LARGE-SCALE MAGNETORHEOLOGICAL FLUID DAMPER FOR VIBRATION MITIGATION: MODELING, TESTING AND CONTROL

A Dissertation

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B.F. Spencer, Jr., Director

Department of Civil Engineering and Geological Sciences
Notre Dame, Indiana

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Abstract

by

Guangqiang Yang

Over the past three decades, a great deal of interest has been generated regarding the use of structural protective systems to mitigate the effects of dynamic environmental hazards, such as earthquakes and strong wind, on civil engineering structures. These systems usually employ supplemental damping devices to increase the energy dissipation capability of the protected structure. One of the most promising new devices proposed for structural protection is magnetorheological (MR) fluid dampers. Because of their mechanical simplicity, high dynamic range, low power requirements, large force capacity, and robustness, this class of devices has been shown to mesh well with application demands and constraints to offer an attractive means of protecting civil infrastructure systems against severe earthquake and wind loading.

The focus of this dissertation is to develop a fundamental understanding of large-scale MR dampers for the purpose of designing and implementing these “smart” damping devices in large-scale structures for natural hazard mitigation. Following a review of pre-
vious research on structural protective systems using supplemental damping devices, an
axisymmetric and a parallel-plate models of MR dampers are developed, incorporating
fluid shearing thinning/thickening effects. Although useful for design purposes, these
models have proved to be insufficient to describe the nonlinear dynamic behavior of MR
damper system. Therefore, a new dynamic model of the overall MR damper system is pro-
posed which is comprised of two parts: (i) a dynamic model of the power supply, and (ii) a
phenomenological model of the MR damper based on the Bouc-Wen hysteresis model.
This dynamic model is shown to be accurate in predicting damper behavior under a wide
variety of operating conditions. To improve the MR damper response time, a force-feed-
back control scheme used in conjunction with a back-driven current approach is proposed
and experimentally shown to be effective. Other practical issues related to MR dampers
are also investigated, including damper piston centering, voltage surge suppression, tem-
perature effects, voltage power supply vs. current driver, etc.

In this dissertation, two specific applications using “smart” damping technology for
vibration mitigation in naval structures are also investigated. In the first of these applica-
tions, stress levels in ship supply transfer ramps due to adverse sea conditions are consid-
ered; in the second, the reduced shock vibration is studied. Simulation results demonstrate
that “smart” damping devices used in conjunction with appropriate control strategies are
effective and practically implementable in these vibration control applications.

The studies reported in this dissertation are intended to provide insight into the behav-
ior of MR fluid dampers and their potential applications to large-scale structures. This
work is expected to accelerate the implementation of these dampers in areas of natural
hazard protection and vibration mitigation in large-scale structures.