System Identification for Aeroelastic Predictions

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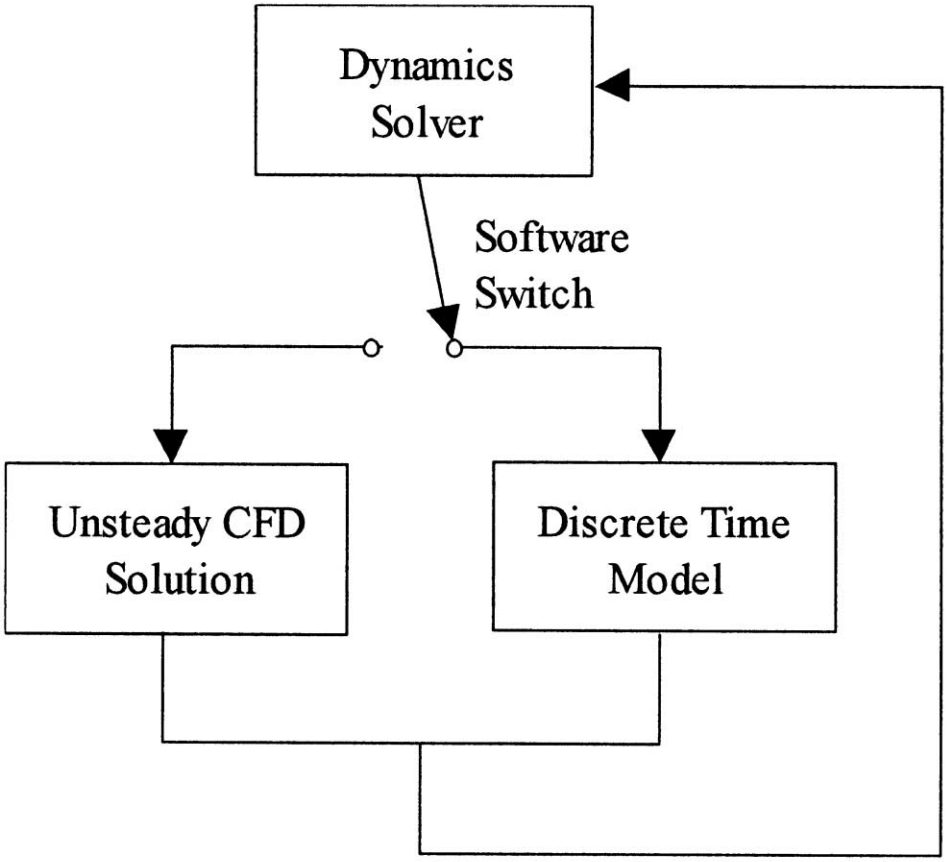
Overview

This study concerns aeroelastic system identification and discrete time representations of unsteady aerodynamics and structural mechanics. Our objective is to find a discrete time representation of unsteady aerodynamics.

- Discussion of System Identification
- Time Scales and Physical Compatibility.
- NACA 0012 Aeroelastic Testcase

Why use System Identification?



System Identification

Our identification process consists of forming a best-fit ARMA model based on a discrete time state-space representation of the previous aerodynamic forces.

$$[\text{Current Forces}] = [A] \cdot [\text{Past Forces}] + [B] \cdot [\text{Past Motion}]$$

$$f_a(k) = \sum_{i=1}^{na} [A]\ f_a(k-i) + \sum_{i=1}^{nb-1} [B]\ q(k-i)$$

$[A]_{(na \times na)} \equiv$ Force influence coefficients.

$[B]_{(nb \times nb)} \equiv$ Motion influence coefficients.

