Project Team

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Simulation in Sports - *Thermoregulation in Open-Water Swimming*

• Swimming • CFD – Simulation • Safety

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Simulation tools have been used for various purposes and are often a more efficient and cost-effective method to gain experimental data.

This project seeks to apply a popular simulation method called Computational Fluid Dynamics (CFD) to applications in sports.

In open-water swimming, athletes are exposed to external conditions such as wind speeds, air and water temperatures, and wetsuit thicknesses.

Internal factors, such as the heat transfer from blood and shivering, can be simulated within Hexagon's, Cradle CFD Software using the Joint System Thermoregulation Model (JOS).

It is hypothesized that CFD paired with the JOS model can be used to account for these various factors and simulate the responses of athletes in competition. Simulation outputs critical to athlete safety such as the core body temperature can be analyzed to ensure athlete safety.

The results are expected to provide insight into rules governing allowable wetsuit thickness and

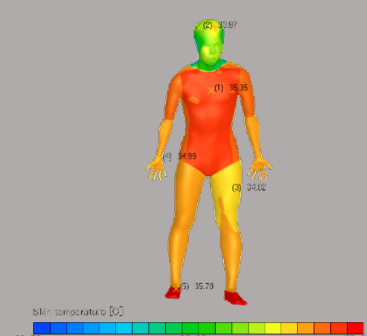

Fig. 1 Sample Human Temperature Output

PROJECT OVERVIEW

This project intends to provide insight into the thermoregulation of open water swimmers using Hexagon's Cradle CFD software and the JOS Model. This model will provide insight into the FINA rules governing allowable water temperatures and wet-suit thicknesses for athletes in open-water swimming competitions (see Figure 2).

Starting from the ground up, fundamental knowledge of CFD needed to be learned, and the external and internal factors that would impact simulation needed to be identified. The model was split up into two separate simulations – one to establish the external field of the water and air flows and another to incorporate the thermoregulatory response in the athlete to these external factors.

Currently, the external environmental simulation is completed with progress toward the internal thermal simulation being made.

These two simulations will be combined to represent a realistic competition and will produce results that can be used to determine an ideal balance of athlete safety and performance.

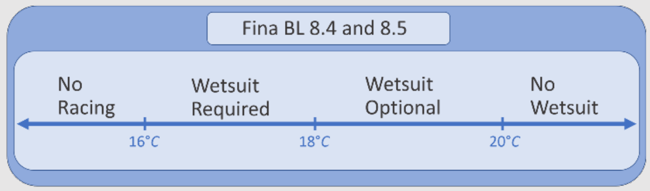

Fig. 2 FINA Bylaws for Open Water Swimming Water Temperature

PROJECT METHOD AND RESULTS

The proposed CFD setup uses several methods often found in various standard CFD simulations. To evaluate thermoregulation in swimming, a 2-phase analysis must be utilized to incorporate the effects of the water and airflow. The JOS Thermoregulation model is used to capture the thermal response of the human body. JOS also consideres factors like heat, radiation, and humidity.

Within the CFD setup, there are three main tasks: environment set-up in the preprocessor, solver, and analysis in the post-processer. The bulk of the model development happens in the preprocessor. Conditions such as air, water, and athlete swimming speeds, as well as total time spent in the water, need to be implemented.

The JOS model also needs a model of an athlete's body with correct body surface area (BSA). Using anthropomorphic data from the 1991 Perth World Championships and the Du Bois BSA equation a model of a standard open-water swimmer was constructed with a BSA of 2.00 (see Figure 3).

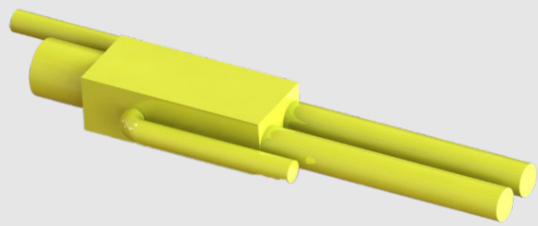

Fig. 3 CAD Model of Swimmer with 2.00m^2 BSA

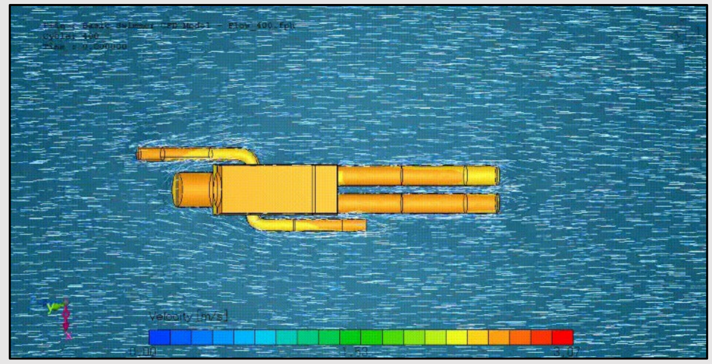

Fig. 5 Birdseye Flow Simulation Results

This initial environmental setup was then used to develop the initial flow field of the air and water an athlete experiences. A visual representation was created in the post-processer and can be found in the following Figure 5.

