

## 07 – Flutter Phenomenon

### PART 2 – SECTION 1:

# INTRODUCTION TO THE FORMULATION OF THE UNSTEADY AERODYNAMIC FORCES

Vibraciones y Aeroelasticidad

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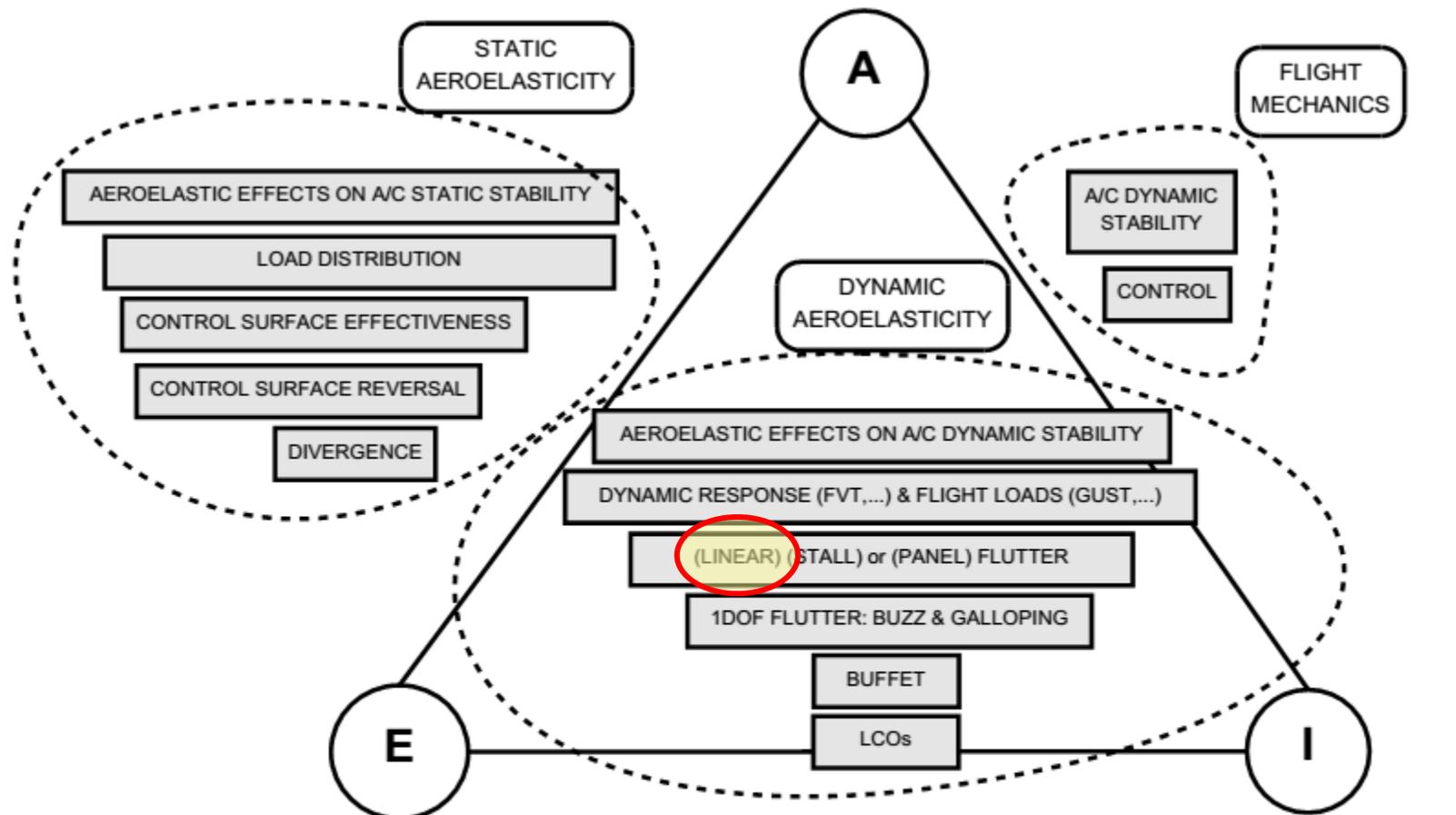
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ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA AERONÁUTICA Y DEL ESPACIO

