DOI: 10.24904/footbridge2017.09130

NEW REAL-TIME CONTROLLED SEMI-ACTIVE TUNED MASS DAMPER FOR HUMAN, VORTEX AND WIND EXCITATIONS

Felix WEBER
Dr. Mech. Eng.
Maurer Switzerland GmbH
Zurich, Switzerland
F.Weber@maurer.eu

Hans DISTL
Dipl. Mech. Eng.
Maurer Söhne Engineering GmbH & Co. KG
Munich, Germany
J.Distl@maurer.eu

Simon SPENSBERGER
Dipl. Mech. Eng.
MAURER SE
Munich, Germany
S.Spensberger@maurer.eu

Oliver Benicke
Dipl. Civil Eng.
MAURER SE
Munich, Germany
O.Benicke@maurer.eu

Peter HUBER
Dipl. Mech. Eng.
MAURER SE
Munich, Germany
P.Huber@maurer.eu

Christian BRAUN
Dr. Civil Eng.
MAURER SE
Munich, Germany
C.Braun@maurer.eu

Summary

The concept of a new real-time controlled TMD based on a semi-active oil damper for human, vortex and wind excitations is described. The desired control force is formulated based on the feedbacks of actual structural acceleration and actual relative motion of damper mass. The associated feedback gains are tuned by the control engineer with respect to the TMD specifications. The desired semi-active control force is generated by a semi-active oil damper with controlled bypass valve in order to minimize energy consumption of the actuator and to maximize fail-safe behaviour, i.e. the system automatically behaves as a correctly tuned passive TMD in case of power break down. The numerical case study of a footbridge demonstrates that the vibration reduction due to the real-time controlled TMD is the same as expected from a passive TMD with approx. 4 times bigger damper mass. On the other hand, for same damper masses, the efficiency of the real-time controlled TMD is far higher than that of the passive TMD without generating greater relative motion amplitudes of the TMD mass.

Keywords: control; damping; human excitation; narrow band excitation; semi-active; TMD; vibration

1. Introduction

The main design parameter of tuned mass dampers (TMD) to guarantee structural vibrations below acceptable limits is their damper mass. However, damper mass is often limited by the space available for installation in the structure and by the maximum acceptable additional load on the structure. It is therefore a need developing new TMD systems requiring less mass for same vibration reduction. Within this context MAURER is committed to developing new TMD concepts since 2002. This engagement led to the semi-active TMD systems installed in the Volgograd Bridge (Russia) that underwent severe bending vibrations in 2010, the Axaiski Bridge (Russia) and the Danube City Tower (Vienna, Austria) [1]. Frequency and damping of these semi-active TMDs are optimally adjusted in real-time to the actual frequency of vibration. This paper describes the newly developed real-time controlled semi-active TMD concept of MAURER (Fig. 1(a)) that can efficiently mitigate structural vibrations due to walking pedestrians, vortex shedding (harmonic excitation) and wind loading (narrow band excitation).

2. New controlled TMD concept for pedestrian, vortex and wind excitations

The desired control force is computed in real-time based on the feedbacks of structural acceleration and TMD relative motion (Fig. 1(a)). The first feedback generates a control force compensating for the excitation force while the second feedback controls the TMD displacement. A semi-active oil damper is adopted to track the desired control force (Figs. 1(b, c)). As semi-active oil dampers are strictly dissipative devices (Fig. 1(c)) the closed-loop cannot become unstable in contrast to active TMDs. In addition, the power consumption on the order of 100 W is far less than that of active actuators, e.g. linear e-motors.

