On-site aerodynamic investigation of speed skating

Alexander Spoelstra[1], Wouter Terra[2], Andrea Sciacchitano[1]
[1] Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands
[2] TeamNL Experts, NOC*NSF, Papendallaan 60, 6816 VD Arnhem, The Netherlands

The aerodynamic drag plays a crucial role in elite speed skating performance contributing to about 90% of the overall opposing force [1]. Reductions of the aerodynamic drag are possible via changes of the athlete's apparel [2] and posture [3]. To the best knowledge of the authors, all the studies on the topic considered skaters, or skater models, in static poses. Skating, however, is a dynamic sport in which the posture of the athlete continuously changes through a repetitive motion of skate strokes. Hence, this work aims to assess the aerodynamic drag measured on a skater moving on ice. For this purpose, the Ring of Fire system is used, which relies on measuring the air flow across a transiting athlete. The system has already been validated in elite cycling [4,5]. The goal is to measure the difference in aerodynamic drag (using Equation 4 from reference 5), between two skating postures: a deep sit and a normal sit (see Figure 1 left).

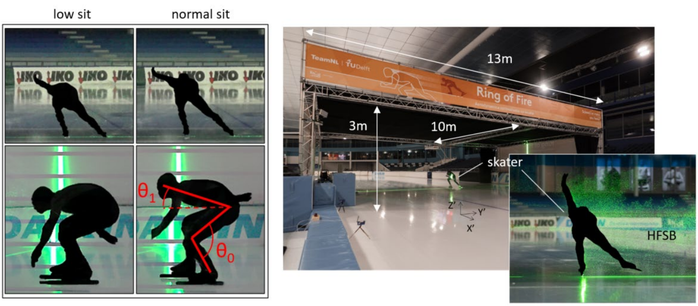

Figure 1: front and side view of the two skating postures (left) and the experimental arrangement (right).

The present measurements, conducted on the 400 m oval of the Thialf arena (Heerenveen, The Netherlands), have been approved by the TU Delft ethical committee. A male professional skater participated in the experiments with a weight and height in the range of 75 - 80 kg and 175 – 180 cm, respectively. During the entire experiment, he skated with both arms loose changing his posture between normal sit ($\theta_0 = 92°$ and $\theta_1 = 16°$) and low sit ($\theta_0 = 84°$ and $\theta_1 = 0°$; Figure 1 left). The flow measurements, prior to and after transit of the skater, relied on large-scale stereoscopic particle image velocimetry (PIV) in a tunnel filled

Corresponding author email: w.terra@tudelft.nl

with Helium filled soap bubbles (HFSB; see Figure 1 right) similar to Spoelstra et al. (2019; indoor measurements). For both postures, the experiment was repeated 10 times to build an ensemble average drag estimate. For all trials, the athlete started on one side of the track, accelerated to the prescribed velocity of about 11 m/s and maintained such velocity on the other straight when passing through the Ring of Fire. The skater's velocity was measured using the ProChip Timing System (MYLAPS, 2021) and two cameras acquired a front and side view of his position (Figure 1 left).

Figure 2 depicts the ensemble average normalized streamwise velocity (u^*_x) measured 0.8 m behind the lower back of skater. Red colors represent quiscient air, while blue colour represents air at high velocity as disturbed by the passage of the skater. For both postures the ensemble average is obtained from 3 skater passages. It is observed that the wake of the skater in a deep sit is narrower and the peak velocity deficit is located closer to the ice. In both postures, the wake of the swinging arm is visible and as well that of the two separate legs. Finally, using all 10 acquired passages per posture, the drag area C_DA is obtained by invoking the conservation of momentum in a control volume containing the athlete [4]. For the normal sit and the deep sit, C_DA is 0.185 m^2 and 0.172 m^2, respectively, with a 95% confidence level uncertainty of ±0.006 m^2 for both postures. It is concluded that the first aerodynamic assessment of a skater on the ice was successful and it was possible to measure a difference in aerodynamic drag of 7.5%, which is statistically significant based on the two-sample t-test.

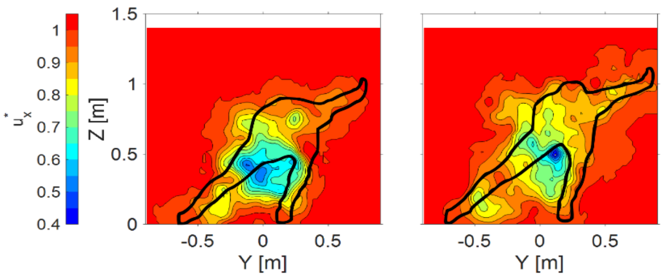

Figure 2: Ensemble average normalized streamwise velocity, u*x measured 0.8 m behind the skater in a deep sit (left) and a norma sit (right).

1. Oggiano L, Sætran LR (2010) Experimental analysis on parameters affecting drag force on speed skaters. Sports Technol 3(4) pp 223-234.
2. Oggiano L, Sætran L (2008) Effect of different skin suits on speed skating performances. Comp Sc Sports 3 pp 139-144.
3. van Ingen Schenau GJ (1982) The influence of air friction in speed skating. J Biomech 15(6) 449-458.
4. Spoelstra A, de Martino Norante L, Terra W, Sciacchitano A, Scarano F (2019) On-site cycling drag analysis with the Ring of Fire. Exp Fluids 60(6) 90.
5. Spoelstra A, Hirsch M, Sciacchitano A, Scarano F (2020) Uncertainty assessment of the Ring of Fire concept for on-site aerodynamic drag evaluation. Meas Sc Technol 32(4).

Corresponding author email: w.terra@tudelft.nl