HIRENASD Analysis & Test Conditions for the Aeroelastic Prediction Workshop

November 2, 2011
Updated:
February 10, 2012:
Excitation amplitudes and frequencies added
Data comparison matrix updated
February 21, 2012:
Corrected location of displacement for FRF reference data
Corrected data point numbers for experimental static data sets

- This information package is assembled corresponding to the November 1 update of models and experimental data on the website. **The files and data used here can be downloaded from the website.**

  Nov 1 Update:
- Aerodynamic grids
- Finite element structural model & modal analysis results
- Experimental comparison data

Contents

- Overview information
- Available grids
- Test conditions
- Geometry
- Reference Quantities
- Data comparison matrix / required calculations
- Examples of comparison data plots
- Experimenal data
  - Static Pressure Data
  - Forced Oscillation Data
  - Static Displacement Data

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- 3-D aeroelastic wing with generic fuselage model
- Fixed transition
- Treated as aeroelastic here
  - Relatively weak aeroelastic coupling
- Forced oscillation at 2nd bending mode frequency
- Time history data available
- Data includes
  - Balance loads
  - Mean and fluctuating pressure data
  - Limited set of surface deformation

<u>Known deficiencies:</u>

- Limited deflection data
- Only excited at natural frequencies

Summary of AePW Grids available on website

Configuration	GRID TYPE																	
	Unstructured												Structured			Overset		
	Node Based						Cell Centered						Hex Multiblock					
	Mixed			Tetrahedral			Mixed			Tetrahedral								
	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F
HIRENASD	√	√	√	√	√	√	√	√	√	√	√	√	√	○	○	√	⊙	⊙

√ = Complete

⊙ = In process

○ = Desired

Updated November 1, 2011

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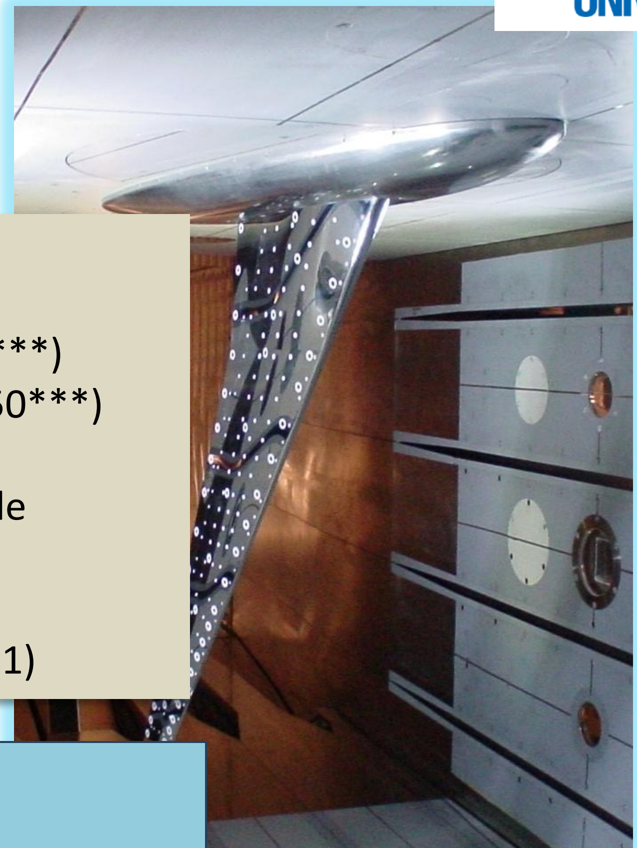

M = 0.80, test medium: Nitrogen

a) Steady (Static Aeroelastic) Cases
   i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW132***)
   ii. Re_c = 23.5 million, α = -1.34°, q/E = 0.48 (ETW250***)

b) Dynamic Cases: forced oscillation at 2nd Bending mode frequency
   i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW159)
   ii. Re_c = 23.5 million, α = -1.34°, q/E = 0.48 (ETW271)

M = 0.70, test medium: Nitrogen

a) Steady (Static Aeroelastic) Cases
   i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW129***)

b) Dynamic
   frequenc
   i. Re_c

*** February 21, 2012: The static data point numbers given above are no longer applicable. These data point numbers correspond to the angle of attack polars that were originally being used for extracting the static pressure distributions. Because the transition between angles of attack was quick, the pressures did not settle to static values before the change to the next angle. The oscillation data points contain sufficient portions of time records where there is no oscillation, such that the static data can be extracted from those data sets. The next slide corrects the numbering. The results posted to the website correspond to this revised methodology.