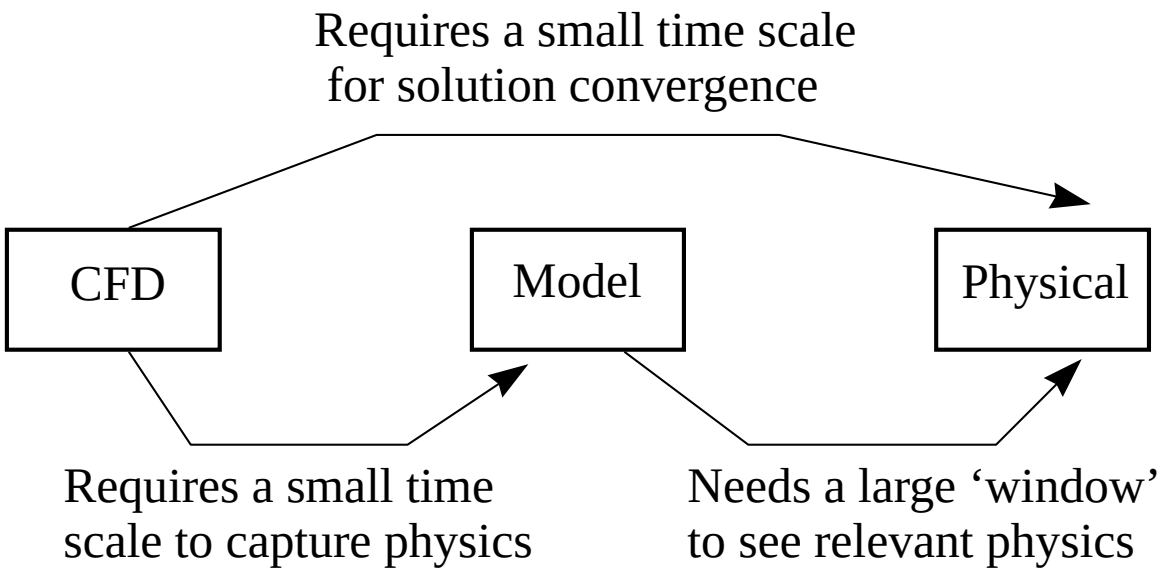
$f_a(k) \equiv$ Aerodynamic Force at time k

