Filippi WRC Monaco 2007

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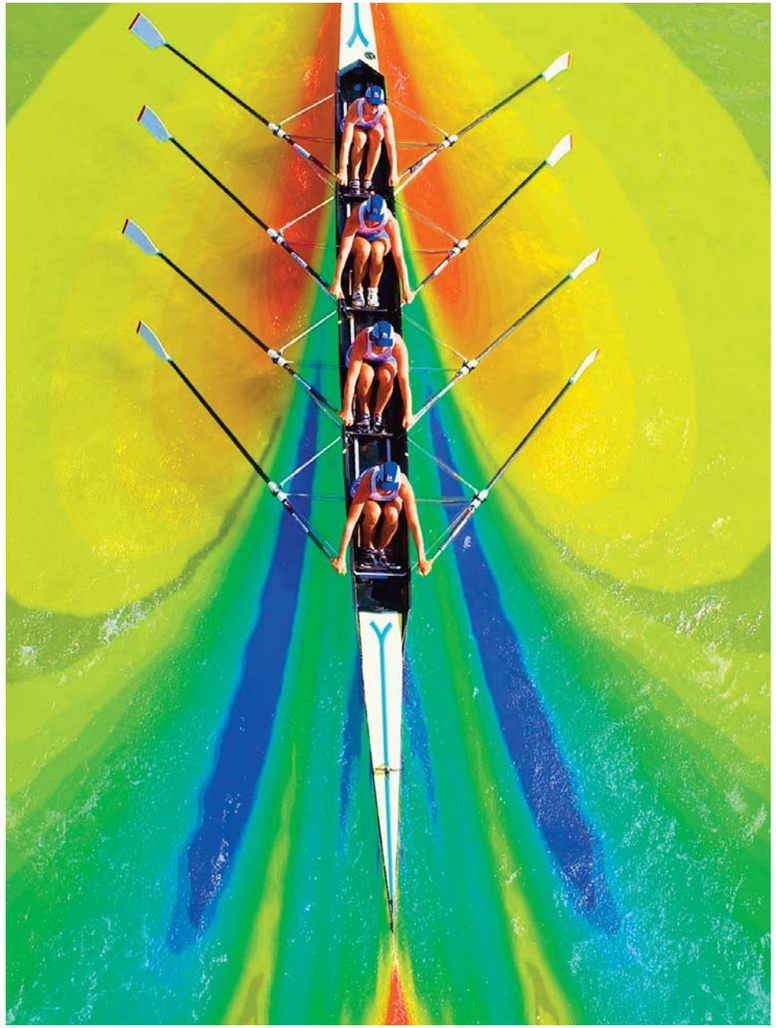


Breaking Waves at the Olympics

Stephen Ferguson, Consultant Engineer, CD-adapco.

Filippi

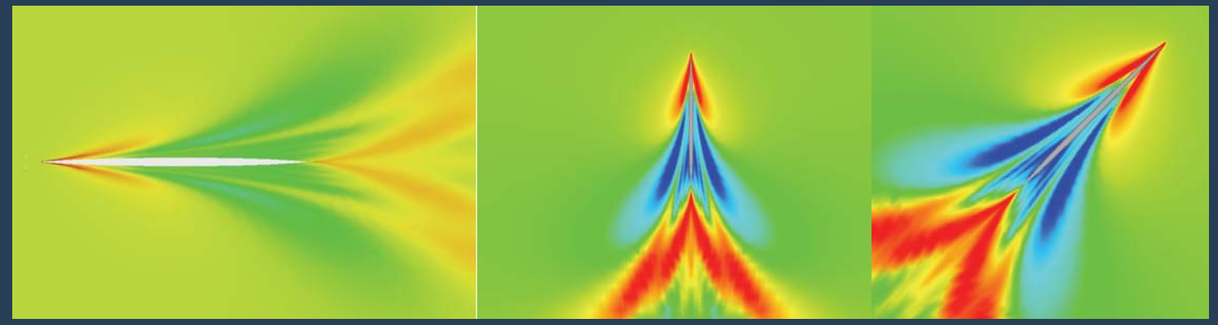
△ **Filippi Boats** are an Italian manufacturer of rowing racing shells. The company was founded in 1980 by Filippi Lido. Today, the running of the boatyard is undertaken by Filippi's son David, the yard employs 50 technicians and produces just over 700 boats each year which supply Federations worldwide.

In the previous 20 years crews in Filippi boats have achieved over 300 medals in World Championships and Olympic Games.

