Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 13 (2011) 188–193

Engineering Procedia

5th Asia-Pacific Congress on Sports Technology (APCST)

Aerodynamics of contemporary FIFA soccer balls

Firoz Alam*, Harun Chowdhury, Hazim Moria, Franz Konstantin Fuss, Iftekhar Khan, Fayez Aldawi and Aleksandar Subic

School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, VIC 3083, Australia

Received 25 March 2011; revised 13 May 2011; accepted 15 May 2011

Abstract

The soccer is the world's most popular and widely watched game. Due to increasing technological advancement and demand for performance, the ball manufacturers have been developing new designs progressively. A traditional spherical football made of 32 leather panels stitched together in 1970s has become only 14 synthetic curved panels thermally bonded without stitches ball in 2006 and more recently 8 panels football in 2010. Despite being most popular game in the world, scan data is available on aerodynamic properties of footballs especially Jabulani, Teamgeist and Fevernova balls. The primary objectives of this study were to evaluate aerodynamic performances of these three soccer balls. The aerodynamic forces and moments were measured experimentally for a range of wind speeds. The aerodynamic forces and their non-dimensional coefficients were determined and compared.

Selection and peer-review under responsibility of RMIT University

Keywords: Jabulani; Teamgeist; Fevernova; soccer ball; football; drag; wind tunnel

1. Introduction

The flight trajectories of sports balls largely depend on the aerodynamic characteristics of the balls. Depending on aerodynamic behavior, the ball can be deviated significantly from the anticipated flight path resulting in a curved and unpredictable flight trajectory. Lateral deflection in flight, commonly known as swing, swerve, curve or knuckle, is well recognized in cricket, baseball, golf, tennis, volleyball and football (soccer). In most of these sports, the lateral deflection is produced by spinning the ball about an axis perpendicular to the line of flight or by other means to make asymmetric airflow around the ball.

* Corresponding author. Tel.: +61-3-9925-6103; fax: +61-3-9926-6108.
E-mail address: firoz.alam@rmit.edu.au.

1877–7058
doi:10.1016/j.proeng.2011.05.071

Therefore, the aerodynamic properties of a sport ball is considered to be the fundamental for the players, coaches (trainers), regulatory bodies, ball manufacturers and even the spectators. It is no doubt that soccer (football) is the most popular game in the world. No other game is so much loved, played and excited spectators than the football. It is played in every corner by every nation in the world. It is also perhaps the only game that can be played by everyone regardless of player's socio-cultural and economic background at all climatic conditions. Although, the soccer ball among all spherical sport balls traditionally has better aerodynamic properties and balance, however, over the years, the design of soccer balls has undergone a series of technological changes, in which the ball has been made to be more spherical and aerodynamically efficient (claimed by the manufacturers) by utilizing new design and manufacturing processes. Adidas, the official supplier and manufacturer of soccer balls to FIFA (Federation Internationale de Football Association), has applied thermal bonding replacing traditional stitching to make a seamless surface design by using 14 and more recently 8 curved panels instead of 32 panels made stitched ball since 2006. Although the aerodynamic behaviour of other sports balls have been studied by Alam et al. [2, 3], Mehta [5], and Smits and Ogg [6], scant information is available to the public domain about the aerodynamic behaviour of new seamless footballs except the experiential studies by Alam *et al.* [1] and Asai *et al.* [7, 8, 9]. Therefore, the primary objective of this work is to experimentally study the aerodynamic properties of 8, 14 and 32 panel soccer balls.

Nomenclature

F_D	Drag Force
C_D	Drag Coefficient
Re	Reynolds Number
V	Velocity of Air
μ	Dynamic Absolute Viscosity of Air
ρ	Density of Air
A	Projected Area
d	Soccer Ball Diameter

2. Experimental Procedure

A brief description of soccer balls, experimental facilities and set up is given in the following two sub sections.

2.1. Soccer ball description

Three new balls have been selected for this study. They are: a) 32 panels Fevernova ball, b) 14 panels Teamgeist ball, and b) 8 panels Jabulani ball. All three balls were manufactured by Adidas and they are FIFA approved. These balls' external surfaces are made of synthetic panels. The Jabulani and Teamgeist balls' panels are thermally bonded whereas the panels of Fevernova ball were stitched together. The side views of all three balls are shown in Figure 1 and their physical dimensions are illustrated in Table 1.

