The Magnus Effect

Flow Around a Rotating Sphere

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- Laminar Flow
  - The influence of spin
  - Analogy with cylinder: 2D
  - Steady and unsteady flow

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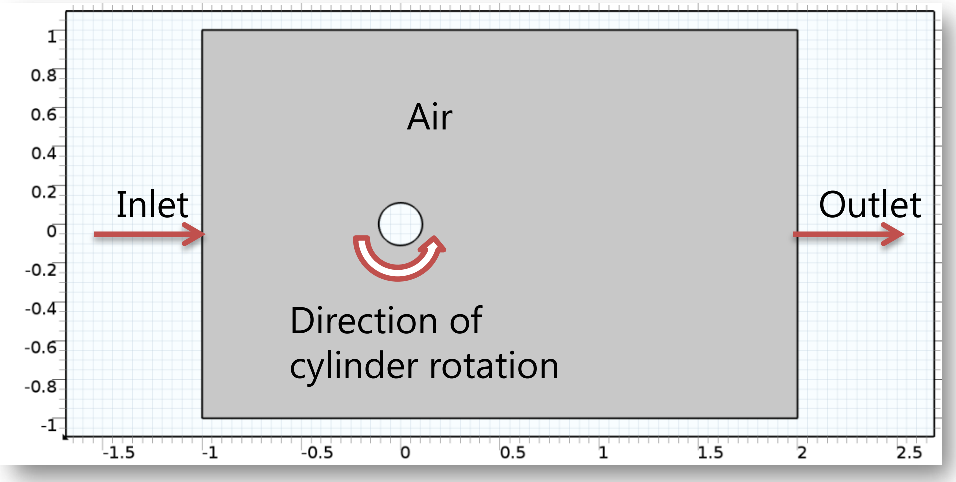
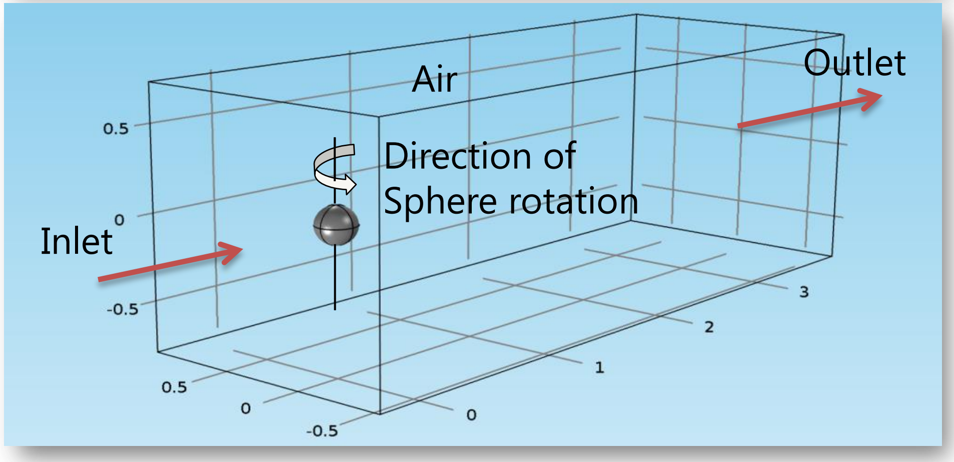
- Concluding remarks

Model Definition

- 2D case, cylinder
  - Upper and lower boundary conditions:
    - Open or analytic solution for potential flow
  - Cylinder boundary:
    - Rotating sliding wall
- 3D case, sphere
  - Top, bottom, and side boundary conditions:
    - Open
  - Sphere boundary:
    - Rotating sliding wall





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Laminar Flow: The Influence of Spin

