EFFECT OF EXTREME CONDITIONS ON ATHLETE PERFORMANCE

Anup Paul[1] and Keith Hanna[2]
[1] Hexagon Manufacturing Intelligence, Miamisburg, Ohio, 45040, USA
[2] Hexagon Manufacturing Intelligence, Cobham, Surrey, KT11 1AN , UK

There was concern over the decision to hold the 2021 Summer Olympic Games in Tokyo's sweltering summer. Tokyo's average temperatures in late July and early August are the highest for any host city going back to 1984. Heatstroke is likely to be the biggest weather-related threat to participants, which is caused by prolonged exposure to high temperatures and humidity with little to no wind and can result in fainting, seizures, or general exhaustion.

To show how close athletes could come to the detrimental impact of the heat with just a few degrees' temperature change, two different scenarios were simulated:

- Hotter than average conditions: negligible wind speed, 32 °C air temperature and 90% humidity
- Average conditions for the time of year: negligible wind speed, 27 °C air temperature and 70% humidity.

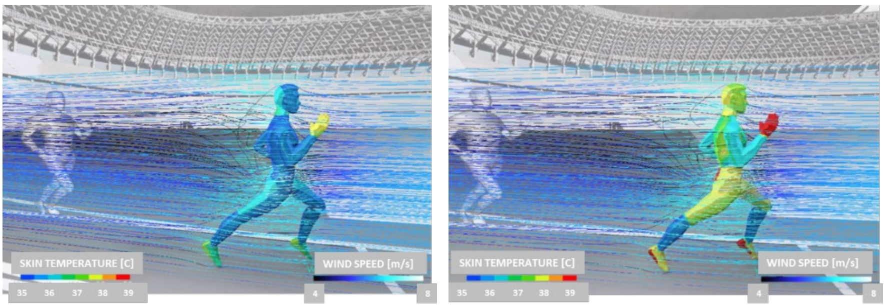
The feasibility of applying Computer-aided engineering (CAE) simulations developed using Hexagon's Computational Fluid Dynamics (CFD) software for simulating thermal and fluid phenomena – Cradle CFD to predict athlete performance in extreme conditions is explored in this paper. The simulated conditions include wind speed and humidity, the heat generated by athletes over 30 mins (approximate duration of the race), and the airflow generated by the running motion. The athlete's body comfort is analysed using the JOS-2 Joint System Thermoregulation Model (JOS model) developed by a research group at Waseda University, Japan [1, 2]. The JOS model can consider body size, gender and age of humans in calculations. By combining the thermoregulation model and CFD, the effects of changes in the surrounding environment on core temperatures and the skin throughout the body can be analysed.

The simulation results (Fig. 1) show the considerable impact a slight weather change can make. If the air temperature rises to just five degrees above average, the simulated core temperature increases to 39.77 °C (103.6 °F) and skin temperature to 37 °C (98.6 °F). In addition, in the hotter of the two scenarios, athletes' core head temperature could reach over 40 °C (104 °F), while even in

Corresponding author email: anup.paul@hexagon.com

average conditions the head core temperature could be 39.2 °C (102.6 °F). Humidity will also play an important factor in athlete performance and health. The increase in sweating water loss due to 20% higher humidity at the severe condition for a 30-minute race is summarized in Table 1 . The wind speed shown in Fig. 1 represents the airflow caused by runner's motion.

This study focused on the 10,000m as the longest track race taking place at the Games and demonstrates the feasibility of using CAE simulations to predict the performance and safety of athletes in extreme conditions. What is most interesting is the small margins of change – a couple of degrees shift in temperature can have a huge impact, so it is only a matter of time to see whether we edge over that 39 °C core temperature 'tipping point'. These simulations provide insight into the extreme conditions that athletes compete under and can be incorporated into athlete training programs and planning of sports events.



(a) (b)

Fig. 1:Athlete's body temperature in, (a) average conditions, (b) severe conditions.

Table 1: Water loss and heat loss for 30-minute running.

Conditions	**Water Loss [ml]**	**Heat Loss by Sweat [kJ]**	**Total Heat Loss [kJ]**
Average	630	1,575	2682
Severe	810	2025	2682

1. Yutaka Kobayashi, and Shin-ichi Tanabe, "Development of JOS-2 human thermoregulation model with detailed vascular system", Building and Environment, Vol.66, pp.1-10, 2013.
2. Kenji Tsukamoto, Masaaki Ohba, Shinya Morikami, Subject experiment on the achievement of validation data for assessing numerical thermalmodel using climate controllable wind tunnel and the numerical study on the improvement of the prediction accuracy of the numerical thermal model, Techinical Papers of Annual Meeting the Society of Heating,Air-conditioning and Sanitary Engineers of Japan, Volume 2013.6 F-7, 2013.

Corresponding author email: anup.paul@hexagon.com