The strongest stable massless column with a follower load and relocatable masses

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Abstract

We consider the problem of optimal placement of concentrated masses along a massless elastic column that is clamped at one end and loaded by a nonconservative follower force at the free end. The goal is to find the largest possible interval such that the variation in the loading parameter within this interval preserves stability of the structure. The stability constraint is nonconvex and nonsmooth, making the optimization problem quite challenging. We give a detailed analytical treatment for the case of two masses, arguing that the optimal parameter configuration approaches the flutter and divergence boundaries of the stability region simultaneously. Furthermore, we conjecture that this property holds for any number of masses, which in turn suggests a simple formula for the maximal load interval for n masses. This conjecture is strongly supported by extensive computational results, obtained using the recently developed open-source software package GRANSO (GRadient-based Algorithm for Non-Smooth Optimization) to maximize the load interval subject to an appropriate formulation of the nonsmooth stability constraint. Our work provides a foundation for new approaches to classical long-standing problems of stability optimization for nonconservative elastic systems arising in civil and mechanical engineering.

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