Aeroelastic Prediction Workshop

Overview of the Benchmark Supercritical Wing (BSCW) Test Case

Presented by:

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On behalf of the AePW Organizing Committee

Outline

- Test Case Selection Rationale
- BSCW Description
  - Geometry and Test Configuration
  - Structural Properties
- BSCW Testing
  - Transonic Dynamics Tunnel (TDT)
  - Oscillating Turntable (OTT)
  - Test Conditions
- BSCW Test Cases and Experimental Data

Overall Workshop Configuration Selection Strategy

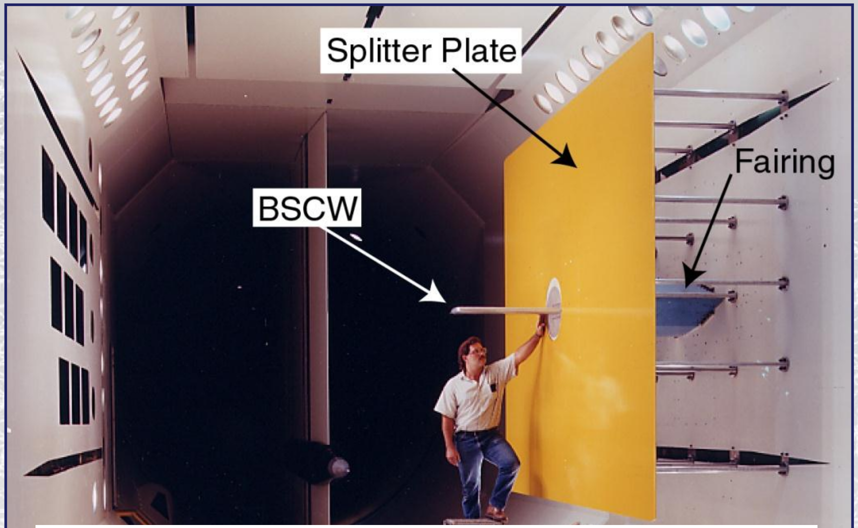
- Aeroelastic prediction requires simulation with many independent variables spanning multiple disciplines.
  – Must work to isolate independent variables and evaluate our ability to predict the processes defined by them.
  – Coarse-grain independent variables:
    - Aerodynamics
    - Structural dynamics
    - Fluid / structural coupling
- Focus of 1st workshop: Prediction of unsteady aerodynamic pressures due to forced modal oscillations

Proposed Content of an "Excellent" Data Set

- Configuration that can be modeled without adding an unnecessary level of uncertainty to the analysis
- High-quality model definition
  - Well-documented geometry
  - Stiffness, mass, and inertia measurements
  - Structural dynamic properties:
    - Natural frequencies
    - Mode shapes
    - Generalized masses
- High-quality wind-tunnel measurements
  - Flow regime: subsonic, transonic, and supersonic
  - Extensive array of unsteady pressure measurements
  - Quantitative displacement measurements
  - Quantitative flow visualization measurements
  - Loads measurements
  - Quantitative definition of instability boundaries (LCO, flutter, divergence, buffet, etc.)

AePW-1 Case 2 Selection Rationale: Benchmark Supercritical Wing (BSCW)

- Simple, rectangular wing
- Fixed transition at 7.5% chord
- Structure treated here as rigid
- Applicable test conditions:
  - Subsonic, transonic flow
  - Mixed attached / separated flow
- Time history data available
- Large, well-positioned splitter plate



BSCW model sidewall-mounted on a splitter plate in the Transonic Dynamics Tunnel (TDT).

- Relatively obscure data that serves as a virtually blind test case for the methods
- Known deficiencies:
  - Limited number of pressure transducers in experimental data
  - Transonic Mach number (M = 0.85) is at edge of acceptable range for quality pressure data with splitter plate

