A beam-like model for the buckling and post-buckling analysis of a thin pipe

Arnaldo Casalotti*, Manuel Ferretti**, Angelo Luongo**, Daniele Zulli**
*Department of Architecture, Roma Tre University, Rome, Italy
**Department of Civil, Construction-Architectural and Environmental Engineering, University of L'Aquila, Italy

Abstract

Thin pipes are structural elements which are widely used in technical applications, especially concerning civil, industrial and aerospace engineering. The careful evaluation of their carrying capacity plays a key role in the design process, in particular due to the possible involvement of local effects related, for instance, to flattening or warping of the cross-sections. As a typical example, when pipes are bent over, the concurrent ovalization of the cross-section can induce a softening behavior, referred to as Brazier's effect [1], leading to a limit point in the bending moment-curvature relationship and a sudden failure of the structure.

Recently, a nonlinear beam-like model of thin pipe was proposed in [2, 3], where the classical kinematic descriptors for the rigid cross-section Timoshenko beams (u, v, ϑ) were combined to further descriptors (a_p, a_w), indicating amplitude of ovalization and warping under prescribed shapes. The formulation required an identification of the nonlinear elastic constitutive law from a three-dimensional continuum, where the pipe was considered as constituted by a bundle of longitudinal fibers and transversal annular ribs. The obtained one-dimensional continuum model turned out to fully catch both nonlinear static and dynamic response of the pipe and, for its simplicity as compared to shell models, it appeared as very convenient to be tackled with perturbation methods.

In this paper, the above mentioned beam-like model is extended to address buckling and post-buckling analysis of thin pipes. For this scope, geometrical stiffness terms are consistently included and consequent evaluation of the critical loads is carried out. Analytical and numerical tools are then used to assess the post-buckling behavior, where the effect of cross-section change in shape can be prominent. In particular, a perturbation method is applied to carry out analytical evaluations. Comparison with outcomes given by finite element method commercial software is finally provided, where the pipe is modelled as assembly of this shells.

References

[1] *Brazier, L., "On the flexure of thin cylindrical shells and other "thin" sections", Proceedings of the Royal Society A, 116: 104–114 (1927).*

[2] *Zulli, D., Casalotti, A., Luongo, A., "Static response of double-layered pipes via a perturbation approach", Applied Sciences 11: 886 (2021).*

[3] *Casalotti, A., Zulli, D., Luongo, A., "Dynamic response to transverse loading of a single-layered tubular beam via a perturbation approach", International Journal of Non-Linear Mechanics, 137: 103822 (2021).*

Acknowledgements. This work is partially funded by the European Union - Next Generation EU, in the framework of the project PRIN 2022 PNRR M4-C2-I.1.1, P2022ZT5X5, Smart Under-Ground Infra-Structures for Secure Communities and Post-Disaster Emergency Response: Eco-Friendly Seismic Protection Solutions (CUP: E53D2301762 0001, University of L'Aquila).