WIND TUNNEL TESTING OF DIFFERENT SPORTS BALLS TO FIND THE SEPARATION POINT THROUGH SMOKE VISUALIZATION

G Nallavan

Department of Sports Technology, Tamil Nadu Physical Education and Sports University, Tamil Nadu, India.

Abstract: The reduction of the drag is an important parameter in the ball aerodynamics in sports, for the far distance flight and manvourness to the player. The pressure drag contributes almost 90% of the drag in the ball, where the turbulent boundary layer is preferred over the laminar boundary layer for the drag reduction which delays the separation point. The wind tunnel is used to measure the force and moments acting on the model in the test section and the visualization of the flow to identify the patterns of laminar, turbulent flow, separation points and reattachment point. The cricket ball, golf ball, baseball, hockey ball and ping pong ball is studied in different seam angles, counter-clockwise and clockwise direction at different Reynolds numbers; the separation point is recorded in the computerized system.

Keyword:- Boundary layer, Separation and Reattachment point, Flow Visualization

Introduction

The ball aerodynamics gained importance in the past decades, where it helps to plan the strategies and to know how the external factor is affecting the ball in various sports. The Magnus and reverse Magnus effects both play crucial roles in turning the ball and for the curve path nature. The separation point from the ball matters the drag reduction, the many flow control techniques have been established to change flow from laminar to turbulent through seam line, dimples and rough patterns. The turbulence on the body can be increased through the increasing diameter of the ball, air density and velocity, but in many situations, it is not possible to modify the diameter more than a limit and velocity were restricted with the maximum human capability to attain. The density is a natural phenomenon and even there is no big change in the air density to trigger the turbulence. The only way to reduce the drag is by shifting the separation point behind the ball to reduce the wake area. The different sports ball at the standard diameter at different velocity and different orientation is tested on the wind tunnel to identify the separation point in the ball surface.

Methodology

The Tamil Nadu Physical Education Sports University (TNPESU) Subsonic Wind tunnel is specially designed and equipped to study ball aerodynamics [Table:-1] [1]. The computational six-axis strain gauge sensor is used for forces and moments and the smoke generator with multi - streamliner is used to visualize the wake and turbulence in the flow pattern [2].

We are going to study the effect of the Magnus on the Cricket ball, Tennis ball, Baseball, Hockey ball and a Golf ball in irrotational and rotational effects in 300 RPM in both Clockwise and Anti-Clockwise to understand the spin and reverse the spin of the sports ball The Tamil Nadu Physical Education and Sports University (TNPESU) had facilitated with the Computerized Wind tunnel [3,4] to test the different sports ball in the six-axis strain gauge to find the Coefficient of Lift [C_L], Coefficient of Drag [C_D], Coefficient of Side force [C_S], Coefficient of Roll moment [C_{RM}], Coefficient of Pitch moment [C_{PM}] and Coefficient of Pitch moment [C_{PM}] [8].

Sl.No	Ball	Weight Kg	Diameter mm
1.	Cricket	0.160	70
2.	Tennis	0.58	65
3.	Baseball	0.147	75
4.	Golf	0.045	42.5
5.	Table tennis	0.0027	40

Table 1:- Types of ball with weight and Diameter

There will be a difference in the surface seam thread of cricket and baseball, the dimples in golf balls, the fuzz in tennis balls and smooth surfaces in table tennis balls [5,6,7]. All sports balls were tested at a velocity of 25 m/s.

Result

The tunnel test section is mounted with a six-axis strain gauge and can rotate in 360^0. The cricket ball with 4 stitches in the seam was tested in the 3 seam angles (0^0,

45^0 and 90^0). In a seam angle 0^0, the flow is smooth and separates readily from the ball surface at the circumference angle 140^0, at the seam angle 45^0 the slight transformation of the smooth streamlines to turbulence and wake area is reduced separation point shifted to 228^0 [Fig:-1]. The cricket ball at 90^0 is efficient where the separation point is 322^0 with less wake area behind the ball [Table:- 2][9].

The tennis ball with asymmetry seams on the surface with clockwise rotation; the flow separated in 272^0 [Fig:-1] mainly because of the turbulence generated due to fur. The baseball similar to tennis has an asymmetrical seam and with a larger diameter compared to other balls to lead a flow in higher Reynolds number, where the separation occurred at the angle 192^0 [Fig:-1] [9] in the clockwise rotation [Table:- 2]. In the golf ball, the diameter is small compared to any other ball which leads to laminar flow in lower Reynolds numbers that have a high drag because of the ready separation point. To avoid this the golf ball is embedded with dimples on the surface which trigger the flow to turbulence to reduce wake behind the ball with less drag force. The separation point in the golf ball is at 332^0 [Fig:-1] which is a high angle of circumference compared to other sports balls [Table:- 2] [9].