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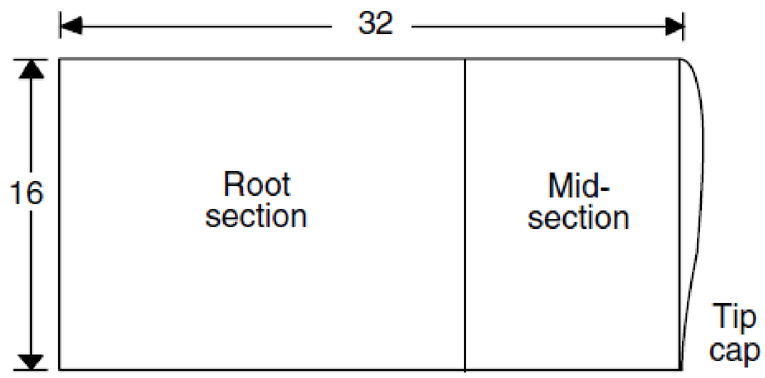
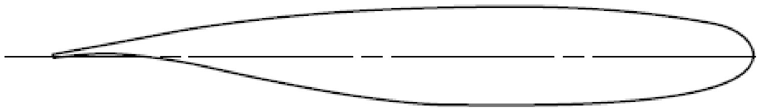
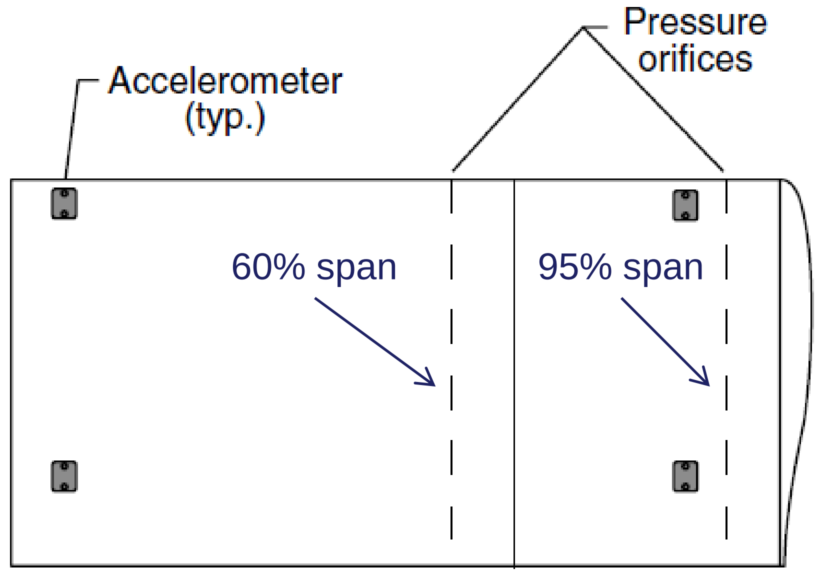
BSCW Geometry



Model planform. Dimensions are in inches.

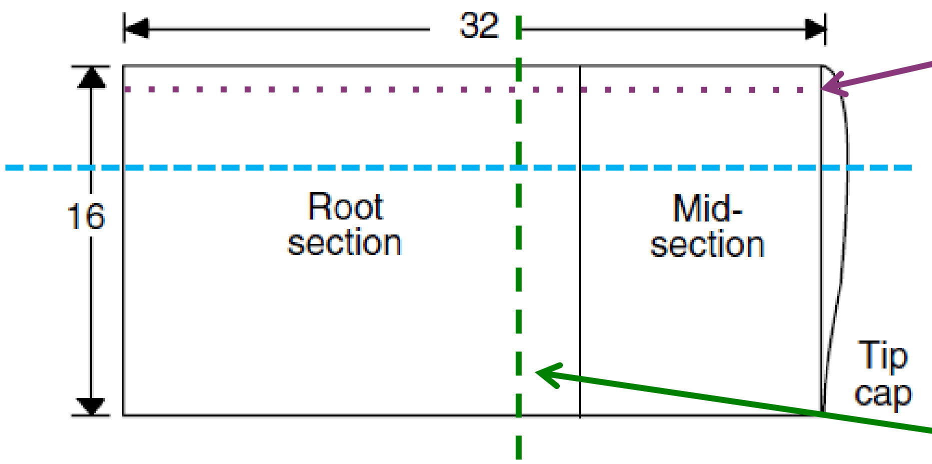


NASA SC(2)-0414 airfoil.



Available instrumentation locations.

