

# ADJOINT SENSITIVITY ANALYSIS FOR TOPOLOGY OPTIMIZATION UNDER TIME-HARMONIC PRESCRIBED DISPLACEMENTS

Olavo M Silva<sup>(1)</sup>, Arcanjo Lenzi<sup>(1)</sup>, Eduardo Lenz Cardoso<sup>(2)</sup>

<sup>(1)</sup>Universidade Federal de Santa Catarina

<sup>(2)</sup>Universidade do Estado de Santa Catarina

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## Abstract

Prescribed displacements are frequently encountered in vibration problems where the excitation is introduced through kinematic constraints rather than externally applied forces, such as machinery mounted on vibrating foundations, piping systems connected to reciprocating compressors, vehicle suspensions subjected to road-induced motion, and structures tested on shaker tables. In these systems, the structural response is governed by the interaction between the imposed motion and the structural impedance, making displacement-driven excitation a fundamental modeling scenario in practical engineering applications. Nevertheless, most topology optimization formulations for dynamic systems remain focused on force-driven excitation, leaving the treatment of prescribed displacements comparatively underdeveloped.

Although a prescribed displacement can be transformed into an equivalent load vector, such a transformation introduces an explicit dependence of the effective excitation on the structural mass and stiffness matrices. In topology optimization, where these matrices vary with the design variables, the equivalent load vector becomes inherently design-dependent. This feature significantly complicates sensitivity analysis, since the derivatives of the effective excitation with respect to the design variables must be consistently incorporated into the gradient evaluation. Approaches that neglect these contributions or rely on simplified force-based approximations may produce inconsistent sensitivities and lead to non-physical or suboptimal designs.

This work presents a rigorous direct adjoint sensitivity formulation for topology optimization of vibrating structures subjected to time-harmonic prescribed displacements. The proposed framework explicitly accounts for the design dependence of the effective excitation and derives analytically consistent sensitivity expressions within the frequency domain, considering direct harmonic analysis. Input power is used as a vibration performance measure and is minimized for several scenarios representative of practical engineering applications. By systematically incorporating all gradient contributions associated with kinematic

excitation, the method provides a reliable basis for the topology optimization of base-excited and displacement-driven systems, including vibration isolation devices, structural fixtures, and components subjected to foundation motion.