Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2011
(ICMERE2011) 22- 24 December 2011, Chittagong, Bangladesh

ICMERE2011-PI-175

# AERODYNAMICS OF A BASEBALL- AN EFFECT OF SEAMS

**Firoz Alam[1,*], Huy Ho[1], Jie Yang[1], Arun Kumar[1], Syed Amimul Ehsan[1], Golam Mainuddin[2], Shariful Islam[3] and Abhijit Date[1]**

[1]School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia
[2]SMEC International Pty Ltd, Dhaka 1206, Bangladesh
[3]Department of Mechanical Engineering, Khulna University of Engineering and Technology, Khulna 9203, Bangladesh
*E-mail: firoz.alam@rmit.edu.au

***Abstract***- *Baseball is one of the popular games in many parts of the world. It is enjoyed both by participants and spectators. The spherical ball is the centre piece of the game. The flight trajectory of a baseball largely depends on its aerodynamic characteristics. Despite the popularity of the game, it appears that scant information on the aerodynamic force experienced by a baseball is available in the open literature. With over 108 curved stitches, complex seams and their orientation, the airflow around the ball is significantly complex and has not been well understood. The primary objectives of this study are to measure the aerodynamic properties of a commercially manufactured baseball. The aerodynamic forces and moments were measured experimentally for a range of wind speeds and seam orientations. The aerodynamic forces and their non-dimensional coefficients were analysed. The results indicate that seam orientations have a profound impact on drag coefficient of a baseball.*

**Keywords:** Drag, drag coefficient, yaw angle, baseball, wind tunnel, Reynolds number

## 1. INTRODUCTION

The flight trajectories of sports balls largely depend on their aerodynamic characteristics. Depending on its 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, football, golf, tennis and volleyball. 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. Therefore, the aerodynamic properties of a sport ball is considered to be the fundamental for players, coaches (trainers), regulatory bodies, ball manufacturers and even the spectators. It is no doubt that baseball is widely recognized as the national sport of the United States. It is at all levels (professional, amateur, and youth) now popular in North America (USA, Canada, Mexico, Cuba), parts of Central and South America and the Caribbean, Japan, South Korea, Australia, New Zealand, and many other parts of Asia, Europe and Africa. Like a sphere, the baseball is not uniformly smooth or rough but is characterized by the yin—yang pattern of raised approximately 108 stitches which makes the airflow around the ball to be very complex and unpredictable [1]. Although the aerodynamic behaviour of other sports balls have been studied by Alam et al. [2, 3], Asai et al. [6], Mehta [8], and Smits and Ogg [10], very limited reliable experimental data concerning the aerodynamic behaviour of baseball is available to the public, except some studies by Adair [1], Alaways [5], Kensrud [7] and Nathan [9]. The primary objective of this work is to experimentally study the aerodynamic properties of a commercially made baseball used in major tournament in Australia.

## 2. EXPERIMENTAL PROCEDURE

### 2.1 Description of Balls

A brand new commercially made baseball has been selected for this study. The ball was manufactured by Easton approved by Baseball Australia. The ball model is 600. The outer surface of the ball is made of leather and the ball diameter is approximately 72 mm. A typical baseball outer surface is illustrated in Figure 1. The side views of baseball's different positions are shown in Figure 2.


