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Aerodynamics of Used Cricket Balls

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Abstract

A cricket ball possesses six rows of stitches with approximately 70 to 90 stretches in each row and a prominent seam at the joining of two halves. Asymmetric airflow over the ball due to seam orientation and surface roughness of the ball can cause the flight deviation (swing) and unpredictable flight. Swing makes difficult for the batsman to hit the ball with the bat and guard the stamps. The primary objectives of this work were to understand the aerodynamic properties of a series of used cricket balls, thus the mechanism of swing as well as drag of a cricket ball. The aerodynamic forces and moments of used and new balls were measured under a range of speeds at various seam orientations. The airflow around the balls was visualized and documented. The preliminary data analysis indicated that the wear & tear and seam angle have significant effect on aerodynamic drag and side forces of the cricket ball.

Introduction

Over 60 countries of the former British Empire are directly involved with a potential viewing audience of over 1.5 billion people in cricket games. Cricket's popularity has already moved outside the boundary of the British Commonwealth nations. With the expected participation of China in cricket in 2012, the game can become potentially the 2nd most viewed game after the football (soccer). The centre piece of the game of cricket is the ball. As a cricket ball has to be projected through the air as a three dimensional body, the associated aerodynamics play a significant role in the motion thereby flight of the ball.

A cricket ball is constructed of a several layers of cork tightly wound with string. The ball is covered with a leather skin comprising 4 quarters stitched together to form a major seam in an equatorial plane. Moreover the quarter seams on both halves of the ball are internally stitched and juxtaposed by 90 degrees. The seam comprises six rows of stitches with approximately 70 to 90 stretches in each row. The height of the seam can be over 1 mm above the surface of the ball. The mass of a cricket ball is around 156 gm. The prominence of the seam can vary from one manufacturer to another as there is no standard for the seam geometry. At present, over a dozen commercial companies manufacture cricket balls under the auspices of the International Cricket Council (ICC), overseeing the game at the highest level (Test cricket).

The aerodynamic properties of a cricket ball can greatly be affected by the prominence of the seam, the surface roughness of the ball in play, and the launch attitude of the ball by the bowler. Based on seam angle and surface roughness of the ball, an asymmetric airflow over the ball due to pressure difference can be generated thereby deviating the flight from the intended path. This potential flight deviation is called swing. Therefore, it is extremely important to understand aerodynamic properties of used cricket balls as wear and tear can have major effect on swing as well as drag. As mentioned earlier, the sideway deviation of the ball during the flight towards the batsman can create significant discomfort for the batsman.

Till to date, the complex behaviour of swing of a cricket ball is not fully understood. Although some studies have been undertaken by Alam et al. [1], Mehta et al. [5-6], Sayers and Hill [7], Barton [2], La Brooy et al. [3] and Brown [4] on new cricket ball aerodynamics, scant information is available on aerodynamics of used cricket balls. Therefore, a comprehensive study to understand the gamut of complex aerodynamic behaviour resulting in a wide range of swing under a wide range of wind conditions, relative roughness, seam orientations and seam prominence is yet to be conducted. The primary purpose of this work is to study the aerodynamic behaviour of a series of used cricket balls as part of a larger study has been undertaken in the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia.

Experimental Procedure

The study was conducted in RMIT Industrial Wind Tunnel under a range of speeds (60 km/h to 140 km/h with an increment of 10 km/h) at seam orientation (seam angles) of 0º, 10º, 20º, 30º & 40º. Three sets of used balls after 10 to 15, 20 to 30 & 40 to 50 overs of bowling were selected for this study. Additionally, a new ball was also tested. The used balls were provided by the Cricket Victoria and the new balls were provided by Kookaburra Australia Pty Ltd.