Table 1. Physical parameters of Adidas balls

	Jabulani ball	Teamgiest ball	Fevernova ball
	2010	2006	2002
Manufacturer	Adidas	Adidas	Adidas
No. of panels	8	14	32
Panel joints	Thermal Bonding	Thermal Bonding	Stitched
Surface material	Synthetic	Synthetic	Synthetic
External diameter	~ 220 mm	~ 220 mm	~ 220 mm
Size	5	5	5

The Jabulani ball was introduced during 2010 FIFA World Cup in South Africa, the Teamgeist ball in 2006 FIFA World Cup in Germany and the Fevernova ball in 2002 FIFA World Cup in Japan and Korea.

(a) Jabulani ball, Side A

(c) Teamgiest ball, Side A

(e) Fevernova ball, Side A

(b) Jabulani, Side B

(d) Teamgiest ball, Side B

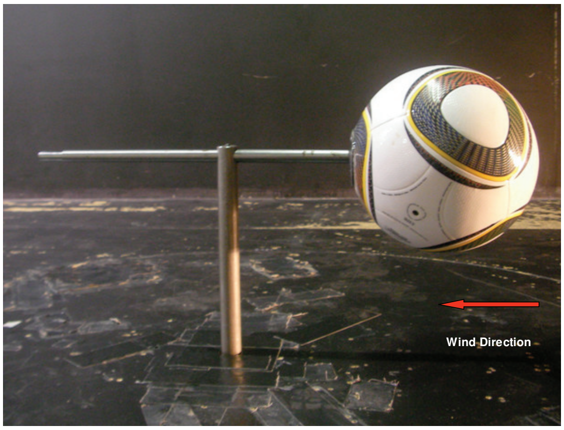
(f) Fevernova ball, Side B

Fig 1. Adidas Jabulani, Teamgiest and Fevernova balls

2.2. Wind tunnel testing

In order to measure the aerodynamic properties of the soccer balls experimentally, the RMIT Industrial Wind Tunnel was used. The tunnel is a closed return circuit wind tunnel with a maximum speed of approximately 150 km/h. The rectangular test section's dimension is 3 m (wide) x 2 m (high) x 9 m (long), and is equipped with a turntable to yaw the model. The balls were mounted on a six component force sensor (type JR-3), and purpose made computer software was used to digitize and record all 3 forces (drag, side and lift forces) and 3 moments (yaw, pitch and roll moments) simultaneously. More details about the tunnel can be found in Alam *et al.* [4].

A strut support was developed to hold the ball on a force sensor in the wind tunnel, and the experimental set up with the strut support in RMIT Industrial Wind Tunnel test section is shown in Figure 2. The aerodynamic effect of the strut support was subtracted from the mount with the ball. The distance between the bottom edge of the ball and the tunnel floor was 300 mm, which is well above the tunnel boundary layer and considered to be out of significant ground effect.



(a) Experimental set up with Jabulani ball

(b) Experimental set up with Teamgiest ball

Fig 2. Wind tunnel testing of soccer balls

The aerodynamic drag coefficient (C_D) is defined as: $C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A}$, where F_D, ρ, V & A are drag, air density, wind velocity and projected frontal area of the ball respectively. The Reynolds number (Re) is defined as: $Re = \frac{\rho V d}{\mu}$. The lift and side forces and their coefficients were not determined and presented in this paper. Only drag and its coefficient are presented here.

3. Results and Discussion

Soccer balls were tested at 30, 40, 60, 80, 100, 120 and 130 km/h speeds. The aerodynamic force was converted to non-dimensional parameter (drag coefficient, C_D) and tare forces were removed by measuring the forces on the sting in isolation and removing them from the force of the soccer ball and support system. The influence of the support on the ball was checked and found to be negligible. The repeatability of the measured forces was within ±0.01 N and the wind velocity was less than 0.5 km/h.