Fig.1: External shape of a Rawlings manufactured baseball

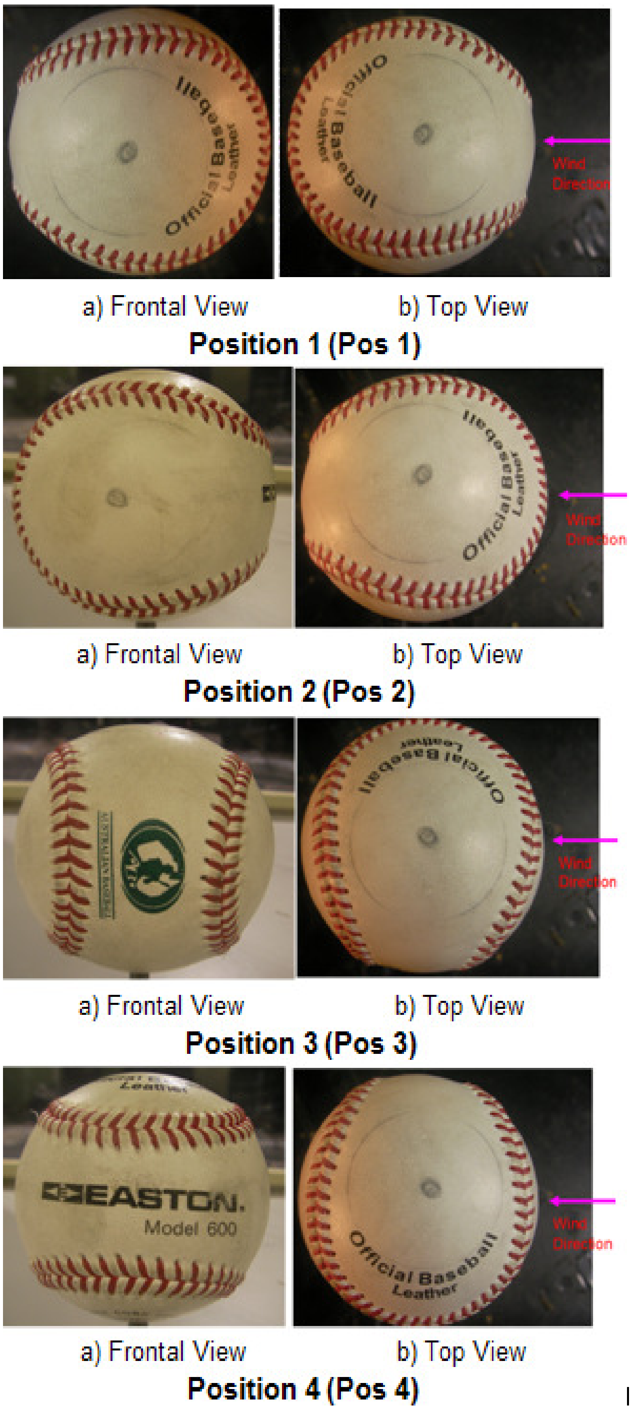



Fig. 2: Seam orientations of an Easton made baseball

## 2.2 RMIT Industrial Wind Tunnel

In order to measure the aerodynamic properties of the baseball 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. A plan view of RMIT Industrial Wind Tunnel is shown in Figure 3. More details about the tunnel can be found in Alam et al. [4].

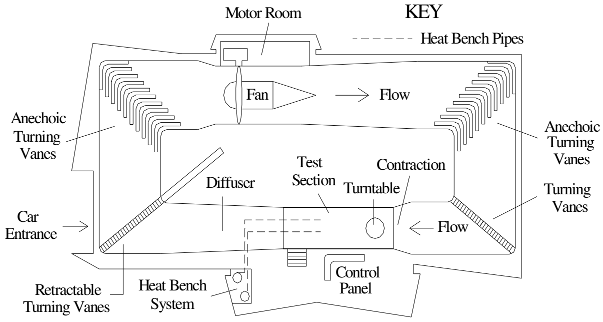
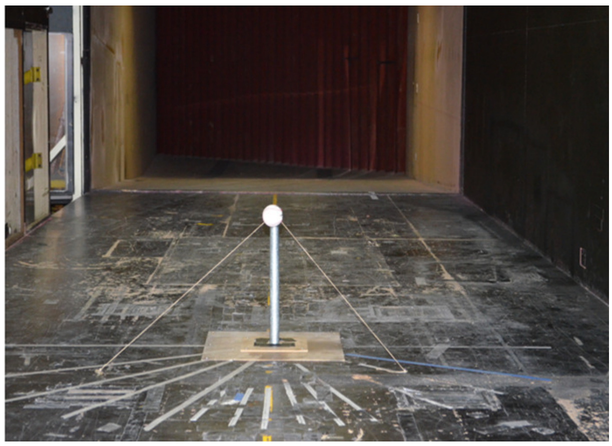



Fig. 3: Schematic of RMIT Industrial Wind Tunnel

A support system previously developed for tennis and cricket balls was used to hold the baseball on a force sensor in the wind tunnel, and the experimental set up with the support system in the test section of RMIT Industrial Wind Tunnel is shown in Figure 4. The support device can also spin the ball with a maximum rotational speed of 3500 rpm. The aerodynamic effect of the support device was subtracted from the support with the ball. The distance between the bottom edge of the ball and the tunnel floor was 400 mm, which is well above the tunnel boundary layer and considered to be free from the ground effect completely.

a) Vertical Experimental Setup



b) Horizontal Experimental Setup

Fig. 4: Experimental methodology for the wind tunnel testing of baseball

All three forces (drag, lift and side force) and their corresponding moments were measured. Tests were conducted at a range of wind speeds under four orientations (positions) of the ball as shown in Figure 2 to evaluate the effects of seam on aerodynamic properties. As a baseball possesses rough and curved stitches on its surface, the aerodynamic behaviour can differ under different orientations of the ball. Additionally, stitch pattern can also influence the airflow and induce drag at different velocities. In order to get insights into potentially different aerodynamic behaviour, as mentioned earlier, the baseball was tested at four seam orientations facing the oncoming wind in the wind tunnel.

