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ScienceDirect

Procedia Engineering 147 (2016) 81 – 86

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

A study of aerodynamic drag of contemporary footballs

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Abstract

Most modern footballs possess varied surface characteristics which can affect the flight trajectory of the football. Although the aerodynamic behavior of other sports balls have been studied well, little information is available about the aerodynamic behavior of newly introduced footballs with varied seam configurations and number of panels. Therefore, the primary objective of this study is to understand the surface characteristics mainly the seam depth and seam height and their effects on aerodynamic of a range of new generation balls. Four new generation footballs: Kapanya, Cafusa, Tango and Brazuca were selected for this study. Seam length and depth of seam for each ball were measured using 3D scanning technology and also manual measurement. Additionally, the aerodynamic drag forces were measured using wind tunnel over a range of wind speeds for two positions of each ball. It was found that the seam length and depth of seam have influence on the aerodynamic drag of these modern footballs. Results also indicate that the sideway variation of aerodynamic drag is minimal for the Brazuca ball. As a result, this ball may have better stability in flight. The lowest aerodynamic drag was found for the Cafusa ball at high speeds which indicates that this ball is suitable for long distance pass. However, it has highest sideway drag variation that may cause instability in flight.

Peer-review under responsibility of the organizing committee of ISEA 2016

Keywords: Football; aerodynamics; wind tunnel; drag coefficient; seam length; depth of seam.

1. Introduction

The flight trajectory of the ball depends on its aerodynamic characteristics. Depending on the aerodynamic behavior of a ball, it can deviate from its anticipated flight path and as a result the flight trajectory becomes unpredictable. Lateral deflection in flight, commonly known as swing or knuckle, is well recognized in cricket, baseball, golf, tennis, and volleyball. However, there is still lack of knowledge in understanding the effect of surface characteristics of football on its aerodynamics behavior. The understanding of aerodynamic behavior of a football is important not only for players and coaches/trainers but also for the regulatory bodies, manufacturers and even the spectators. Over the years, the design of the ball has undergone a series of technological changes to make the ball more spherical by utilizing new surface design and manufacturing processes, Alam *et al.* [1, 4].

Adidas, the official supplier of footballs to FIFA, has applied thermal bonding replacing traditional stitching to make the seamless surface design by using 6 curved panels instead of 32 panels in its 2014 FIFA World Cup ball in Brazil. The surface structure (texture, grooves, ridges, seams, etc.) of the ball has also been altered in the process. Although the aerodynamic behavior of other sports balls have been studied well by Mehta *et al.* [2] and Smits and Ogg [3], little information is available about the aerodynamic behavior of new footballs except few studies by Alam *et al.* [1, 4], Asai and Kamemoto [5]. Studies by Goff and Carre [6] and Barber *et al.* [7] provided some insights about the effects of the surface structure of 32 panel balls. No such data is available for new generation footballs. Hence, the primary aim of this study is to measure aerodynamic drag of

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Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.193

recently introduced Adidas made FIFA approved balls and understand the impact of their surface characteristics on aerodynamic parameters such as drag.

Nomenclature

A	projected frontal area (m^2)
C_D	drag coefficient (dimensionless)
D	aerodynamic drag force (N)
Re	Reynolds number (dimensionless)
V	wind speed (m/s)
μ	dynamic viscosity of air (Pa.s)
ρ	air density (kg/m^3)

2. Methodology

2.1. Physical Features of Selected Balls

Four footballs (Cafusa, Brazuca, Tango and Kopanya) - all manufactured by the leading sports equipment manufacturer Adidas were chosen for this study. The physical parameters of these balls are measured. These parameters are shown in Table 1.

Table 1. Physical parameters of different balls

Ball name	Ball Picture	Seam Length (mm)	Seam Depth (mm)	Number of Panels	Events
Brazuca		3,220	1.54	6	FIFA World Cup 2014 (Brazil)
Cafusa		3,600	1.52	32	Confederation Cup 2013 (Brazil)
Tango 12		3,530	1.22	32	UEFA Cup 2012 (Europe)
Kopanya		3,450	0.52	14	Confederation Cup 2009 (South Africa)

In order to determine each ball's seam length and seam depth, two different methods (manual and numerical) were used. In numerical method, a 3D laser scanner was used to obtain the dimensions of all balls including the total seam length and seam depth. GeoMagic software was used to refine the mesh surface and SolidWorks was used to measure the depth and seam length of each ball. A print screen of the measurement process using software is shown in Fig. 1.

In the manual method, a rope was used to measure the seam length. Plasticine was used to determine the seam depth for all the balls. The dried unplugged plasticine was put to a shadow machine to find out the seam height (or depth). The largest seam length was found to be 3600 mm for the Cafusa ball and the smallest was 3220 mm for the Brazuca ball. The highest observed seam depth was 1.54 mm for the Brazuca ball and the minimum depth was 0.52 mm for the Kopanya ball. The inflated air pressure (0.8 bar = 11.6 psi) was maintained for all the balls during investigation.