BSCW Test Configuration



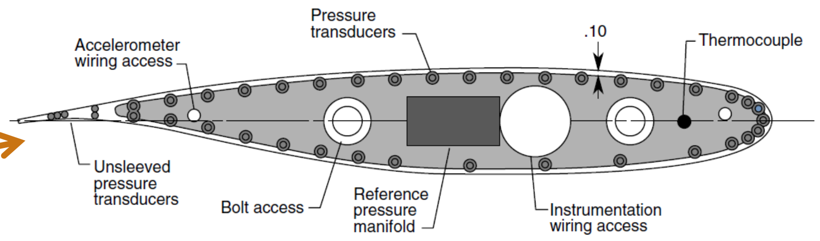
Model planform. Dimensions are in inches.

<u>Transition Strip</u>:
7.5% chord

<u>Forced Oscillation</u>:
Pitching motion about 30% chord

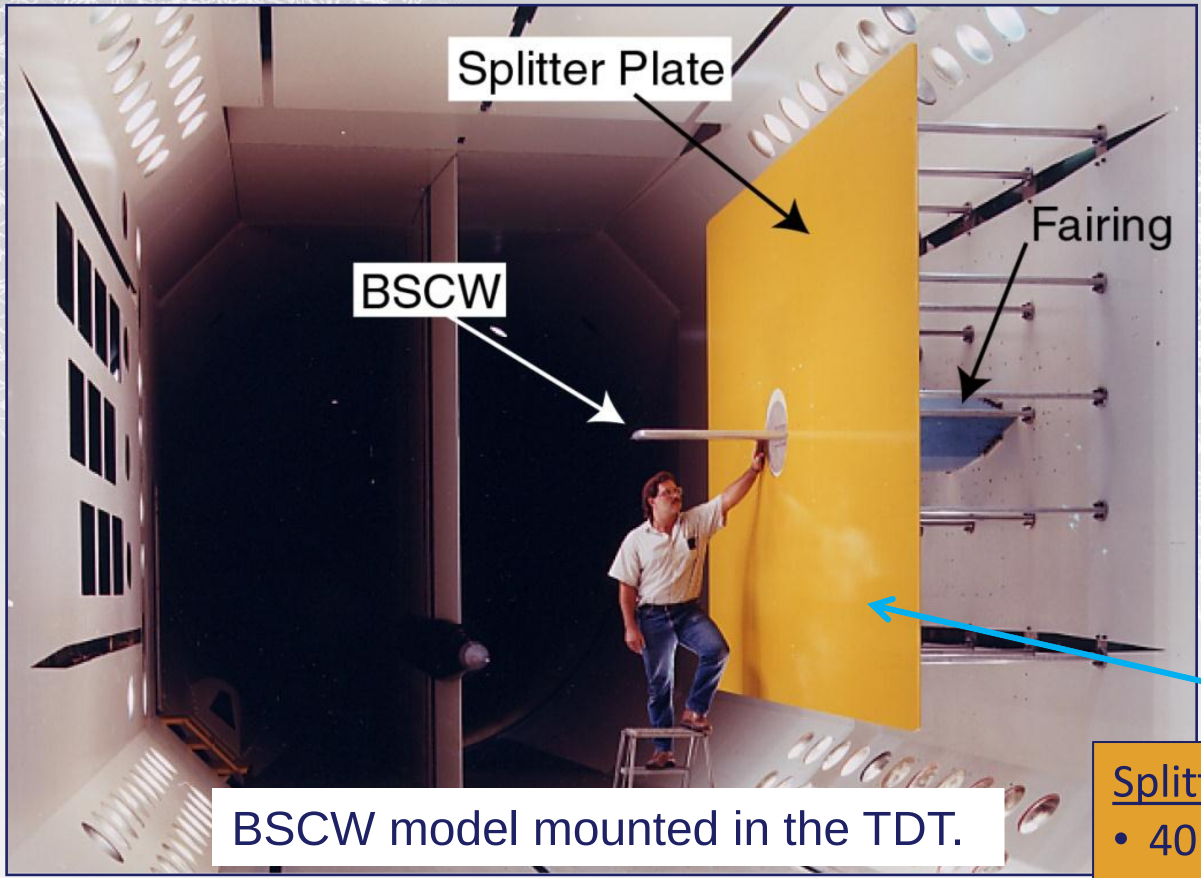
<u>Unsteady Pressure Measurements</u>:
- 1 chord fully-populated at 60% span
- Outboard chord at 95% span NOT populated for this test

<u>40 In-Situ Unsteady Pressure Transducers</u>:
- 22 upper surface
- 17 lower surface
- 1 leading edge



Cross-section at 60% span, showing the layout of the unsteady pressures.

