A New Energy-Efficient Device for Active Control of Bridge Vibrations

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Summary

The system characteristics and effects of a novel active mass damper are investigated by means of its application for control of wind-induced bridge vibrations. Due to the presence of self-excited forces, stability issues are considered and a stability measure proposed. By virtue of the generation mechanism of the control forces, a superior low power demand of the actuators is achieved in comparison to other proposed mass dampers. The performance of the new damper is studied using a numerical example.

Keywords: Active control; active mass damper; wind-induced vibrations; bridge deck flutter; flutter stability.

1. Introduction

A decisive drawback of active mass dampers for the control of structural vibrations as described in the literature is their requirement for large actuators with high power demands. In [1], a novel active mass damper is presented. Its basic unit – a rotor – consists of an actuator-driven rotating rod with length r_l and a mass attached to its free end. The rotor performs complete revolutions. In a preferred damper configuration, the rotor is intended to operate at constant velocities. The generated centrifugal forces are used for the control of the structural vibrations. Accelerations are only necessary to control the relative motion between the damper and the structure. In this way, the power demand is considerably smaller in comparison to other proposed active mass dampers.

2. Damper concept and performance

The novel active mass damper is a very adaptable system. For structural control, it is possible to generate moments only, forces in predefined directions and combinations of moments and forces. Various moment and force time histories can be generated by combining damper units with appropriate damper parameters and specific rotor velocities. However, harmonic or nearly harmonic time histories are easily generated by operating at constant rotor velocities. Practical control forces and associated damper parameters are described in detail in [1].

In this study, the application of the new damper concept for the control of bridge deck vibrations due to wind is investigated. For this purpose, two pairs of rotor units are arranged in a bridge

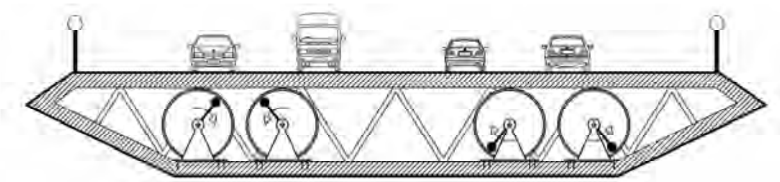

Fig. 1: Proposed Damper Configuration

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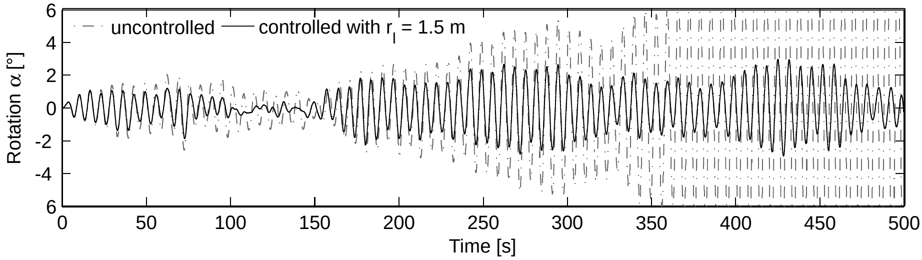

Fig. 2: Numerical Simulations in Time Domain: Controlled and Uncontrolled Response for Mean Wind Speed of 39.7 m/s and Rotor Length of 1.5 m

section which can be located inside of a box girder as depicted in Figure 1. To achieve a low power demand of the actuators, the rotor velocities should be maintained as steady as possible.

A construction stage of the Great Belt Bridge in Denmark is chosen for numerical simulations in time domain. For a mean wind velocity of 39.7 m/s, controlled and uncontrolled bridge responses represented by the time histories of the bridge rotations α are depicted in Figure 2. In this example, the damper mass is 0.5 % of the generalized bridge deck mass. The standard deviations of the rotations for different mean wind velocities are calculated and show an improvement in the range of 20 to 60 % in comparison to the uncontrolled system. The critical wind speed of the system is also increased.

The maximum actuator power of the rotor damper is an order of magnitude smaller than those of a comparison system. Furthermore, it can be shown that the total mechanical actuator energy of the new rotor damper becomes negative after a period of time (Fig. 3). Hence, the new system converts energy of the air flow into mechanical energy, i.e. energy is generated by the actuators.

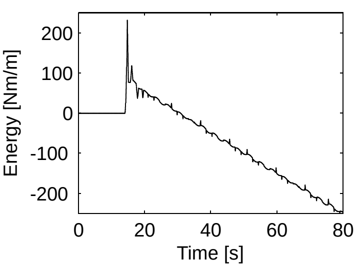

Fig. 3: Example of Total Mechanical Energy of Damper Actuators

3. Conclusions

The capability of a novel active mass damper to control wind-induced bridge vibrations was studied. The performance of the new damper was examined using numerical simulations of an example bridge. Even with a small damper mass and relatively compact damper dimensions, wind-induced vibrations of the bridge were substantially attenuated. Additionally, the critical wind speed of the bridge was increased. The damper possesses an extremely small power demand and generates energy after a certain period of operation.

The influence of the forces involved in the vibration process on the system stability was discussed. A stability measure was proposed to allow the comparison of different system configurations or different bridge systems. This measure could also be useful for stability considerations of other vibrating systems.

Because of the adaptability of the force generation, other applications of the new damper are conceivable, e.g. for the control of vertical bridge deck vibrations induced by moving traffic or for the control of pedestrian-induced lateral vibrations of footbridges. A patent application has been filed for the new damper.

References

[1] STAROSSEK U. and SCHELLER J., “A Novel Active Mass Damper for Vibration Control of Bridges”, *Proceedings of the 4th International Conference on Bridge Maintanance, Safety and Management*, Seoul, Korea, July 13-17, 2008, accepted.