Point	Excitation Frequency, Hz
55	78.9
59	78.9
71	80.3

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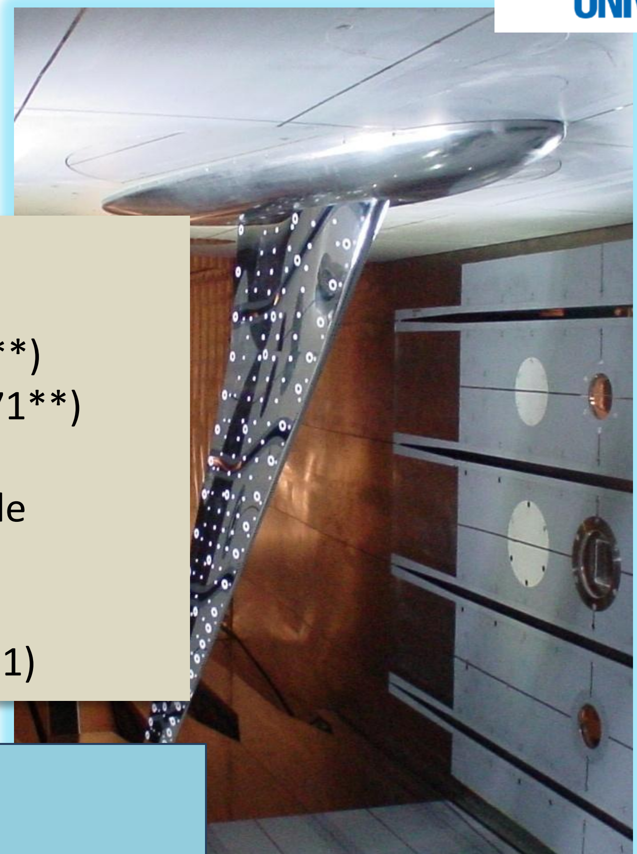


M = 0.80, test medium: Nitrogen

a) Steady (Static Aeroelastic) Cases
  i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW159**)
  ii. Re_c = 23.5 million, α = -1.34°, q/E = 0.48 (ETW271**)

b) Dynamic Cases: forced oscillation at 2nd Bending mode frequency
  i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW159)
  ii. Re_c = 23.5 million, α = -1.34°, q/E = 0.48 (ETW271)

M = 0.70, test medium: Nitrogen

a) Steady (Static Aeroelastic) Cases
  i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW155**)

b) Dynamic Cases: forced oscillation at 2nd Bending mode frequency
  i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW155)

Data Point	Excitation Frequency, Hz
155	79.3
159	78.9
271	80.4

** February 21, 2012: The static data is extracted from the same data points as the oscillatory data. The oscillation data points contain sufficient portions of time records where there is no oscillation; the static information is extracted from those regions of the time records.

HIRENASD Response Amplitudes

- Updated information:
  - Amplitude of excitations for 2nd bending modes for each of the 3 unsteady cases, extracted from the experimental data:

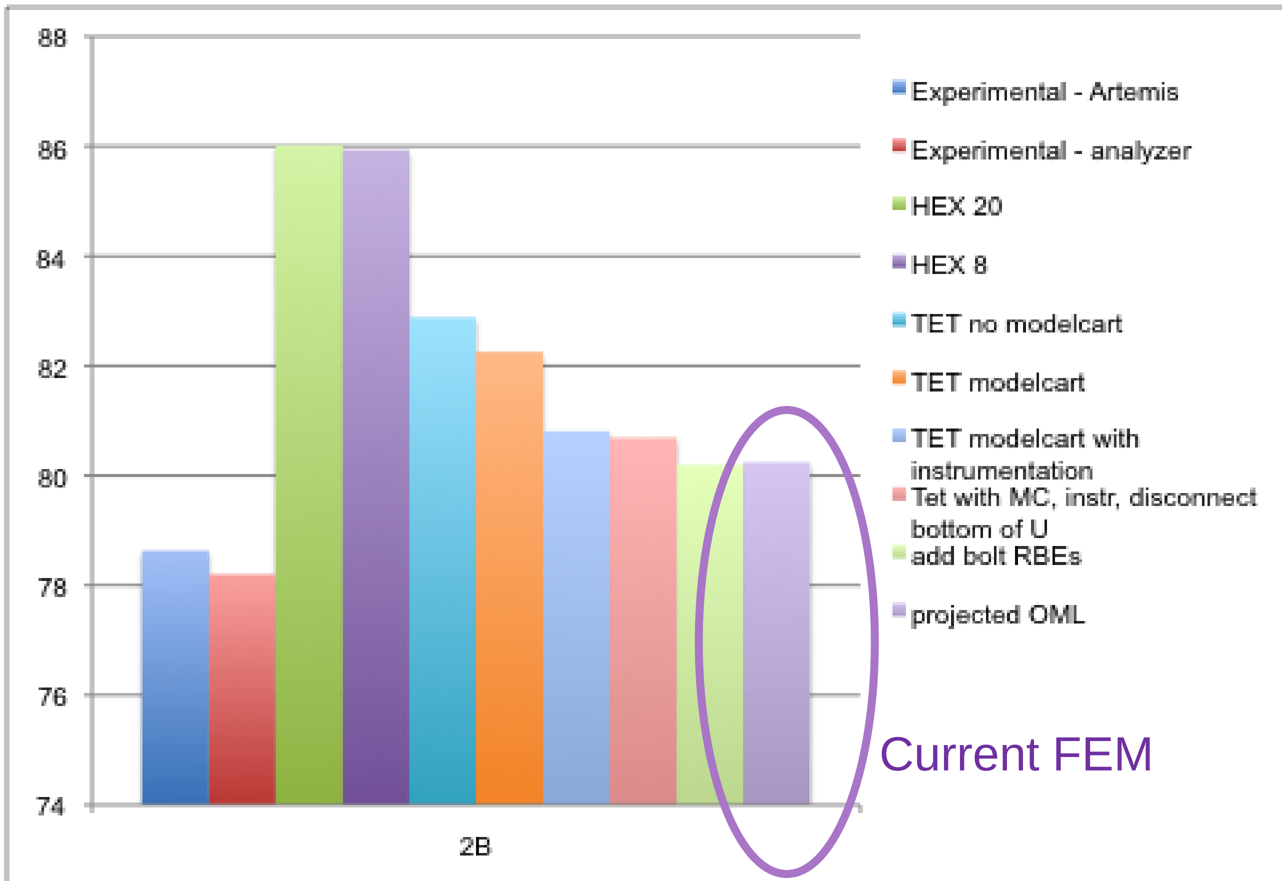
Exp Test Pt	159	271	155
Mach #	0.8	0.8	0.7
Re_c	7M	23.5M	7M
Amplitude (mm)	2.4	0.90	2.0
Frequency (Hz)	78.9	80.4	79.3

For those analysts using strictly forced oscillations (similar methodology to RSW and BSCW), it is recommended that they use the frequencies extracted from the experimental data at the test conditions, as given in the table above. It is recommended that they oscillate the model in the 2nd bending mode shape as given by the finite element model.

For those analysts who are performing a coupled aeroelastic analysis, proximity of the oscillatory frequency to the modal frequency may be a dominant effect, and these frequencies are likely not exactly correct. The next slide contains a summary of the air-off natural frequencies of the 2nd bending mode. The first 2 columns show the experimental data; the last column shows the current finite element model frequency.