Sl.No	Ball	Separation point (θ)
1.	Cricket (Seam angle = 0^0)	140^0
2.	Cricket (Seam angle = 45^0)	228^0
3.	Cricket (Seam angle = 90^0)	322^0
4.	Tennis (Clockwise)	272^0
5.	Baseball (Clockwise)	192^0
6.	Golf (Counter - Clockwise)	332^0

Table 2:- Separation point in various ball

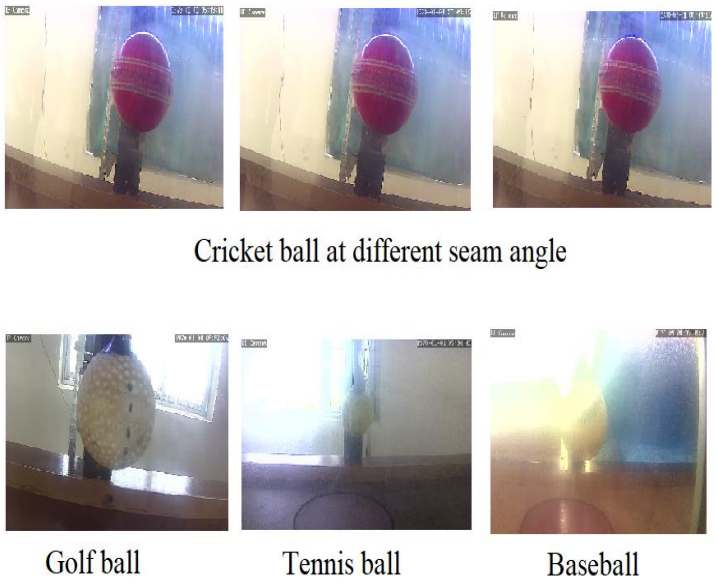

Fig 1:- Smoke flow visualization in various ball in the test section

Conclusions

The ball surface plays a major role in the separation point, where the pressure drag depends. Increasing the roughness in the ball will increase the skin friction drag or shear stress but the pressure drag is tremendously decreased with an increase in roughness, where the total drag is reduced compared to no roughness pattern. The orientation of the roughness and unsymmetrical roughness swings the ball according to need in sports. It's a huge challenge to understand the flow pattern and separation point in the ball surface.

The smoke flow visualization technique [Fig:-1] is used for studying the flow pattern and separation point. In laminar flow, the separation occurs readily, but the turbulence will be delayed. To attain the turbulence flow pattern, the Reynolds number must be increased, where the density and viscosity is the natural phenomenon, the velocity and diameter is a sports constraint. The only way is to play with the roughness pattern in the ball and give a hand to trigger the turbulent pattern to delay the separation to decrease the drag.

In the case of a cricket ball, the ball usage will increase the roughness and the seam threads in the ball orientation will trigger the unsymmetrical separation point where the ball spins from the pitch. The orientation of the seam threads decides the drag and the spin of the ball, the study attempts to find the separation at different seam orientation at 0^0 ,45^0 and 90^0 the separation points are 140^0, 228^0 and 322^0 [Table:- 2] which clearly implies that the seams orientation affects the separation point. In Tennis and Baseball, the asymmetrical

seam lines widely have unorganized flow patterns with the delayed separation on the surface 272^0 and 192^0 [Table:- 2]. The golf ball will have the most delayed separation due to the dimples on the surface which increase the roughness pattern linearly around the ball, the separation occurred at 332^0.

References

1. Jonas Danvind, Andrey Koptyug, David Sundström, Mats Tinnsten; **"A New Wind Tunnel Facility Dedicated to Sports Technology Research and Development"** Procedia Engg,, 147 (2016), PP, 62-67.

2. Barelle Caroline; **"Sport Aerodynamics: on the Relevance of Aerodynamic Force Modelling versus Wind Tunnel Testing"** Wind Tunnels and Experimental Fluid Dynamics Research, 16 (2011), PP, 349-368.

3. Stefano Mauro, Rosario Lanzafame, Michele Messina, S. Brusca; **"Small-Scale Open-Circuit Wind Tunnel: Design Criteria, Construction and Calibration"** International Journal of Applied Engineering Research, volume12, Number 23 (2017) pp. 13649-13662.

4. Kevin Owen, Andrew Owen **"Measurement and assessment of wind tunnel flow quality"** Progress in Aerospace Sciences 44(5) 2008:pp.315-348.

5. Karthigeyan S, Jai bhavani K S, Jenifer Z **"Wind Tunnel Instrumentation System"** International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Special Issue 4, May 2014.

6. V.L. Kakate, D S Chavan, P.B Karandikar, Niraj Mahulkar **"Study of Measurement and Control Aspects of Wind Tunnel"** International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering Vol. 2, Issue 3, 2014

7. A.Nishi, H.Miyagi, K.Higuchi; "**A Computer-Controlled Wind Tunnel"** 1st International Symposium on Computational Wind Engineering (CWE 92), Tokyo, Japan, August 21–23, 1992, pp.837-846.

8. G. Nallavan "**Educational Wind Tunnel for the Sports Aerodynamics"** Test Engineering and Management Volume 82Page Number: 3244 - 3247 Publication Issue: January-February 2020

9. G.Nallavan "**Study on Magnus effect of the different sports ball in the wind tunnel"** AIP Conference Proceedings 2271, 030009 (2020); https://doi.org/10.1063/5.0024806