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ON THE NUMERICAL UNCERTAINTY OF UNSTEADY FLOW SIMULATIONS

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Most of the engineering applications of the Offshore industry and other fields involve turbulent flows that are not statistically steady, i.e. applying time-averaging to obtain the mean flow field and the Reynolds-Averaged Navier Stokes (RANS) equations does not make sense. This makes the simulation of these flows extremely challenging, because simulating directly turbulence (DNS) for such applications is not feasible due to the complex wall-bounded geometries and high Reynolds numbers. Therefore, several mathematical models have been proposed to handle such type of flows with Computational Fluid Dynamics (CFD), which range from ensemble-averaged RANS to Large-Eddy Simulation (LES) with several Hybrid and Bridging models in between, see for example [1, 2].

Nowadays, several papers are presented every year including CFD simulations for statistically unsteady flows using models that attempt to determine part of the turbulent field, as for example Detached Eddy-Simulation (DES) and its variants, Partially Averaged Navier Stokes (PANS) equations or even LES. In fact, RANS is becoming the exception instead of the rule. However, before we are able to judge the (modeling) accuracy of such simulations, it is necessary to guarantee that we are obtaining correct solutions of the selected model, i.e. we must assess the numerical error of the simulations, [3]. Otherwise, a fortuitous canceling of modeling and numerical errors may lead to misleading/dangerous conclusions about the quality of the simulations.

In this paper we demonstrate that controlling the numerical error in unsteady flow simulations is not a trivial task even with the simplest mathematical models available. To this end, we selected the laminar, two-dimensional flow of an incompressible fluid around a circular cylinder at the Reynolds number of 100. Obviously, this is not a representative test case for the so-called practical enginnering applications, but it is sufficient to exemplify the effects of iterative, discretization and statistical (induced by the initial condition) errors! Nonetheless, we also present results for a three-dimensional structure formed by two vertical columns connected by a pontoon at two different headings: 45 and 77.5 (at 0 degrees the flow is aligned with the axis of the pontoon). These simulations are performed with ensemble-averaged RANS for an incompressible fluid at Reynolds number of 2.25×10^5. The results for this “practical” test case confirm the need to control iterative and statistical errors even before addressing discretization errors, i.e. grid/time refinement.

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