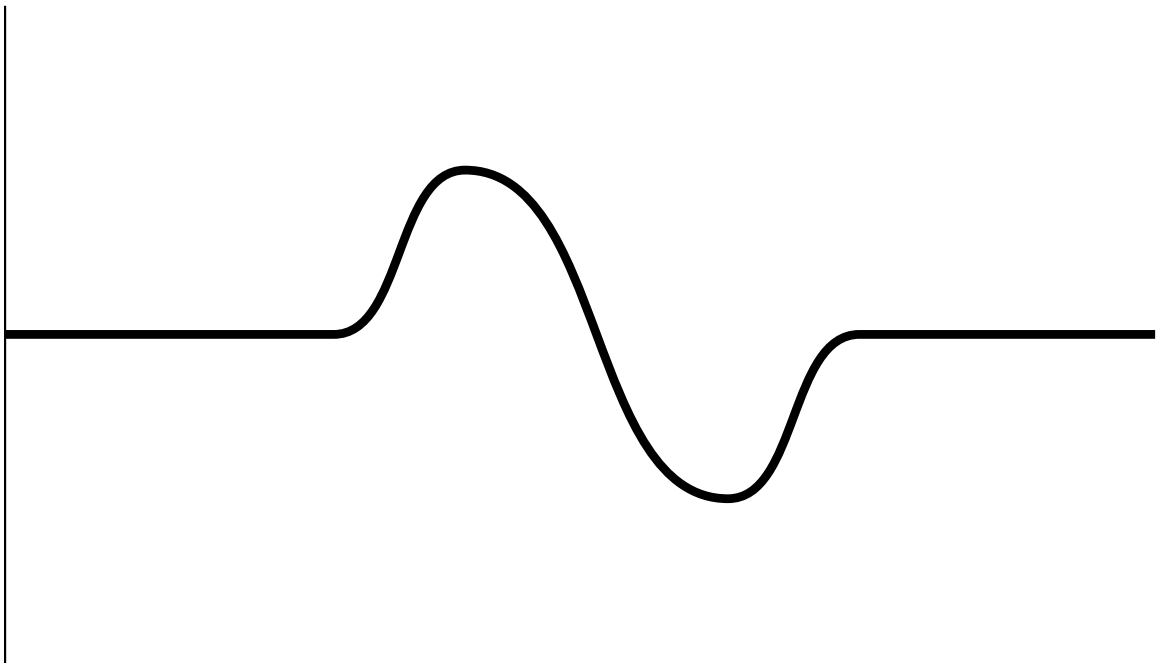
$q(k) \equiv$ Displacement at time k

$na \equiv$ Model Order for Aerodynamic Forces

$nb \equiv$ Model Order for Displacement Motion

Time Scale Compatibility

