INSTITUTO SUPERIOR TÉCNICO
Universidade Técnica de Lisboa

Aerodynamics

Professor: Luís Eça

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Program

1. Introduction

- Aerodynamical forces.
- Flow description. Dependent variables and physical principles that govern the flow

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2. Incompressible, Viscous Flow

- Analytical solutions of the equations that govern the flow.
- Two-dimensional, incompressible, steady flow (laminar regime).
- Transition from laminar to turbulent flow.

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Program

2. Incompressible, Viscous Flow

- Turbulent flow.
- Boundary-layer control. Transition, suction and blowing.

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3. Incompressible, Ideal Flow

- Euler equations. Bernoulli equation. Irrotacional flow.
- Vorticity and velocity circulation.
- Two-dimensional, incompressible, irrotational flow.
- Tri-dimensional potential flow.

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4. Lifting Surfaces

- Geometrical definitions.
- Lift and drag coefficients.
- Airfoils.
- Finite wings.

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5. Bluff Bodies

- Near and far wake.
- Vortex shedding.
- Strouhal number.
- Vibrations induced by the flow.

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6. Use of Numerical Methods (CFD)

- Numerical error.
- Code verification.
- Solution verification.
- Validation.

Bibliography

1. Fundamentos de Aerodinâmica Incompressível
   Vasco de Brederode - Edição do Autor,
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2. Fluid Flow, A First Course in Fluid Mechanics
   Sabersky R.H., Acosta A.J., Hauptmann E.G, Gates E.M.
   Prentice Hall, 4th Edition, 1999.

3. Momentum Transfer in Boundary Layers
   Cebeci T., Bradshaw P.
   Hemisphere Publishing Corporation, McGraw-Hill, 1977.

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4. Boundary Layer Theory
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   McGraw-Hill, 7th Edition, 1979.

5. Theory of Wing Sections
   Abbott I.H., Doenhoff A.E. Von
   Dover Publications, 1959.

6. Aerodynamics of the Airplane
   Schlichting K., Truckenbrodt E., Ramm H.J.
   McGraw-Hill, 1979.

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7. Fluid Mechanics: Problems and Solutions
Spurk J.H.
Springer Verlag, 1997.

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Assessment

- Problems classes:
- Problems proposed on the Fenix Web page the previous week
- Each week, volunteers to present the problems may register until Monday (2 students per class)
- 0,5 marks for each problem presented (maximum of 2 marks in the final grade)

Assessment

- Written exam, N1 (Minimum = 10/20)
- Two practical tasks :
  a) Laboratorial : Test of an airfoil, N2
  b) Numerical : Calculation of the flow around a finite wing, N3

These assignments are to be performed by groups of 3 students. A report must be delivered for each task followed by a 15 minutes oral presentation (N2). The numerical assignment is not mandatory.

Weighted classification=0.7N1+0.1N2+0.2N3+P
Oral exam may be required for any student with a weighted classification larger or equal than 10.
P – Problems classes

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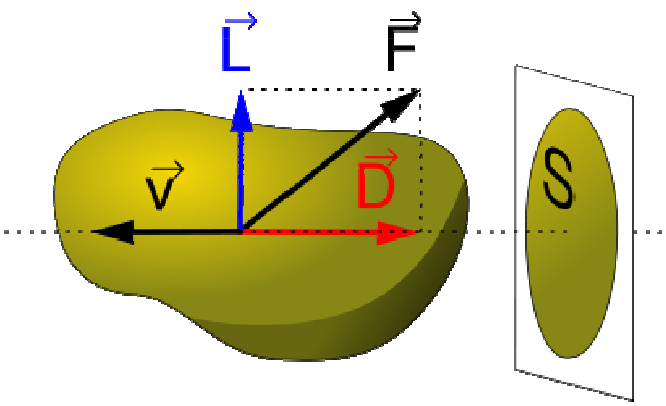
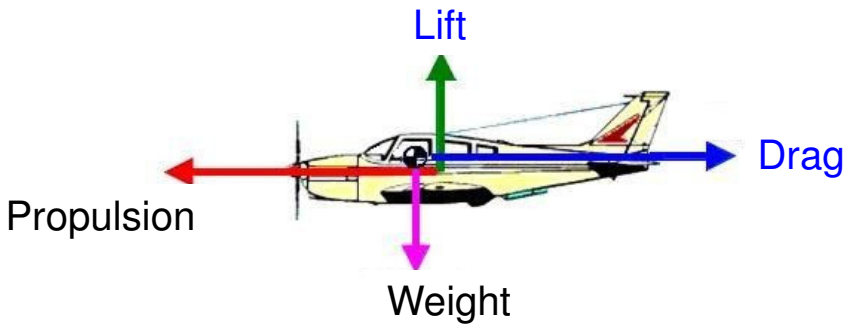
Objective: Determine the forces acting on a body immersed in a flow



Introduction



For an airplane flying at constant height and speed
Weight = Lift
Propulsion = Drag

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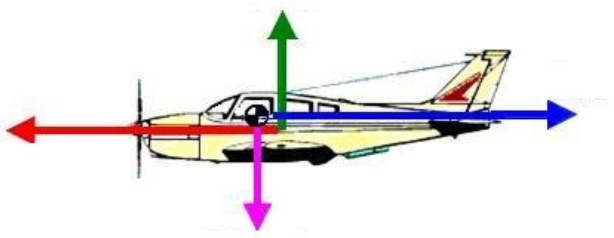
Lift is the aerodynamic force component in the direction perpendicular to the undisturbed incoming flow.

