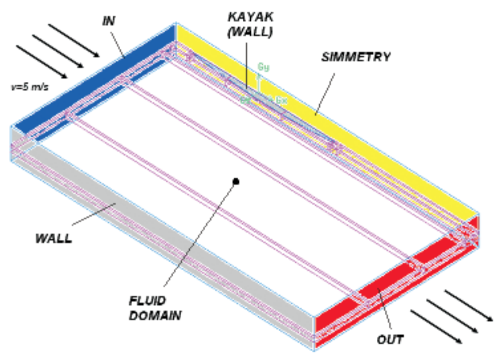
Digitalized kayak surface obtained by a reverse engineering optical scanning process

Olympic Kayak Makes Waves

By Francesco Crotti, Davide Mazzini, Marco Beghini, and Sandro Barone, The University of Pisa, Pisa, Italy

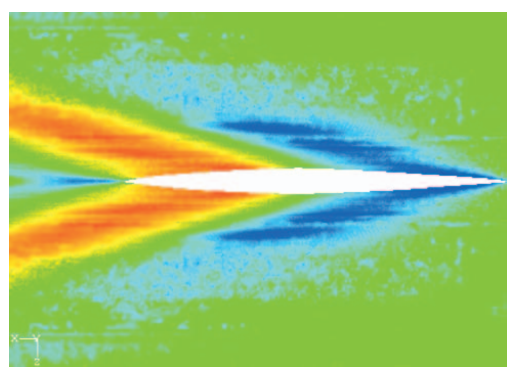
SINCE THE 1936 GAMES IN BERLIN, the sport of flatwater sprint kayaking has been part of the Olympic tradition. In solo races, a kayaker maneuvers a 17 ft (5.2 m) boat over distances of 500 or 1000 meters using an unattached double-bladed paddle and a foot rudder. The motion of a kayak is similar to the motion of a ship. By advancing on the free surface of a basin, the kayak moves a certain quantity of water in a continuous process, thereby creating waves. To simulate the wave-creation process, a study of the hydrodynamic forces acting on a one-person sprint kayak was performed at the University of Pisa in the Department of Mechanical, Nuclear and Production Engineering. This study was performed in the framework of a laurea degree in Mechanical Engineering.

Typically, the total force required to maintain a kayak's speed must overcome two forms of drag or resistance: the viscous drag on the hull's wetted surface and the wave-making resistance. The goal of the Pisa study was to create a CFD model to predict the total hull drag, comprised of these two components. Starting from a digitized surface obtained by an optical coordinate measuring machine (CMM) reverse engineering process, the study consisted of two main challenges. The first concerned the definition of a proper procedure to correctly input the digitized geometry, since the scanned kayak surface had patches with different sizes and irregular shapes. The second was to validate the CFD tool using its postprocessing capabilities.



3D computational fluid domain

A detection procedure based on reverse engineering was adopted to obtain an accurate geometric description of the external surface of the hull. Compared to the real kayak, the final surface had an accuracy on the order of 0.1 mm. The computational grid was created using GAMBIT, taking into account one half of the kayak's surface by defining a plane of longitudinal symmetry. The final 3D fluid domain was represented by a parallelepiped with sides 12m x 3m x 7m, which was subsequently meshed into a grid of three million tetrahedral cells. This final grid, though not optimized for the computation time, was found to give stable solutions.



Volume fraction contours of air illustrate the bow wave generated by the motion of the kayak

For the purpose of the study, the kayak speed was assumed to be 5m/s, a typical quantity for the Olympic races. At that speed, the fluid regime is turbulent ($Re > 10^6$) and the wave resistance accounts for the main contribution to the total drag. FLUENT's VOF multiphase model was used to simulate the motion of the air and water phases. Assuming the wave-making process to be a steady-state phenomenon, an implicit scheme was adopted. The k-ω turbulence model was used together with the body-force-weighted interpolation algorithm because both gravity and the surface tension between the fluids were considered in the numerical model.

The results were analyzed from both a qualitative and quantitative perspective. The wave motion around the kayak was evaluated by plotting the volume fraction of air on the initial (unperturbed) water surface. The total drag was obtained from the integral of the drag coefficient along the wetted kayak hull. The total resistive force on the hull computed by FLUENT, 102N, was in good agreement with that computed using an analytical method that relies on a power balance (112N). ■