Germany Rocks on Water

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Advances in boat equipment design via simulation help to sustain Germany's Olympic excellence.

In the pantheon of Olympic sports, boating competitions have been around since the very beginning. Rowing was to have its debut in the 1896 games in Athens but was delayed until the 1900 games in Paris by bad weather. Canoeing and kayaking were first contested in the Berlin games of 1936. Over the course of modern Olympic history, no country's teams have won more medals in the rowing, canoeing and kayaking events than the German teams. This winning tradition has been upheld in recent years due in part to engineering innovations originating from the Institute for Research and Development of Sports Equipment, which is known by its German acronym, FES.

From its first successes — creating more aerodynamic bicycles for the 1988 games in Seoul, South Korea, to more recent efforts — designing more streamlined bobsleds for the 2006 Winter games in Turin, Italy — FES has continued to achieve international success by developing sports equipment in accordance with the latest engineering technology. Numerical simulation has been a part of the company's toolbox for over a decade as FES engineers have used ANSYS CFX to optimize the fluid dynamics for different classes of racing boats. Their work contributed to several medal-winning performances at the 2008 Beijing games, and it is helping the German team prepare for the 2012 London games.

The focus of recent simulation efforts at FES has been on some of the smaller boats, specifically the pairs (two-person) sweep rowing shell and K-1, K-2 and K-4 (one-, two- and four-person) racing kayaks. From both construction and simulation points of view, FES decided that it made sense to analyze these smaller boats; even though they require less material to build, they are more difficult to optimize. For example, the K-1 kayak must be no longer than 17 feet (5.2 meters) with a minimum weight of 26 pounds (12 kilograms). With this relatively small amount of boat surface to modify while taking into account the surrounding air flow, water flow, free surfaces and complex boundary conditions, simulation was a necessary and crucial part of the design process.

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In the case of the pairs rowing shell, drag reduction was at the top of the list for optimization. In a sport timed to the

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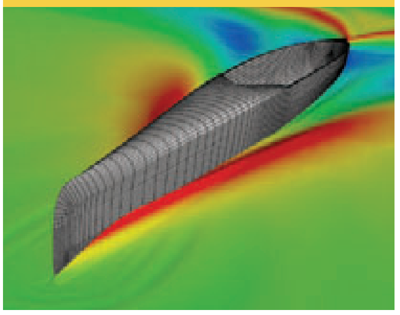
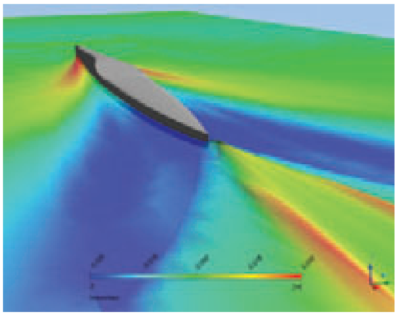
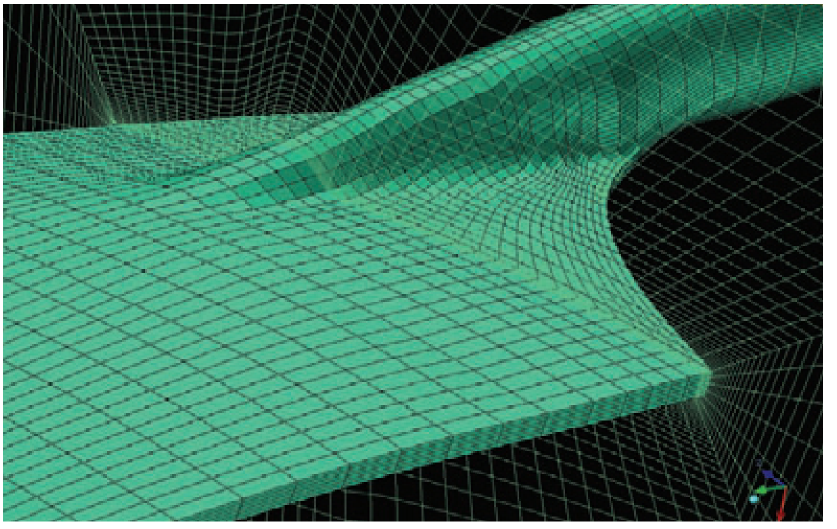


