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Finite element beam formulation for modelling of hyperelastic beams with arbitrary cross-sections and transverse isotropy

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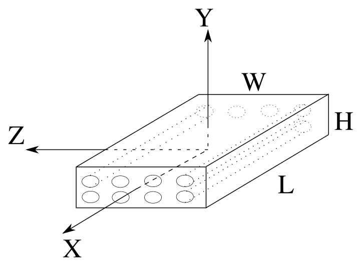
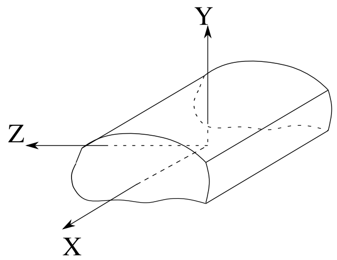
ABSTRACT

The deformation of a flexible body is a problem with numerous practical applications. One example is soft robotic technologies, where precise knowledge of the mechanical response is required. The soft robot bodies are generally made of hydrogels and elastomers and undergo high strains and deformations. Therefore, for their modeling, nonlinear materials are generally considered. Other issues are porosity presence, either as a part of models or for the creation of anisotropy in initially isotropic solid [1], and non-standard form of the bodies. Due to these challenges, only a certain number of analytical solutions are available and only for bodies of elementary forms, such as prismatic or cylindrical. The finite element (FE) modeling provides a way and possibility to handle significant geometrical and materials non-linearities with avoiding the need for analytical models. However, the FE involving results in high computational costs because of the standard usage of 3D elements for these tasks. Such the primary object under consideration for soft robotics is a flexible beam, then the development of beam formulations can increase the computational efficiency. The study aims to describe beam-like hyperelastic structures in a framework of the absolute nodal coordinate formulations (ANCF) via Green's numerical integration scheme formula. Such description allows creating various cross-section types, including longitudinal and aligned pores as the cause for the transverse isotropy (Fig.1a), and, if it is necessary, even forming arbitrary beam cross-sections (Fig.1b).



(a) A beam with longitudinal porosity



(b) A beam with an arbitrary cross-section

Keywords: Large strains, Nonlinear elasticity, Transverse isotropy, Porosity, Arbitrary cross section

REFERENCES

[1] BACCIOCCHI, M., AND TARANTINO, A. M. Finite bending of hyperelastic beams with transverse isotropy generated by longitudinal porosity. European Journal of Mechanics - A/Solids 85 (2021), 104131.