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Validation of URANS and Stress-Blended Eddy Simulations (SBES) in ANSYS CFD for the Turbulent Mixing of Two Parallel Planar Water Jets Impinging on a Stationary Pool

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Rectangular jets are encountered in many types of engineering applications and provide a challenge in nuclear reactor systems. In the present study the turbulent mixing and penetration of two parallel planar jets is investigated at Reynolds numbers, which are typical for twin jet behavior in the upper plenums of both a liquid-metal cooled reactor and the very high temperature gas-cooled reactor. The investigation follows the ASME V&V 30 Committee, Benchmark Problem 1 specification for the corresponding experiment carried out by H. Wang & Y. Hassan, Texas A&M University (2015/2016) at the Twin Jet Water Facility (TJWF) designed and built at the University of Tennessee, Knoxville and applies standard best practices and required investigations of experimental and boundary condition uncertainties as far as applicable. The applied high-fidelity measurement techniques like LDA and PIV as well as the broad set of measured local fluid flow quantities like mean velocities, turbulence intensity, Reynolds stresses and other parameters acquired enable a thorough comparison to CFD simulations for V&V efforts of the same facility and boundary/initial conditions.

The mixing and penetration of two parallel planar jets impinging on a stationary water pool has been investigated for nozzle exit Reynolds number Re=9100 using three ANSYS CFD solvers (ANSYS Fluent, ANSYS CFX and AIM Fluids) and by applying steady-state as well as transient, time-averaged Shear-Stress Transport (SST) and Stress-Blended Eddy Simulation (SBES) turbulence models. In a first investigation the provided stationary inlet boundary conditions at the two nozzle exits for mean axial velocity and turbulence intensity were compared to results of a flow simulation, where mass flow and turbulence intensity boundary conditions were applied to the inlet pipes to the two stagnation boxes upstream the nozzle exits. In this study it was found, that despite the flow development in the narrow nozzle channels over a length of L/a~48 the irregular turbulent flow in these stagnation boxes lead to a transient and irregular fluid flow profile at the planar channel nozzle exits and that the provided experimental boundary condition can only be matched in a statistical time-averaged sense. For this reason, further investigations have been carried out as transient and time-averaged URANS SST or SBES simulations.

Further best practices oriented investigations have been carried out to determine the proper time resolution and flow averaging time to achieve appropriate resolution of all relevant flow phenomena as well as statistical reliability of time-averaged fluid flow quantities for the comparison to the experimental data. A mesh independency study has been carried out on two hexahedral meshes with 6.5 Mill. and 54 Mill. mesh elements as well. Both the time-averaged URANS SST and the time-averaged, scale-resolving SBES model simulations have led to a very good agreement for mean streamwise jet velocities, turbulent kinetic energy and individual Reynolds stress tensor components in comparison to the LDA and PIV data, showing only some minor deviations at intermediate elevations between z/a=5 and z/a=10. In addition, the SBES simulation provides detailed insights into the turbulent jet breakup and mixing by fully resolving different turbulent scales on the fine mesh and leading to a slightly more accurate prediction of the jet mixing point in comparison to URANS SST. Furthermore, the transient flow recirculation on top of the nozzle pedestal is resolved by the SBES simulations. The simulation results are highlighting the need to accurately quantify upstream flow conditions when downstream mixing is the phenomenon of interest.