The RMIT Industrial Wind Tunnel is a closed return circuit wind tunnel with a turntable to simulate the cross wind effects. The maximum speed of the tunnel is approximately 150 km/h. The dimension of the tunnel's test section is 3 m wide, 2 m high and 9 m long and the tunnel's cross sectional area is 6 square meter. The experimental set up in the test section of RMIT Industrial Wind Tunnel is shown in Figure 2. The tunnel was calibrated before conducting the experiments and tunnel's air speeds were measured via a modified NPL ellipsoidal head Pitot-static tube (located at the entry of the test section) connected to a MKS Baratron pressure sensor through flexible tubing. A mounting stud was manufactured to hold the ball and was mounted on a six component force sensor (type JR-3). Purpose made computer software was used to compute all 6 forces and moments (drag, side, lift forces, and yaw, pitch and roll moments) and their non-dimensional coefficients. However, only the drag and side forces via their non dimensional coefficients are presented in this work.

Four balls (3 used balls and 1 new ball) that have been used in this study and are shown in Figure 1. Figure 1a shows a new (unused) ball. On the other hand, Figure 1b, 1c and 1d illustrate the used balls after 10 to 15 overs, 20 to 30 overs and 40 to 50 overs of bowling respectively.

a) A new ball

b) An used ball (10-15 overs)

c) An used ball (20-30 overs)

d) An used ball (40-50 overs)

Figure 1. Types of ball used in the study

Figure 2. Experimental Set-up in RMIT Industrial Wind Tunnel

Results and Discussion

As mentioned earlier, the aerodynamic properties (drag, lift and side force and their corresponding moments) at wind speeds of 60 km/h to 140 km/h with an increment of 20 km/h) at seam angles of 0°, 10°, 20°, 30° and 40°with the mean direction of winds were measured. It is believed that a practical seam angle during bowling is approximately 20 to 30 degree with the mean direction of flight. The aerodynamic forces acting on the balls were determined by testing balls with the supporting gear and then subtracted from the forces acting on the supporting gear only. A cricket ball with the mounting device on a six component force sensor is shown in Figure 2.

The drag and side force were converted to their non-dimensional drag coefficient (C_D) and side force coefficient (Cs) using the following two formulas respectively:

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 A} \quad \text{and} \quad C_S = \frac{S}{\frac{1}{2}\rho V^2 A}.$$

Where, D, ρ, V, S & A are drag, air density, wind velocity, side force and projected frontal area of the ball respectively. The C_D represents the drag or resistance of the cricket ball, Cs represents the swing (side) force acting on the ball. The C_D and Cs as a function of Reynolds numbers ($\mathrm{Re} = \frac{\rho V d}{\mu}$) varied by wind velocity for all used balls and a new ball are shown in Figures 3 to 14. Figures 12 to 14 show the C_D and C_S values variation of all cricket balls at zero seam angle and 40º seam angle.

In order to check the validity of the data, the drag coefficient of the new cricket ball was compared with the drag coefficient of a sphere. The drag coefficient of a smooth sphere in free stream flow over the Reynolds number range of $7.5\times10^4 < \mathrm{Re} < 1.85\times10^5$ that has been covered by this experimental study is approximately 0.5 [8]. Generally, the boundary layer of a smooth sphere becomes turbulent at a critical Reynolds number of approximately 3×10^5 and the separation point moves downstream around the surface of the sphere. As a result, the drag coefficient is reduced to almost 0.1 due to a narrower wake. The cricket ball (although looks like a sphere) with stitches and seams also undergoes a transition in this Reynolds number range at zero seam orientation (see Figure 7 for the new ball and Figures 3 to 6 for the used balls). However, the transition is more prominent for the new ball than the used balls. The average C_D values are approximately 0.45 and 0.65 for the new and used balls compared to the C_D value of 0.5 for a smooth sphere. The high drag coefficient for the used balls is believed to be due to comparatively rough surface, seams and wear & tear of the cricket ball.

