Aerodynamic properties of soccer balls

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The free flight aerodynamics of three different brand soccer balls have been investigated using the techniques described in the earlier publication *Free Flight Aerodynamics of Sports Balls* at www.acoustoscan.com.au

Balls

The following balls were used:

Telefina:	4 balls
Samba:	3 balls
Puma:	2 balls.

The balls were first inflated to about 30 kPa and left for a week to condition before full inflation.
Before testing was carried out the balls were inflated such that they complied with the FIFA *Vertical Ball Rebound* criterion. At a pressure of 100 kPa they all complied so this pressure was used in the subsequent testing.

Dimensions

The mass, size and shape of the balls were measured to ensure they complied with FIFA regulations viz:

Mass:	410 – 450 g
Circumference:	680 – 700 mm
Sphericity:	no criterion

Mass

The balls were weighed with the overall results:

Telefina:	Mass = 441 (1.5)
Samba:	Mass = 434 (7)
Puma:	Mass = 438 (1)

The balls were then weighed on an improvised inertia balance to determine the position of the centre of mass of each ball. The offset from the true centre of the ball is summarised as:

Centre of Mass

Telefina:	Centre of Mass offset = 5.5 (1.0) mm
Samba:	Centre of Mass offset = 5.0 (1.0) mm
Puma:	Centre of Mass offset = 4.5 (1.0) mm

Size and Shape

The circumference of each ball was measured using a calibrated string, in three orthogonal directions. This enabled a measure of the sphericity of the ball, this being defined as the percentage ratio of maximum to minimum circumference.

The average results for the three types of ball were as follows:

Telefina:	Circumference = 696 (3)	Sphericity = 99.7 (0.3) %
Samba:	Circumference = 687 (6)	Sphericity = 99.8 (0.5) %
Puma:	Circumference = 688 (3)	Sphericity = 100.0 (0.3) %

The estimated uncertainties have been determined at the 95 % confidence level, ie the chance that a result is not in error by more than its stated uncertainty is 95 in 100. These are shown in brackets.

Aerodynamic Properties

Experimental

The balls were projected without spin down an open stair well 17 m deep.
Air temperature was noted as 19 degrees Celsius.

The flights of the balls were observed from above and their speeds during flight tracked using a radar (31 GHz) speed gun connected to a Notebook computer. The resulting data were recorded at 30 Hz and then used to calculate the accelerations of the balls, and hence the two parameters – Speeds and Drag Coefficients.

Results

All balls were observed to waver (move erratically in a horizontal plane) towards the end of flight, ie. at the higher speeds – 40 to 60 kph. No quantitative measure of waver was made.

Data recorded from the speed gun was subjected to a light smoothing filter and then plotted as Drag Coefficient versus Speed (in Reynolds Number), a typical example being shown in Fig. 1.

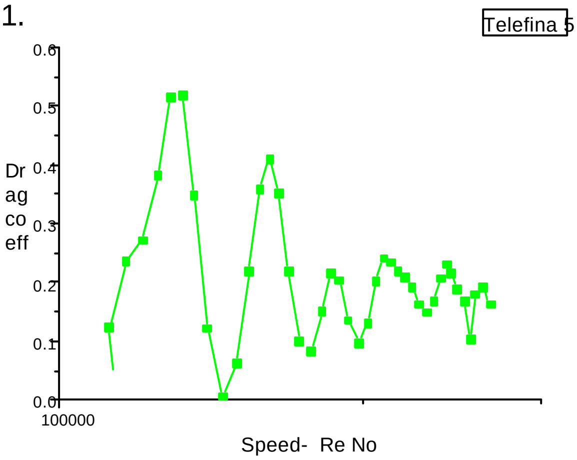

Fig. 1 Plot of Drag Coefficient versus Speed for a Telefina soccer ball

The graphs obtained indicated that the Drag Coefficients for all of the balls average about 0.2 - 0.3 at Reynolds Numbers 150k to 250k (corresponding to ball speeds in the range 35 to 60 kph). This is in agreement with the results of the earlier paper but the peaks and troughs seen here were not shown previously due to the heavier data filtering then used to determine average values of Drag Coefficient.

At speeds around 200k Reynolds Number the characteristics of the air flow around the falling ball is in the transition zone between laminar and turbulent. Vortex formation and vortex shedding at the surface of the ball would be expected. This phenomenon will produce random fluctuating forces and because of the relatively low densities of the balls may cause significant variations in speed or instability in flight, resulting in the peaks and troughs of the Drag Coefficient plots observed. It is unlikely that the minor deviations in dimensions of the balls from spherical symmetry would contribute to this.

A similar plot for a relatively denser golf ball is shown in Fig. 2 from which it can be seen that the fluctuations are of much lesser magnitude as the ball is of higher density and therefore not so susceptible to these aerodynamic forces. (The fluctuations seen here may indicate the noise floor of the data).

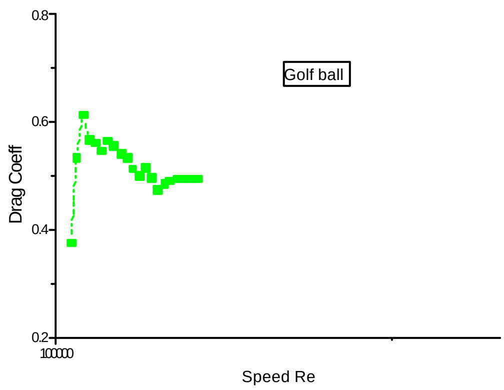

Fig. 2 Plot of Drag Coefficient versus Speed for a golf ball

Vortex formation is a random phenomenon and thus not exactly reproducible, even using the same ball. This can be seen in Fig 3, which is a different flight of the same ball as that shown in Fig 1. The variations in Drag Coefficient are present in both cases but are not exactly the same.

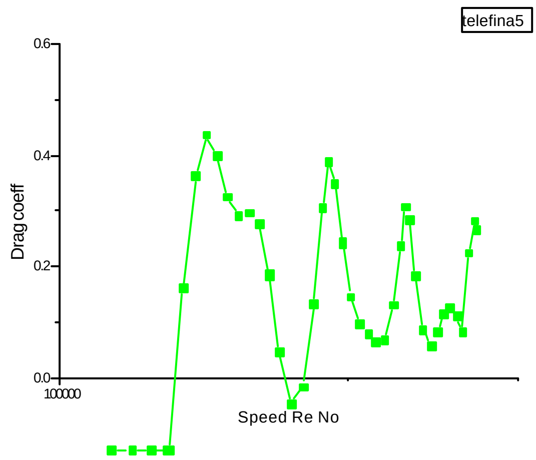

Fig. 3 Plot of Drag Coefficient versus Speed for a Telefina soccer ball

For all of the balls tested there were no distinguishable overall differences in the characteristics of the plots of Drag Coefficient versus speed. The plots indicated fluctuations in Drag Coefficient (instability in the flights) of about the same magnitude. This may not be unexpected as the balls were of very similar construction and physical properties.

Conclusion

Instability in the flight paths, or wavering, of typical soccer balls manufactured to FIFA specifications is an expected phenomenon particularly when the speed of the ball enters the aerodynamic transition zone – about 40 to 60 kph in this case.
The speed zone may vary slightly depending on the smoothness of the ball.
This instability will probably be more pronounced with a non-spinning ball. If the ball is projected with spin the stability of flight may be increased, but *lift* will be generated and the trajectory of the ball may not be a straight line (in a horizontal plane).

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