Topological optimisation of friction dampers for nonlinear resonance mitigation

Enora Denimal*, Ludovic Renson* and Loic Salles *
*Dynamics Group, Imperial College London, London, United Kingdom

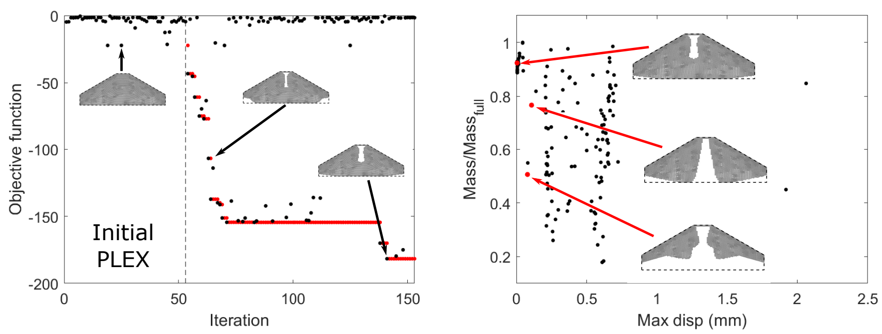
Abstract. Friction dampers are commonly used to reduce the vibration amplitude of aircraft turbine blades. However, the shape of such friction dampers can affect significantly damping characteristics and the overall nonlinear dynamic behaviour of the structure. The present work exploits topological optimization to identify damper geometries that minimize response amplitude. The (near-)maximum responses are efficiently computed by solving the harmonic balance equations and a phase quadrature condition. Moving Morphable Components (MMC) are used to describe the damper geometry and an Efficient Global Optimization (EGO) algorithm is used for the optimization.

Introduction

In the design of aircraft turbines, under-platform dampers (UPD) are commonly used to reduce vibration amplitudes. The UPD geometry at the interface can significantly affect the overall nonlinear dynamic behaviour of the structure. In this work, topological optimisation (TO) is exploited to identify new UPD shapes that improve vibration reduction. A recent approach called Moving Morphable Component (MMC) proposes to describe the geometry of 2D systems with a limited number of parameters [1], which enables the use of global optimisation methods [2]. In [3], a similar approach was applied to minimise the nonlinear frequency response of blades with an UPD. Large computational times were required due to the computation of the full dynamic response over a large frequency range. In the present work, the computational cost associated with the nonlinear resonance calculation is reduced by augmenting the harmonic balance equations with a phase quadrature condition [4].

Results and discussion

The proposed method is demonstrated on a simplified geometry composed of one UPD and two blades. The MMC parameters are optimised with an EGO algorithm where points are added iteratively by maximizing the Expected Improvement criterion. Results of an optimisation are displayed in Figure 1. The proposed approach shows promising results. New UPD geometries that reduce the level of vibrations are found at reasonable computational costs. Directly tracking the resonance in this way also allows us to exploit the resonance's sensitivities to forcing frequency and amplitude to perform robust topological optimisation.



(a) (b)

Figure 1: (a) Evolution of the objective function versus the iteration number and (b) the mass of the different damper geometries versus the maximum of displacement with a few geometries illustrated

Acknowledgements

E. Denimal and L. Salles have received funding from Rolls-Royce and the EPSRC under the Prosperity Partnership Grant CornerStone (EP/R004951/1). L. Renson has received funding from the Royal Academy of Engineering (RF1516/15/11). Rolls-Royce, the EPSRC and the Royal Academy of Engineering are gratefully acknowledged.

References

[1] Guo, X., Zhang, W., Zhong, W. (2014). Doing topology optimization explicitly and geometrically - a new moving morphable components-based framework. *Journal of Applied Mechanics*, 81(8).

[2] Raponi, E., Bujny, M., Olhofer, M., Aulig, N., Boria, S., Duddeck, F. (2019). Kriging-assisted topology optimization of crash structures. *Computer Methods in Applied Mechanics and Engineering*, 348, 730-752.

[3] Denimal E., El Haddad F., Wong C., Salles L., (2020). Topological optimisation of under-platform dampers with moving morphable components and global optimisation algorithm for nonlinear frequency response, *in TurboExpo 2020 (in press)*.

[4] Renson, L., Hill, T. L, Ehrhardt, D. A., Barton, D.A.W., Neild, S.A. (2018) Force appropriation of nonlinear structures. Proc. R. Soc. A.474:20170880.