The C_D variations with Reynolds numbers for all three balls are shown in Figure 3. The C_D value of the smooth sphere has clearly demonstrated notable variation and flow transition from laminar to turbulent flow as expected. According to Achenbach [10], the airflow undergoes from laminar to fully turbulent between $Re = 1.0 \times 10^5$ to $Re = 4.0 \times 10^5$, which is the case for the C_D value of the smooth sphere used in this study (see Figure 3). The airflow around the Fevernova ball undergoes laminar to turbulent much earlier Reynolds number compared to the smooth sphere and other two balls (Teamgeist and Jabulani). The Fevernova ball generates turbulent airflow around it due to its edges created by the stitches of hexagon panels. The airflow around the Teamgeist ball also undergoes laminar to turbulent a little later than that of Fevernova ball. A visual inspection indicates that the Teamgeist ball's surface is slightly rougher compared to the surface of the Jabulani ball. The surface roughness triggers the flow transition earlier for the Teamgeist ball compared to the Jabulani ball. This observation agrees well with the findings by Asai et al. [6] and Mehta & Asai [11]. The airflow becomes fully turbulent for the Fevernova ball at 30 km/h ($Re = 1.1\times10^5$), Teamgeist ball at 40 km/h ($Re = 1.6\times10^5$), Jabulani ball at 60 km/h ($Re = 2.4\times10^5$) and the smooth sphere at 100 km/h ($Re = 3.7\times10^5$). The average C_D values after the transition for the Teamgeist and Jabulani balls have the similar trend. However, the C_D value for the Jabulani ball is lower almost 15% compared to the C_D value of the Teamgeist ball. However, as mentioned earlier, a sudden rise in C_D was noted for the Jabulani ball after 110 km/h. The reason for this sudden rise is not fully understood. Further study is underway to comprehend this phenomenon.

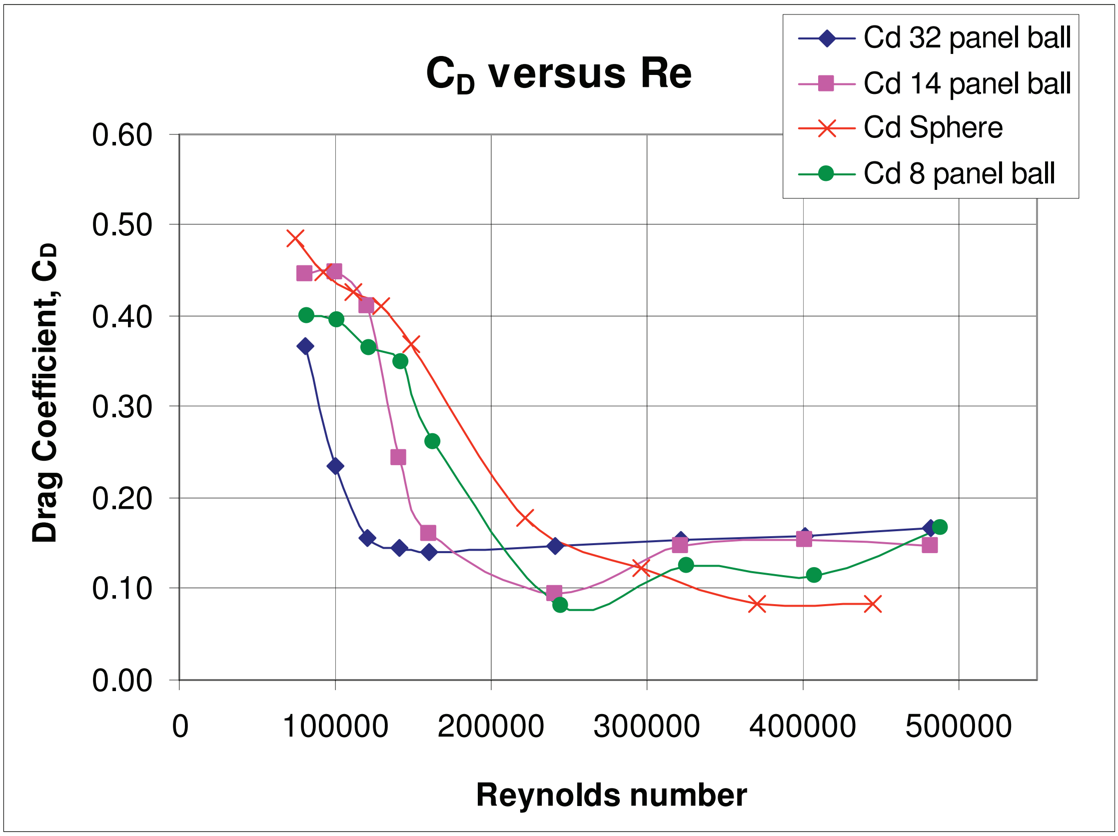


Fig. 3. C_D variations with Reynolds numbers for the Fevernova, Teamgeist and Jabulani balls.

