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STUDY OF SWING OF A CRICKET BALL IN AIR

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Abstract An experimental investigation has been done to study the swing of a cricket ball in air. The aerodynamic forces acting on the ball are determined for two different bowling speeds and different seam angles. Two different bowling speeds are selected as the average medium fast bowler's bowling speed (74 mph) and medium pacer's bowling speed (67 mph). For different seam angles drag forces and side forces increase up to a certain seam angle and then begin to decrease. This happens for both bowling speed but the magnitude of forces is less in case of low speed. From these forces the optimum seam angle for maximum swing can be predicted. The effect of surface roughness on the swing is also discussed.

Keywords: Air-Swing, Side-force, Drag Coefficient

INTRODUCTION

In present days, cricket has become a very popular game especially, in commonwealth countries. The popularity of this game lies in the degree of its uncertainty. Cricket is a highly grammatical and scientific game. At the early stage, cricket was not as complicated as today. At that time, most of the bowlers bowled straightforward without trying to swing the ball. For objects near the earth's surface there is, however, always the force of gravity pulling directly downwards, and it is this that brings things back to earth. But there is no similar sideways force to deflect an object and so as a rule, the path in which an object moves freely will be expected to lie in a vertical plane. This is what at that time the bowler believed. But the bowler who understands the mechanics of swing can make a new ball to change its course in mid-air under practically any conditions. That is, it may move out sideways from the vertical plane, and do what is called swerve in the air
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Experimental data on drag experienced by a smooth sphere in a flowing stream hardly assists in explaining the reasons for the flight trajectories of a cricket ball. This is due to the surface roughness of the leather cover and the presence of the seam, which is made up of six rows of prominent stitching; with typically 60-80 stitches in each row and which protrude about 1 mm above the surface of the ball. This seam makes the difference between the flow over a smooth sphere and a cricket ball. Sherwin and Sproston [1] compared flow over a cricket ball with that over a smooth sphere by introducing a trip wire of 1 mm diameter around the complete smooth sphere and found discrepancy. They mentioned the reasons for this discrepancy in addition to the above is that there is a secondary seam at right angles to the main seam that can modify the flow behaviour at different angles of attack. They placed trip wire around the sphere to simulate the seam on a cricket ball and compare the sideways force and drag force with that on cricket ball at seam and corresponding trip wire angle of 30^0 and 45^0. The force measurement was made using a strain gauge attached to the cricket ball support string. Barton [2] suspended a cricket ball, like a pendulum, in an air stream and measured the sideways angular deflection, from which he calculated the side force on the ball for seam angles of 15^0 and 30^0 to the free air stream. When used (after using 10 overs) balls were tested, he found that at 0^0 seam angle a relatively large side force also developed unexpectedly. He regretted those tests were not carried out on a new ball.

Here we measured side force on a new ball at 0^0 seam angle and found a relatively high side force. Although not considered in this paper, atmospheric condition can also affect the flight of a cricket ball and were discussed analytically by Binnie [3]. Environmental factors such as humidity of air affect the swing of a cricket ball, although quantitative evidence concerning this is difficult to obtain. An investigation was carried out by Sherwin and Sproston [1] in order to ascertain whether the humidity had any marked influence on the swing. Although relative humidity values of between 61% and 100% were recorded, no noticeable change was found. Nevertheless, there is a wealth of observation from the field of cricket to indicate that a ball swing more in a damp and humid atmosphere. Binnie [3] has suggested that when relative humidity reaches 100%, rapid change of pressure occurs over the ball and transform the boundary layer from laminar to turbulent on the seam side.

The swing is caused by a side force, the magnitude of which depends on the ball, the angle of seam to the free stream, the condition of the ball surface and the

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atmospheric condition. It is argued [4] that the side force is caused by an asymmetric pressure distribution on the two sides of the cricket ball resulting from a different boundary layer on seam side as compared to non-seam side leading part of the ball is covered by a film of fast moving air, called the boundary layer. About halfway round the ball, the boundary layer separates from the surface (fig:1). On the non-seam side the boundary layer peels away before the halfway mark. But on the seam side the flow is disrupted by the protuberance of the seam, the boundary layer is tripped into a chaotic turbulence and peels away after the halfway mark. The effect is to make the air pressure on the seam side of the ball lower and this pushes the ball towards the seam side. The main contributor to aerodynamic drag is the point of separation of the boundary layer and turbulent flow holds the layer on to the surface longer, reducing the pressure on that side of the ball.