The aerodynamic forces and moments were measured under a range of wind speeds (40 km/h to 140 km/h with an increment of 20 km/h) under each orientation (position). The non-dimensional parameters such as drag coefficient ($C_D$) and side force coefficient ($C_S$) were estimated from

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 A} \tag{1}$$

$$C_S = \frac{S}{\frac{1}{2}\rho V^2 A} \tag{2}$$

where $D$, $\rho$, $V$, $S$, $A$ are the drag, air density, wind velocity, side force, projected frontal area of the ball respectively. The projected frontal area was determined by

$$A = \frac{\pi d^2}{4} \tag{3}$$

where $d$ is the diameter of the ball measured at the midpoint of the ball with the seam height.

## 3. RESULTS AND DISCUSSION

In this paper, only the non-dimensional coefficient ($C_D$) is presented for all four orientations for the entire range of speeds (40 to 140 km/h) tested. The $C_D$ values are shown in Figure 5. It is evident that there are significant variations in drag forces as well drag coefficients at four different orientations. As expected, the drag force increases with an increase of speed. However, the seam position 1 and seam position 2 which are the mirror image have lower magnitude of drag forces than position 3 and position 4. The position 3 and position 4 are also the mirror image and possess no significant drag difference between them. However, a notable variation in drag force is observed between positions 1& 2 and positions 3 & 4.

The $C_D$ variations with Reynolds numbers for all four seam positions indicate that there is significant disparity in $C_D$ values among four positions at low Reynolds number however these variations are minimal at high Reynolds numbers. The minimum variation at high Reynolds number is attributed to the elimination and/or minimization of local flow separations from seams. The average $C_D$ value for all four positions is approximately 0.40 at high Reynolds number. However, the $C_D$ value is over 0.50 at low Reynolds number. The $C_D$ value published by Alam et al. [2] was slightly higher. This is due to the aerodynamic interference of the experimental set up. Therefore, data was obtained using a new experimental set up (see Section 2.2). The $C_D$ values found in this study agree well with the published data [1]. There is no notable evidence on the flow transitional effect on the baseball from laminar to turbulent flow under the speed range tested here. The maximum speed used is 140 km/h in our test however an average speed of a professional pitcher is around 155 km/h which is well beyond the maximum speed limit of RMIT Industrial Wind Tunnel. According to Adair [1], the baseball does not display a notable transitional effect like a smooth sphere owing to the presence of its complex seams and stitches. Our data also indicate no transitional effect on baseball. As mentioned earlier, the effects of seam and stitches are evident at all Reynolds numbers as the local flow separation is generated due to seams, stitches and their complex orientation. Nevertheless, these local flow separations become minimal at high Reynolds number thus reducing the effects of seams and stitches. The seam position 4 has the highest effect compared to other seam positions whereas the seam position 1 has the lowest average $C_D$ value in contrast to the $C_D$ value of position 4. The average $C_D$ value is much lower than positions 3 and 4 $C_D$ values whereas the $C_D$ value is higher than positions 1 and 2 $C_D$ values.

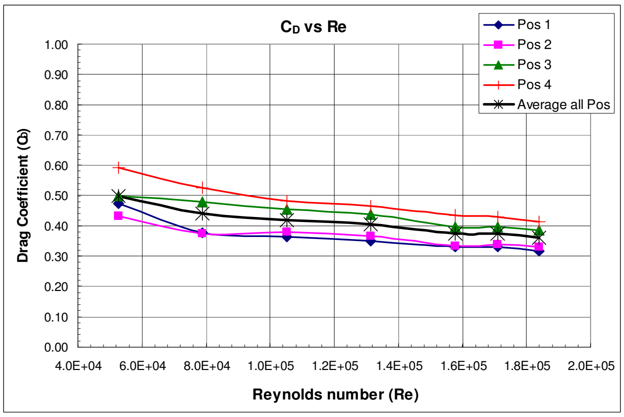



Fig. 5: Drag coefficient ($C_D$) as a function of Reynolds number for all four positions

A comparison of $C_D$ values with the published data (Adair [2] is shown in Figure 6. The findings in this study indicate that the flow transition occurred much earlier compared to Adair data which is believed to be due to the flow quality of the tunnel. Overall, the flow transition pattern found to be similar. As mentioned earlier, the baseball is usually played at speeds greater than 100 km/h. The asymmetric forces can be considerable for baseballs due to the complex seam orientation, stitches, and most importantly, spin. These asymmetric forces can swerve the flight path of the ball so sharply that it is almost impossible to hit and catch. However, the most skilful pitcher has great difficulty in throwing the ball with the precision required to generate a reproducible break. As a result, the behaviour of the ball often surprises players - batter, catcher and pitcher. Therefore, it is utmost important to understand the complex aerodynamics of the baseball under spinning and non-spinning conditions. This study considers no-spinning condition only. Further study is underway to investigate the effect of spinning on baseball aerodynamics.