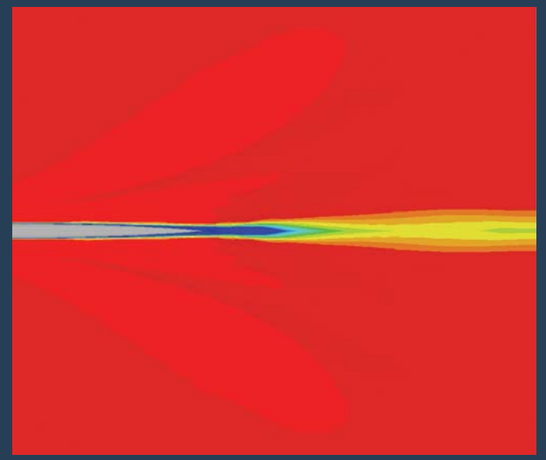
To become an Olympic Rowing champion you need two qualities in fair measure: grace and guts. More than any other sport, rowing combines sheer explosive power with fine technique. With winning margins measured in just tenths of a second, Gold Medals are traditionally won by working harder and suffering more than your opponents. At the last two Olympics, however, those rules have changed; blood, sweat and tears alone are good enough. Nowadays, the best teams have another weapon in their armory. At the Olympics, Computational Fluid Dynamics could be the difference between Gold and Bronze.

CFD is already widely used as an engineering tool within the maritime industry. Long used for optimizing hull designs under steady cruising conditions, it is also becoming increasingly important for predicting the complex three-dimensional phenomena applicable to manoeuvring conditions. Used effectively, it reduces the reliance on expensive towing tank tests and allows the investigation of a wider variety of more radical designs than would otherwise be possible.

Simulating the flow around a rowing boat, however, presents a complex challenge. While most boats are propelled at a constant rate, a rowing boat moves forward under the rhythmic rowing action of the crew. As the boat accelerates and decelerates through each successive stroke, both the position of the boat and its attitude in the water are dynamically modified, making this a complex problem with multiple-degrees of freedom. At the forefront of the pioneering work in this field is Filippi Boats (part of Filippi Lido shipyards) and partners.



▲ **Fig:01a**
Below surface pressure contours.



◄ **Fig:02**
Velocity defect in wake of boat.

As a leading manufacturer of high-quality, race-standard, rowing boats, they have been using CD-adapco's CFD code to optimize their high-tech designs for the Summer Olympics. Working together with a prestigious Italian university, Politecnico di Milano-MOX (Milan), their aim is to provide enough advantage to propel their oarsmen to the top of the Olympic podium.

Using CD-adapco's technology they have, for the first time, been able simulate the influence of moving rowers on the boat and the periodic accelerations caused by each stroke of the oars and thereby the time-dependant changes of resistance and propulsion. The simulation takes full account of both squat (aka 'dynamic sinkage'), the tendency of a moving boat to rise out of the water, and trim, its tendency to pitch in the water. Through these simulations, both squat and trim were shown to have major effects on resistance experienced by the boat.

This simulation was only possible due to the open structure of the CFD solver that allows users to easily add their own routines for rigid body movement, extending the simulation of all six degrees of freedom.

CFD calculates the position of the water surface around the boat in a rapid, accurate and efficient manner. The free surface between the water and the air is captured without smearing using the proprietary High-Resolution Interface-Capturing scheme (HRIC). The CFD results are used to get an in-depth understanding of the flow field around the race boats under actual race conditions - something impossible in a scaled-down towing tank test. Although a racing rowing boat may look, to the layman, like a simple hull form, it is actually quite a complex geometry and a difficult task to model and optimize.

The wrong amount of trim or squat in adverse conditions may allow water to flow over the side of the boat with immediate and devastating consequence. This point was all too clearly illustrated at the trial regatta for the Olympic Rowing Lake in 2004, which had to be abandoned after many of the boats sunk in choppy conditions. In rowing, 'taking on fluids' is a real risk.

Due to their leading-edge performance requirements, sports applications are an important benchmark for CFD. The application by Filippi Boats is a key example of the current trend in the marine world of how CD-adapco's software and services can perform multi-fluid six-degrees-of-freedom simulations. ■

THE WORLD'S OLDEST RACE

Doggett's Coat and Badge was first contested in 1715 and is held annually from London Bridge to Chelsea and is believed to be the oldest sporting contest in existence!

Thomas Doggett, an Irish comedian and joint manager of the Drury Lane Theatre, provided in his will dated 10th September 1721, for a prize of a coat and silver badge to be rowed for annually by six watermen within a year of completing their apprenticeships.

"... Five Pounds for a Badge of Silver weighing about Twelve Ounces and representing Liberty to be given to be rowed for by Six Young Watermen according to my Custom, Eighteen Shillings for Cloath for a Livery whereon the said Badge is to be put, One Pound One Shilling for making up the said Livery and Buttons and Appurtenances to it.....
...all which I would have to be continued yearly forever in Commemoration of His Majesty King Georges happy Accession to the Brittish Throne..."

