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

Arnaldo Casalotti[1], Manuel Ferretti[2], Daniele Zulli[2], Angelo Luongo[2]
[1] *Department of Architecture, Roma Tre University, Rome, Italy*
E-mail: *arnaldo.casalotti@uniroma3.it*

[2]*Department of Civil, Construction-Architectural and Environmental Engineering, University of L'Aquila, Italy*
E-mail: *manuel.ferretti@univaq.it, daniele.zulli@univaq.it, angelo.luongo@univaq.it*

Keywords: Buckling; Ovalization; Beam-like Models.

Thin-walled pipes are common structural elements in civil, industrial, and aerospace engineering. Accurately assessing their load-bearing capacity is crucial, especially due to local phenomena such as cross-section flattening or warping. For example, bending may cause ovalization, leading to structural softening known as Brazier's effect [1], which can trigger sudden failure.
A nonlinear beam-like model has recently been introduced in [2,3] to describe such pipes, extending the classical Timoshenko beam theory by including parameters for ovalization and warping. This model derives a one-dimensional continuum by idealizing the pipe as composed of longitudinal fibers and transverse ribs, enabling accurate prediction of both static and dynamic nonlinear responses. Its reduced complexity compared to shell models makes it suitable for perturbation techniques, with the goal of obtaining analytical solutions to the problem.
This study builds on that model to investigate buckling and post-buckling behavior. Geometric stiffness effects are incorporated to determine critical loads, while analytical and numerical tools—especially perturbation methods—are used to explore post-buckling responses. Results are compared with commercial finite element simulations where the pipe is modeled using shell elements.

References

[1] Brazier, L., "On the flexure of thin cylindrical shells and other "thin" sections", Proceedings of the Royal Society A, ***116****, page 104–114 (1927).*
[2] Zulli, D., Casalotti, A., Luongo, A., "Static response of double-layered pipes via a perturbation approach", Applied Sciences, ***11****(2), 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, Mission 4 Component 2 Investment 1.1, in the framework of the project PRIN 2022 PNRR, "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).