Flow visualization around panel shapes of soccer ball

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Abstract

In recent study, trajectory analysis and wind tunnel experiments were used to glean information for comparing the non-spin aerodynamics of various soccer balls. However, there has been no study on the flow of air around soccer balls with respect to the shape, number, and orientation of their panels. The subject of our experiment was a soccer ball known as Cafusa and the air flow on the surface of the ball was examined using PIV. The Cafusa is characterized by the shapes of the panels changing significantly depending on the orientation of the ball, so our experiment with the Cafusa was performed in order to examine the effects of the panels. Therefore, the present study has focused its investigation on the flow visualizations applied to a soccer ball through its three faces by 2D-PIV. The results showed the separation point changes depending on the number of seams. Moreover, even with a panel orientation that has the same number of seams, the separation point can change depending on the panel intervals and the lift force.

1. Introduction

With the soccer ball evolving in this manner, a variety of aeromechanical studies have been conducted on 14 and 8 panel balls, as well as the conventional 32 panel balls [1~12]. At the FIFA Confederations Cup 2013, held in Brazil in June 2013, the new Cafusa ball (32 panels, Adidas) was used as the official ball. Currently, it is also frequently used as the match ball in professional soccer leagues and international games. It is identical to the conventional 32-panel ball in terms of its number of panels. However, in contrast with the simple panel arrangement
of pentagonals and hexagonals in the conventional ball, the Cafusa ball panels vary in shape depending on their orientation (or face), and can be broadly divided into three ball orientations, or faces. However, insufficient aeromechanical research has been conducted on the Cafusa ball or the aerodynamic characteristics of the faces that affect the ball; and the latter requires elucidation. Therefore, the present study has focused its investigation on the actual effect of the ball orientation on the flying soccer ball’s trajectory using a kicking robot.

2. Methods

2.1. Kicking robot test

The flight characteristics of the soccer balls were investigated by the points of impact on a goal net using the impact-type kicking robot. An actual regulation-sized soccer goal was positioned 25 m in front of the kicking robot (Fig. 1), and the robot kicked non-rotating balls at the center of the goal. A stationary ball was placed at 25 m in front of the soccer goal on the kicking robot, and a semi-high-speed video camera (EX-F1 by Casio Computer Co., Ltd., Tokyo, Japan) was installed to one side (0.5 m left of the kick robot) to record each kick.

Fig. 1. Kicking robot.

The kicking robot was set to launch the balls with an initial velocity of 30 m/s with no spin (<1 rotation), and launches were repeated continuously during the test. The points where the ball hit the goal net were recorded by the camera positioned at 25 m in front of the goal to measure the points of impact of the soccer balls. The ball was launched 20 times in each panel orientation (Fig. 2), and the data collected on the points of impact for each panel orientation of Cafusa ball were analysed.

2.2. 2D-PIV test

The 2D-PIV measurements were carried out on the centerline of the soccer ball. Micro-droplet particles with diameters of 1μm were generated by an aerosol generator (PivPart40, PivTec), and were introduced into the flow.
from the sirocco fan in the wind tunnel. A high repetition-rate pulsed Nd:Yag laser (LDP-100MQG, Lee Laser) illuminated the microdroplet particles. A high-speed camera (Memrecam GX-8, Nac) was used to record tiff images at a sampling frequency of 1000Hz. The wind speed was set at 30m/s.

3. Results and discussion

3.1. Point of ball impact using the kicking robot

First, actual balls were launched by the impact-type kicking robot at the goal net 25 m away, and the points where the balls hit the goal net are plotted in the following figure as the points of impact (Fig. 3). The Cafusa ball showed unstable impacts as the ball trajectory varied considerably according to the panel orientation. When comparing the standard deviations of the impact point, the Cafusa ball showed standard deviations of 0.17, 0.19 and 0.17 m for the vertical direction, and 0.45, 0.36 and 0.68 m for the horizontal direction (face A, B and C, respectively). This indicates a relatively irregular flight trajectory for face B. Based on these results, the orientation of a soccer ball can be considered to produce extreme changes in the ball’s flight trajectory and significantly affect its flight characteristics.

3.2. Velocity vectors on the suction side of the balls

In the Cafusa soccer ball that is the object of this experiment, since the number of seams and their position on the surface vary greatly depending on the orientation of the panels, 2 different panel orientations were examined using a 2D-PIV (Fig 4). The position of the separation points differed according to the position of the seams and their number in the sagittal plane of the soccer ball. First, in the case when there were 2 seams with a spacing of about 80mm between them (the angle formed with the stagnation point in seam 1 was 95 °, and in seam 2 was 150 °), the separation point was at a position of about 120 °, (nearly 65mm from the center of the ball) (Fig 4a). Furthermore, in the panel type with 2 seams and a relatively narrow spacing of about 50mm between them, (100 ° in seam 1, and 130 ° in seam 2), the seams affected the flow of air and the separation point was moved to about 140 ° (about 85mm) (Fig 4b). The phenomenon observed here was that the flow of air was separated once by the first seam (seam 1), but was re-attached immediately and then completely separated by the next seam (seam 2). It was learnt from these results that, the separation point varied greatly depending on the orientation of the panels even in identical soccer balls. Thus it is seen that the type of seam on the surface of the soccer ball (such as the number and spacing) changes the air flow around it and by actually acting upon its aerodynamics, affects the flight of the ball. Hence, the seams that make up the surface of a soccer ball (the number of seams, spacing, and position) can be said to be one of the factors that determine the flight trajectory of the ball. As this experiment has only made a two-dimensional
analysis, it is necessary to carry out a 3-dimensional analysis of the structure of the seam in order to examine the relationship between the seam and the aerodynamics acting on the soccer ball in more detail.

![Fig. 4. Velocity vectors on the suction side of the soccer balls.](image)

4. Conclusion

1. Results for the flight trajectory (point of impact) of an actual soccer ball using a kicking robot showed the highest and lowest points of impact for faces A and B, respectively, with a difference of approximately 2 m between them. Moreover, the point of impact for face C varied significantly compared to the other orientations, and showed a relatively irregular flight trajectory.

2. The results of the 2D-PIV experiments on the soccer ball show that the separation point of the air around the ball had a large variation from 120° to 145° depending on the position, number and spacing of the seams on it; this had an influence on the force applied to the ball, which in turn, affected the trajectory of the soccer ball in actual flight.

Based on these results, we can conclude that the flight trajectory of a soccer ball, which has drawn attention for its panel characteristics, is significantly affected by variations in the panels’ shape, depending on the ball’s orientation and rotation.

References


