Vibration Mitigation of Stay Cable using Optimally Tuned MR damper based on Frictional Equivalent Model

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Summary

Magnetorheological (MR) damper has been proved to be one of the most effective Semi-active control devices for the vibration mitigation of stay cables in various cable-stayed bridges. However, the highly nonlinear feature of the MR damper lead to a relatively complex representation of its mathematical model, and makes it difficult to be applied to suppress cable vibration with an efficient control algorithm. Therefore, this paper aims to develop a simplified mathematical model for the MR damper with less parameters involved, and to propose a semi-active control strategy using the universal design curves of nonlinear dampers model for the vibration control of stay cables. Theoretical analysis and simulation studies will be carried out to evaluate the performance of the cable-MR damper system and the efficiency of the proposed semi-active control strategy.

Keywords: long stay cable, vibration mitigation, MR damper, semi-active control, performance evaluation.

1. Introduction

Oscillation problem of cables was occurred with the birth of modern cable-stayed bridges. Dampers were widely used to reduce the vibration of cables. As the main force-bearing components, the length of stay cables increase with the main span of cable-stayed bridge increases which has exceeded 1000m for the reason of new materials and new construction technologies applied. Thus, using passive dampers alone may not satisfy the control requirement of the stay cables. Therefore, semi-active MR dampers have been proposed for the vibration mitigation of long stay cables for the advantage of lower energy consumption, adjustable input and wide control range. Stanway et al. [1] proposed an idealized mechanical model based on the stress-strain behavior of the Bingham viscoplastic model. Wen [2] proposed Bouc-Wen model which is numerically tractable and has been used extensively for modelling hysteretic systems. Weber et al [3-5] applied the energy equivalent approach to model MR damper as equivalent linear viscous damper or nonlinear friction damper in the theoretical and experimental studies of cable vibration control using MR dampers. Liu et al [6] conducted series of scaled cable vibration tests to verify the control effectiveness of semi-active MR damper as compared to the passive dampers. Wu and Cai [7] carried out performance test on MR damper and studied the effect of input current, frequency, type of excitations and temperature on damper behaviour, and they also conducted the scaled cable vibration tests and found that MR damper is effective for mitigating cable vibrations. Besides theoretical work and lab testing, MR dampers have also been applied to real bridge projects, such as the Eiland bridge nearby Kampen, The Netherlands [8], the Dongting Lake Bridge [9-11], Third Qiantang River Bridge [12], Bingzhou Yellow River Highway Bridge [13] and Sutong Bridge in China. Field tests have been conducted on those bridges to study the effectiveness of MR dampers for mitigating cable vibrations and investigate factors that affect the performance of MR dampers.

Although various theoretical and experimental studies have been carried out on the implementation of MR dampers on stay cables, the highly nonlinear feature of the MR damper lead to a relatively

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