# CLASSICAL LINEAR FLUTTER

## WHERE WE ARE IN THE COLLAR'S DIAGRAM ?



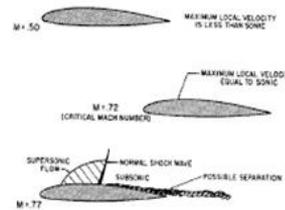
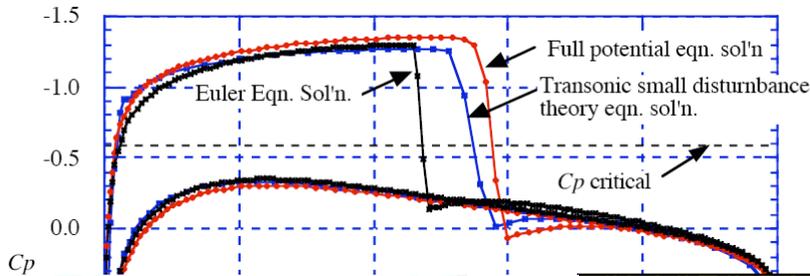
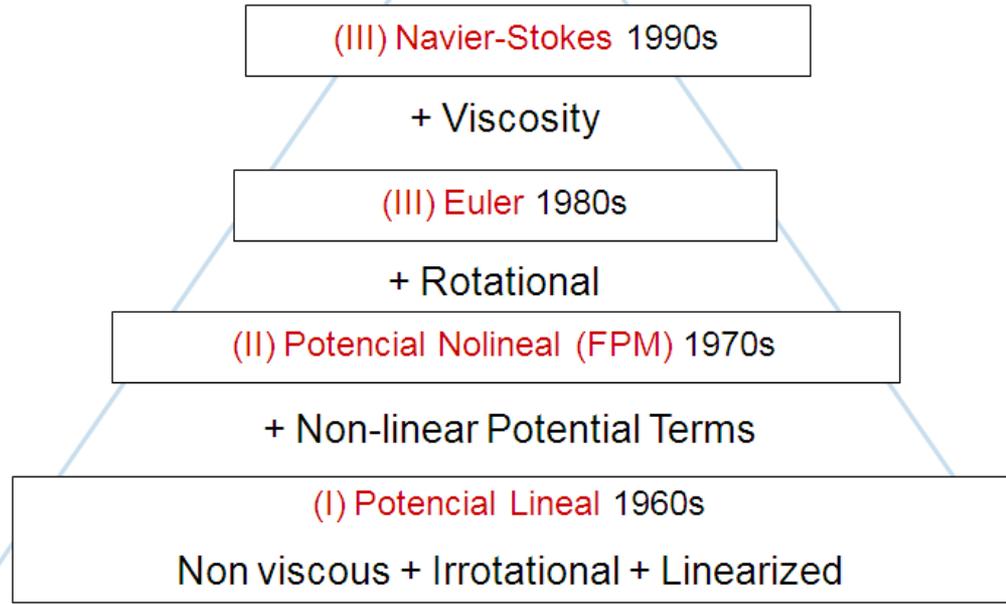
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# COMPUTATIONAL AERODYNAMICS

↑ Accuracy + Complexity

↓ Computational Resources



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## AERODYNAMICS

### STEADY

- Analysis of steady flight condition (trim)
- Coupling structure-fluid : flexibility factors, divergence, control surface reversal, ...

### UNSTEADY

- Small disturbances with respect to the nominal condition
- Unsteady coupling fluid-structure: Flutter, LCOs, ...

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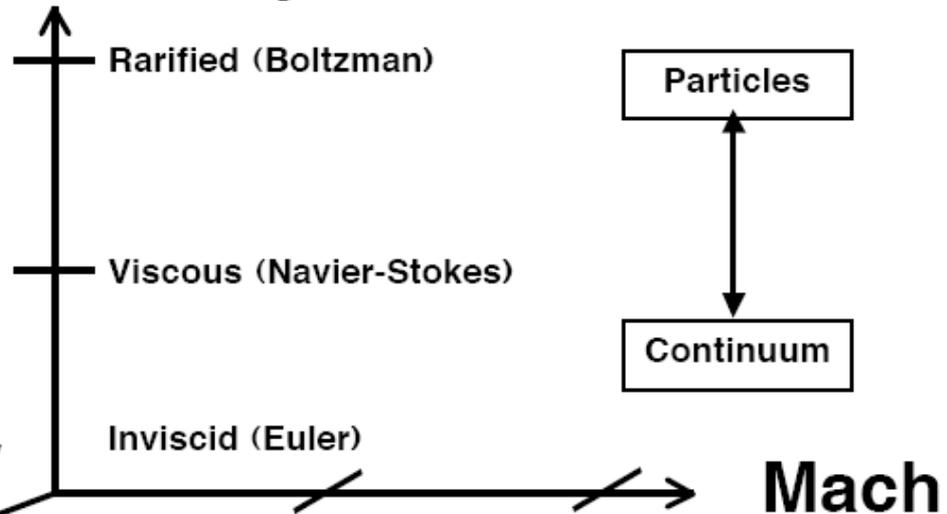
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## • Gas Dynamics

