Nonlinear dynamics of a visco-elastic beam under pulsating dead and follower forces

Francesco D'Annibale*, Manuel Ferretti* and Angelo Luongo*

Department of Civil, Construction-Architectural and Environmental Engineering, University of L'Aquila, L'Aquila, Italy

Abstract. The effects of the interaction between pulsating dead and follower forces on the linear and nonlinear behaviours of a cantilever visco-elastic beam are discussed in this research work. The beam is modelled as an inexstensible and shear-undeformable one-dimensional polar continuum, that is loaded at the free end by both periodically varying in time dead and follower forces. Linear and nonlinear stability analyses of the trivial rectilinear configuration are performed via asymptotic and numerical methods. The effects of the combined load actions on the critical response, i.e. on the stability threshold, and on the post-critical behaviour, i.e. on the limit-cycle amplitude, are detected and discussed.

Introduction

The dynamic stability and the nonlinear analysis of structures under the action of pulsating loads, and follower forces, has been the object of several studies in the literature [1,2]. Due to these actions, different dynamic interesting phenomena may arise, also including: simple and circulatory Hopf bifurcations [2-4], damping destabilization paradox [2], double-zero bifurcation [5], parametric excitation inducing instability [1], super- and sub-critical limit-cycles, hard loss of stability and quasi-periodic motion.

However, although all these kind behaviours have been in-depth analysed when a single action, dead or follower, is applied, periodically varying in time or constant, less attention has been devoted to the interaction phenomena, on both the linear and nonlinear fields, occurring when these kinds of actions are simultaneously applied.

This research line is framed in previously mentioned context, and aims to shed the light on the above discussed interaction phenomena, by analysing the linear and nonlinear dynamics of a clamped visco-elastic Beck's beam (sketched in Fig. 1), loaded by two type forces: i) a dead load, whose intensity is periodically varying in time; ii) a follower force, keeping its direction tangent to the axis line, whose intensity consists of a constant plus a periodically varying part. The analysis is carried out trough asymptotic and numerical approaches, grounded Multiple Scale Method and Finite Difference Method, respectively.

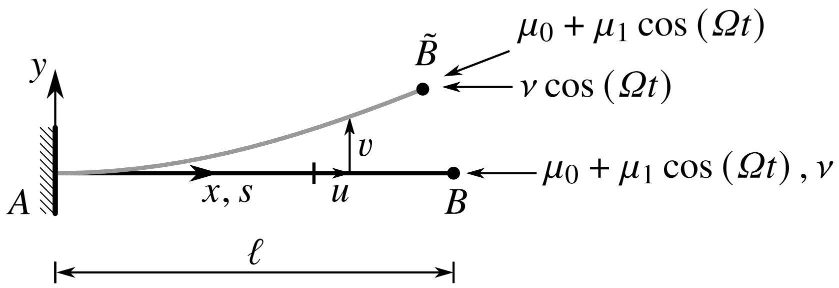

Figure 1: Clamped beam under the action of pulsating dead and follower forces.

Results and discussion

The main results of this work can be summarized in: (i) the asymptotic and numerical detection of the stability charts and (ii) of the bifurcation equations, governing the dynamics around the simple Hopf bifurcation; (iii) the analysis of the limit-cycle amplitude, arising in the post-critical regime. The effects of the interaction between dead and follower parametric excitations have been discussed both in the linear and nonlinear field, thus finding safe and dangerous loading conditions, with respect to the overall dynamic behaviours.

A good agreement between the asymptotic results and the numerical solutions has been detected, thus entailing that the developed multiple-scale algorithm is an effective tool in analysing the linear and nonlinear behaviours.

References

[1] Bolotin V.V. (1964) The dynamic stability of elastic systems. Holden-Day, SF.

[2] Bolotin V.V. (1963) Nonconservative problems of the theory of elastic stability. Macmillan, NY.

[3] Beck M. (1952) Die Knicklast des einseitig eingespannten, tangential gedrückten Stabes. *Z Angew Math Phys* **3**(3):225-228.

[4] Luongo A., D'Annibale F. (2017) Nonlinear hysteretic damping effects on the post-critical behaviour of the visco-elastic Beck's beam. *Math Mech Solids* **22**(6):1347-1365.

[5] Luongo A., D'Annibale F. (2013) Double zero bifurcation of non-linear viscoelastic beams under conservative and non-conservative loads. *Int. J. Nonlin Mech* **55**:128-139.