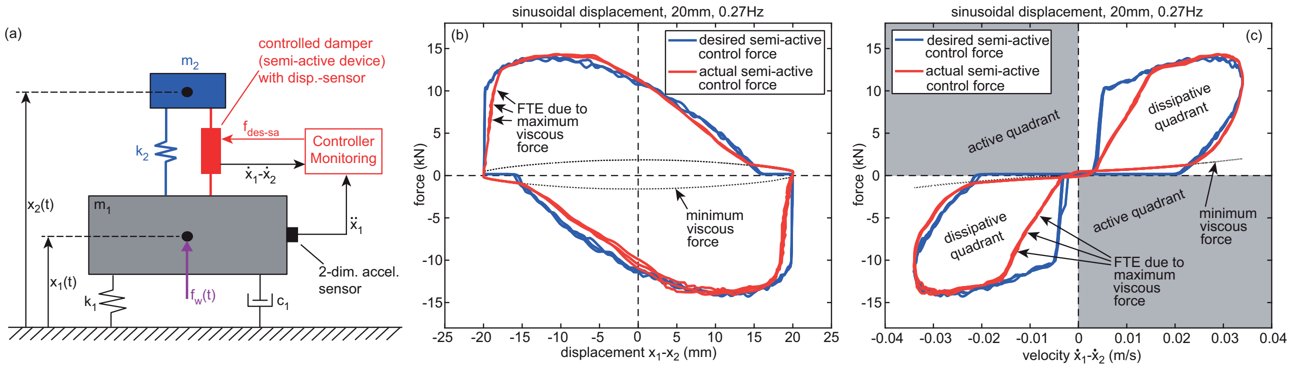

Fig. 1. (a) Sketch of controlled semi-active TMD, (b, c) Force tracking test results with semi-active oil damper

The new controlled semi-active TMD concept is numerically tested for a structure excited by pedestrians according to [2], vortex-shedding (harmonic) and wind (narrow band). The results that are compared to those of the passive TMD with same damper mass demonstrate the superior efficiency of the new TMD concept (Fig. 2). To generate the same vibration reduction as the new controlled semi-active TMD the passive TMD would require a mass ratio μ of 6.45% and 8.65%, respectively, for the loading cases of pedestrian and harmonic excitations, respectively.

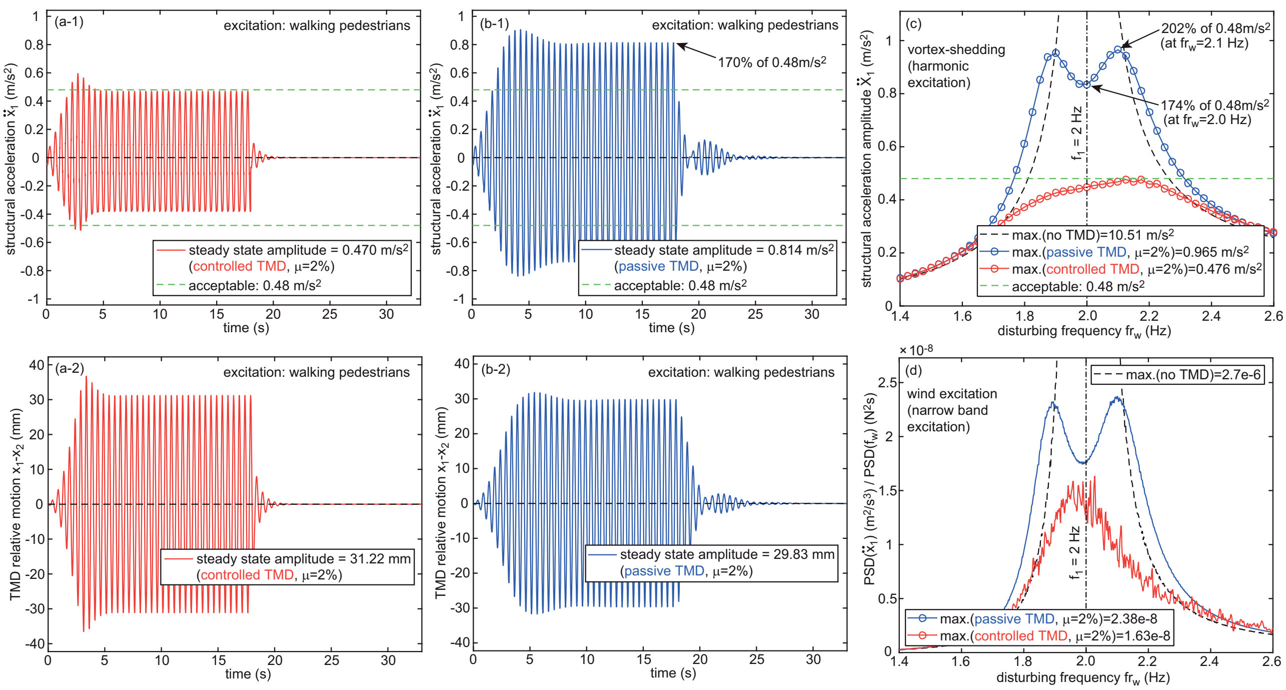

Fig. 2. Vibration reduction by new controlled semi-active TMD compared to passive TMD

[1] WEBER F., DISTL H., FISCHER S. and BRAUN C., "MR Damper Controlled Vibration Absorber for Enhanced Mitigation of Harmonic Vibrations", Actuators, Vol. 5, 2016, doi:10.3390/act5040027.

[2] BACHMANN H and AMMANN W., Vibrations in Structures induced by Man and Machines, IABSE – AIPC – IVBH (publ.). 1987.