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# A Comparative Study of Baseball and Softball Aerodynamics

**F. Alam[1], V. Djamovski[1], H. Chowdhury[1], L. V. Smith[2], S. Watkins[1] and A. Subic[1]**

[1]School of Aerospace, Mechanical and Manufacturing Engineering
RMIT University, Melbourne, 3083, Australia
[2]School of Mechanical and Materials Engineering
Washington State University, Pullman, WA 99164-2920, USA

## Abstract

The baseball and softball games are popular sports in American continent as well as some other parts of the world. In both games, spherical balls are used. The flight trajectory of a baseball and softball 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 and softball is available in the open literature. Having over 108 curved stitches, complex seams and their orientation, the airflow around a baseball is believed to be significantly complex and little understood. The primary objectives of this study were to evaluate aerodynamic parameters of several commercially manufactured baseballs and softballs. The aerodynamic forces and moments were measured experimentally. The aerodynamic forces and their non-dimensional coefficients were analysed. The results indicate that the drag coefficient of a base ball is close to other closely related balls such cricket ball. The result also indicates that there is a variation in drag coefficients between a baseball and a soft ball. The findings also indicate that the seam orientation has profound impact on ball's aerodynamic characteristics.

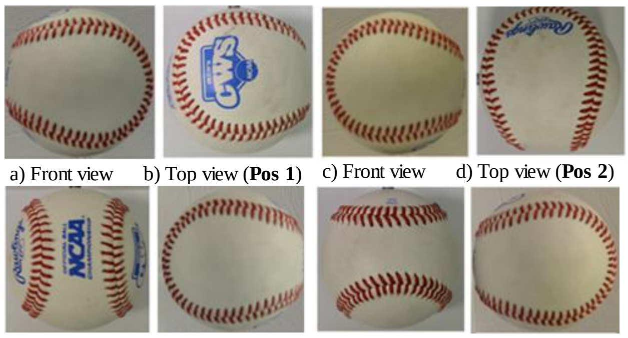
## Introduction

The actual flight path of a sports ball can be deviated from its anticipated trajectory due to aerodynamic interaction caused by the exterior surface of the ball. This deviation can be more complicated if spin is involved. Hence, the aerodynamic properties of a sport ball are considered to be the fundamental for understanding the aerodynamic behaviour and its anticipated flight route. Baseball and softball are considered as one of America's favourite sports. It is popular at all levels (professional, amateur, and youth) not only in the USA but also in Canada, Mexico, Cuba, parts of Central and South America and the Caribbean, Japan, South Korea, Australia, New Zealand. Unlike a sphere, the external shape of a baseball and softball is not totally uniform and smooth. The surfaces of baseballs and softballs are characterised by the 'yin – yang' pattern of raised stitching, comprising of approximately 108 stitches for baseballs and 88 to 96 stitches for softballs. Stitches, seams and their orientations can make the airflow around these balls complex and unpredictable, as they alter the flow regime over the surface of the ball. Although the aerodynamic behaviour of other spherical and oval shape sports balls have been studied by Alam et al. [2-4], Asai et al. [6] and Mehta [8], scant and reliable experimental aerodynamic data for baseballs and softballs is available to the public domain except some studies by Adair [1], Alam et al. [10], Alaways [5] and Kensrud [7]. The variation in data reported by these studies is significant. Therefore, the primary objective of this work is to experimentally investigate the aerodynamic properties of several commercially made baseballs and softballs used in major tournaments around the world.

## Methodology

### Description of Balls

Four brand new commercially balls: two baseballs and two softballs were selected for this study. The baseballs were manufactured by Rawlings. Two baseballs are: (i) Rawlings NCAA Championship and (ii) Rawlings Major League. The external diameters of both balls are approximately 72 mm. The diameter included the seam height. Despite having the diameter, their seam characteristics (seam width, space and height) are significantly different. The NCAA ball has high and wider seams whereas the Major League ball has relatively flat and narrower seam widths. Nevertheless, both balls have the same pair number of stitches (108). The side views and their seam orientations of these two baseballs are shown in Figures 1 and 2.