The course was originally four and half miles long from "The Swan" at London Bridge to "The Swan" at Chelsea. The Barge Master of the Fishmongers' Company would start the race and the Clerk of the Watermen and Lightermen's Hall would receive a fee of thirty shillings from each competitor (indicating that at one time the whole event was arranged by that company). As a real test of stay and endurance, the race used to be rowed in heavy old wherries which had to be pulled up against the ebb tide - sometimes it took contestants nearly two hours to row the distance!

The race soon became open to abuses as contestants realized the advantages of using lighter undersized vessels. In some instances riotous behavior was reported between competitors. In 1723, one of the leaders of the race had his *"scull knocked away and a big boat rowed across his bows"*. As a result, in 1769, the Fishmongers' Company decided to draw up some regulations to prevent such abuses. All vessels had to be "common Scullers Boats" and examined by the company. Originally, the six watermen were drawn by lots which meant that not all contestants had a fair chance of winning. Later in the 19th century a trial heat system at Putney was introduced to select the final best six men for the race. *Guildhall Library Manuscripts Section*

Finish of the Race for Doggett's Coat & Badge - Thomas Rowlandson (1756-1827)

❒ FACTS

ⓘ MORE INFORMATION ON FILIPPI BOATS: **http://www.filippiboats.com**

CTO & Plastex Paddle to Olympic Glory using CFD Simulation

Tomasz Bugalski, Ph.D and Marek Kraskowski - Centrum Techniki Okrêtowej.

For most of the competitors at the 2008 Beijing Olympic Games, the possibility of mounting the podium to claim an Olympic medal represents the very pinnacle of sporting achievement: usually the payoff of many years of blood, sweat and tears. However, in 2008, being the best athlete is not longer necessarily enough: in most events the Gold Medal winner will also have had the aid of the very best sporting equipment.

△ **Plastex Composite** is producer and exporter of boats and paddles of the highest quality for canoeing and rowing. They have a track history that far exceeds any of their competitors as far as sporting medals go, their athletes have simply won far more using their products.

Since 1998 Plastex has begun, in cooperation with the Institute of Hydrodynamics, the research of more effective models of kayaks and canoes based on the application of CFD.

For this reason, the battle for Gold begun long ago in the offices and testing facilities of research centres, where the sports equipment used by the competitors in the Beijing Olympics has been constantly optimized and improved. Canoeing is one of the fields where extensive research has been performed into minimizing hull resistance using state-of-the-art measurement and experimental techniques, backed extensively by Computational Fluid Dynamics simulation using CD-adapco software.

The Polish company, Plastex Composite, recognized worldwide as one of the leading producers of competition canoes, has provided state-of-the-art equipment for Olympic Games and World Championships for many years. In 2005, during the 1st World Canoe Championships in Poznań, 56 out of 81 medals were won by competitors using Plastex boats. The boats themselves are designed by the company's owner, Ryszard Seruga, in cooperation with Tomasz Bugalski, Ph.D, from the Ship Design and Research Centre (CTO) S.A. - Poland.

In the spring of 2007, Plastex and CTO began to work on the shape of new canoes for the Olympic Games in Beijing. Optimization of the new design started with extensive investigation of the existing hull shapes in CTO's model basin, with the principal aim of determining the dependency of the canoe's performance on the basic design parameters and initial trim. Although such experiments provide a large amount of reliable data in a short timescale, they do not always illuminate the physical mechanisms that affect the performance of the hull.

For this reason, the experimental research was widely supported with extensive CFD simulation, which is more suited to a detailed comparison of the influence of flow properties such as wave elevation and pressure distribution on the hull for different designs.

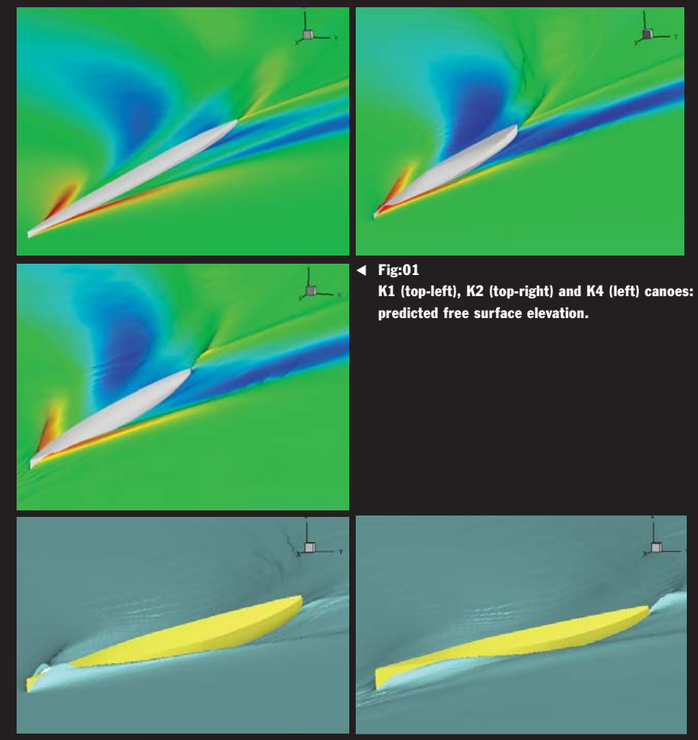
Each CFD simulation considered a canoe hull towed at constant speed through calm water. The computational analyses yielded numerical data, such as hull resistance, as well as allowing the design team to visualize the flow field around the hulls, thereby helping them identify the mechanisms behind variations in physical performance, e.g. bow and stern wave height or wave interaction. After testing the existing boats, the best design was chosen based on analysis results and work on new designs began. By implementing CFD into the design process, timescales and costs have been significantly reduced. The viability of each new design was first tested numerically, so that only a small number of optimized designs were selected for manufacturing and testing in the model basin. Final tests were carried out in real conditions - with the professional competitor rowing along the basin.