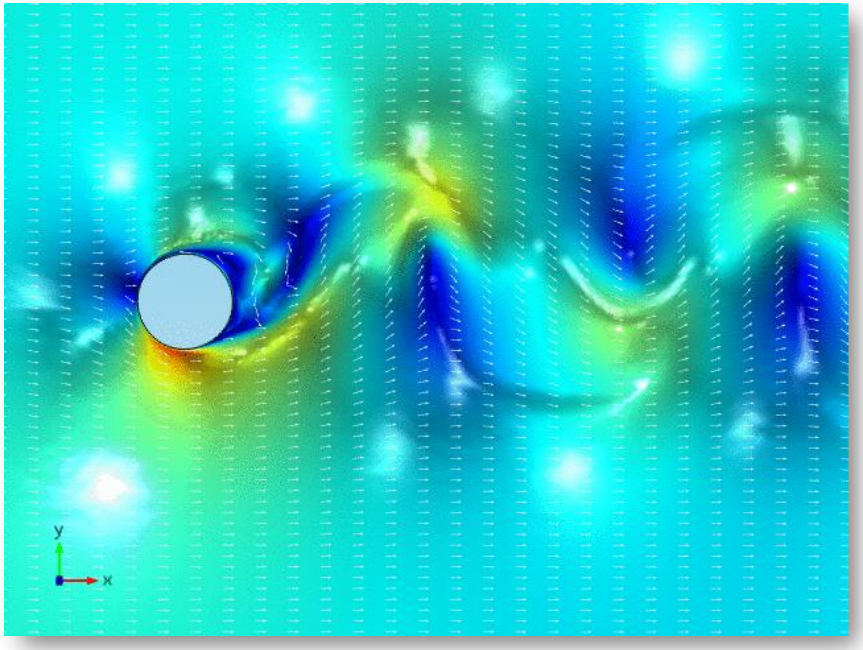
- 2D cylinder, laminar flow

$$S_p = \frac{r\omega}{v}$$ Spin

$r =$ Radius
$\omega =$ Angular velocity
$v =$ Flow velocity or velocity of a moving cylinder at the center

$v =$ 1 (m/s) $S_p =$ 1 (dim. less)

No stationary solution found!



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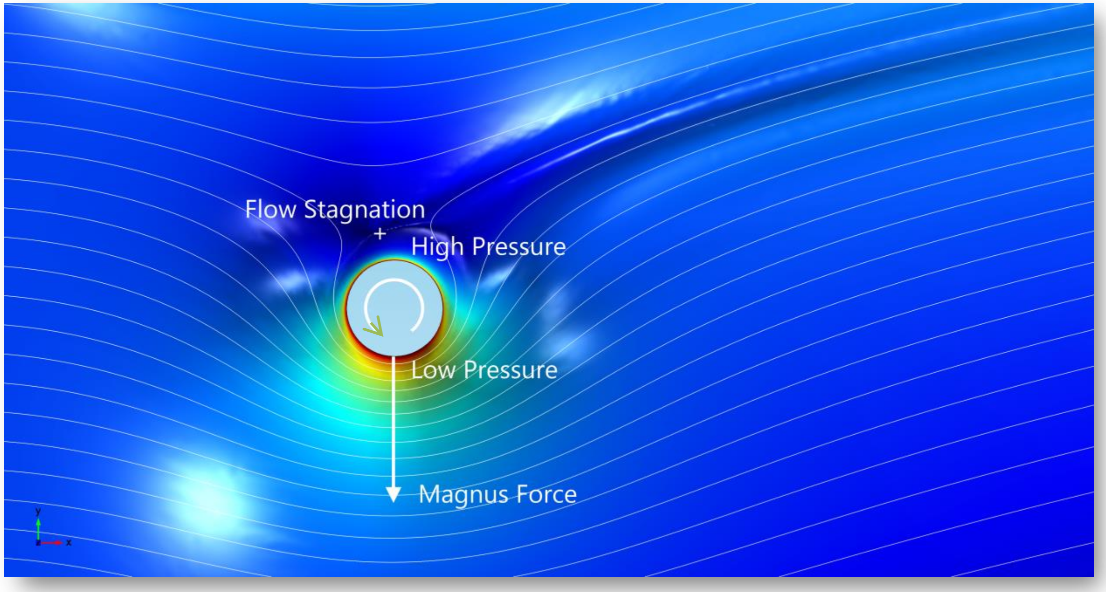
Laminar Flow: The Influence of Spin

