Impact of Soccer Balls

Hydrodynamics and Elasticity Course Project

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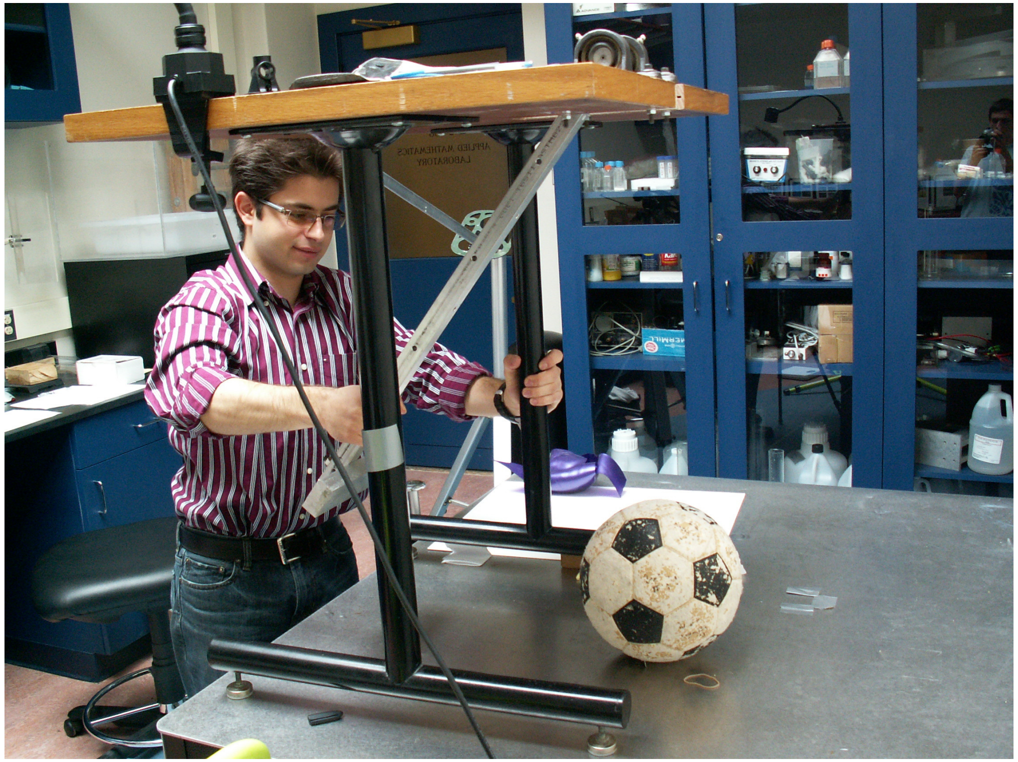
Motivation

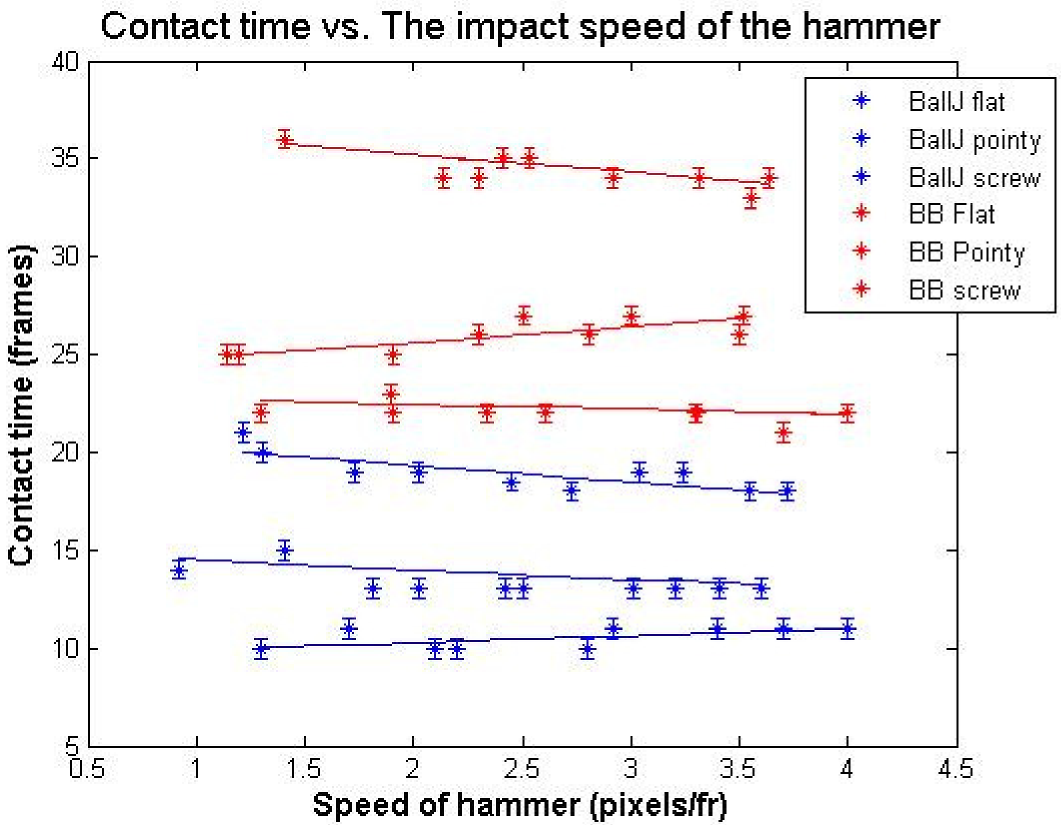
- We originally wanted to know:
  - Why kicking a soccer ball with the tip of one's foot results in the ball going farther?
  - Show movies

