Press Release

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Simulation shows athletes face dangerous conditions at Tokyo Games as heat risks pushing runners over 39 degrees Celsius 'tipping point'

A new simulation showing the impact of the heat and humidity in the Tokyo Stadium has highlighted the dangerous conditions facing athletes, risking heatstroke, dehydration and exhaustion, at the hottest Games on record.

Engineers at Hexagon's Manufacturing Intelligence division, whose simulation software is used by manufacturers such as Airbus, Toyota, and Samsung, simulated the effects of the hot, humid conditions on a male athlete competing in the 10,000m race (the longest stadium-based track race). Despite the race taking place after sunset, the simulations show athletes still face gruelling conditions.

The simulations show that even under average July weather conditions of 27 degrees C (80.6 F) and 70% humidity, runners of the 10,000m could experience core temperatures of above 39 degrees C (39.07 or 102.3 F). A temperature of above 38 degrees C (100.4 F) is considered feverish and research shows that humans need to maintain their core temperature between 35 and 39 (95 and 102.2 F) for optimal functioning of biochemical reactions. People exposed to "feels like" temperatures (i.e. how the temperature feels to the individual) above 32.2 degrees C (90 F) run the risk of heatstroke, heat cramps, and heat exhaustion.

There has been growing concern over the decision to hold this year's games in Tokyo's sweltering summer, with experts warning "You should never run in this kind of heat and humidity". Tokyo's average temperatures in late July and early August are the highest for any host city going back to 1984, and the last time Tokyo hosted the games in 1964, officials moved the games to October due to similar concerns over the heat. 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, the engineers simulated two different scenarios:

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

The simulations 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 degrees C (103.6 F) and skin temperature to 37 degrees C (98.6 F).

In addition, in the hotter of the two scenarios, athletes' core head temperature could reach over 40 degrees (104 F), while even in average conditions the head core temperature could be 39.2 degrees C (102.6 F). Of all organs, the brain is one of the most vulnerable to heat, which can change the delicate neural activity patterns leading to neuronal death and seizures. The thighs and pelvis (both 40.7 degrees C or 105.3 F) are other areas of the body shown to be susceptible to particularly high core temperatures if the air temperature edges above the average.

Humidity will also play an important factor in athlete performance and health. Average humidity for Tokyo in July is 70%, but if humidity rises to 90% athletes will sweat an average of 810ml (almost 1.5 pints), compared to 630ml (approximately 1.3 pints) over the duration of the approximately 30-minute race. While sweat helps the body cool down by evaporating on the

skin, on humid days when the air is already carrying a lot of moisture, our bodies lose much of the cooling effect of evaporation, so the effect on the athletes in these conditions is exacerbated. At the same time, dehydration accelerates the rise in whole-body temperature, further exaggerating the impact.

This simulation focuses on the 10,000m as the longest track race taking place in the stadium, but the findings offer insight into the tough conditions facing all athletes at the Games, particularly those in high-endurance events, and those competing in the scorching midday temperatures which could reach above 30 degrees C (87.8 F). Climate change has been highlighted as a key factor in Tokyo's rising temperatures, with the average temperature having risen by 2.9 degrees C since 1900, more than three times faster than the global average rise.

To create these simulations, the engineers used Computational Fluid Dynamics (CFD) – the discipline of simulating thermal / fluid phenomena. Hexagon's Cradle CFD software utilises unstructured mesh to accurately represent complicated geometry. The software is commonly used to design air conditioning systems, understand driver comfort and even design more efficient tumble driers.

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. The JOS model can consider body size, gender and age of humans in calculations. By combining the thermoregulation model and CFD (computational fluid dynamics) the effects of changes in the surrounding environment on core temperatures and the skin throughout the body can be analysed.

Keith Hanna, VP Marketing for Design & Engineering, Hexagon's Manufacturing Intelligence division said: "There's been much discussion about the decision to hold the Games in the Tokyo summer. These simulations show the extreme conditions that athletes will be competing under. Athletes are accustomed to pushing themselves to the limits and these simulations show how racing conditions impact performance as well as the risks undertaken when the human body is pushed to extremes. What's most interesting is the small margins of change – a couple of degrees shift in temperature can have a huge impact, so it's only a matter of time to see whether we edge over that 39 degree C core temperature 'tipping point'."

You can find a video of the simulations and more detail on the science behind it here.

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Hexagon's Manufacturing Intelligence division provides solutions that utilise data from design and engineering, production and metrology to make manufacturing smarter. For more information, visit hexagonmi.com.

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