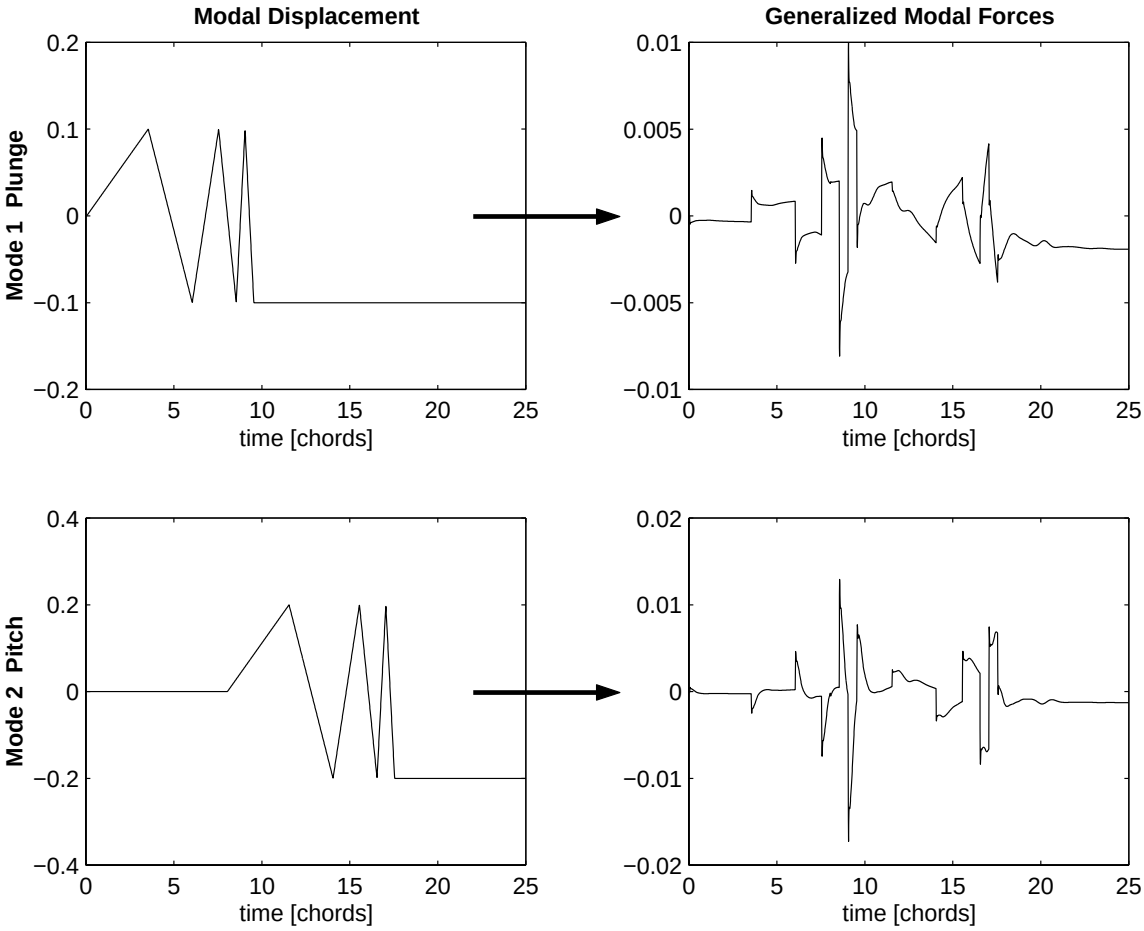




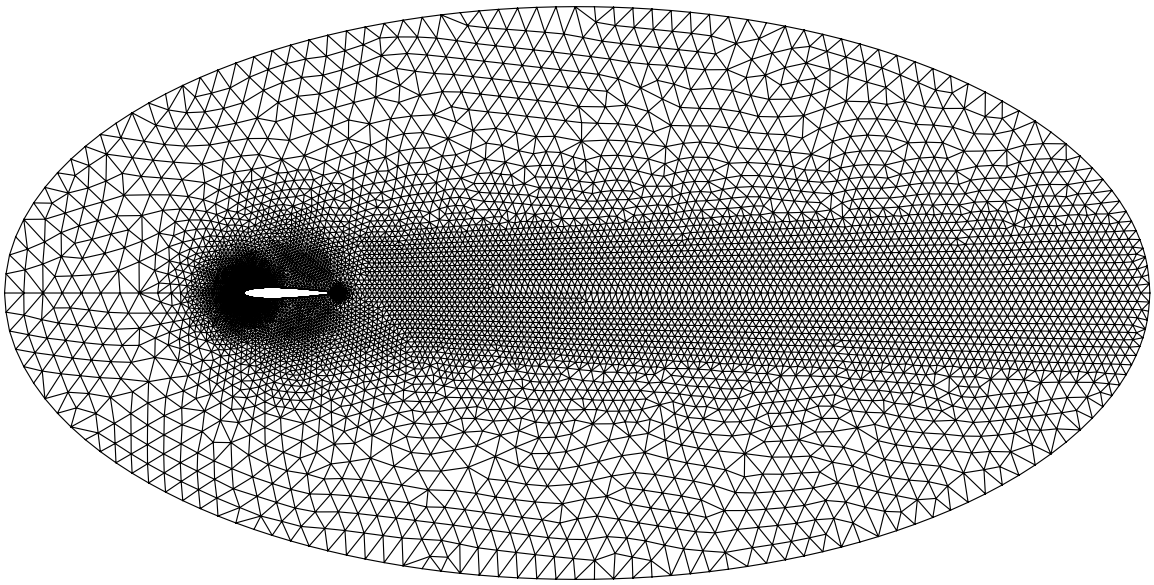
Training Signal

Input

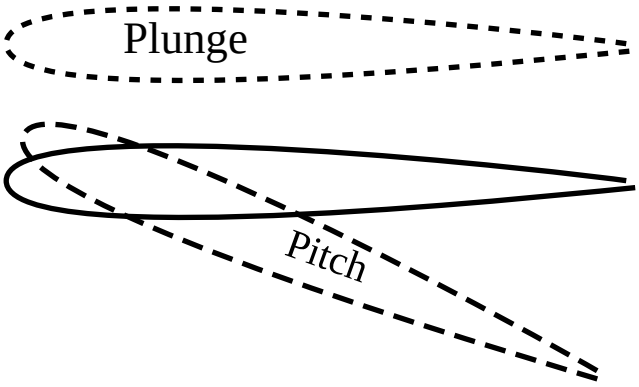
Output



CFD Mesh Geometry (NACA 0012)