The simulations were carried out using the Volume Of Fluid (VOF) model for multiphase flows and the RNG k-ε turbulence model and specially constructed 1.5 million cell hexahedral meshes. The surface models of the existing canoes were obtained by digitally scanning the hulls, carried out using an ATOS II optical scanner and a TRIPOD photogrammetric system provided by GOM GmbH.

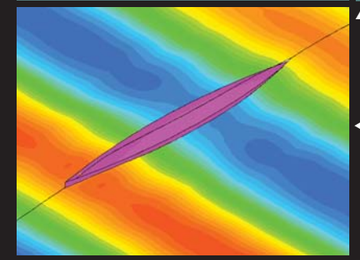
Due to the fact that the Olympic canoes travel at relatively high speed (of the order of 6m/s), it is absolutely necessary to take into account the dynamic trim and sinkage of the hull in the numerical analysis of the flow around it, requiring either experiment data, or if not available, adjusting the hull position during the CFD simulation until force and moment equilibrium is reached. Although this can be done iteratively, based on the hull hydrostatics, CTO uses an in-house, automated procedure for coupling the flow solver to the hull motion equations, allowing for accurate evaluation of the canoe's position. The computational mesh in this approach remains rigid, it moves together with the hull without relative motion of the nodes, which proved to be sufficiently accurate, robust and very simple, no re-meshing is required when the hull changes its position.

At present, the CFD simulations and model tests of the canoe's performance are limited to steady-state analyses - the hull is towed with constant speed and fixed centre of mass. Such a simplified approach allowed for effective optimization of the hull shapes based upon resistance with an identified 1% reduction, which could easily be the difference between Olympic Glory and ignominious defeat. The use of CFD methods allowed reduction in costs by limiting the number of designs tested and so reducing the need to manufacture many hull shapes. Further to this, identification of the flow phenomena by CFD allowed optimization to be carried out far quicker than previously possible.

It is very likely that the present shapes of the Olympic canoes are already very close to the absolute minimum resistance obtainable in steady flow. In the future, significant further development will only occur by optimizing the dynamic behavior of the hull, which means taking into account all the phenomena encountered during a race, motion of the competitor, and unsteady forces exerted on the hull. For that reason, the next step for CTO is to study 6 degrees of freedom (6-DOF) analyses to help aid hull optimization and to try to adjust the shape so as to minimize the loss of energy due to the hull motion and interaction with other canoes. CTO have already performed a trial simulation of the Wigley hull in head waves. In this simulation, the hull was free to pitch and heave (2-DOF motion), while sailing with constant speed and fixed zero drift angle results revealed good accuracy and robustness of the method. ■



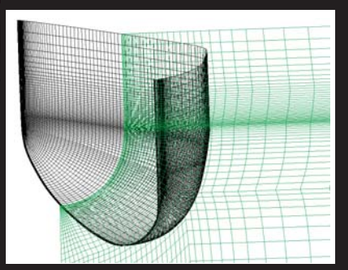
◄ **Fig:01**
K1 (top-left), K2 (top-right) and K4 (left) canoes: predicted free surface elevation.



▲ **Fig:02**
The canoe hull in its static (left)) and dynamic (right) position in the flow.

◄ **Fig:03**
Example of the hull dynamics analysis: Wigley hull in waves.

▲ **Fig:04**
Final tests were carried out with a professional rower.



▲ **Fig:05**
Example of the computational mesh.

Olympic Classification:

Kayak:	*K1 - single seat kayak*	*Canoe:*	*C1 - single kneeling canoe*
	K2 - double seated kayak		*C2 - double kneeling canoe*
	K4 - 4 seated kayak		*C4 - 4 person kneeling canoe*

❒ FACTS