a) Front view b) Top view (**Pos 1**) c) Front view d) Top view (**Pos 2**)
e) Front view f) Top view (**Pos 3**) g) Front view h) Top view (**Pos 4**)

Figure 1. Seam positions for Rawlings NCAA ball

Two selected softballs are: (i) Wilson NCAA Championship and (ii) Diamond Fastpitch Flyer 375. The approximate diameters of these two balls are 97 mm. The Wilson NCAA Championship ball possesses 88 pair of stitches and the Diamond Fastpitch Flyer 375 possesses 96 pair of stitches. The Diamond ball has slightly higher seams than the Wilson NCAA Championship ball. However, the NCAA ball has little wider seams than that of the Diamond ball. The side views and seam orientations of both softballs are shown in Figures 3 and 4.

Two baseballs were tested at four seam orientations placing towards the oncoming wind as shown in Figures 1 and 2. However, the Wilson NCAA softball was tested for two seam orientations, i.e., position 1 and position 2. The Diamond softball was tested for seam positions 3 and 4 due to shortage of balls (only one sample for each of these two softballs was available) during the test. Two more softballs are currently being tested for the remaining seam positions. The results for these orientations will be published at a later date. In Figures 1 to 4, the view from the front when looking parallel to the wind direction from the entry to down stream in the wind tunnel and the Top View is when looking vertically down from the top, perpendicular to the wind direction.

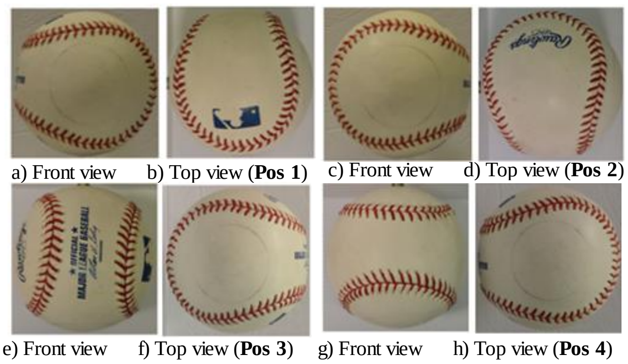



Figure 2. Seam positions for Rawlings Major League ball

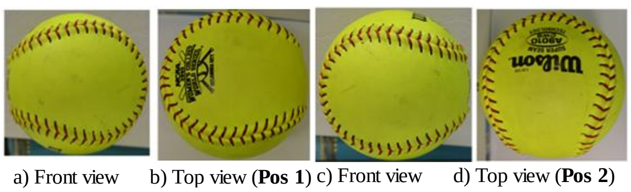



Figure 3. Seam positions for Wilson NCAA Softball


Figure 4. Seam positions for Diamond Fastpitch Flyer 375 Softball

## Experimental Procedure

In order to determine the aerodynamic properties of baseballs and softballs experimentally, the RMIT Industrial Wind Tunnel was used. It is a closed return circuit wind tunnel with a maximum speed of approximately 150 km/h. The dimension of the rectangular test section is 3 m (wide), 2 m (height), 9 m (long). The test section is equipped with a turntable to yaw the model. A plan view of RMIT Industrial Wind Tunnel is shown in Figure 5. The balls were mounted on a six component force sensor (type JR-3) and a purpose made computer software was used to digitize and record all 3 aerodynamic 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. [10]. Two support systems for vertical and horizontal setups were developed. A notable variation in results was noted using these two experimental setups. The results using the vertical experimental setup have been reported in Alam et al. [2]. In this study, all results were obtained using horizontal set up as shown in Figure 6. 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 out of ground effect completely. The aerodynamic drag coefficient ($C_D$) is defined as "equation (1)".

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 A} \qquad (1)$$

where $F_D$, ρ, V and A are drag, air density, wind velocity and projected frontal area of the ball respectively. The Reynolds number (Re) is defined as "equation (2)".

$$R_e = \frac{\rho V d}{\mu} \qquad (2)$$

where ρ, V, d and μ are the air density, wind velocity, ball diameter and the air absolute dynamic viscosity respectively. The lift and side forces and their coefficients were not determined and presented in this paper. Only drag coefficients are presented here.