The Fevernova, Teamgeist and Jabulani balls are made of 32, 14 and 8 synthetic panels (see Figure 1) creating a series of seams and grooves. Although Teamgeist and Jabulani balls look more spherical compared to the 32 hexagon panels Fevernova ball, the two side of Jabulani and Teamgeist balls are not fully symmetrical (see Figure 1). The two sides (Side A and Side B) of all three balls facing the wind have been tested under a range of speeds (30 km/h to 130 km/h). The average C_D values of Side A and Side B vary significantly. For example, the variation of drag coefficient between the two sides (Side A and Side B) of the Jabulani ball is around 8 to 9% in the range of 30 to 120 km/h speeds compared to 3 to 4% of the two sides of the Teamgeist ball at the same speed range. The difference in C_D value for the Fevernova (32 panels) ball under the same speed range is less than 2%. The C_D variation of the Jabulani ball is almost 5% more than that of the Teamgeist ball. This variation is enough to create an unpredictable flight trajectory even without any spin involved.

4. Conclusions

The following conclusions have been drawn from the work presented here:

- The average C_D values for the Fevernova, Teamgeist and Jabulani balls are 0.15, 0.19 and 0.21 respectively.
- The Fevernova and Teamgeist ball exhibit flow transition earlier compared to the Jabulani ball and the smooth sphere.
- The Jabulani ball possesses lower C_D value at speeds over 60 km/h compared to the Teamgeist ball.
- The C_D value for the Teamgeist ball is relatively lower between 30 to 60 km/h.
- The variation of C_D value of two sides of the Jabulani ball is around 5% and 7% more than the Teamgeist and Fevernova balls respectively.

Acknowledgements

Authors are highly grateful to Mr. Dinh Le and Mr. Mustafa Salehi, School of Aerospace, Mechanical and Manufacturing Engineering for their assistance with the wind tunnel data acquisition and processing.

References

[1] Alam F, Chowdhury H, Subic A and Fuss FK. A Comparative Study of Football Aerodynamics. *Procedia Engineering* 2010;**2(2):**2443-2448.

[2] Alam F, Subic A, Watkins S, Naser J, Rasul MG., An experimental and computational study of aerodynamic properties of rugby balls. *WSEAS Transactions on Fluid Mechanics* 2008; **3**:279-286.

[3] Alam F, Subic A, Watkins S, Smits AJ. Aerodynamics of an Australian rules foot ball and rugby ball. In: M. Peters, editor. *Computational Science and Engineering*, Springer, 2009, p. 103-127.

[4] Alam F, Zimmer G, Watkins S. Mean and time-varying flow measurements on the surface of a family of idealized road vehicles. *Experimental Thermal and Fluid Sciences* 2003;**27**:639-654.

[5] Mehta RD, Alam F, Subic A. Aerodynamics of tennis balls- a review. *Sports Technology* 2008;**1(1):**1-10.

[6] Smits AJ, Ogg S. Golf ball aerodynamics. *The Engineering of Sport 5* 2004;**1**:3-12.

[7] Asai T, Carré M J, Akatsuka T, Haake S J. The Curve Kick of a Football. *Sports Engineering* 2002;**5**:183–192.

[8] Asai T, Akatsuka T, Haake SJ. The physics of football. *Physics World* 1998;**11**:25–27.

[9] Asai T, Seo K, Kobayashi O, Sakashita R. Fundamental aerodynamics of the soccer ball. *Sports Engineering* 2007;**10**:101-110.

[10] Achenbach E. Experiments on the flow past spheres at very high Reynolds numbers. *Journal of Fluid Mechanics* 1972**;54:**565–575.

[11] Mehta RD, Asai T. Soccer Ball Aerodynamics. Unpublished Report 2010.