Quality checking of CFD

Complementary to model testing, Computational Fluid Dynamics (CFD) has carved out a firm position in the MARIN portfolio. But when go or no-go decisions are at stake, the question naturally arises: how reliable is a particular CFD application? Report examines how this question is being addressed.

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The advantage of CFD is that it gives insight into flow details, most of which are not directly revealed in a physical experiment. However, the CFD practitioner can do a lot of things wrong and even if he is careful, his model is not a perfect representation of the real world. To understand the consequent uncertainty of the results, a research field has evolved known as "Verification and Validation". MARIN's CFD team has taken an active part in this research, the greatest efforts been made by Luís Eça within the productive MARIN - Instituto Superior Técnico (IST) cooperation, which has now lasted more than 20 years!

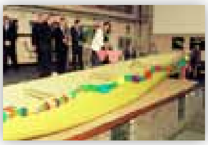
Validation CFD is essentially the numerical solution of a mathematical model supposed to govern the behaviour of the flow past an object under proper boundary condition settings. That mathematical model typically contains simplifications and these introduce modelling errors. Validation checks the adequacy of the model and involves the comparison of numerical results with experimental data, taking the uncertainties of both into account.

… and Verification Even if the mathematical model would be perfect, the results of CFD still have numerical errors. The process of estimating the numerical error of a computational result of a specific code is called "verification". Three error sources can be distinguished: round-off, iterative and discretisation errors. Verification has two aspects: verification of the results of a CFD application and verification of the code. The latter is to make sure that the mathematical model has been implemented correctly, in other words that the code is bug-free. For now, let us suppose that this has been accomplished. Then a good estimate of the numerical error of the CFD result has to be made. The aim is to attach an uncertainty interval to a particular result so that the true solution will be found within that interval with 95% confidence. Without getting its absolute value, an impression of the variation of the discretisation error is obtained by solving the same flow problem on a set of systematically refined grids, keeping everything else the same. To avoid contamination of the results by the iterative error, the solution must be properly converged on each grid. Comparison of solutions on two grids is already informative but with solutions on three or more grids, procedures are available to estimate the uncertainty of the solution on any of the grids.

The validation process Validation is more than plotting the results of CFD with experimental data on the same graph. Validity of the mathematical model can only meaningfully be checked after having established the uncertainty of both the numerical and experimental result. Incidentally, it may happen that a coarse grid solution is closer to the experimental data than a finer grid solution. This does not mean that the coarse grid is good enough. Numerical errors may have cancelled the modelling errors but their nature being different, they may well add up rather than cancel in the next application. Evidently, one cannot validate a code but only validate the results of a particular application against a corresponding experimental data set.

What does this mean for practicing CFD? To get a good guess of the uncertainty, it seems hardly feasible to solve the flow in any application on several systematically refined grids. But a CFD group taking its work seriously will make verification and validation studies for representative flow problems time and again. That is what MARIN's CFD team does to make sure customers get value for money.

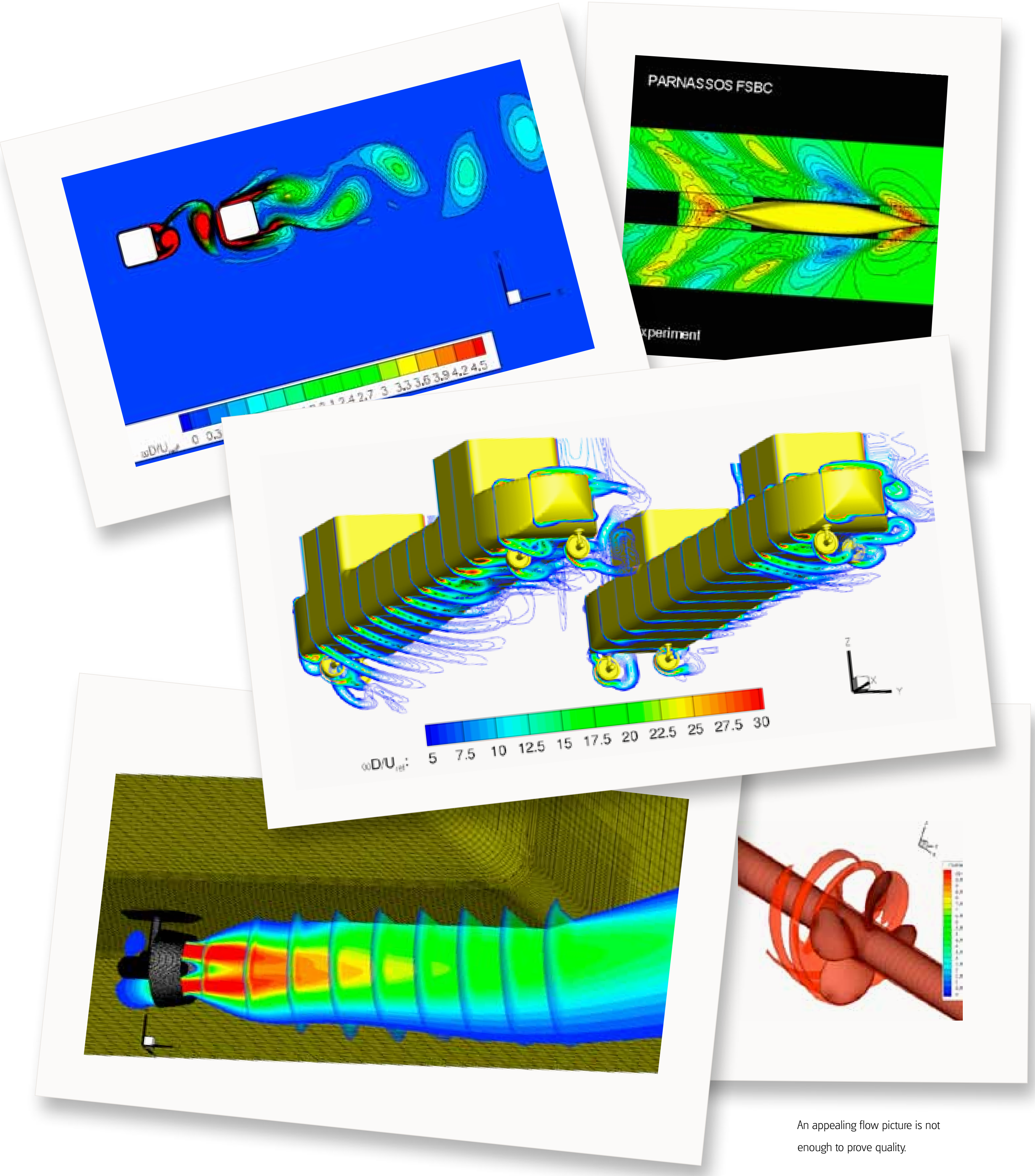
1994



Model no. 7500 tested for Chantiers de l'Atlantique

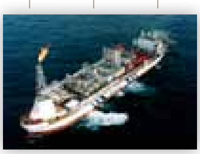
1994

First FREDYN ultimate stability simulation



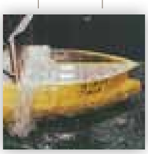
An appealing flow picture is not enough to prove quality.

1996



Start FPSO Integrity JIP on fatigue loads on FPSOs

1997



Green Water JIP

1998

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