A Calculation of Cricket Ball Trajectories

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January 8, 2021

Introduction

This article shows:

- Constant force coefficient in sub-critical and super-critical Reynold number region.
- The transition between this two region with variable gradient.
- Approximate analysis of the trajectory equation which results very simple forms of trajectories.
- From the approximate analysis, the governing parameters are also observed.
- The effect of "No wind" and "Cross wind" on the trajectories of the cricket balls.

Literature Survey

- In [1-3], the authors have shown various forces on stationary balls with/without spin in wind tunnels of different types. So, **drag** and **side** forces are determined.
- In [4], some major simplifications are done in trajectory measurement. The trajectories of balls are studied in presence of different aerodynamic force profile.
- In [5], the trajectory of flying debris during extreme windstrom is calculated.

Trajectory Equation

- The trajectory equation is derived from [5], where the author sets an equation for both compact debris and sheet debris.
- For cricket balls, compact debris equation is used.

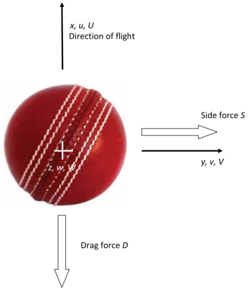


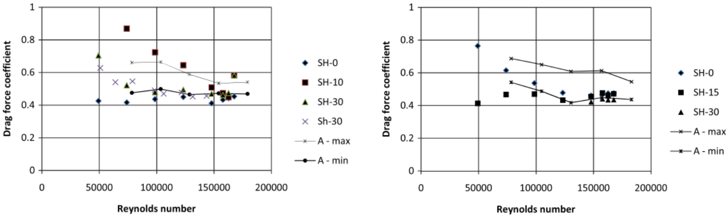
Figure: Axis system, velocities, and forces

Trajectory Equation

The basic trajectory equation for cricket balls:

- $\frac{du}{dt} = -[(\mathrm{u} - \mathrm{U})^2 + (\mathrm{v} - \mathrm{V})^2 + (\mathrm{w} - \mathrm{W})^2]^{0.5}(\mathrm{u} - \mathrm{U})C_D T$
- $\frac{dv}{dt} = -[(\mathrm{u}-\mathrm{U})^2+(\mathrm{v}-\mathrm{V})^2+(\mathrm{w}-\mathrm{W})^2]^{0.5}[-(\mathrm{v}-\mathrm{V})C_D T+(\mathrm{u}-\mathrm{U})C_S T]$
- $\frac{dw}{dt} = -[(\mathrm{u} - \mathrm{U})^2 + (\mathrm{v} - \mathrm{V})^2 + (\mathrm{w} - \mathrm{W})^2]^{0.5}(\mathrm{w} - \mathrm{W})C_D T - 1$
- Where, drag coeff. $C_D = \frac{D}{0.5A\rho Q^2}$ and side coeff. $C_S = \frac{S}{0.5A\rho Q^2}$ and $T=$ Tachikawa number.

Results of Past Experiments



(a) Smooth sphere/New Ball (b) Rough Sphere/Old Ball

Figure: Compilation of cricket ball drag coefficient data

Results of Past Experiments

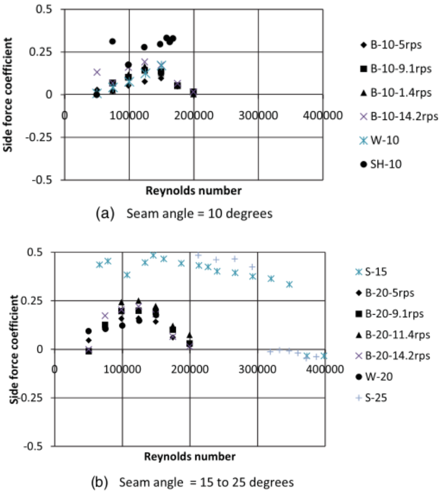
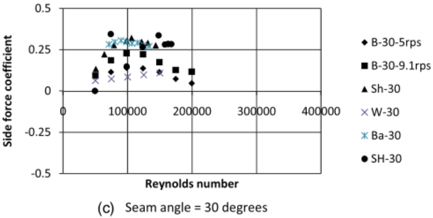
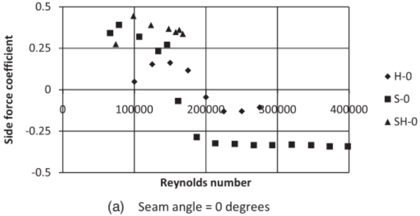


Figure: Compilation of side force coefficient data for smooth spheres/new balls.