### 1/Reynolds



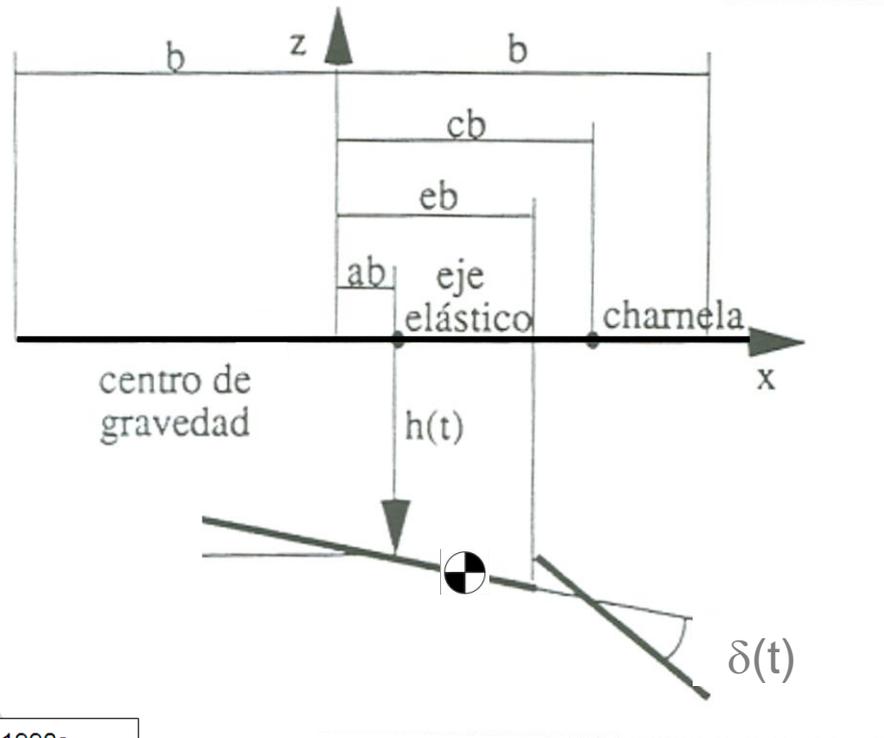
Frequency  
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Elliptic ↔ Hyperbolic

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# 3DOFs "TYPICAL SECTION"

## THEODORSEN'S SOLUTION FOR 2D INCOMPRESSIBLE UNSTEADY FLOW



(III) Navier-Stokes 1990s

+ Viscosity

(III) Euler 1980s

+ Rotational

• Gas Dynamics

1/Reynolds



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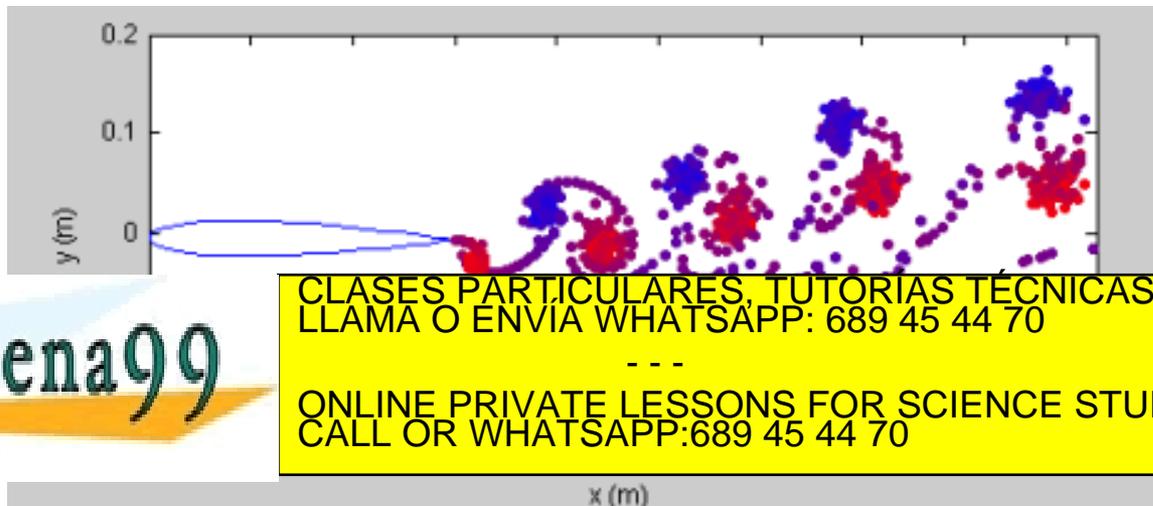
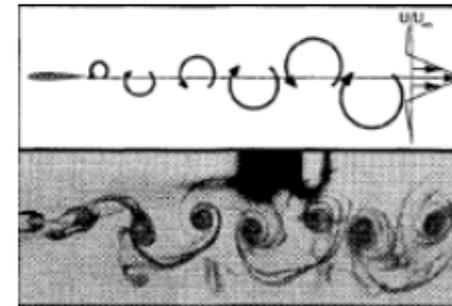
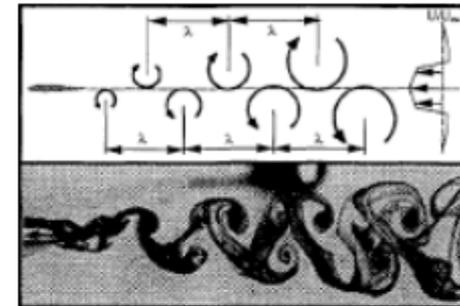
Frequency



