

The Importance of Airflow in The Beautiful Game

By Keith Hanna, *Fluent News*

The quadrennial FIFA World Cup Final is one of the largest sporting events on the planet, with over a billion fans estimated to tune in to this year's championship match in Berlin, Germany. However, beyond the aspirations of the 32 nations competing for the title, there is also an unprecedented amount of leading-edge science and engineering going on in the background.

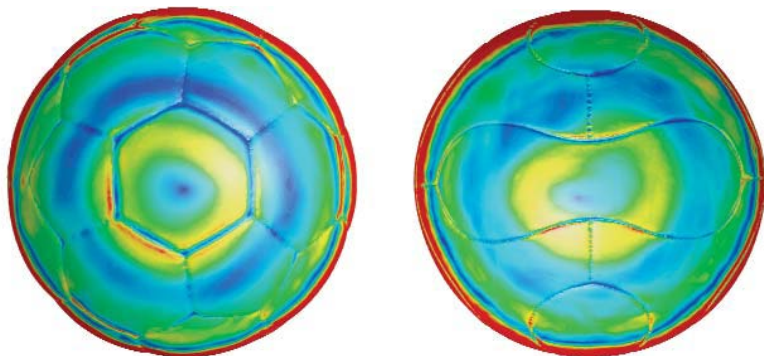
As evidenced by the experience of many players and spectators alike, the impact of aerodynamics on soccer is reckoned to be one of the most complicated and perplexing in sport, especially when related to soccer ball trajectories and the design of soccer stadiums. Nevertheless, through a combination of fundamental research and applied engineering, various groups from around the world are starting to discover new aerodynamic insights into "the beautiful game."

In 2002, Dr. Matt Carré and his team of researchers at the University of Sheffield in England helped to elucidate several aspects of the aerodynamics of spinning soccer balls when they explained the physics behind the

technique used by English star David Beckham on his famous bending kicks. Since then, a combination of CFD simulation techniques using FLUENT along with wind tunnel experiments and high-speed video camera analysis (in association with Dr. Takeshi Asai of Tsubaka University in Japan) have been employed to expand the knowledge of what happens to soccer balls as they fly through the air.

Dr. Carré's PhD student, Sarah Barber, an avid soccer player herself,

has extended the earlier research to look at computer-based flow simulations of soccer balls typically used in tournaments from 1966 (supplied courtesy of Sheffield Football Club), 2002, 2004, and 2006 to try to understand the aerodynamic impact of the evolution of ball design over the last 40 years. She used a 3D scanner, similar to those used in Formula 1 auto racing, to accurately capture the fine details all the way down to the actual stitches on the balls. Using the scanned soccer balls, she then



CFD predictions of surface shear stress patterns on the rear of the Fevernova Ball (left) and Teamgeist Ball (right) for a zero degree tracking orientation (red = high shear, blue = low shear)



Pathlines colored by velocity show the detailed flow field surrounding a soccer ball in flight

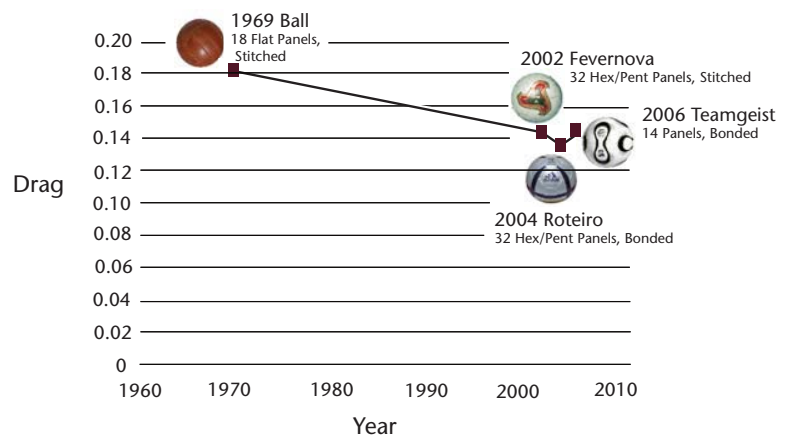
simulated virtual airflows over them in collaboration with David Mann, a Principal Engineer at Fluent Europe Ltd. Together they accessed Fluent's Remote Simulation Facility based in the company's US headquarters to carry out many CFD simulations on the multi-million cell meshes that were created.

