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Aerodynamic characteristics of soccer balls

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Abstract

The aerodynamic characteristics of the official soccer ball used in this Premier League (2020 – 2021) are not understood clearly. Therefore, in this study, using wind tunnel tests, we compared the aerodynamic characteristics of the official balls used this year in the Premier League (Nike Flight, 4 panels) and major FIFA tournaments (Adidas Tsubasa, 6 panels) along with the traditional 32-panel official ball (Molten Pelada, 32 panels).

The tests were conducted using the closed-circuit low-speed low-turbulence wind tunnel (San Technologies Co., LTD) at the University of Tsukuba. The maximum flow velocity of this wind tunnel is 55 m/s and the blower outlet size is 1.5 m × 1.5 m. The flow velocity distribution is within ±0.5 % and the turbulence is 0.1 % or less. The four-panel Nike Flight, six-panel Adidas Tsubasa, and 32-panel Molten Pelada balls were analysed in this study (Figure 1). The drag forces (*D*) acting on the soccer balls were measured using a sting-type six-component force detector (LMC-61256, Nissho Electric Works). The drag coefficient (*Cd*) (given by Equation (1)) was calculated using the drag force measurements.

$$Cd = \frac{D}{\frac{1}{2}\rho U^2 A} \tag{1}$$

Where ρ = 1.2 kg/m^3 is the mass density of air, U is the flow velocity, and $A = \pi \times 0.112 = 0.038$ m^2 is the cross-sectional area of the soccer ball.
Moreover, the flight distances of the balls were calculated using two-dimensional motion measurements by only considering the drag forces on the non-spinning balls.

In the wind tunnel tests, the critical Reynolds number was 1.54×10^5, 1.97×10^5, and 2.52×10^5 for Flight, Tsubasa, and Pelada, respectively (Figure 2). Moreover, the corresponding *Cd* was 0.150, 0.148, and 0.153 for Flight, Tsubasa, and Pelada, respectively. The *Cd* in the supercritical region tended to increase in the order of Flight, Tsubasa, and Pelada, respectively.

For an initial velocity of 15 m/s and initial angle of attack of 40°, the horizontal flight distance was 19.4 m, 18.7 m, and 18.0 m for Flight, Tsubasa, and Pelada, respectively (Figure 3a). Moreover, for an initial velocity of 25 m/s and initial angle of attack of 40°, the horizontal flight distance was 42.8 m, 44.1 m, and 45.0 m for Flight, Tsubasa, and Pelada (Figure 3b).

The critical Reynolds number of Flight, Tsubasa, and Pelada were small, as mentioned in the ascending order. Generally, it is known that smaller the critical Reynolds number, larger the surface roughness [1]. Accordingly, the present finding likely indicates that the surface roughness of Flight was comparatively larger than the other balls. The comparison of (horizontal) flight distances of the balls revealed that for the subcritical to critical region (U < ~15 m/s) for Pelada, the distance increases in the order of Pelada, Tsubasa, and Flight. Conversely, in the supercritical region (U > ~25 m/s), the distance increases in the order of Flight, Tsubasa, and Pelada. These findings indicate that compared to other balls, Flight has larger surface roughness and slightly larger drag in the supercritical region.

Fig. 1 (a) 32-panel Molten Pelada, (b) 6-panel Adidas Tsubasa, (c) 4-panel Nike Flight.

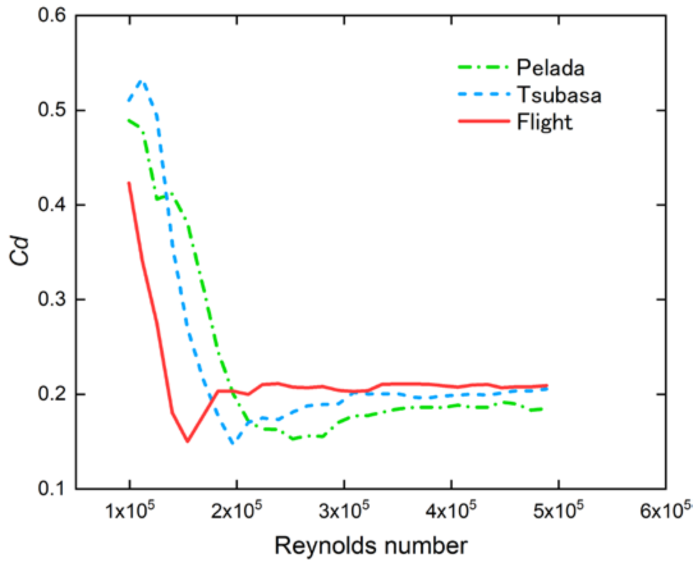

Fig. 2 Drag coefficient (Cd) of each ball as measured in wind tunnel tests.

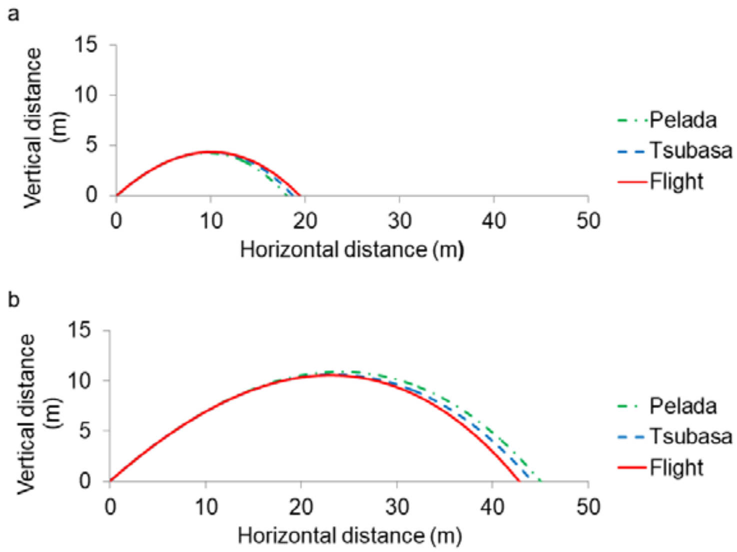

Fig. 3 Flight distance of each ball based on the drag coefficient at an initial velocity of (a) 15 m/s and (b) 25 m/s.

References

1. Achenbach, E. (1974) Vortex shedding from spheres. J Fluid Mech 62(2):209-221.