Numerical prediction of pipe flows with uncertain inflow conditions

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ABSTRACT

In many metrological fluid flow applications, the pipe flows are of special interest, since they build the basis for many flow meters. In this context, the exact determination of the flow rate is of great importance in flow metrology. However, most of the flow meters sensitively react to a deformed inflow profile caused for example by flow history in a real piping system. Thus, the determination of the influence of uncertain inlet velocity profiles on the flow measurements can contribute to a significant decrease of the measurement uncertainty. Furthermore, the velocity profiles at different cross sections further downstream in the pipe are investigated to get information about the suitability of flow meter positions. For the propagation of the inflow uncertainty a generalized Polynomial Chaos (gPC) method in conjunction with a commercial deterministic CFD code is used to quantify the uncertainty in the flow field. The so-called "non-intrusive" spectral projection approach is based on the spectral representation of the uncertainty and proprietary software can be used as a black box. In connection with modern sampling methods the expense is considerably smaller than for conventional Monte Carlo (MC) analysis, at least for only a few simultaneous random parameters. It can be stated that for computationally expensive models, as usually in fluid dynamics, the use of MC methods is impractical. In our contribution we present results for Legendre-chaos corresponding to uniform random parameters and subsequently we discuss the extension to Gaussian distributions. The results characterize the uncertainty of the velocity profiles in possible meter positions, for example the effect is clearly indicated in figures for the standard deviation. Large values identify regions which are strongly influenced by the random inflow, but for nearby zero values the influence vanishes. The presented procedure is qualified for extensions to other flow situations and uncertain quantities.

Keywords: generalized polynomial chaos, non-intrusive spectral projection, pipe flow, computational fluid dynamics