Two Mode Motion



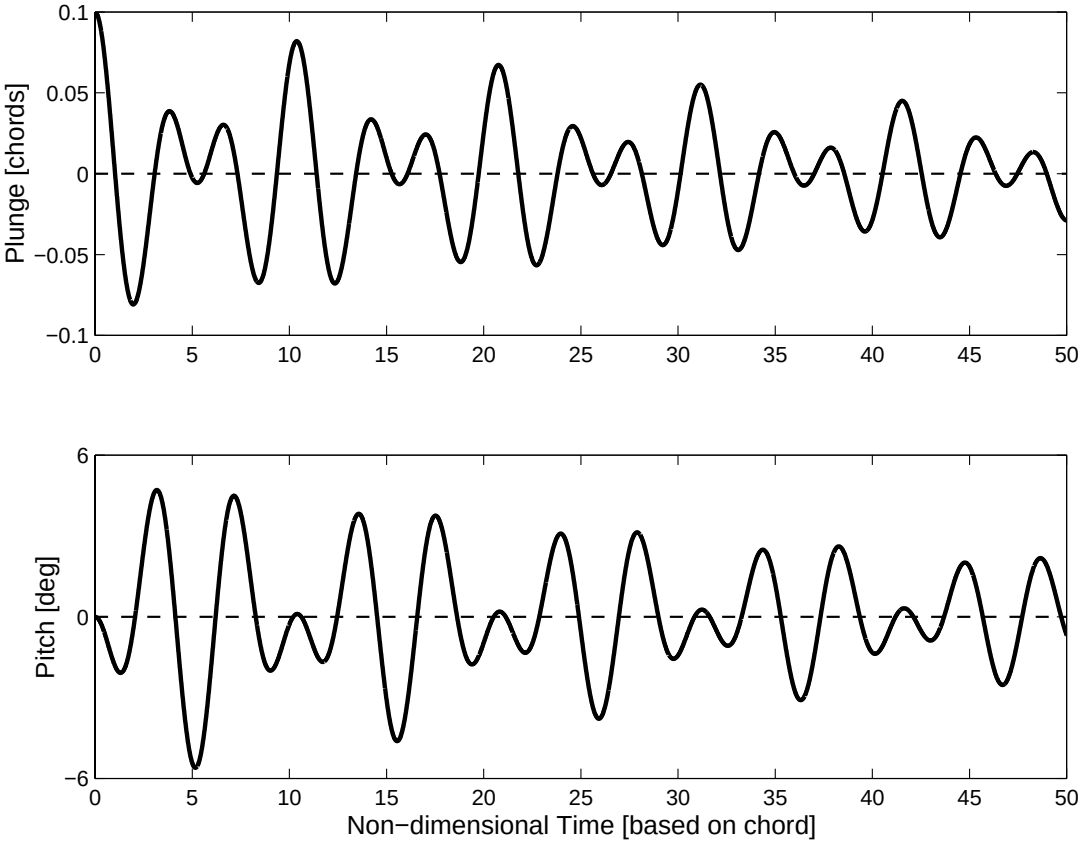
Bending Stiffness

Torsional Stiffness

Elastic axis	35% chord
Center of gravity	45% chord

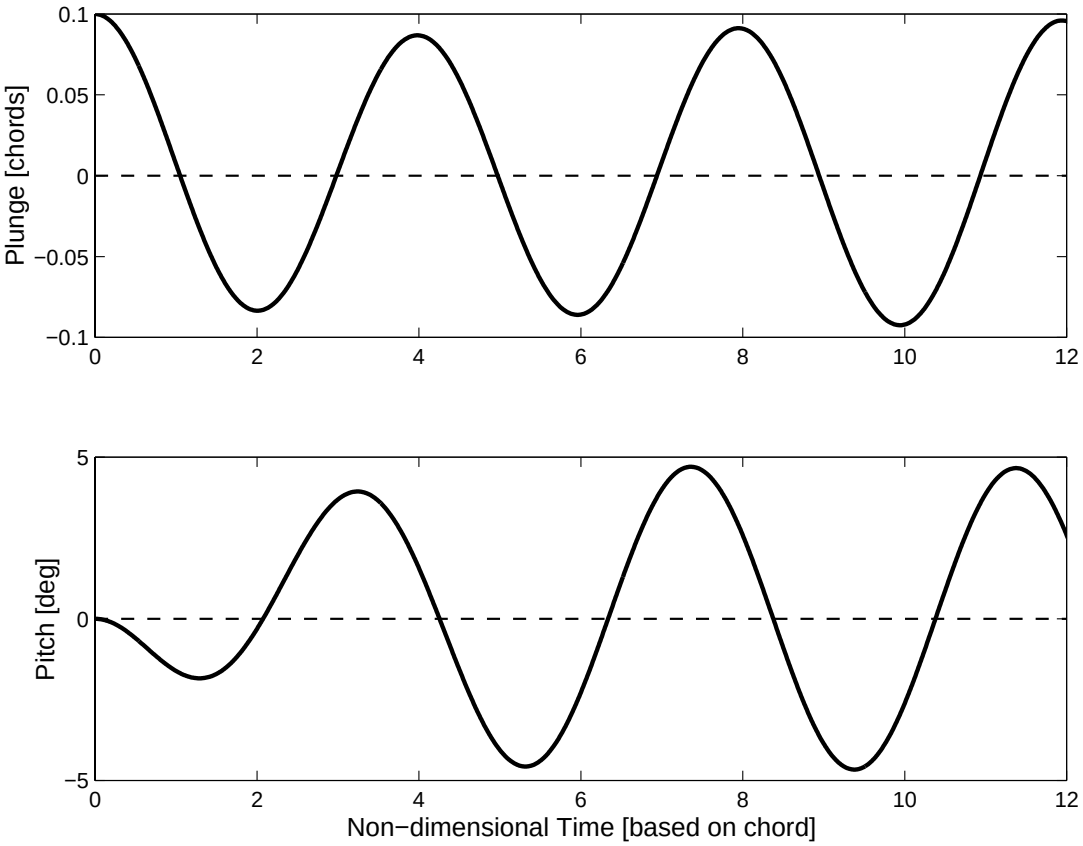
NACA 0012: Stable