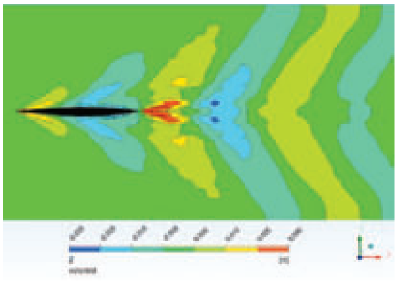


Contours of the free surface at steady state colored by wave height: canoe single (C1) boat (top); kayak single (K1) boat (bottom)



Close-up of surface mesh and surrounding fluid zone mesh for rowing oar blade

Sequence of blade stroke as the blade contacts water: rowing oar (top); kayak paddle (bottom)



Overhead view showing wave pattern produced on water surface by a K1 boat. Colors indicate the height above (yellow and red) or below (blue, light blue) initial undisturbed water (green).

thousandth of a second, even a 1 percent improvement can make a crucial difference in a close race. The main components that cause drag are friction on the wetted surface and the formation of waves during the rowing process. Other parameters that come into play include the location of the center of gravity and the volume of water that the boat displaces. During simulation efforts, it became apparent that the initial assumption of a fixed boat position in the water was not correct, as results deviated significantly from towing-tank experiments on scale models.

To correct this issue, FES engineers used the CFX Expression Language, with its capability to integrate user-defined FORTRAN™ subroutines, to automatically determine the variable floating position of the boat, which was dependent on the actual velocity during the calculation. For every iteration, the new floating position of the boat was calculated and the mesh deformed. Using a structured mesh generated by ANSYS ICEM CFD that contained 3 million cells, engineers could perform extensive transient simulations with reasonable calculation times.

The FES team expanded their efforts through interaction with experts at CFX Berlin, an ANSYS channel partner, which provided support for meshing, simulation, and setting up the high-performance computing (HPC) cluster at FES for both Linux® and Windows® hardware. Transient simulations of moving boats — once prohibitively expensive — could now be accomplished in just two or three days.

Using HPC, the FES team was able to efficiently consider up to 20 different virtual designs per boat class, and from those 20 designs engineers gained enough confidence to build a single prototype for testing. Since flatwater sprint courses have generally the same conditions around the world, the goal was not to exactly reproduce the towing-tank test results with simulation; rather it was to understand the relative difference in performance between hull designs under the same boundary conditions. As a result of these numerical investigations, optimizing hull shapes that reduce the friction on the wetted surface and the formation of waves — and hence the overall drag — should assist the German team in its quest for medals.

Beyond boat hydrodynamics, the other main process that FES has studied is the oar and paddle stroke. Both rowing and kayak strokes consist of a drive phase, in which the boat is propelled,

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and a recovery phase, during which it slows down. The resulting cyclic velocity is responsible for changes in immersion, trim, drag resistance and lift. Though numerous parameters and influencing factors strongly depend on the individual habits of the athletes, some promising first steps have been taken using simulation to optimize the designs of oar and paddle blades.

Throughout all these efforts at boat optimization, the athletes themselves have been closely involved with the development, since changes in equipment can necessitate adjustments in how Olympic team members need to perform to realize the full benefits of the simulation-driven design changes. This collaboration is essential, as top performers can be reluctant to risk changing routines or well-honed rowing and paddling techniques in advance of a showcase event.

Extending the success of German athletes on the water was an excellent incentive for FES engineers in overcoming technical challenges and gaining valuable insights into oar, paddle and boat performance.