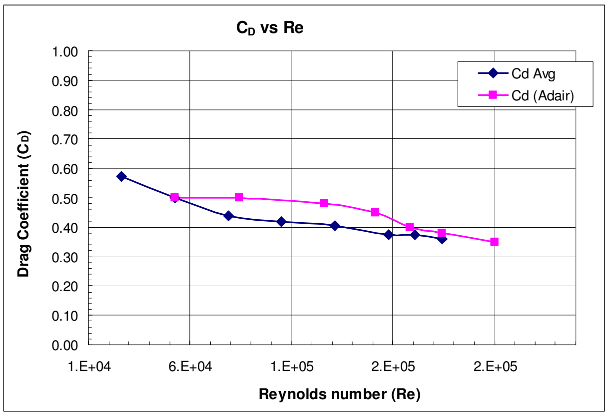



Fig. 6: A comparison of $C_D$ value with the published data

## 4. CONCLUSIONS

The following conclusions were made based on the study presented here:

- The average $C_D$ value for a baseball obtained in this study is around 0.40 at high Reynolds number.
- Seam orientation and stitches have significant effects on baseball aerodynamics at low Reynolds numbers however these effects are minimal at high Reynolds numbers.
- No significant transitional effect is evident in the baseball $C_D$ value.
- The variation of $C_D$ value between sides of a baseball facing the wind can vary be up to 25%.

## 5. FUTURE WORK

a) Measure aerodynamic properties of baseballs with varied seam heights and widths;
b) Undertake a comparative aerodynamic analysis of baseball and softball
c) Visualise airflow around a baseball to understand the flow dynamics;
d) Measure the effects of spin on aerodynamic properties of baseball.

## 6. ACKNOWLEDGMENTS

The authors are expressing their sincere thanks to Mr Patrick Wilkins, School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia for his assistance with the experimental set up.

## 7. REFERENCES


[1] Adair, R.K. (1995), The Physics of Baseball. *Physics Today*, 1:26-31.
[2] Alam, F., Huy, H., Chowdhury, H. and Subic, A. (2011), Aerodynamics of baseballs, *Procedia Engineering*, 13:207-212, Elsevier
[3] Alam, F., Subic, A., Watkins, S., Naser, J. and Rasul, M. G. (2008), An Experimental and Computational Study of Aerodynamic Properties of Rugby Balls, *WSEAS Transactions on Fluid Mechanics*, 3(3): 279-286.
[4] Alam, F., Subic, A., Watkins, S. and Smits, A. J. (2010). Aerodynamics of an Australian Rules Foot Ball and Rugby Ball in Computational Fluid Dynamics for Sport Simulation (edited by M. Peters), ISBN 13: 978-3-642-04465-6, 103-127. Springer
[5] Alam, F., Chowdhury, H., Subic, A. and Fuss, F.K. (2010), A Comparative Study of Football Aerodynamics, *Procedia Engineering*, 2(2):2443-2448.
[6] Alam, F., Subic, A., Watkins, S., Naser, J., Rasul, M.G. (2008), An experimental and computational study of aerodynamic properties of rugby balls. *WSEAS Transactions on Fluid Mechanics*; 3:279-286.
[7] Alam, F., Zimmer, G., Watkins, S. (2003), Mean and time-varying flow measurements on the surface of a family of idealized road vehicles, *Experimental Thermal and Fluid Sciences*; 27:639-654.
[8] Alaways, L.W. (1998), Aerodynamics of the curve ball: An investigation of the effects of angular velocity on baseball trajectories. PhD Thesis, University of California Davis, USA
[9] Asai, T., Seo, K., Kobayashi, O., Sakashita, R. (2007), Fundamental aerodynamics of the soccer ball, *Sports Engineering*; 10:101-110.
[10] Kensrud, J.R. (2010), Determining aerodynamic properties of sports balls in situ, M.Sc Thesis 2010, Washington State University, USA.
[11] Mehta, R.D., Alam, F., Subic, A. (2008), Aerodynamics of tennis balls- a review, *Sports Technology*; 1(1):1-10.
[12] Nathan, A. (2009), The effect of spin on the flight of a baseball, *American Journal of Physics*; 76:119-124.
[13] Smits, A.J and Ogg, S. (2004), Golf ball aerodynamics, *The Engineering of Sport 5*; 1:3-12.


## 8. NOMENCLATURE

| Symbol | Meaning | Unit |
|---|---|---|
| D | Drag Force | (N) |
| L | Lift Force | (N) |
| S | Side Force | (N) |
| $C_D$ | Drag Coefficient | - |
| $C_L$ | Lift Coefficient | - |
| $C_S$ | Lateral-Force Coefficient | - |
| Re | Reynolds Number | - |
| V | Velocity of Air | m/s |
| $\rho$ | Density of Air | kg/m$^3$ |
| A | Projected Area | m$^2$ |