BSCW Test Configuration (Cont'd)



BSCW model mounted in the TDT.

Splitter Plate:

- 40" from wall
- Boundary layer measured as 8"-14"
- Additional studies and data available on this splitter plate

BSCW Structural Properties

- Designed as a rigid wing on a rigid mounting system.
  - Mounting system oscillates wing in pitch about 30% chord.
- Structural frequencies of installed wing and mounting system:
  - 24.1 Hz spanwise (wing flapping)
  - 27.0 Hz in-plane
  - 79.9 Hz torsion

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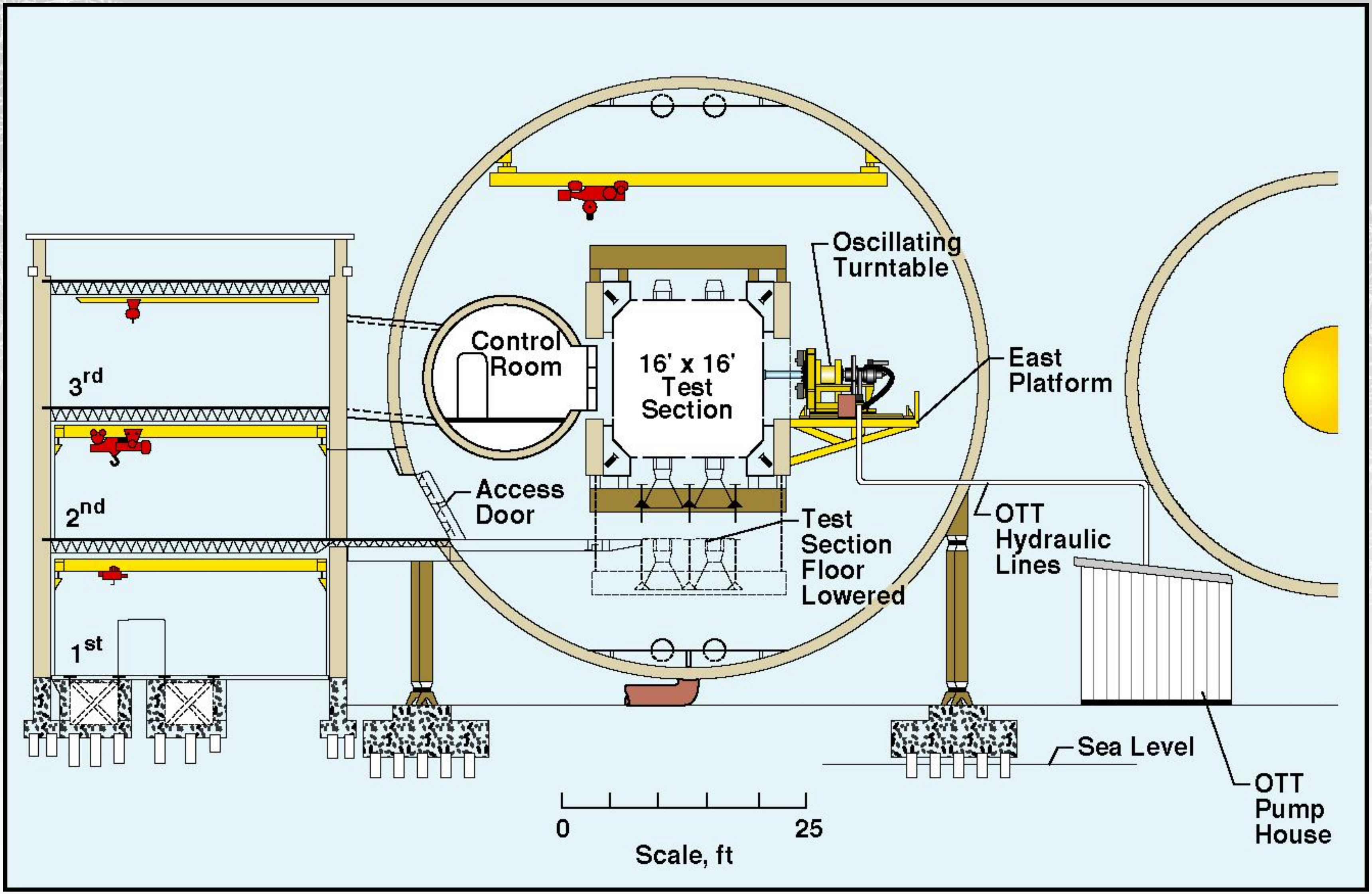
NASA Langley Transonic Dynamics Tunnel (TDT)