- 2D cylinder, laminar flow
  - Boundary conditions, top and bottom, obtained from the analytical solution for potential flow

$v =$ 1 (m/s) $S_p =$ 5 (dim. less)

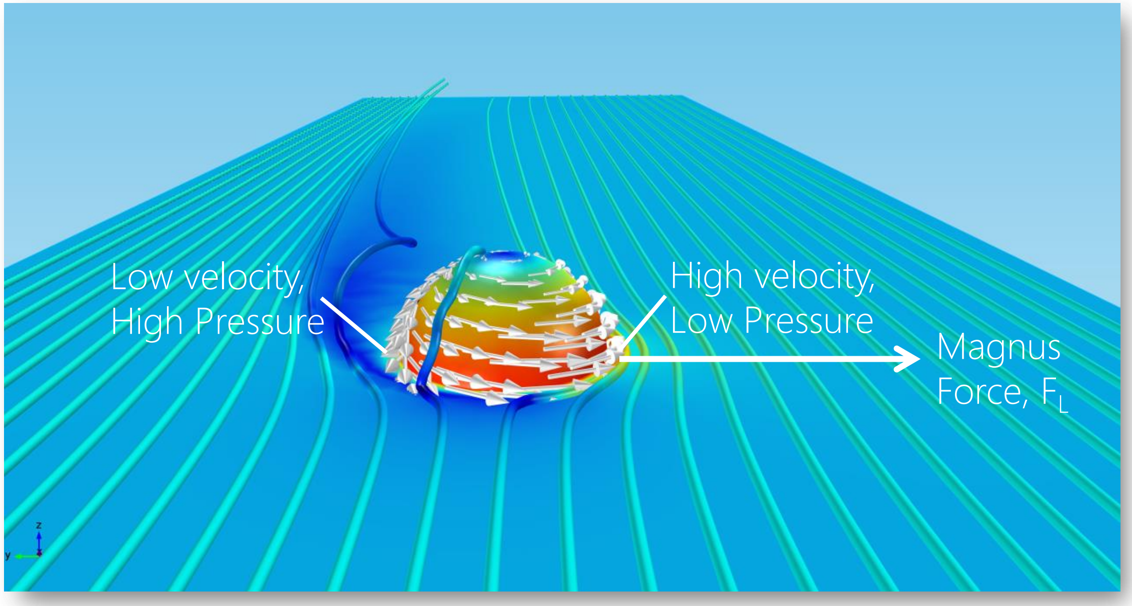
Higher spin yields stationary solution



Laminar Flow: The Influence of Spin

- 3D sphere, laminar flow
  - The rotational velocity at the surface of the ball decreases from the equator to the poles: No stationary solution

$v =$ 1 (m/s) $S_p =$ 5 (dim. less)