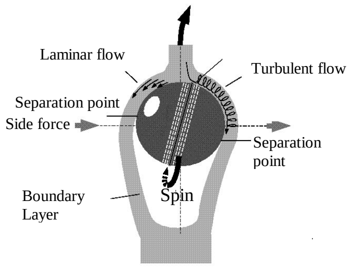

Fig. 1 Boundary layer analysis for in-swing position

EXPERIMENTAL SETUP

Measurement of aerodynamic forces on the cricket ball has been done with the help of a wind tunnel. The cricket ball is placed at the outlet of the open wind

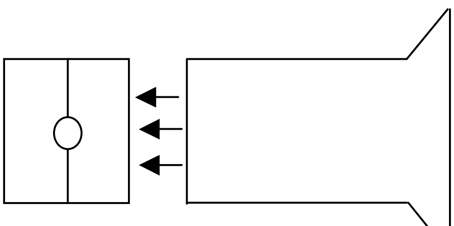

Fig. 2 The experimental setup

tunnel on a frame (fig 2) made of angles. The frame was made in such way that it would ensure that the blockage of wind tunnel outlet by the frame was sufficiently small so as to ensure the validity of the experimental results. The frame also ensures that the ball is placed at the central position of the wind tunnel.

The main purpose of this experiment is to find the drag force and side forces over the surface of the ball for which the pressure distribution around the surface is to be measured. The internal diameter of the ball is 6 cm. A wooden sphere of 6 cm is divided into two parts. In one part the pressure taps were inserted 10^0 apart as shown in figure 3 and then the two parts were joined. The wooden ball is then placed inside the leather surface of the ball.

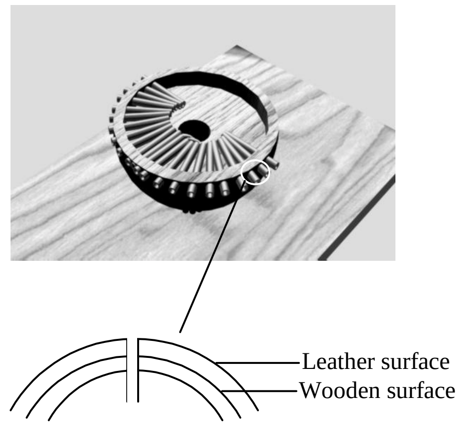

Fig. 3 Arrangement of pressure taps along the surface of the ball

RESULTS AND DISCUSSIONS

The test was carried out to measure the drag forces and side forces on the cricket ball for different seam angles of the ball to the line of flight at two different bowling speeds. Figures 4 and 5 show the plot of drag coefficients and side forces against seam angles at high and low speeds respectively. It can be seen from fig-4 that both the side forces and drag coefficient are maximum at 15^0 seam angle which means that the ball will swing more if the seam angle is about 15^0 with the line of flight.

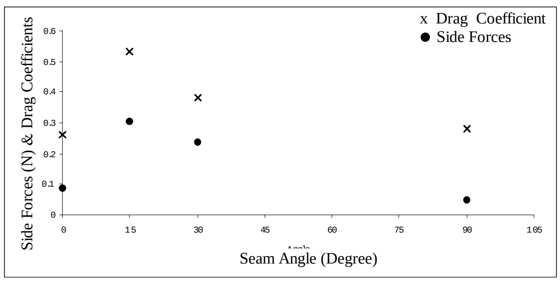

Fig. 4 Seam angle vs side force and Drag co-efficient (High velocity)

The reason behind this can be explained by the boundary layer theory. As mentioned earlier, the secret of swing of the ball is to make the boundary layer separate asymmetrically i.e. making flow turbulent on one side and laminar on the other. If the seam angle becomes large then the boundary layer separates before reaching the seam. This would result in symmetrical separation on the ball and hence zero side force. Again if the seam angle becomes too small then the boundary layer would peel away too early, since the turbulent boundary layer grows at a faster rate and would therefore separate relatively early compared with large seam angle.