The magnitudes of the side force coefficient (C_S) of all balls (both new and used) vary significantly with Reynolds number, seam angles and surface roughness (see Figures 9 to 14). Generally, seam of a sphere if aligned with the wind direction (at zero seam angle) should not generate any side force due to the symmetrical air flow around it. However, it is not the case with the cricket ball. A new cricket ball with its complex seams and stitches can even generate side force at zero seam angle (see Figure 13). However, the side force is slightly reduces at zero seam orientation at high Reynolds numbers. The seam angles have significant on aerodynamic drag and side force (see Figures 10 to 14). If the seam angle is not sufficiently large (less than 45º), the boundary layer is tripped on the seam side of the ball, thus the boundary layer becomes turbulent but remains attached for a longer period than on the other side, where separation of the laminar boundary layer takes place relatively early around the surface. The turbulent boundary layer has a longer low pressure region extending around the surface than does the laminar boundary layer, resulting in a net force in the direction of seam turn. However, the large negative side force implies that separation has taken place in the previously attached boundary layer with a corresponding increase in pressure on that side (see Figures 11 to 14.

At 40º seam angle, the average C_D value for the new ball is slightly lower compared to the C_D values of the used balls. For example, the C_D value for the new ball is approximately 0.59 in comparison of 0.64, 065 & 0.67 of the used balls after 10 to 15, 20 to 30 and 40 to 50 overs of bowling. The rise of the drag coefficient is believed to be due to the increased skin friction drag over the roughened surface as opposed to any later separation occurring which would cause a narrower wake and reduced drag.

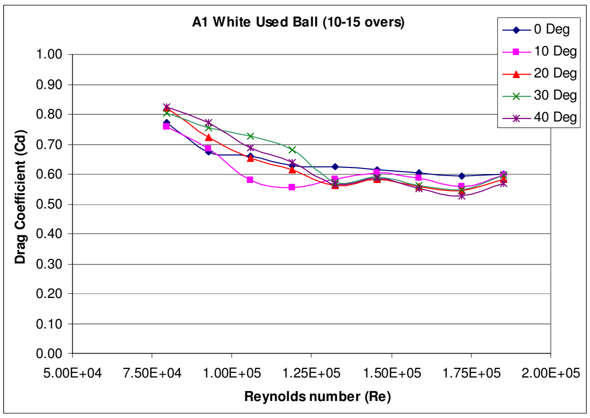

Figure 3. C_D variation with Re for used ball (10-15 overs)

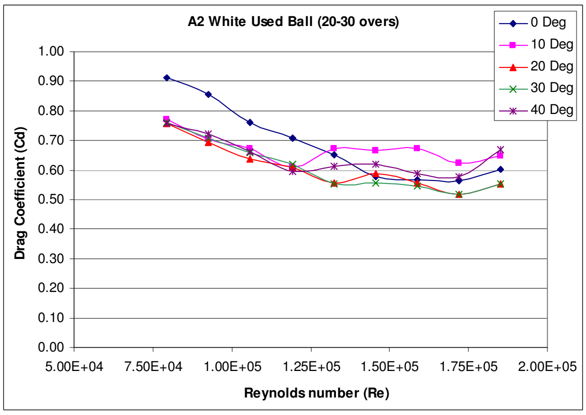

Figure 4. C_D variation with Re for used ball (20-30 overs)

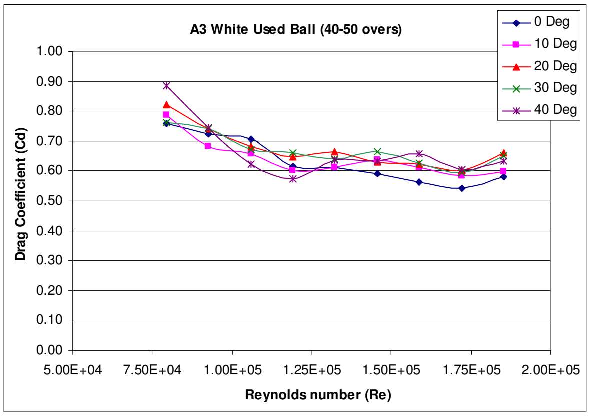

Figure 5. C_D variation with Re for used ball (40-50 overs)

