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A DETAILED CFD AND EXPERIMENTAL INVESTIGATION OF A BENCHMARK TURBULENT BACKWARD FACING STEP FLOW

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A benchmark turbulent Backward Facing Step (BFS) flow was studied in considerable detail using a program of tightly coupled experimental and CFD analysis. The theoretical and experimental approaches were developed simultaneously during each “building block” step and the results continuously used to verify and validate each experiment and CFD model.

The most important step in this investigation compared high-resolution cross-correlation Particle Image Velocimetry (PIV) data with well-converged CFD data, for the BFS cross-sectional plane. As both methods generate global velocity and turbulence statistics data over a 2D area, direct and detailed comparison of streamlines, contours and vector plots was made possible. CFD simulations made use of two common turbulence models, namely RNG k-ε and the Reynolds Stress Model (RSM) in order to reveal accuracy and reliability compared to each other and the PIV data. Hot Wire Anemometry and PIV were used to precisely measure the inlet velocity and turbulence statistics in the BFS cross-sectional plane. These profiles formed the inlet boundary conditions for the CFD simulations to ensure “equivalence” between CFD and experimentation at the system boundaries.

PIV and CFD results showed excellent agreement in comparison of velocity components, streamlines, Reynolds Stresses and vorticity and allowed complex flow structures in the BFS recirculation region to be revealed. Access to both data sets proved to be invaluable, as they tended to supplement each other for any weaknesses inherent in either approach. PIV for example is limited in the number of velocity samples it can measure, which makes contours of turbulence statistics noisy and error prone. In each case, CFD turbulence statistics showed the same variation as PIV, but contained considerably more detail, which in comparison clearly highlighted the PIV errors. Similarly, PIV revealed that CFD failed to predict the full extent of the low speed second vortex that forms behind the BFS.

These insights were only possible because “equivalent” CFD and experimental data sets where generated at each step. They allowed regions of the BFS flow to be investigated at greater spatial resolution than previous studies and provided evidence to settle several outstanding BFS issues. A new vortex structure behind the step was discovered and the 3D nature of the second vortex highlighted. At a very fine resolution (<2 mm) no evidence of the much sort after, third vortex was found.