A different picture prevails in case of low speed. At lower speed, the side force and the drag force are maximum at 30^0 seam angle. At this speed, if the seam angle become large, the flow gets more time to accelerate around the seam by that time. But the magnitude of the forces at 15^0 and 30^0 seam angle do not differ much. So it can be concluded that a medium fast bowler can bowl at a relatively wider range of seam angle (15^0 - 30^0) and can still swing the ball. Again the magnitude of the forces are greater for higher speed than that for lower speed. So a bowler can obtain maximum swing if he bowls at a seam angle of 15^0 with the line of flight at a speed of 74 mph. In the early 1980s, research at Imperial College, London showed that the maximum side force was generated by a new ball bowled at 70 mph with a seam angle of 20^0 and a backspin of 11 rps. When a bowler bowls at a speed greater than 74 mph, for example in the range of 80-90 mph then the aerodynamics are completely changed and the ball swings in the reverse direction which is called a reverse swing. As a ball moves faster through the air, the shear begins to cause turbulence in the laminar boundary layer as it would even if the ball were a perfectly smooth sphere. The turbulence begins towards the middle of the ball, moving forward as the balls speed increases. If the ball is bowled fast enough, the boundary layer will trip into turbulence even before it reaches the seam. Then the seam acts like a ramp, pushing the air on the sideway from the ball. This makes the boundary layer thicken and separates more quickly on the seam side, which creates a side force pushing the ball from the seam side to the smooth side.

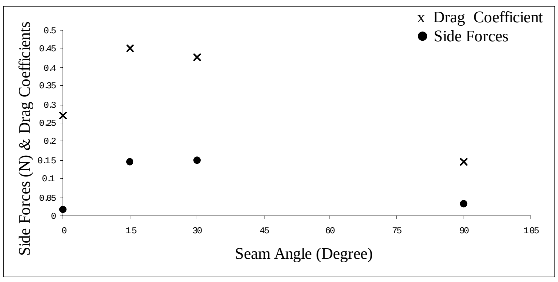

Fig. 5 Seam angle vs side force and drag co-efficient (Low velocity)

Tests were also carried out to determine the effect of surface roughness by roughening the seam side. Figure 6 and figure 7 show the results for high speed and low speed respectively. It can be seen from these figures that for high speed, side force is maximum at 15^0 seam angle and for low speed it is at 30^0 seam angle. After roughening the ball, results remain the same for high speed as that without roughness. But the corresponding magnitude of forces are greater in case of relatively rough ball than that in case of new ball, which indicates that surface roughness enhance the swing. Another fact observed in case of low speed is that, there is a great variation in the magnitude of the forces between 15^0 and 30^0 seam angles. The flow itself gets more time to accelerate and moreover, the roughness enhances the acceleration when the seam angle is 30^0.

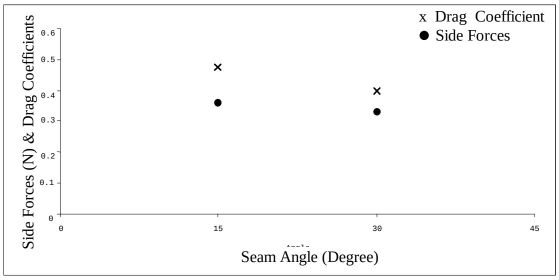

Fig. 6 Seam angle vs force and drag co-efficient (High velocity with roughness)

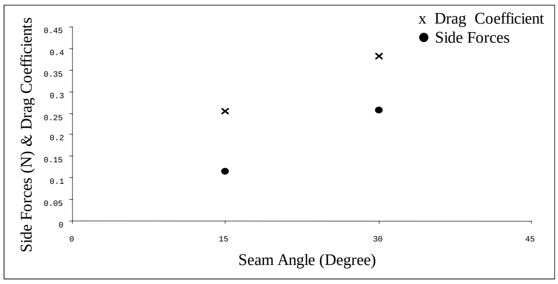

Fig. 7 Seam angle vs force and drag co-efficient (Low velocity with roughness)

Another factor, which is not considered in this paper is the initial backspin imparted by the bowler on the ball during the delivery. This can be explained by Magnus effect. A swirling object creates a sort of whirlpool of rotating air about itself. On the side where the motion of whirlpool is in the same direction as that of the ball, the velocity will be increased and the pressure will be decreased. On the opposite side, where the motions are in the opposite directions, the velocity will be decreased and the pressure will be increased. When initial backspin is given to the ball, it can impart a spinning motion to only a very thin layer next to the surface. The motion imparted to this layer affects the manner in which the flow separates from the surface in the rear. Boundary layer separation is delayed on the side of spinning ball that is moving in the same direction as the free stream flow, while the separation occurs early on the side moving against the free stream flow.

CONCLUSIONS

It has been clearly demonstrated that the maximum swing of a cricket ball can be obtained at a speed in the range of 70-80 mph delivering the ball at a seam angle of 15^0 with the line of flight. But the medium pacers can bowl with relatively wider range of seam angles (15^0 - 30^0). Again the effect of roughness is much more prominent in case of medium fast bowler. So used balls are preferable for a medium pacer rather than a new ball.

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