Numerical modeling of thin and thick shells using the scaled boundary finite element method

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Abstract

Over the last decades, engineering design processes have become more and more sophisticated across all engineering disciplines. Examples include complex architectural designs in civil engineering and resource-efficient designs in mechanical engineering. The use of numerical methods is essential in such design processes.

In this context, the development of robust and efficient techniques for the numerical analysis of shell structures has been an active area of research for many years. Classical shell elements are based on kinematic assumptions with respect to their through-thickness behavior. Requiring the discretization of the mid-surface only, they lead to a significant reduction in the number of degrees of freedom compared to solid elements. However, classical shell elements have been shown to exhibit locking effects. In a finite element analysis, locking describes an overly stiff behavior of a numerical model. The most dominant locking effects for shells are transverse shear locking and membrane locking. Locking in shell formulations is heavily influenced by the shell’s thickness, where more severe locking effects are observed with decreasing thickness. While there are several techniques to mitigate these locking effects, the development of locking-free finite elements is still an active research topic. Since the description of the through-thickness behavior seems to be crucial to avoid locking, the scaled boundary finite element method (SBFEM) with its semi-analytical approach presents itself as a potential method to obtain locking-free shell formulations. This assumption is supported by previous research on locking-free plate formulations based on the SBFEM.

This contribution presents the derivation of a scaled boundary finite-element based static stiffness matrix for shell structures. The proposed method is applied to several benchmark problems for thin shell structures, and the results are compared to reference solutions based on existing shell elements. These results illustrate the potential of the proposed method. Additionally, stress analysis results for a thick spherical shell are presented to further emphasize the versatility of the proposed technique. Particular challenges observed when modeling shells with SBFEM are also discussed.

Keywords: scaled boundary finite element method, thin shells, thick shells, locking