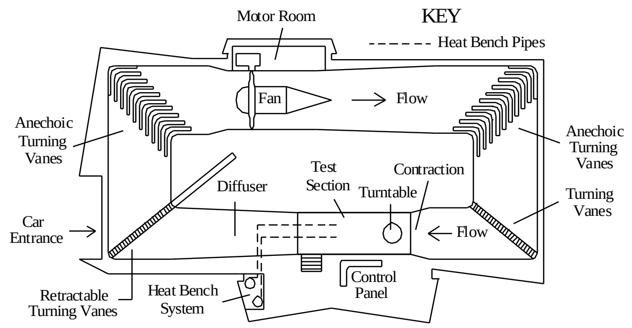



Figure 5. Plan view of RMIT Industrial Wind Tunnel

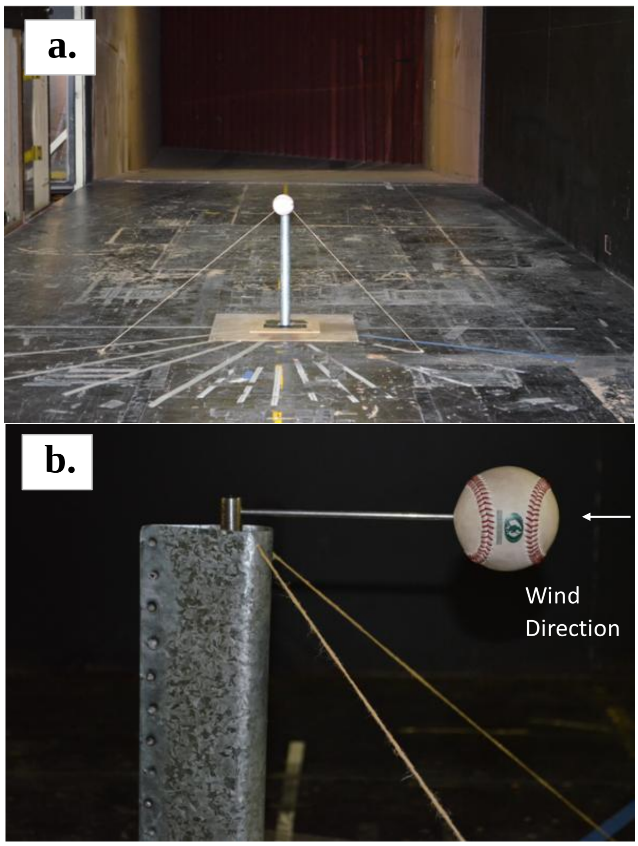



Figure 6. Experimental setup for wind tunnel testing of baseballs: (a) Front view and (b) Side view

## Results and Discussion

The baseballs and softballs were tested at 20, 40, 60, 80, 100, 120 and 140 km/h wind speeds. However, the results are shown here from 40 km/h to 140 km/h. The aerodynamic force was converted to non-dimensional parameter (drag coefficient, $C_D$). The effect 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 0.1 km/h. As a baseball and softball possesses rough and curved stitches on its surface, the aerodynamic behaviour is expected to differ for different orientations of the ball. Additionally, different sectors of the stitching can influence the airflow differently and generate induce drag at different velocities. As mentioned earlier, baseballs have been tested at four seam orientations and the softballs at 2 orientations facing the oncoming wind in the wind tunnel.

The $C_D$ variations with Reynolds numbers for all four seam positions of both baseballs (NCAA and Major League) are shown in Figures 7 and 8.

