Active Warping Control for Damping of Torsional Beam Vibrations

David Hoffmeyer* and Jan Høgsberg

Department of Mechanical Engineering
Technical University of Denmark
Nils Koppels Allé, Building 404, DK-2800 Kgs. Lyngby, Denmark
E-mail: davhoff@mek.dtu.dk, jhg@mek.dtu.dk

ABSTRACT

Slender structures like long bridge decks, aircraft wings, wind turbine blades and general thin-walled beams may be prone to vibrations due to loads like wind, traffic etc. If the loads act with an eccentricity relative to the shear center or if the cross-section lacks double symmetry torsional vibrations may be induced. For some structures the aerodynamic instability flutter may occur when flexural and torsional vibrations couple. To potentially avoid flutter, to reduce fatigue stresses, reduced structural mass and limit accelerations, supplemental damping may be required.

Torsion of thin-walled beams generates out-of-plane, axial warping displacements that are often significant at the boundaries of beams with open cross-sections. Thus, for these types of thin-walled beams the restraining of warping results in an often considerable increase in natural frequency and change in vibration characteristics. The localized effect of restrained warping is used in [1] to introduce a substantial amount of supplemental damping by applying discrete viscous dampers on a beam cross-section constituting a pure bimoment.

For beams with closed cross-sections or if torsion couples with flexure, viscous dampers may not be sufficient or even practically convenient. Thus, in the present work an active damping concept is used for damping of pure torsional vibrations. A position feedback signal is passed by a sensor through a simple linear filter to an actuator which produces an active force stroke. The damping concept is applied with a beam element and compared with a full three-dimensional FE analysis. In an actual structures the dampers are placed as discrete actuators on a beam cross-section and thus only partially restrains warping. This is associated with an additional flexibility that lowers the damped frequency associated with infinite gain and thereby the damping ratio. This flexibility is incorporated into the beam element as a Maxwell-type boundary condition, and is calibrated by dedicated finite element results. The system is solved in state-space form and it is shown that substantial damping ratios may be obtained for the lowest torsional mode. For the position feedback a stability limit is reached when the damper gain becomes large enough. At this point the damper will eliminate the structural stiffness at the location of the damper and the response becomes unbounded. This limit, however, is based on a static condition and it is shown how the additional flexibility from restraining warping partially affects this limit.

It is demonstrated that the beam element provides very accurate results compared with the full three-dimensional FE model, when the additional flexibility from partial restrainment of warping is taken into account.

REFERENCES

[1] D. Hoffmeyer and J. Høgsberg, *Damping of Torsional Vibrations in Thin-Walled Beams by Viscous Bimoments*, Mechanics of Advanced Materials and Structures, in preparation, DOI: 10.1080/15376494.2019.1567885.