Results of Past Experiments



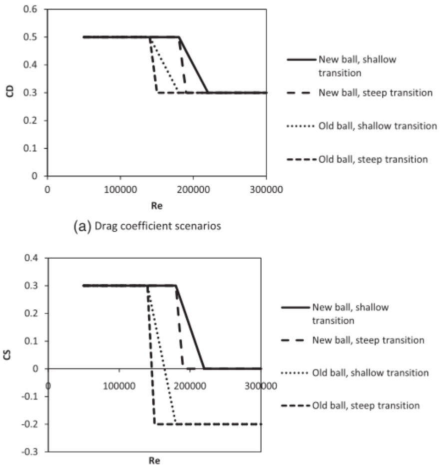
(a) for smooth spheres/new balls



(b) for semi-roughened spheres

Figure: side force coefficient data

Results of Past Experiments

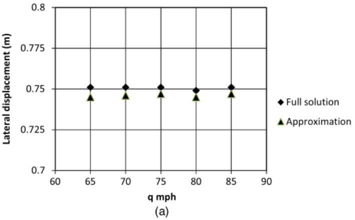


(a) Drag coefficient scenarios

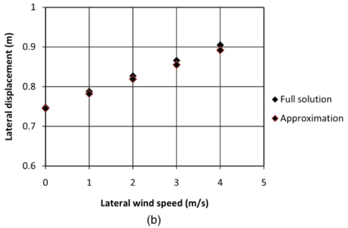
(b) Side force coefficient scenarios

Figure: Force coefficient scenarios for trajectory calculations

Approximate Solution



(a) No wind case

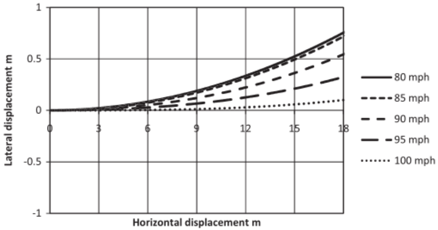


(b) Cross wind case

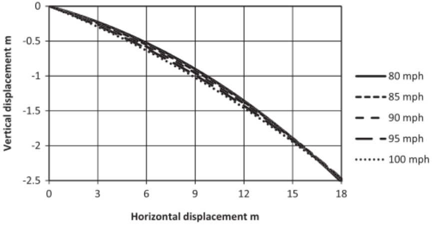
Figure: Accuracy of approximate methods

- **No wind case:** $U = V = W = 0$ and $C_D, C_S =$ constant, $y = \frac{C_S T}{2} x^2$
- **Cross wind case:** $U = W = 0$ and $V \leq u$ and $y = \frac{(C_S + C_D V) T}{2} x^2$

Full Solution Trajectory Equation



(a) Lateral displacements



(b) Vertical displacements

Figure: Trajectories for new ball/shallow transition sce- nario.

Full Solution Trajectory Equation

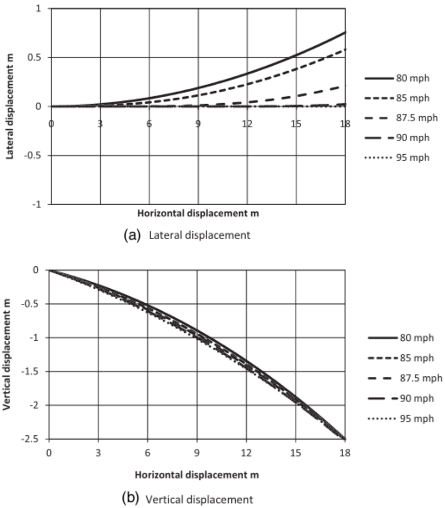
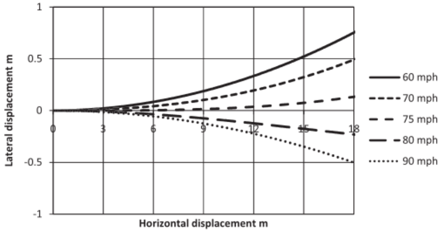
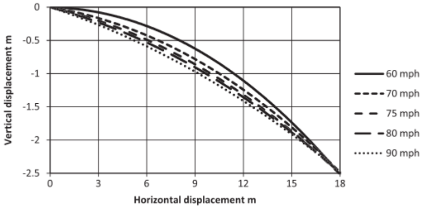


Figure: Trajectories for new ball/steep transition scenario.

Full Solution Trajectory Equation



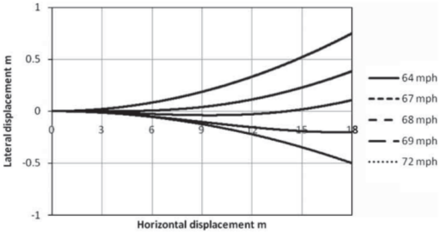
(a) Lateral dispacement



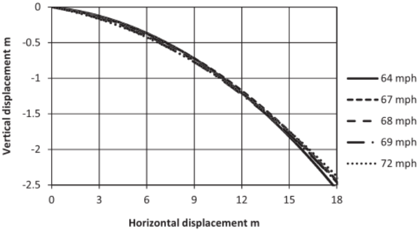
(b) Vertical displacement

Figure: Trajectories for old ball/shallow transition sce- nario.

Full Solution Trajectory Equation



(a) Full lateral trajectories



(c) Vertical trajectories

Figure: Trajectories for old ball/steep transition sce- nario.

Conclusion

- In trajectory equation, the main governing parameters are C_D, C_S and T.
- The drag and side forces are reasonable constant in the sub and super crical Re number region.
- The supercritical values of the side force coefficient are in general zero for new balls, and less than zero for old balls.
- The approximate analysis of the trajectory equations shows that, for constant drag and side force coefficients, the trajectories take on a simple parabolic form.
- A full solution of the trajectory equations enables the trajectories to be calculated for all bowling speeds for different types of ball.

Reference

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3 Mehta, R. D. A review of cricket ball swing. Sports Eng., 2005, 8, 181–192.

4 Bentley, K., Varty, P., Proudlove, M., and Mehta, R. D. An experimental study of cricket ball swing. Imperial College Aero Technical Note, 1982, pp. 82–106.

5 Baker, C. J. The debris flight equations. J. Wind Eng. Ind. Aerodyn., 2007, 95(5), 329–353.