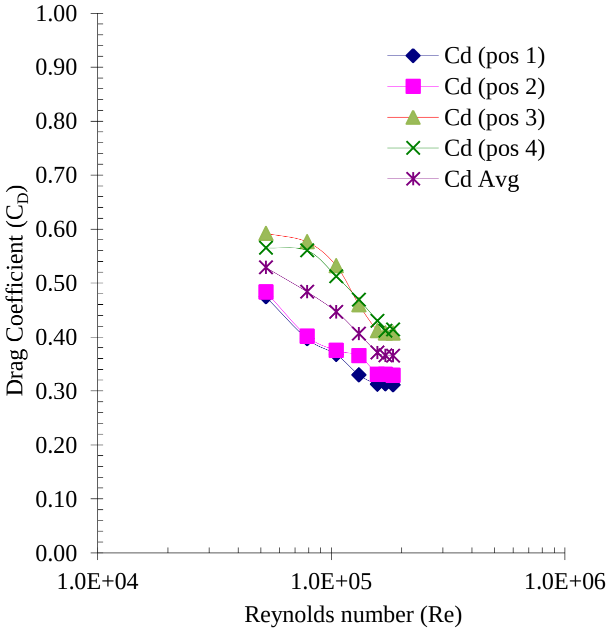



Figure 7. $C_D$ variation with Reynolds number (Rawlings NCAA baseball)

The $C_D$ value variations between positions 1 and 2 and positions 3 and 4 are evident at all Reynolds numbers tested for both balls. However, the variation between position 1 and position 2 is negligible as these two positions are considered to be a mirror image. The seam height has significant effect on drag coefficient. The Rawlings NCAA ball has relatively higher seam height compared to the Major League ball. The variation in $C_D$ values of two baseballs for the same set of seam orientation is shown in Table 1. The average $C_D$ values for both baseballs and softballs are shown in Figure 9. Unlike a sphere, there is no significant drag crisis due to the flow transition from laminar to turbulent noted for the baseballs as well as softballs. However, a less prominent drag crisis is apparent for both set of balls. The flow transition from laminar to turbulent seems to start at around 40 km/h ($Re = 5.2 \times 10^4$) for both baseballs and becomes fully turbulent at around 120 km/h wind speeds (e.g., $Re = 1.5 \times 10^5$). The average $C_D$ values after the transition for both baseballs are 0.37. It may be noted that the flow transition to fully turbulent flow for Rawlings Major League ball (with lower seam height) occurs at slightly higher speeds compared to Rawlings NCAA Champion ball with higher seam height as shown in Figures 7 and 8. The $C_D$ values after the flow transition agreed well with the published data by Kensurd [7].

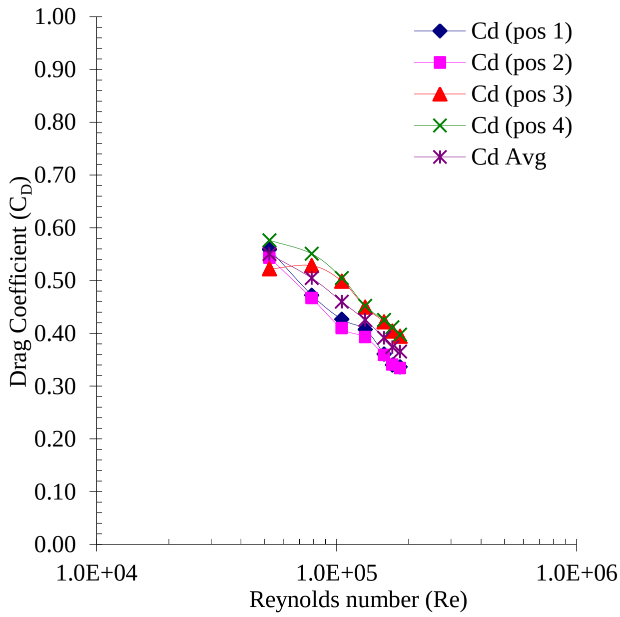



Figure 8. $C_D$ variation with Reynolds number (Rawlings Major League baseball)

The minimal difference in $C_D$ values for baseballs with the higher and lower seam heights after the flow transition occurred indicates that the local flow separation due to seams is minimised or fully eliminated. The effect of seam and stitches are highly evident at low speeds as the local flow separation is present due to seams, stitches and their complex orientation.