Mach 0.5 Dynamic Pressure 24.5 psi



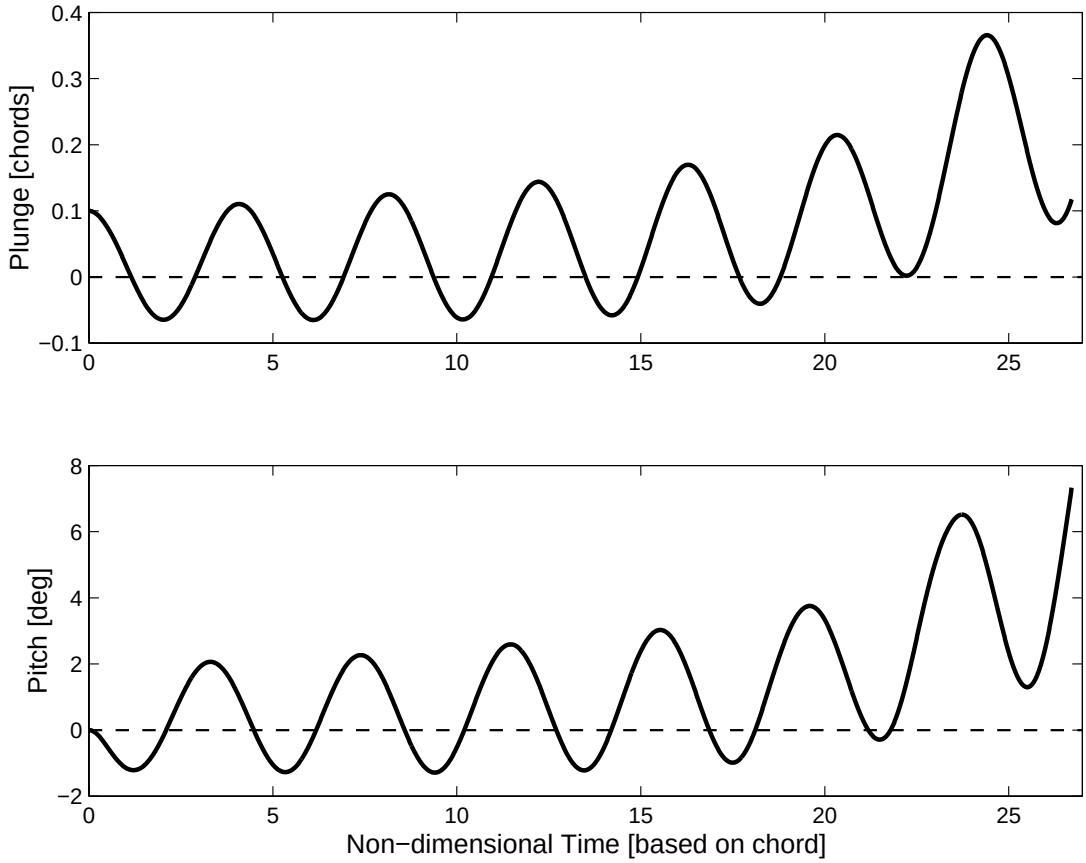
NACA 0012: Flutter

Mach 0.5 Dynamic Pressure 245 psi



NACA 0012: Static Divergence

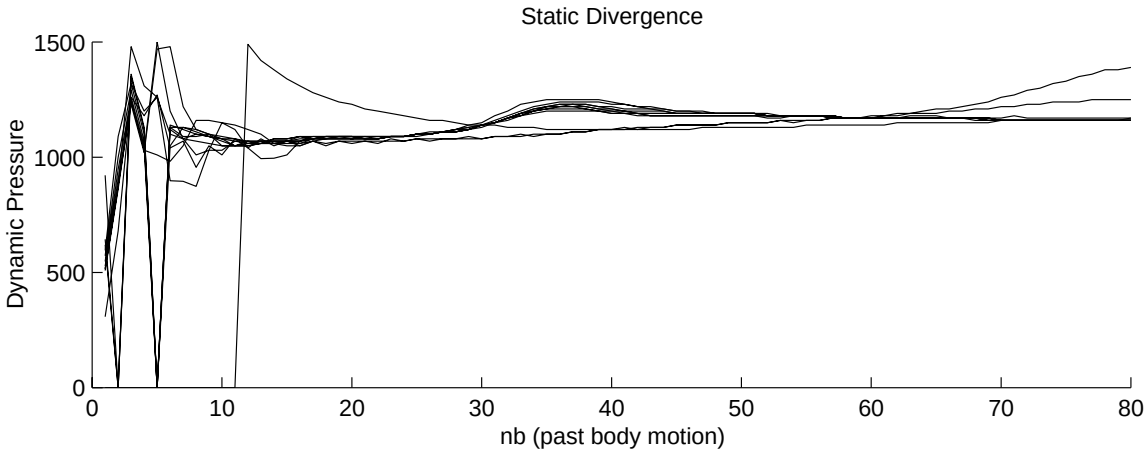