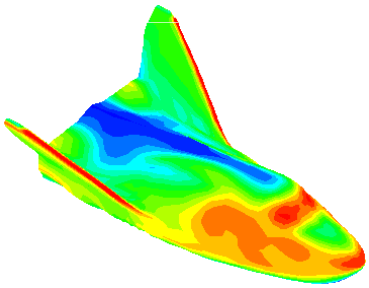


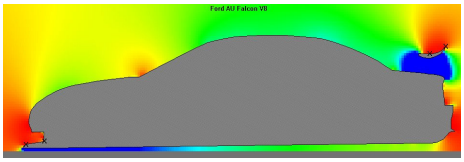
Drag is the aerodynamic force component in the direction parallel to the undisturbed incoming flow.

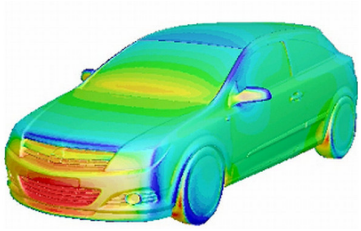
Introduction

Origin of the aerodynamic force:

1. Pressure on the surface of the body







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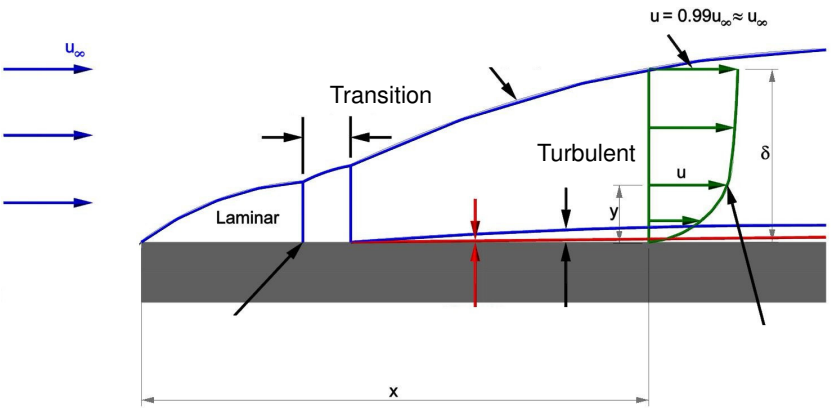
Origin of the aerodynamic force:

2. Shear-stress on the body surface



Shear-stress at the wall

$$\tau_w = \mu \left(\frac{\partial U}{\partial y} \right)_{y=0}$$

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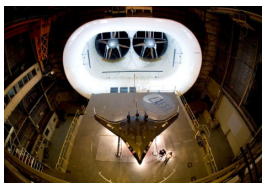
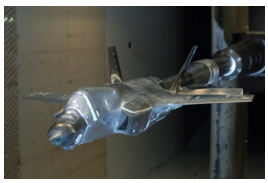
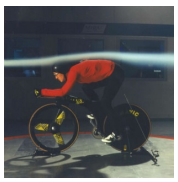
Determination of the aerodynamic force:

a) Experimental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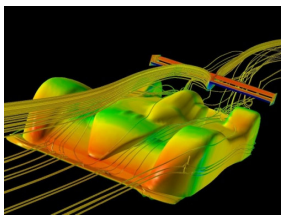
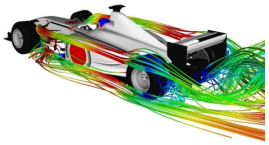
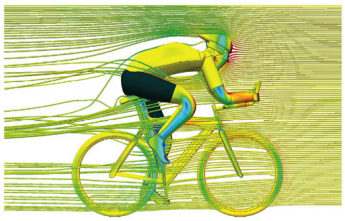
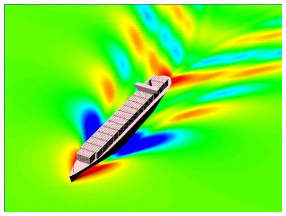
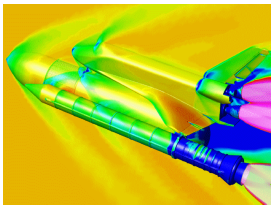
Determination of the aerodynamic force:

b) Theoretical (Numerical solution of a mathematical model)



Masters of Mechanical Engineering

Description of the flow field

Dependent variables:

- Pressure (1)
- Velocity (3)
- Density (1)
- Temperature (1)

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Description of the flow field

- Fluid is treated as a continuum field
- Equation of state(1)
  - Incompressible fluid $\rho = constant$
  - Perfect gas $p = \rho RT$
- Mass Conservation (1)
- Newton's 2nd law (Momentum balance)(3)
- 1st Law of Thermodynamics (Energy balance)(1)