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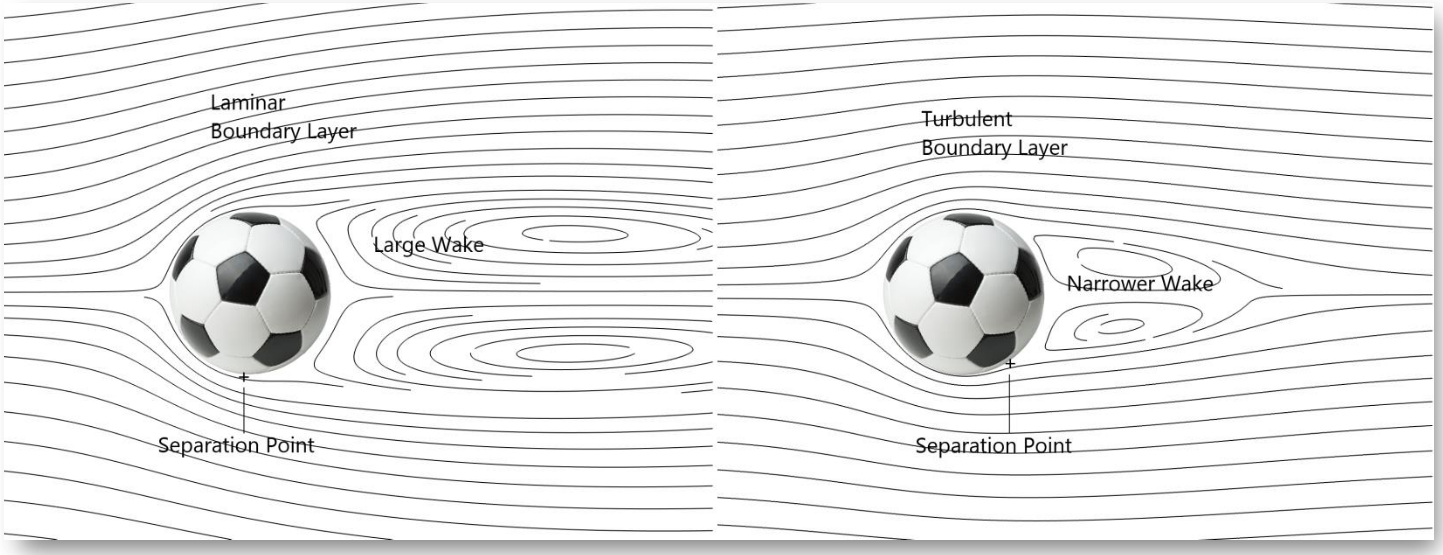
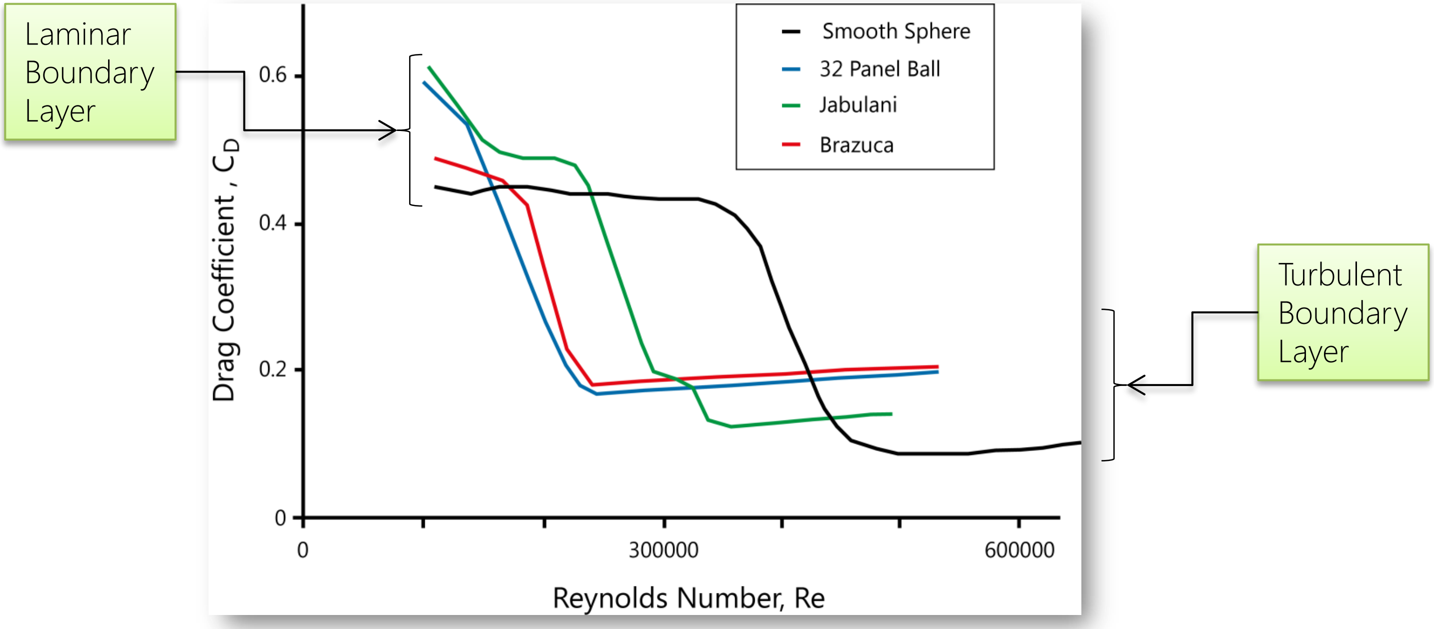
Turbulent Flow