- Closed-circuit, continuous-flow wind-tunnel
- Air or R-134a heavy gas test medium
- Mach numbers up to 1.2
- Dynamic pressures up to 550 psf in R-134a
- Model and facility protection systems

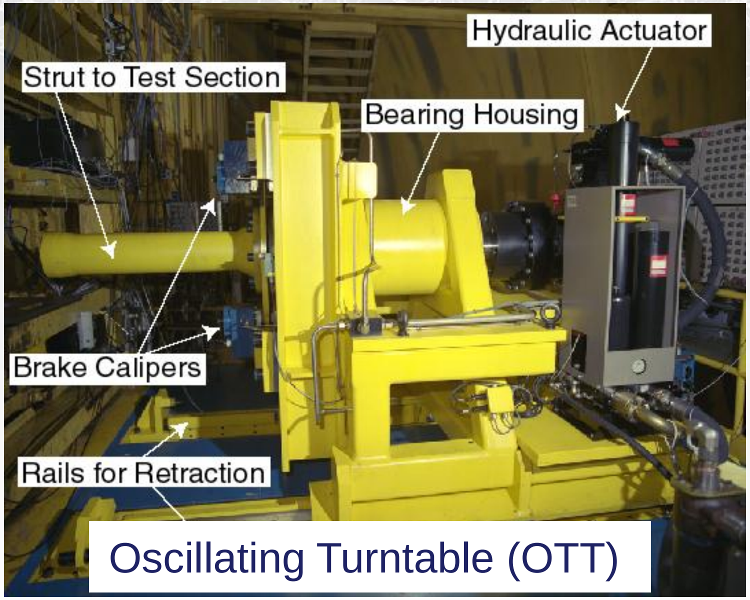
TDT Cross-Section



TDT's Oscillating Turntable (OTT)

- Complex flow phenomena associated with transonic flutter and LCO pose challenges to the prediction of unsteady loads and pressures
- Room for improvement of advanced unsteady CFD codes (high reduced frequencies at transonic conditions)
- Experimental data required for code validation and understanding of complex flow phenomena

The OTT satisfies the need for a system to measure unsteady flow phenomena on large wind-tunnel models undergoing precisely controlled pitch motions in the TDT.



Oscillating Turntable (OTT)

BSCW Test Conditions on the OTT

- 1 to 30 Hz oscillations
- M = 0.4 to 0.85
- q = 100, 170, & 200 psf
- α_{mean} = -1 to 5 deg
- R-134a & air test mediums

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BSCW Test Cases

- Target experimental data acquired in R-134a @
  - M = 0.85
  - q = 200 psf
  - Re_c = 4.49 million
  - α = 5.0 deg
- This M / α combination was selected due to transient attached and separated flows.
  - Two dynamic cases chosen to demonstrate ability of methods to properly capture frequency effects.
  - Frequencies chosen to minimize potential structural coupling that could occur at the high oscillation frequencies.
- Static data: Mean C_p
- Forced oscillation data:
  - Mean C_p
  - Real and imaginary C_p/θ
  - C_p time histories

