Nonlinear Dynamics of Beam-Like Thin Tubes Considering Cross-Sectional Flattening and Longitudinal Stretch

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Abstract. The dynamic analysis of a thin tubular beam, involving large deflections and the possible change in shape of the cross-sections, is addressed here. More specifically, a beam-like model, previously proposed by the authors and able to catch the main structural response of thin tubes under transverse loads, is extended to involve the contribution of the longitudinal stretch of the mid-line, which assumes a fundamental role in the nonlinear analysis if external constraints prevent longitudinal displacement of end sections, e.g., in clamped-clamped cases.

Introduction

The response of thin tubes to external solicitations is generally greatly influenced by the change in cross sectional shape. For example, the Brazier effect, which is widely addressed in literature, addresses the coupling which occurs between global bending of pipes and their cross-sectional flattening, inducing a nonlinear softening moment-curvature relationship [1]. Recently, a beam-like model accounting for that effect was proposed by the authors to study the nonlinear dynamics of thin tubes under transverse loads where, because of the external constraints assumed therein, i.e. clamped-free cross-sections, the mid-line of the beam-like was consistently assumed inextensible [2]. There, possible internal resonances between global (bending) and local (flattening) modes were analyzed, leading to energy exchanges among them. As the terminal cross-sections was considered free to move in the longitudinal direction, the assumption of inextensional axis-line was reliably taken on. However, when the longitudinal displacement of the extreme sections is inhibited, as happens for instance in clamped-clamped pipes, the longitudinal stretch of the mid-line becomes one of the main sources of nonlinearity [3]. Here, the model introduced Ref. n. 2 is reformulated and extended to take into account the longitudinal stretch of the mid-line. The dynamical response of the pipe is then analyzed, assessing how the bending-flattening coupling is modified.

Results and Discussion

The nonlinear dynamics of the thin pipe in Fig 1a, where R is the mid radius of the annular cross section, h is the thickness (R»h) and L the initial length, is addressed under the action of time-harmonic transverse loads. For this scope, a nonlinear beam-like model is used (Fig 1b), in case of clamp-clamp external constraints. Under the guidelines of Ref. n. 2, the nonlinear kinematic and dynamic problems for a beam with additional descriptors as compared to the Timoshenko beam model are derived. Then, the nonlinear elastic material response function is identified after comparison from a refined 3D model of the pipe realized by fibers. The effect of the longitudinal stretch, which was disregarded in previous applications, is analyzed here. **Acknowledgements** This

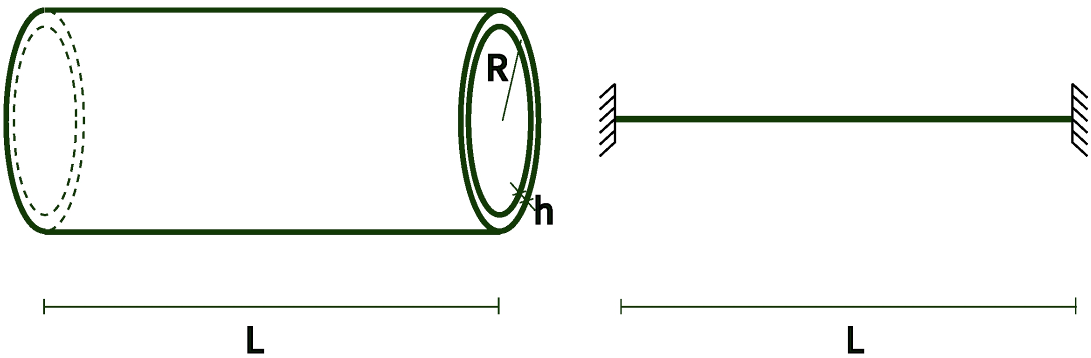

Figure 1: a) Pipe of length L, radius R and thickness h. b) Equivalent clamped-clamped beam-like model.

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