- In the case of turbulent flow, we can have laminar or turbulent boundary layers:
  - Example soccer ball: Large wake causes large drag



Turbulent Flow: Adidas® World Cup™ Ball

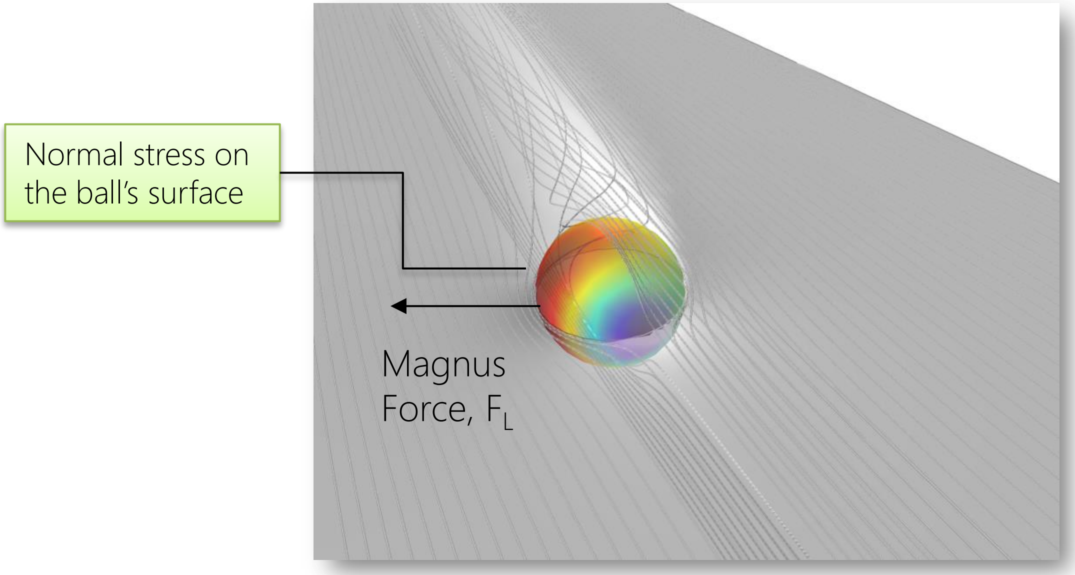
- Measurements of drag with no spin:
  http://www.nature.com/srep/2014/140529/srep05068/full/srep05068.html



Turbulent Flow and Turbulent Boundary Layer

- 3D sphere
  - Turbulence model: k-ε model
  - Wall functions and rough surface to mimic a soccer ball

$v =$ 5 (m/s) $S_p =$ 1 (dim. less)



Concluding Remarks

- Accurate model requires the description of the transition of the flow from laminar to turbulent, and vice versa, in the boundary layer:
  - Transition models may work

- The geometry of the seams has an influence on both transition and drag and has to be accounted for in accurate models

- However, experiments on the soccer field show that curling the ball has a stabilizing effect on its flight

Enjoy The Magnus Effect!

- http://www.youtube.com/watch?v=rEKGTq3onIo