Effects of Dimple on Soccer Ball Aerodynamics

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Abstract: Typically, soccer balls are constructed with 32 pentagonal and hexagonal panels. More recently Teamgeist and Jabulani balls have 14 and 8 panels, respectively, with dramatically different panel shapes and designs from conventional balls. The latest model called Beau Jeu, made with 6 panels, has been adopted by many soccer leagues. However, there are few studies on the aerodynamic characteristics of these balls. This study examined the trajectory and aerodynamic characteristics of soccer balls constructed with different numbers and shapes of panels. Results of wind tunnel tests indicated that the aerodynamic forces varied significantly according to the surface forms. The results showed that the ball trajectory changes according to surface form, suggesting that surface form has significant effects on the flight of the balls.

1 INTRODUCTION

The pattern of the official ball of the recently concluded World Cup Soccer is significantly different from that of the conventional soccer ball (having 32 pentagonal and hexagonal panels) as several changes have been made in the design such as the number of panels making up the ball or its surface form. Further, it is said that the aerodynamic force applied on the ball changes depending on the number of different panels and their orientation, which in turn changes the trajectory of the ball (Goff et al., 2014; Hong & Asai, 2014; Hong et al., 2015). However, the surface form of the soccer ball is a complex combination of various types of ball panels and seams and not much is known about the impact of these surface forms on the aerodynamics of the ball. Therefore, in the present study, 6 soccer balls, each with a different number of panels and surface design (such as the presence or absence of dimples) were produced and their aerodynamic properties were studied by wind tunnel experiments.

In addition, the comparison of the official balls of the 2014 World Cup and the 2016 EURO Cup that had different kinds of roughness revealed that even when the balls had the same number and shapes of panels, the aerodynamic force acting on the balls varied greatly depending on the surface form of the of the ball. Besides making clear the aerodynamic characteristics of the latest soccer ball, the present study also shows that it is possible to predict, to some extent, the flight trajectory of the soccer balls that will be developed in future.

2 METHODS

Wind Tunnel Experiment

The circulating type low speed low turbulence wind tunnel located in the University of Tsukuba (San Technologies Co., LTD) (Figure 1) was used in this experiment. The maximum wind speed was 55 m/s, blow off size 1.5 m × 1.5 m, wind speed distribution within ± 0.5%, degree of turbulence less than 0.1 %, and the blow cage of the measured soccer ball was within 5% of the blow off size. Using this wind tunnel, experiments were carried out using 6 types of balls in all: balls with dimples and without dimples in each of 32, 12 and 6 panel type of balls.

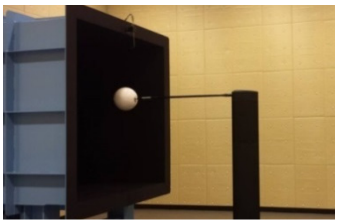

Figure 1: Set-up wind tunnel test.

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The force acting on the soccer ball was measured by the Sting-type 6-component force detector (LMC-61256, Nissho Electric Works). The aerodynamic force measured in this experiment was converted into the drag coefficient (C_d), lift coefficient (C_l) and side force coefficient (C_s) as shown in equations (1), (2) and (3).

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

$$C_l = \frac{2L}{\rho U^2 A} \tag{2}$$

$$C_s = \frac{2S}{\rho U^2 A} \tag{3}$$

Here, the density of air was taken to be $\rho = 1.2$ kg/m^3, U is the flow velocity and the projected area of the soccer ball was taken as $A = \pi \times 0.112 = 0.038$m^2.

3 RESULTS

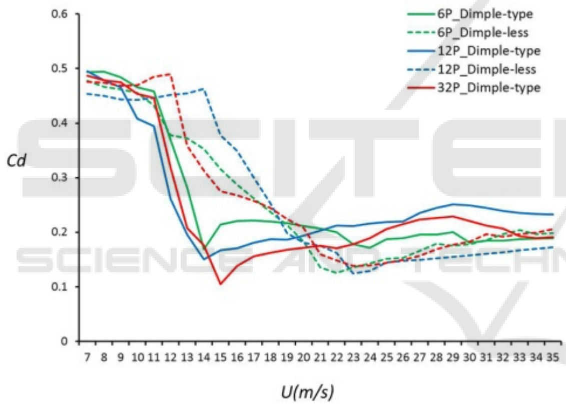

Figure 2: Change in Cd values for the 6 types of soccer balls having different surface forms.

Figure 2 shows the drag characteristic curve of the ball for soccer balls consisting of 32, 12 and 6 panels. From the aerodynamic coefficients of the balls it is seen that the aerodynamic drag tends to drop faster in the case of the dimple type soccer balls than in the case of the no dimple type. Further, the 32 panel dimple type soccer ball showed the smallest value of about 0.10 ($Re = 2.3 \times 10^5$) for the supercritical drag coefficient and the 12 panel dimple type ball showed a value of about 0.15 ($Re = 2.1 \times 10^5$). In the case of the no dimple type ball, the value for the 32 panel ball was about 0.13 ($Re = 3.5 \times 10^5$) and for the 12 panel ball it was about 0.12 ($Re = 3.5 \times 10^5$). The 6 panel ball without dimples showed a value of about 0.12 ($Re = 3.4 \times 10^5$).

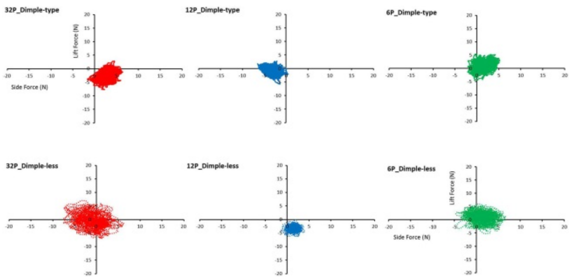

Figure 3: Force variation in lift and side forces due to wind speed (30 m/s).

In a powerful shot at wind speed as high as 30 m/s (Figure 3), the variation in lift force and side force in the case of the 32 panel no dimple type ball is 2.5 N and 2.6 N respectively, while it is 1.3 N and 1.7 N in the case of the 32 panel dimple type ball. Thus, the value is smaller for the dimple type than the no dimple type ball and is believed to provide a relatively greater sense of stability. Further, the variation in lift force and side force is smaller for the 12 panel type of ball compared to other types, showing relatively greater stability.

4 DISCUSSION

First, with regard to the impact of dimples on the drag of the soccer ball, it was found that the drag acting on the ball changed depending on the wind speed interval (Figure 2). In the intermediate speed interval (10 m/s ~ 20 m/s), the dimple type of soccer ball has a relatively smaller drag (resistance) compared with the no dimple type and therefore the dimple type ball is perceived to be faster. On the contrary, in the high speed interval (25 m/s ~ 35 m/s) such as while taking a shot, the no dimple type showed a smaller drag value. Thus it is conceivable that the dimple type ball flies faster in the intermediate speed and the no dimple type flies relatively faster in the high speed interval. Further, with regard to the impact of dimples on the lift and side forces of the ball, the dimple type ball was observed to have relatively less force variation than the no dimple type (Figure 3). In particular, this study has made clear the fact that changing the texture of the ball surface changes the aerodynamic characteristics of the ball. This suggests that, by considering the change in aerodynamic characteristics obtained thus far by modifying the number and shape of the panels together with the modification in the surface form, soccer balls with even more diverse aerodynamic characteristics can be developed.

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