The set up:



- Movie of the contact

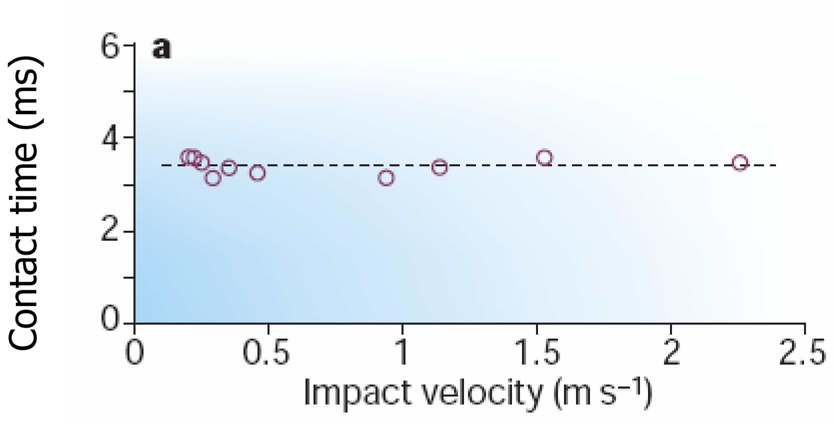
Suggestive observation: “constancy of the contact time”



Although the deformation amplitude and details of the collision vary, the contact time remains constant.

Switching Gears:

- How analogous are soccer balls to droplets?



Denis Richard*, Christophe Clanet†, David Quéré*
Nature VOL 417 | 20 JUNE 2002

Second experiment

- Measuring the deformation properties of the soccer ball

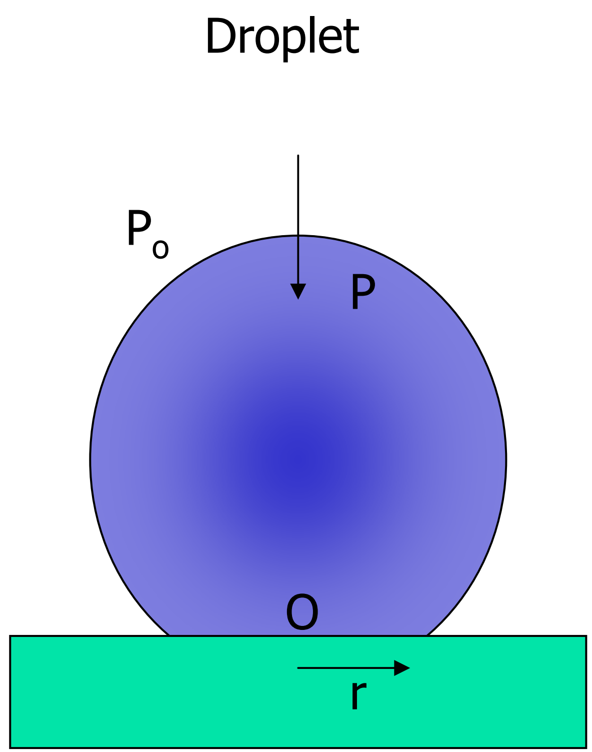
Some theoretical expectations

- Pressures balance at O (Linear Regime):

$$\frac{mg}{\pi r^2} = \sigma\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{2\sigma}{R}$$