Oscillating airfoils leave behind them a strong vortex street. The vorticity in the wake affects the flow over the airfoil:

*The instantaneous aerodynamic forces depend not only on the instantaneous position of the airfoil but also on the position and strength of the wake vortices.*

This means that instantaneous aerodynamic forces depend not only on the current motion of the airfoil but on all its motion history from the beginning of the motion.



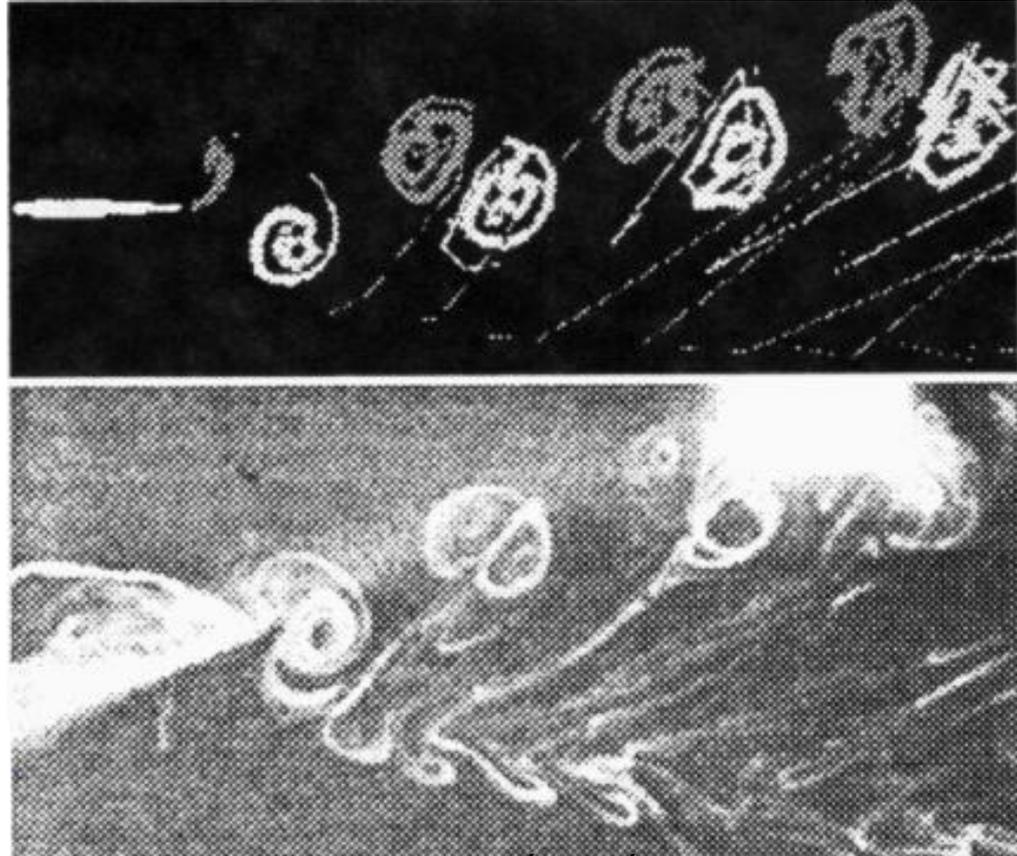
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Wake vorticity is a real-world phenomenon. Here is a comparison between numerical simulation results (top) and flow visualization in a water tunnel (bottom) by Jones and Platzer.



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