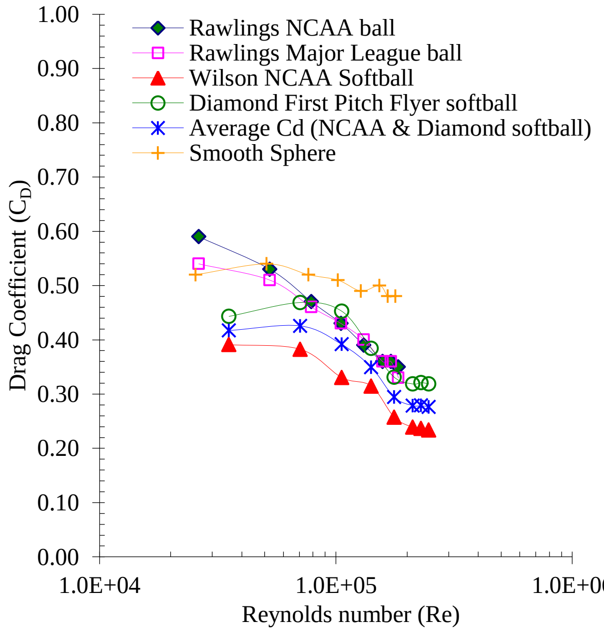



Figure 9. Average $C_D$ variation for baseballs and softballs

The Wilson NCAA softball displays the lowest $C_D$ value compared to Diamond softball as shown in Figure 9. The flow transition for both softballs starts at 60 km/h compared to 40 km/h for baseballs and becomes fully turbulent at 120 km/h. There is no flow transition for the smooth sphere noted for the Reynolds numbers tested as shown in Figure 8. The results agreed well with the published data (e.g., Adair [1]).

Only the drag forces and its coefficients are presented in the paper. However, the data related to lift and drag forces can be found in Alam et al. [2].

Table 1. Difference of drag coefficient ($C_D$) between seam positions 1 & 2 and 3 & 4 (NCAA ball)

| **Speed** | **Rawlings NCAA (High Seams) baseball** | | |
|---|---|---|---|
| km/h | Position 1 & 2 | Position 3 & 4 | $C_D$ difference (%) |
| 40 | 0.48 | 0.58 | 17.3 |
| 60 | 0.40 | 0.57 | 29.8 |
| 80 | 0.37 | 0.52 | 28.9 |
| 100 | 0.35 | 0.46 | 25.2 |
| 120 | 0.32 | 0.42 | 23.6 |
| 130 | 0.32 | 0.41 | 21.4 |
| 140 | 0.32 | 0.41 | 22.0 |
| | | **Average** | **24.0** |

Table 2. Difference of drag coefficient ($C_D$) between seam positions 1 & 2 and 3 & 4 (Major League ball)

| **Speed** | **Rawlings Major League (Low Seams) baseball** | | |
|---|---|---|---|
| km/h | Position 1 & 2 | Position 3 & 4 | $C_D$ difference (%) |
| 40 | 0.55 | 0.55 | -0.30 |
| 60 | 0.47 | 0.54 | 13.03 |
| 80 | 0.42 | 0.50 | 16.73 |
| 100 | 0.40 | 0.45 | 11.26 |
| 120 | 0.36 | 0.42 | 15.11 |
| 130 | 0.34 | 0.41 | 16.54 |
| 140 | 0.33 | 0.40 | 15.47 |
| | | **Average** | **12.55** |

## Conclusions

The aerodynamic behaviour of baseballs and softballs significantly differ from a sphere as their transitional effects are not similar to that of a sphere.

The average $C_D$ value for a baseball at high Reynolds number (120 km/h and above) is around 0.40 however at low Reynolds number (40 km/h) could be as high as 0.55.

The average $C_D$ value for a softball at high Reynolds number (120 km/h and above) is lower than the baseball (e.g., approximately 0.30 at high Reynolds number and 0.50 at low Reynolds number.

The average $C_D$ value for a softball is found to be lower than the baseball at all Reynolds numbers tested.

Seam orientation and stitches have significant effects on baseball and softball aerodynamics. The average variation of $C_D$ value between sides of a baseball facing the wind can vary up to 24%. A similar variation is also noted for the softball as well.

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