Stochastic sensitivity analysis of numerical predictions of the flow around a 5:1 rectangular cylinder

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The international benchmark BARC deals with the flow around a rectangular cylinder with chord-to-depth ratio equal to 5. This flow configuration is of practical interest for civil and industrial structures and it is characterized by massively separated flow and unsteadiness. The related flow is complex, being turbulent with separation from the upstream corners and reattachment on the cylinder side and vortex shedding from the rear corners. In a recent review of BARC results, significant dispersion was observed both in experimental and numerical predictions of some flow quantities, which are extremely sensitive to various uncertainties that may be present. After an introduction to the main uncertainty quantification techniques, viz, the generalized polynomial chaos and the stochastic collocation method, the results of two stochastic sensitivity analyses of numerical predictions of the flow around the considered cylinder are presented.

Since in simulations it is difficult to exactly reproduce the experimental conditions due to uncertainties in the set-up parameters – which sometimes cannot be exactly controlled or characterized – the first study is aimed at investigating on the effect of uncertainties in some set-up parameters. Probabilistic methods and URANS simulations are used. The angle of incidence of the incoming flow, its free stream longitudinal turbulence intensity and its length scale are chosen as uncertain parameters. Stochastic collocation is employed to perform the probabilistic propagation of the uncertainty. The discretization and modeling errors are estimated by repeating the same analysis for different grids and turbulence models.

In the second investigation, a stochastic analysis of the impact of discretization and numerical errors in large eddy simulations (LES) of the flow around the 5:1 rectangular cylinder is carried out. Sensitivity to grid resolution and modeling of LES results and the deterministic sensitivity analyses presented in the BARC review were indeed not conclusive. In the presented work, LES are carried out by using the open-source spectral-element code Nek5000. An explicit quadratic low-pass filter in the modal space is used, characterized by a cut-off value and by a weight function, which provides dissipation of the modes higher than the cut off and acts as a SGS dissipation. The uncertain parameters are the size of the spectral elements in the spanwise direction and the weight of the explicit filter. The impact of the uncertainty in these parameters is evaluated through generalized polynomial chaos. The stochastic variance of the results is compared to the overall dispersion of the BARC results.