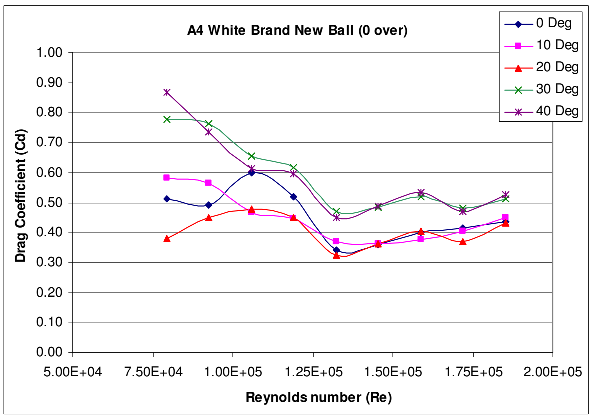

Figure 6. C_D variation with Re for new ball (0 over)

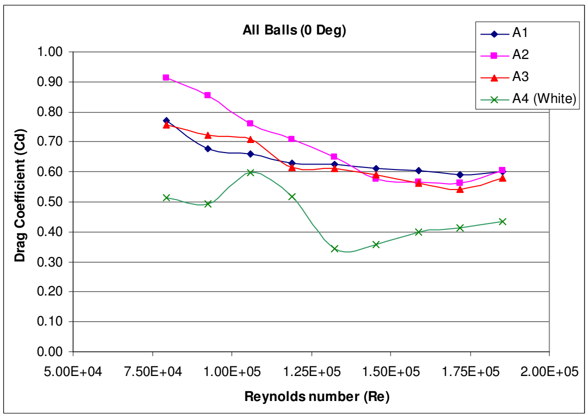

Figure 7. C_D variation with Re for all balls at 0º seam angle

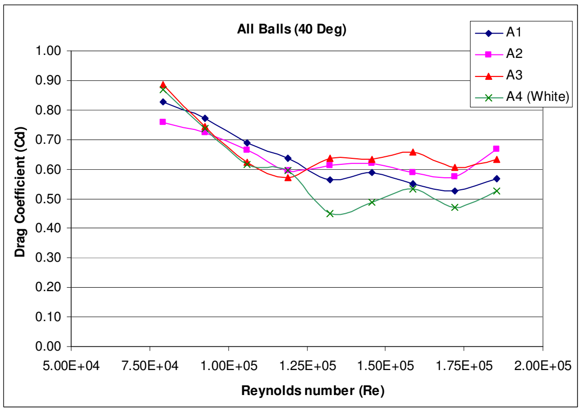

Figure 8. C_D variation with Re for all balls at 40º seam angle

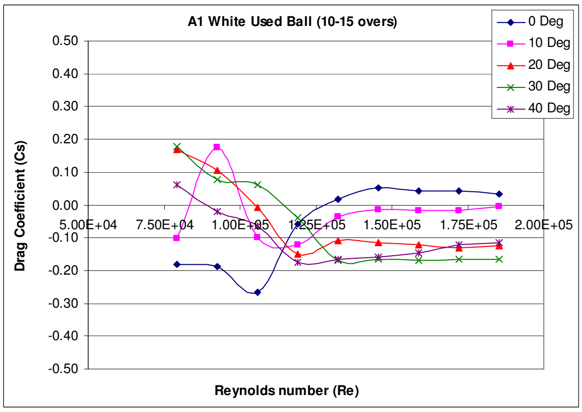

Figure 9. C_S variation with Re for used ball (10-15 overs)

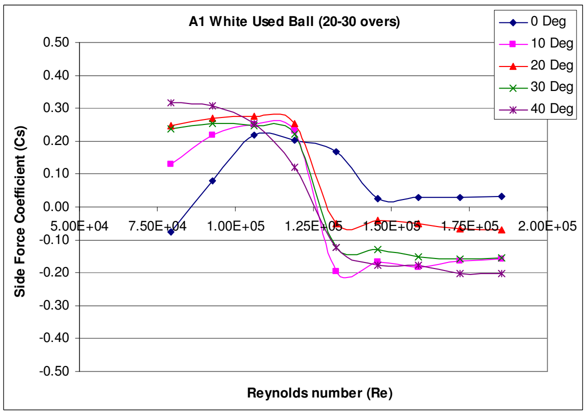

Figure 10. C_S variation with Re for used ball (20-30 overs)