This combination of CFD studies and wind tunnel measurements demonstrated that the drag of non-spinning soccer balls in turbulent airflows has fallen by as much as 30% since 1966. When this is coupled with the different seam/panel configurations of today and the fact that manufacturers make lighter balls because of the move away from leather, soccer balls have clearly experienced significant technological advances. Modern balls are still evolving in both design and performance as they move closer to being perfectly round while still retain-

ing some form of seam patterns.

A significant finding of the CFD analysis carried out by the team was the impact of different seam widths, seam depths, and seam orientations on the performance of a conventional 32-panel soccer ball (such as the 2002

Adidas Fevernova). They found that seam width has a larger effect on the ball's drag than seam depth because the width directly affects airflow separation points on the ball's surface. Since the new thermally bonded balls (the 2004 Adidas Roteiro and 2006



The evolution of soccer ball drag at high speeds for different ball designs from 1969 to the present day



Airflow patterns in the Allianz Arena in Munich were designed for optimum ventilation

Adidas Teamgeist, for example) have shallower and more uniform seams than their old stitched counterparts, they are closer to being perfectly round, and as such they should be more controllable in their flight through the air.

A 2002 Fevernova 32-panel ball studied at the University showed a value for its drag that stayed relatively constant in CFD simulations where the oncoming flow was altered from 0° to 90° relative to the ball's periodically repeating seam pattern. This "tracking"

covers a single cycle of panel structures that the airflow is likely to see repeatedly as the ball moves through the air.

However, this ball exhibited significant variations in sideways forces during the computational tracking study as its orientation was altered relative to the oncoming airflow. These forces varied from angle to angle, and were both negative and positive with magnitudes approaching that of the drag force. This important new finding suggests that the seams of the ball seen

by the oncoming airflow are critical in terms of the ball's trajectory through the air when little or no spin is simultaneously applied to it. This may account for the observed phenomenon in soccer matches of balls that appear to have little spin yet still move left and right (as well as up and down) by as much as a ball diameter, even though they initially go straight through the air, similar to a knuckle ball pitch in baseball. The Sheffield team's CFD simulations also showed that any inherent asymmetry



Making Sure the Grass is Greener

The first game of the 2006 World Cup took place in the Allianz Arena in Munich. This 70,000 seat stadium, home of both Bayern Munich FC and TSV Munich 1860, has a futuristic design and the biggest parking garage in Europe, with four levels under the stadium and a capacity of 10,000 cars. Like all modern stadiums, the Allianz has to have good spectator comfort, but it must also be designed to meet a variety of smoke and fire hazard scenarios.

In addition, the stadium has been designed with the quality of the field in mind. Uniform airflows going over the turf when the stadium roof doors are open help to ensure that the field grass has optimal growing conditions between matches. Dr. Peter Vogel of GTD GmbH in Dresden, Germany was commissioned to do a stadium airflow modeling study. No wind tunnel results were available prior to the simulations.

He used FLUENT to simulate all wind directions in and around the stadium complex, with the roof doors both open and closed. His detailed virtual flow simulations illustrated the relatively gentle airflow patterns players are expected to experience in the area above the playing field surface during games. In addition, he was able to show that the garage's ventilation system would be adequate even with 5,000 cars starting up nearly simultaneously, as would happen when the spectators leave after a game.

of a few millimeters in the ball's diameter, due to design or poor manufacture, will affect both the ball's overall roundness and its subsequent predicted aerial trajectory.

"Our work clearly points to the fact that any non-uniformity of design or asymmetry of manufacture will have a profound effect on the side forces the soccer ball will experience when there is no induced spin applied to it. The non-uniformity will therefore impact the ball's trajectory through the air,"

says Dr Carré. "The 2006 World Cup Teamgeist ball has several lines of symmetry, unlike conventional 32-panel balls which effectively have only one 90° repeated shape. Indeed, the Teamgeist ball has 14 bonded curved panels, better symmetry, lower drag, no stitched seams, and it's not made of leather. All of these features will impact its performance."

These trailblazing studies show that the aerodynamic performances of a soccer ball and the stadium in which

it flies are closely linked to their designs. The work of Drs. Carré and Vogel clearly points toward modern computer-based simulation techniques for modeling any soccer ball or soccer stadium design under a variety of external conditions. The day will come when these types of simulations will be linked together, so that the prevailing airflow in each section of a stadium can be used to predict the trajectory of a ball kicked from any point on the field. ■