The second half of the simulation uses the previous fluid field as an input that is paired with the JOS model to evaluate the thermal response of the athlete to given open-water swimming conditions.
The procedure for the simulation can is summarized in Figure 4.

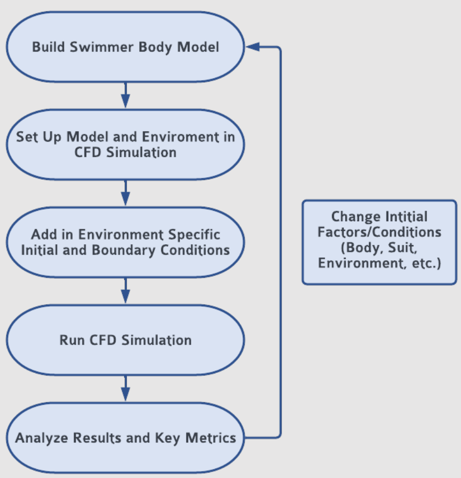

Fig. 4 Project Procedure and Outline

At this phase of the project, this thermal simulation is still in development but many of the important factors that will be used such as wetsuit clothing conditions and air/water temperature have been identified to be 22 °C and 17.4 °C respectively based off the FINA Qatar Marathon Swim World Series 2020.

CONCLUSIONS AND FUTURE WORK

In conclusion, using computational fluid dynamic simulation appears to be a promising method to model athletes' responses in open water swimming. So far, the development of a scale CAD model athlete, compilation of key initial end environmental factors, and creation of fluid field simulation has been achieved. The following bullet points outline work for the future.

- Complete thermal simulation
- Verify simulation accuracy
- Compile thermoregulation data set at different conditions
- Establish safe minimum and maximum water temperatures and wetsuit thickness guidelines

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ABOUT RESEC

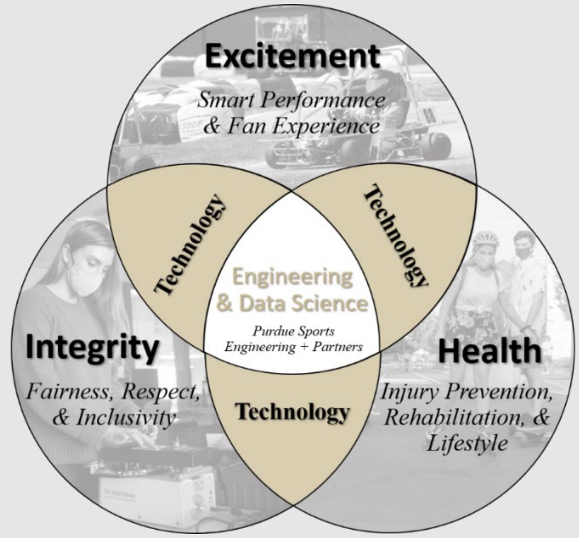
The Ray Ewry Sports Engineering Center (RESEC) was launched as a joint collaboration between Purdue College of Engineering and Purdue Intercollegiate Athletics, highlighting Purdue's reputation as the Cradle of Quarterbacks and Astronauts.

Sports have the power to unite, to teach, to challenge, and to initiate change, and those are our goals for RESEC. We are driven by our passion for sport and a deep understanding of the influence it has in shaping society. As technology continues to advance, there is enormous room for opportunity to rethink how athletes train, coaches coach, fans engage, and event organizers plan events. We collaborate closely with partners in athletics, industry, academia, and more to create the solutions that will help bring sports into the future, specifically in the three key research areas highlighted below.

Smart Performance & Fan Experience

Injury Reduction & Rehabilitation

Sports Integrity, Fairness, & Societal Integration



WHAT IS SPORTS ENGINEERING?

Sports engineering is a global, fast-paced, and multidisciplinary industry that brings people from different backgrounds, cultures, and experiences together. It is an industry that is heavily influenced by advances in other sectors as well as societal pressures and shifts, making working as a sports engineer very exciting. However, it also means being keenly aware of how these innovations and discoveries can be integrated and applied, especially as digitalization expands and what people – the athletes, fans, coaches, governing bodies – expect from sport evolves.

Engineering and data science are at the center of excitement, health and safety, and the integrity of sport, and by bringing a data-driven, human-centered approach to this industry, we can address the growing need and desire to increase participation and engagement of athletes and fans.

WHO IS RAY EWRY?

A Boilermaker track and field athlete, Ewry (1873-1937) won eight gold medals in three Olympic Games from 1900 to 1908. But his story is relatively unknown: at the age of five he became an orphan, and at seven he contracted polio and was confined to a wheelchair. Doctors had little hope he would be able to walk. Later nicknamed "The Human Frog," Ewry won gold in the standing long and high jumps and standing triple jump. By the end of the 1908 Games, Ewry had set a medal count record that lasted more than 100 years.

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