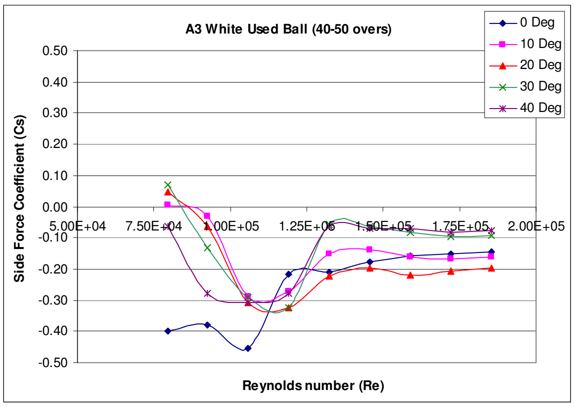

Figure 11. C_S variation with Re for used ball (40-50 overs)

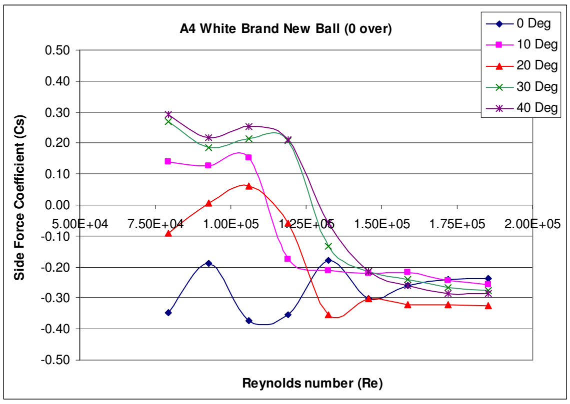

Figure 12. C_S variation with Re for a new ball (0 over)

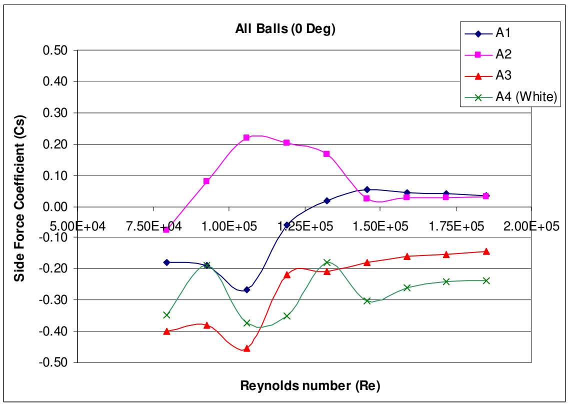

Figure 13. C_S variation with Re for all balls at 0° seam angle

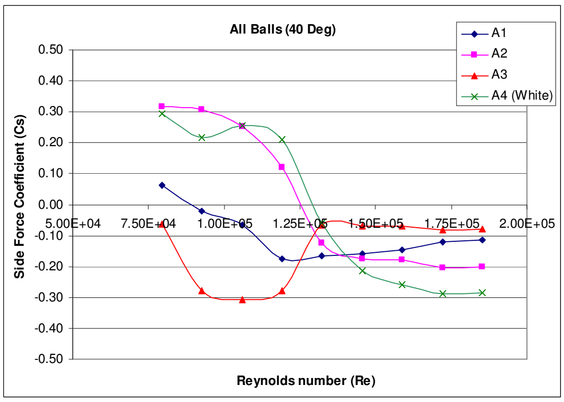

Figure 14. C_S variation with Re for all balls at 40° seam angle

Conclusions

The following concluding remarks have been drawn based on the research work presented here:

- The aerodynamic behaviour of a cricket ball significantly differs from the aerodynamic behaviour of a smooth sphere
- The air flow around a cricket ball does not undergo a rapid reduction of drag in critical Reynolds number as it is the case of a sphere.
- The seam, stiches and surface roughness-all have significant effects on the drag and side force of a cricket ball.
- The wear and tear increases the aerodynamic drag of a cricket ball.
- The change of swing direction (side way deviation) can take place with the increase of Reynolds numbers.

Future Work

A multi axes spin device is being developed to spin the cricket ball around its different axes.

Further tests are being conducted to understand the various swings (including reverse swing) of a cricket ball.

Acknowledgments

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