Mach 0.5 Dynamic Pressure 1225 psi

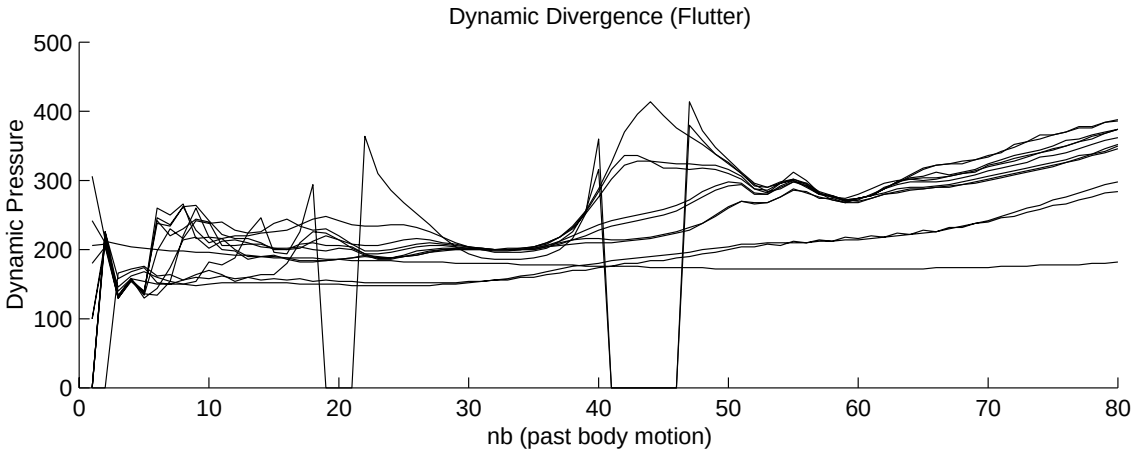


Model Order Sensitivity Study

$$\text{Resample Rate} = \frac{\Delta T_{model}}{\Delta T_{CFD}} = 1$$

Observation window is $nb/100$ chords.

