Sensitivity analysis for generalized Navier-Stokes models

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Abstract

Sensitivity analysis plays a central role in the assessment of the impact of uncertainties on mathematical models arising in fluid mechanics. It provides quantitative information on how variations in physical or geometrical parameters affect the solution of the governing equations, and it is a key ingredient for uncertainty quantification, model validation, and robust numerical simulations.

Sensitivity analysis is performed for the incompressible Navier–Stokes equations [2, 3] and for the Navier–Stokes equations coupled with heat transfer [4, 5]. First-order sensitivities with respect to uncertain parameters are derived using intrusive methods based on Intrusive Polynomial Chaos Method (IPCM). Extensions to turbulent flow models, including Reynolds-averaged Navier–Stokes equations with k–ε closure, are also considered, highlighting the difficulties introduced by nonlinear and non-quadratic terms.

In ongoing work, particular attention is devoted to fluid–structure interaction problems, which play a major role in nuclear engineering applications. In such systems, the strong coupling between fluid dynamics and structural mechanics makes sensitivity analysis especially challenging. Performing sensitivity analysis, including shape sensitivity [1], is shown to be essential for understanding the influence of physical and geometrical uncertainties on the global behavior of coupled fluid–structure systems.

References

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