for Predicting the Behaviour of MR Dampers

**J. Goldasz*, B. Sapinski†, L. Jastrzebski† and Michal Kubik††**

* Faculty of Electrical and Computer Engineering
Cracow University of Technology
ul. Warszawska 24, 31-155 Krakow, Poland
e-mail: jgoldasz@pk.edu.pl

† Department of Process Control
AGH University of Science and Technology
al. Mickiewicza 30, 30-059 Krakow, Poland

†† Faculty of Mechanical Engineering
Brno University of Technology
Technicka 2896/2, 616 69 Brno, Czech Republic

## ABSTRACT

Hysteresis, and magnetic hysteresis in particular, is one of factors affecting the output of magnetorheological (MR) dampers. Specifically, the magnetic hysteresis is a property of ferromagnetics used in the magnetic circuit of MR valves. Although the magnetic hysteresis of MR fluids is considered negligible, the magnetic hysteretic behaviour of MRF-based valves needs to be included in the controls development. In comparison to mechanical or hydraulic contributors, the magnetic hysteresis does not vanish as the exciting current frequency approaches zero. Although the need for MR damper hysteresis models have been early recognized, see e.g. Spencer et al. [1], the behaviour of MR dampers has been typically analyzed with curve-fitted phenomenological models in which the force is examined in terms of position, velocity and current. Rather few studies have focused on separating the mechanical hysteresis from the magnetic one [2]. In our study we consider the simplest serial lumped parameter model of an MR solenoid. The model includes the voltage source $u(t)$, the coil resistance $R_c$ and the nonlinear inductance $L_c(i)$. The model equation is then

$$u(t) = iR_c + \frac{d\lambda}{dt} \tag{1}$$

where $u$ – supply voltage, $i$ – coil current, and $\lambda = L(i)i = N_c\phi$ – flux linkage, $N_c$ – coil turns, $\phi$ – magnetic flux. We assume the relationship between the exciting current and the flux linkage is represented by a suitable law incl. hysteresis. In the paper several existing hysteretic operators are examined by studying the $\lambda - i$ relationship of two MR actuators - one flow-mode damper and one rotary brake. We consider the existing models of magnetic hysteresis, namely, Stoner-Wohlfarth, Jiles-Atherton, Duhem, Bouc-Wen by fitting each model's output to the $\lambda - i$ characteristics (extracted from current and voltage measurements). The acquired flux information represents the averaged flux in the solenoid, therefore, the identified models would be suitable for control purposes. We study the performance of each model subjected to fluctuating current inputs, compare their accuracy, parameter estimation feasibility and the application range.

## REFERENCES

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[2] Zheng, J. and Li, Y. and Li, Z. and Wang, J. Transient multi-physics analysis of a magnetorheological shock absorber with the inverse Jiles–Atherton hysteresis model. *Smart Mater. Struct.* (2015) 105024.