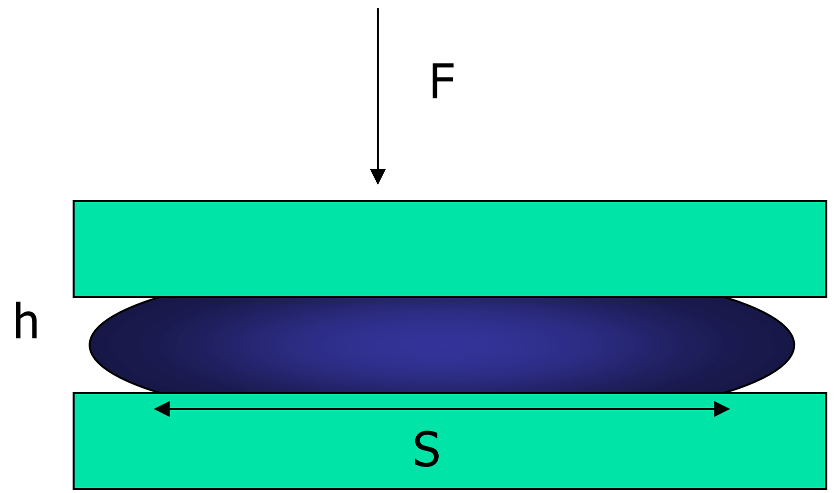
$$r^2 = \frac{mgR}{2\sigma\pi} = \frac{mgR}{2\pi}\left(\frac{1}{\sigma}\right) \sim m\left(\frac{1}{\sigma}\right)$$

$$\therefore S \sim m\left(\frac{1}{\sigma}\right)$$



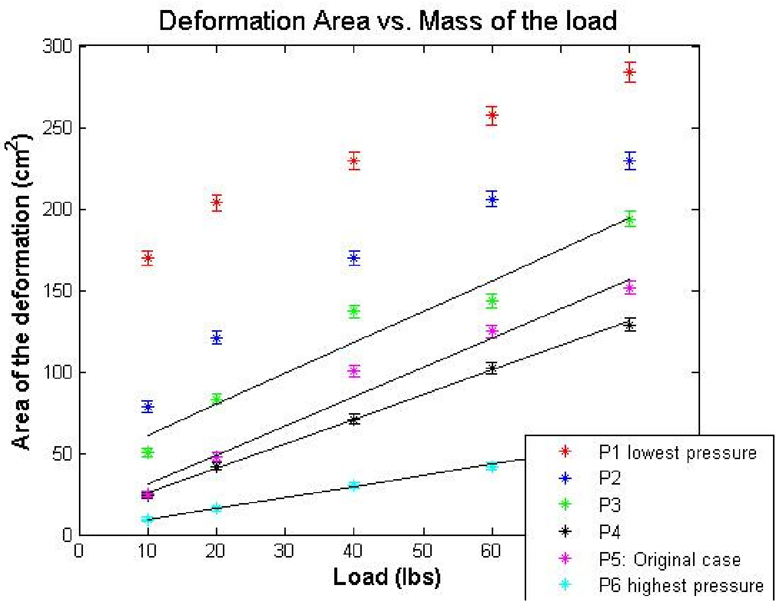
Scaling for large deformation of droplets:

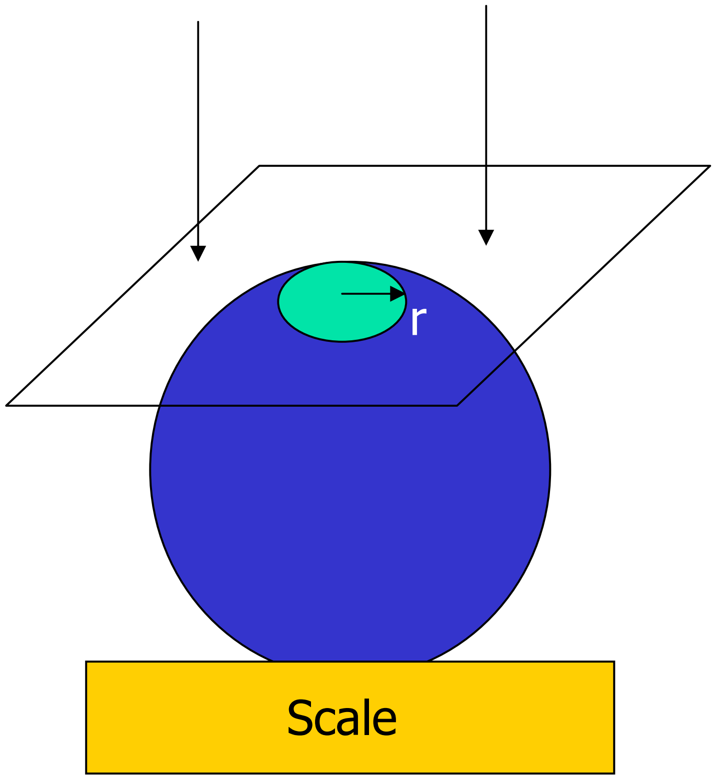
$$\left.\begin{array}{l}\left(\dfrac{2\sigma}{h}S\right) \sim F \\ Sh = \Omega\end{array}\right\} \quad \frac{2\sigma}{\Omega}S^2 = F$$



$$\therefore S \sim F^{1/2} \sim m^{1/2}$$

Experimental Results





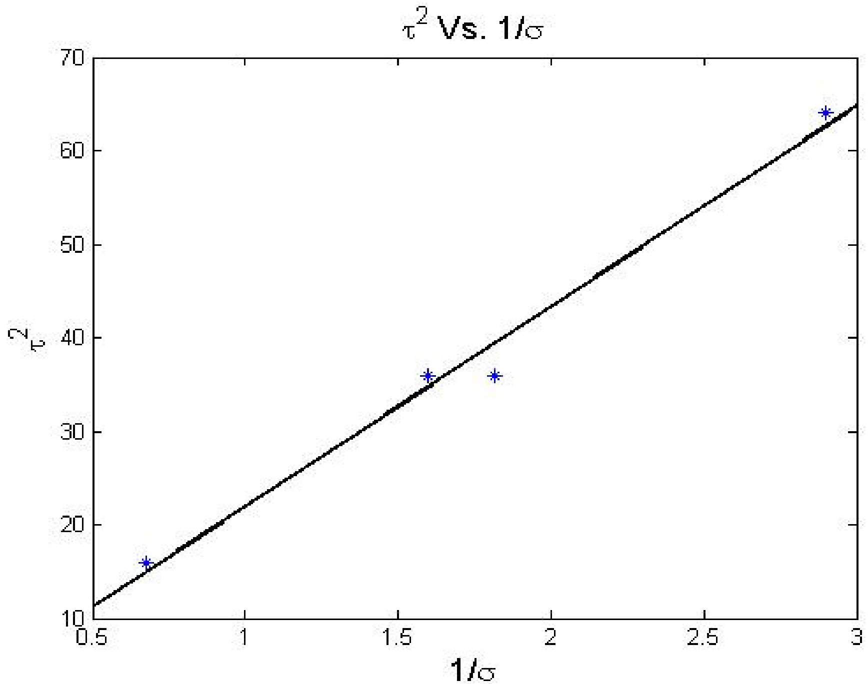
Contact time for droplets

- The forces to be considered are inertia and capillary
  - Inertia: $\rho R / \tau^2$
  - Capillary: σ / R^2

- Hence balancing:
  - Explains the plot
  - Contact time independent of impact speed.

$$\tau \sim \left(\frac{\rho R^3}{\sigma} \right)^{1/2}$$

Contact time and surface tension



The square of the contact time scales linearly with 1/(surface tension)

Theoretical expectation

$$\tau \sim \left(\frac{\rho R^3}{\sigma} \right)^{1/2}$$

Conclusions

- The Soccer ball in small deformation regime does behave like droplets
  - Surface area of contact ~ mass
  - Contact time : $\tau^2 \sim \left(\frac{1}{\gamma}\right)$
- The soccer ball is tension dominated like droplets and one can use an effective surface tension to describe it.

Future work

- More data
- Better exploring the nonlinear regime
- The original soccer ball question.

Thank You

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