BSCW Test Cases

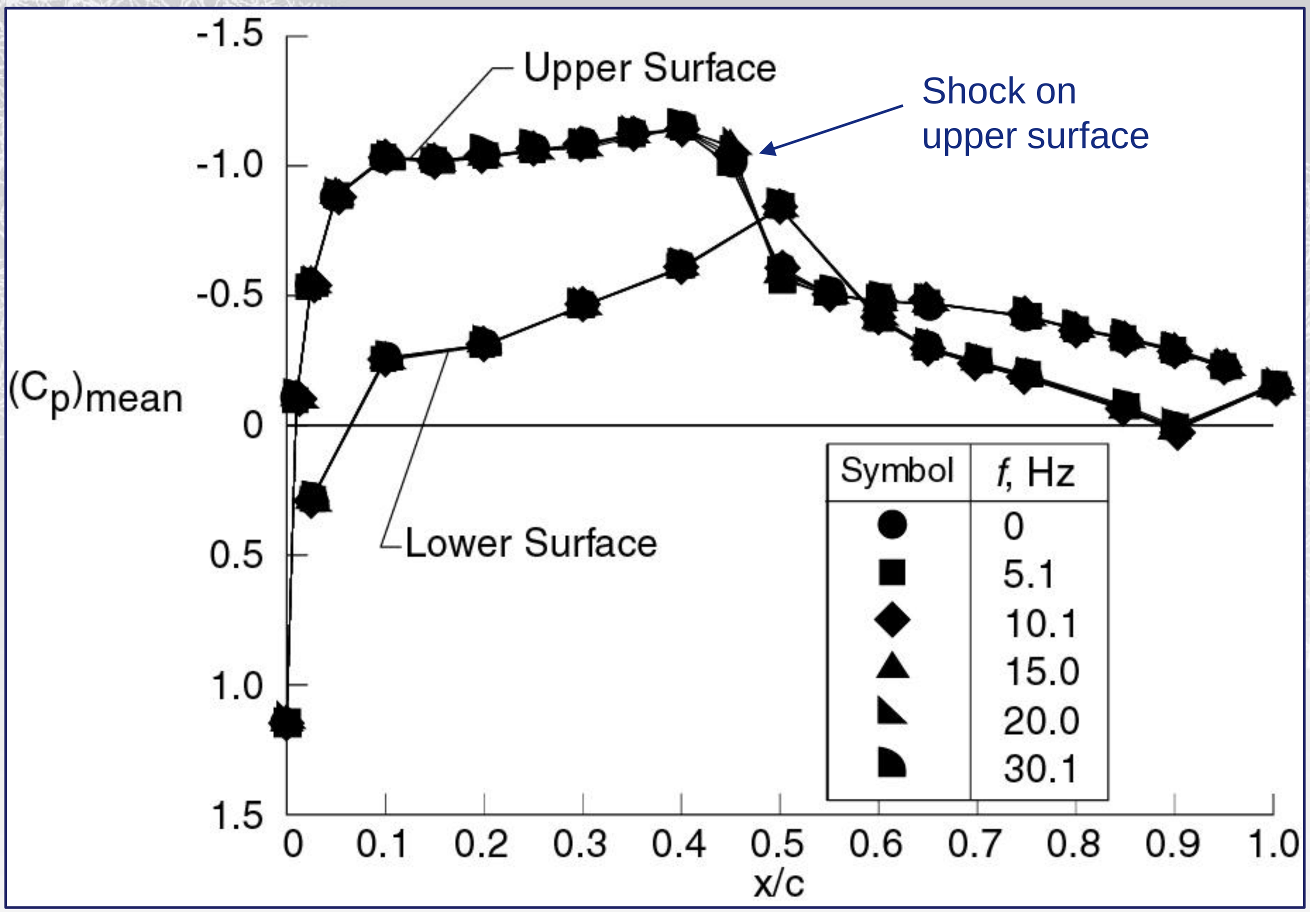
M = 0.85, q = 200 psf, Re_c = 4.49 million
test medium: R-134a

a) Steady Case
   i. α = 5°
b) Dynamic Cases
   i. α = 5°, θ = 1°, f = 1 Hz
   ii. α = 5°, θ = 1°, f = 10 Hz

BSCW Experimental Data

Mean Pressure Coefficient Distribution During Oscillations

M = 0.85, q = 200 psf, Re_c = 4.49 million, α_{mean} = 5º, 60% span



- Mean pressure coefficient distributions are identical for each oscillatory frequency.
- At high frequencies, OTT oscillations are consistent, and mean AOA is held.
- Shock on upper surface indicated by the adverse pressure gradient.