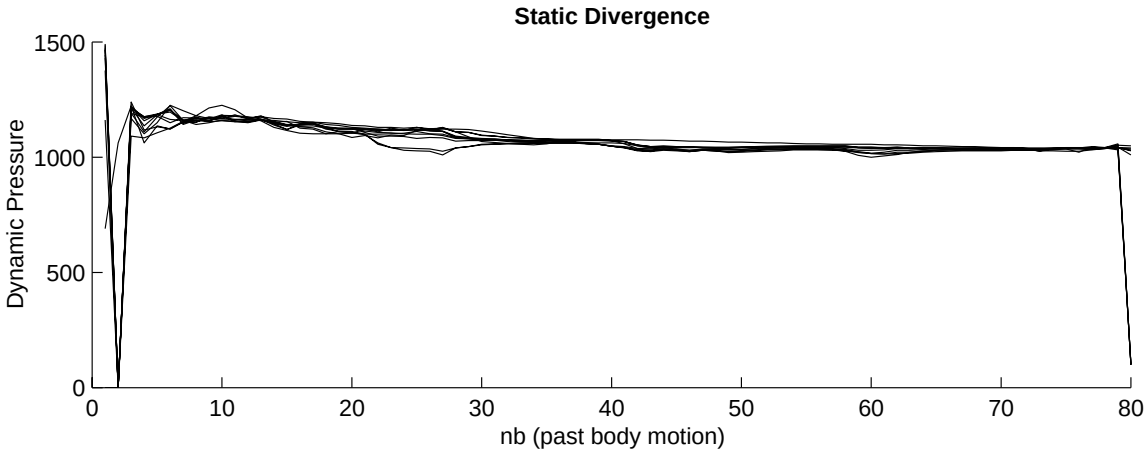


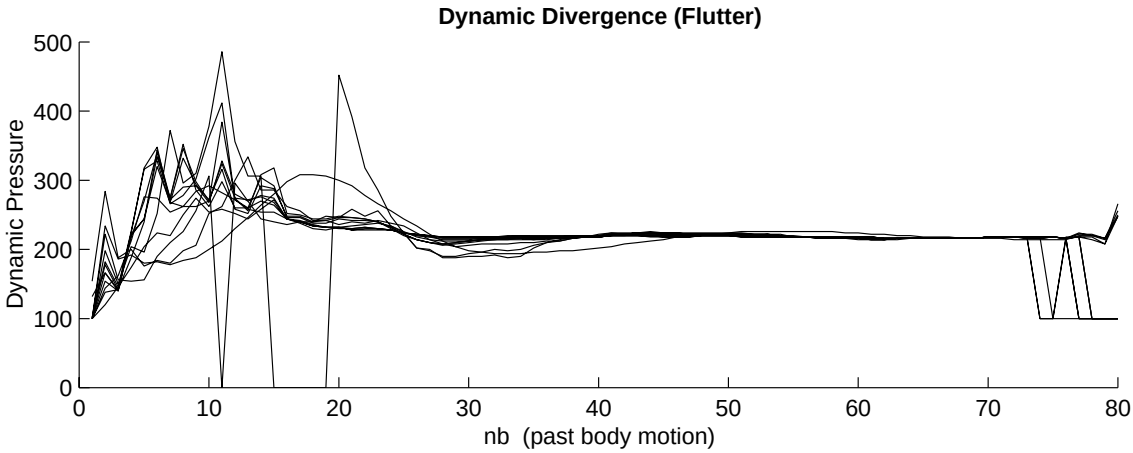


Model Order Sensitivity Study

$$\text{Resample Rate} = \frac{\Delta T_{model}}{\Delta T_{CFD}} = 10$$

Observation window is $nb/10$ chords.





System Identification Guidelines

- The CFD, model and physical time scales must be compatible.
- The model must have a sufficient "observation window".
- Decoupling the CFD solver and the ARMA model increases the model efficiency.