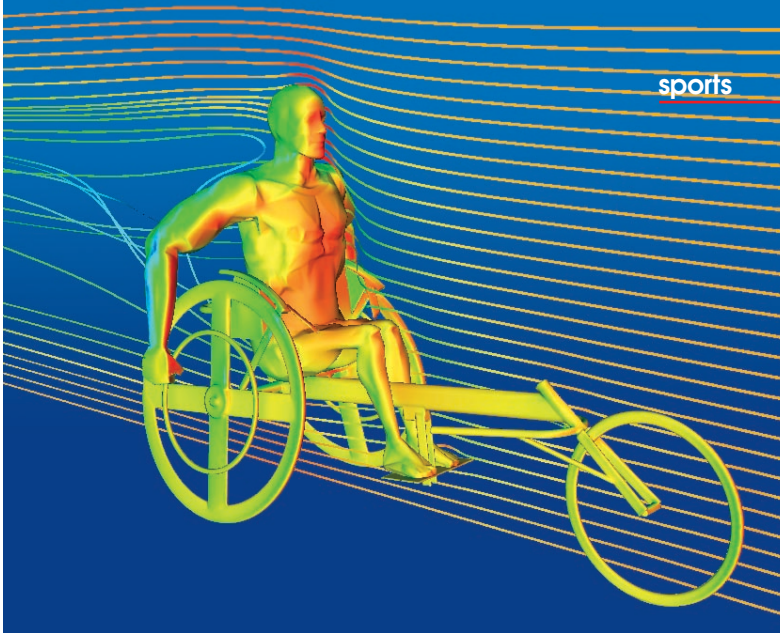
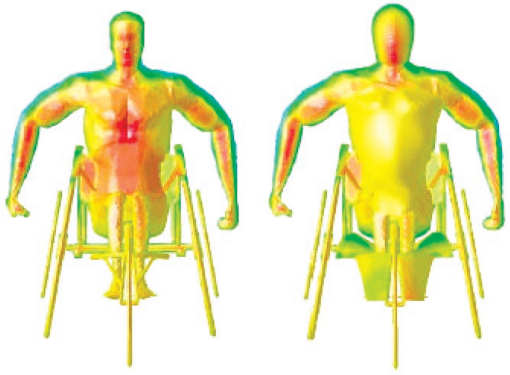
From Bronze to Gold

By Steve Haake, University of Sheffield, Sheffield, UK; and Leigh Bramall, Fluent Europe Ltd.



Surface pressure and pathlines for the unoptimized chair geometry
Visualization done using EnSight from CEI



Surface pressure on the athlete before (left) and after (right) optimization

Recirculation zone behind the athlete after optimization of the wheelchair; the athlete is in an un-optimized position

Due to its successful use by the America's Cup and Formula 1 series teams around the world, CFD has become widely recognized as an effective tool in yacht and automotive racing design. One outgrowth of this success has been the crossover of CFD technology to other areas of the sporting world. While swimming, cycling, and skiing have already benefited from CFD analysis, the sport of wheelchair racing in Great Britain has recently begun to make use of fluid flow modeling to help its athletes in their quest for Paralympic glory in the 2004 Athens games and beyond. Toward this goal, in August 2001 UK Athletics commissioned a feasibility study from the Sports Engineering Research Group (SERG), a leading center for research in sports technology based at the University of Sheffield, and the Center for Sports & Exercise Science at Sheffield Hallam University. Together, the two institutions have applied a range of sports science and technology resources, including CFD, to the project.

The CFD focus of the project has been to provide visual and numerical data on the aerodynamic performance of Dave Holding, a British athlete competing in the 100-meter and 200-meter wheelchair sprints, and whose physical shape was considered the least aerodynamic among the five athletes in the overall study. Assessing the performance of Holding and his chair required mechanical studies to be initiated, in which a series of resistant forces were analyzed to measure their impact on his performance. The wheel alignment of the chair was tested to identify its effect on rolling resistance, and the effect of the chair's mass was also thoroughly investigated. Eventually, a final optimized design was achieved. The mechanical modifications were further supplemented by conceptual ideas for specialized sportswear, such as an aerodynamically optimized helmet, to ensure minimum resistance for Holding and his chair in racing position.

To compare the aerodynamics of each chair design, two geometries were created – one representing Holding in the chair prior to any design changes, and the other incorporating the suggested modifications. Solid CAD models of the wheelchair were built using Pro/ENGINEER, while two human forms representing Holding were constructed using SAMMIE CAD Ergonomics Design software. The geometries were imported into GAMBIT, and meshes were generated for each model of Holding in position in the chair. The geometries were complex, requiring tetrahedral meshes of several hundred thousand cells to ensure the accuracy of the results. The meshes were read directly into FLUENT, where inlet boundary conditions were used to simulate wheelchair speeds of approximately 7 m/s.

The initial results showed the existence of a recirculation zone behind the wheelchair and a large wake effect, caused by separation over the shoulders of the athlete. Design modifications to the clothing and wheelchair structure, however, were found to minimize the impact of these phenomena, making a 3% reduction in drag possible – equivalent to a reduction of 0.03 seconds over 100 meters. Other tests showed that these drag reductions, combined with modifications that resulted in a total mass reduction of 2.2% and improvements to the alignment of the rear wheels, could deliver a further improvement of 0.16 seconds over 100 meters. For the 100-meter race at the Sydney Paralympics in 2000, a time reduction of this magnitude would have propelled the third-place competitor into first place! These findings reinforced the potential significance of the research. The success of the project has prompted further study across an expanded range of sports with a view toward boosting the success of UK athletes in forthcoming Olympic and Paralympic games. ■