BSCW Experimental Data

Unsteady Pressure Coefficient Magnitudes

M = 0.85

q = 200 psf

Re_c = 4.49 million

α_{mean} = 5°

60% span

BSCW Test Cases

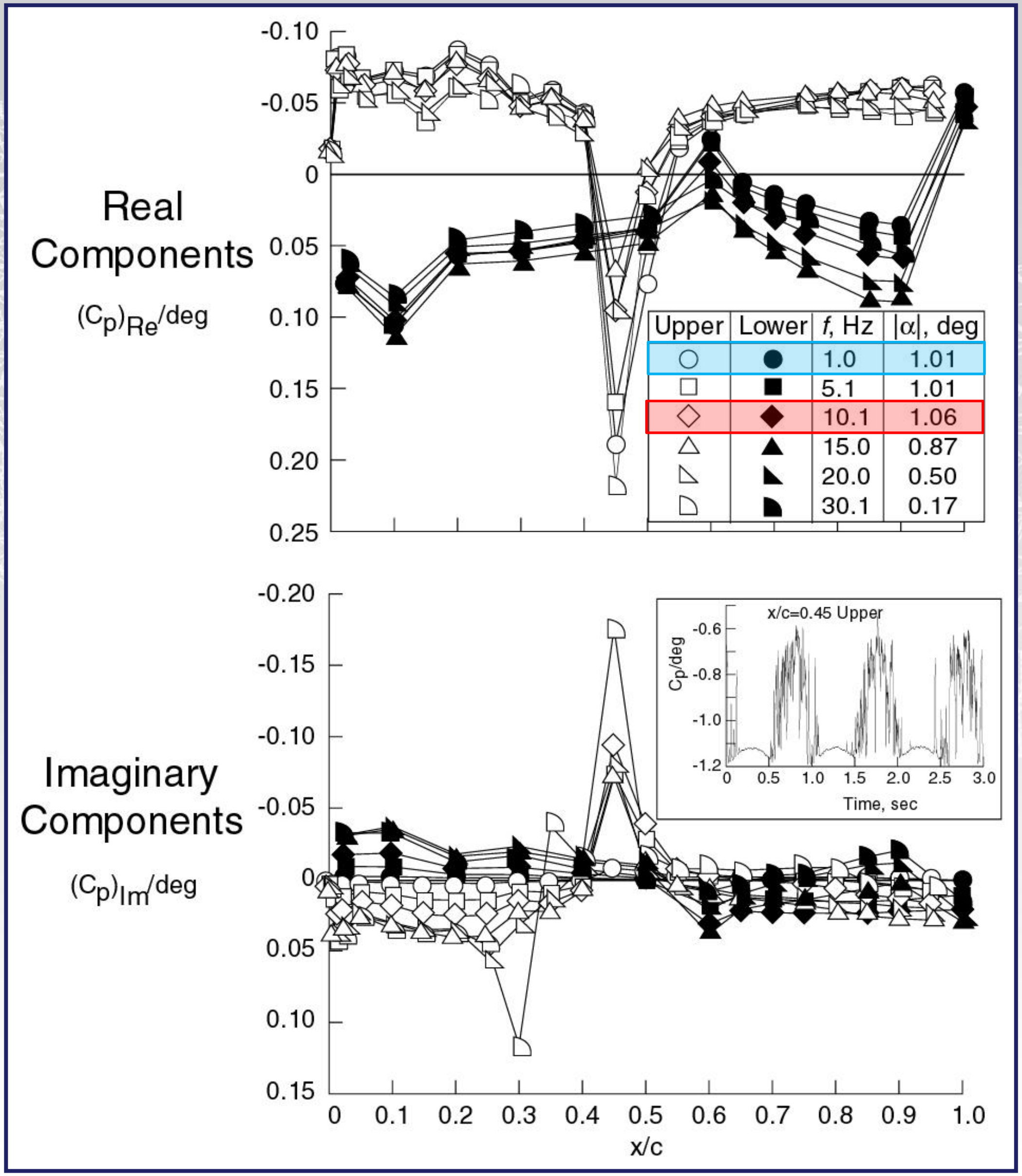
a) Steady Case

  i. α = 5°

b) Dynamic Cases

  i. α = 5°, θ = 1°, f = 1 Hz

  ii. α = 5°, θ = 1°, f = 10 Hz



Upper	Lower	f, Hz	|α|, deg
○	●	1.0	1.01
□	■	5.1	1.01
◇	◆	10.1	1.06
△	▲	15.0	0.87
◺	◣	20.0	0.50
◗	◗	30.1	0.17