HIRENASD 2nd Bending Mode Air-off Natural Frequency

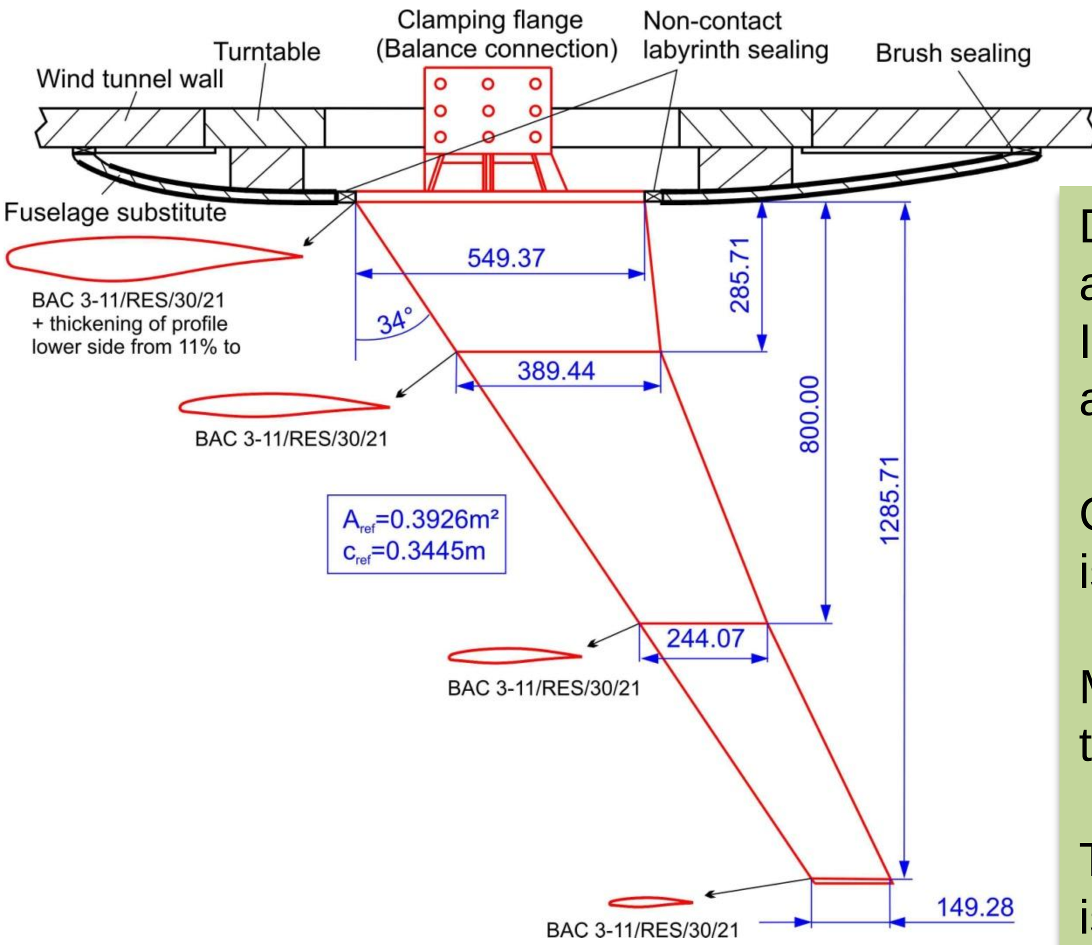
	Case 1	Case 2	Case 10
	Experimental - Artemis	Experimental - analyzer	Current finite element model
1B	26.015	26.250	25.550
2B	78.635	78.203	80.245
1FA			106.193
3B	166.250	166.250	160.349
4B	245.002	245.000	241.995
1T	265.855	265.781	271.844
2T			437.830
5B			354.155
2FA			252.225
3T			569.737
3FA			443.805
6B			497.802
3T			569.737
7TB			643.234



Analysis Condition Parameters

Parameters		Units	Configuration: HIRENASD		
		SI	Mach 0.8 Low Re#	Mach 0.8 High Re#	Mach 0.7 Low Re#
Mach number	M		0.8005	0.8	0.7
Reynolds number (based on ref chord)	Re_c		6999999	23486600	6997830
Reynolds number per meter	Re/m	Re/m	2.032e+07	6.8176e+07	2.031e+07
Dynamic pressure	q	Pa	40055.4	88696.9	36177.3
Velocity	V	m/s	256.5	219.5	227.0
Speed of sound	a	m/s	320.3	274.8	324.3
Static temperature	Tstat	deg K	246.9	181.8	253.1
Density	ρ	kg/m^3	1.22	3.70	1.41
Ratio of specific heats	γ				
Dynamic viscosity	μ				
Prandtl number	Pr		0.72	0.72	0.72
Test medium			Nitrogen	Nitrogen	Nitrogen
Total pressure	H	Pa	136180	301915	146355
Static pressure	P	Pa	89289	198115	105529
Purity	X				
Total temperature	T	deg K	278.5	205.0	277.9

HIRENASD Geometry



Dimensions shown
are in millimeters.
IGES file and grids
are also in **millimeters.**

Coordinate system origin
is the wing root leading edge.

Moment reference point is
the balance measurement point.

The finite element model
is in **meters**.

HIRENASD Reference quantities

		HIRENASD
Reference chord	c_{ref}	0.3445 m
Model span	b	1.28571 m
Area	A	0.3926 m^2
Moment reference point, relative to axis system defns	x	0.252 m
	y	-0.610 m
	z	0
Transfer function reference quantity		Vertical displacement (at y=1.24521m, x=0.87303m)

Feb 21, 2012:
Corrected the verical displacement location.
Previously, the x and y coordinates were swapped

HIRENASD Comparison Data Matrix

CONFIGURATION	REQUIRED CALCULATIONS		
	CONVERGENCE STUDIES	STEADY CALCULATIONS	DYNAMIC CALCULATIONS
Static-Aeroelastic Cases (HIRENASD)	Grid Convergence: C_L, C_D, C_M vs. $N^{-2/3}$	• Mean C_p vs. x/c • Vertical displacement vs. x/c • Twist angle vs. x/c • Means of C_L, C_D, C_M	
Forced Oscillation Cases (all configurations)	Grid convergence: TBD Time step convergence: TBD		• Magnitude and Phase of C_p vs. x/c at span stations corresponding to transducer locations • Magnitude and Phase of C_L, C_D, C_M at excitation frequency • Time history of Cp at each span station for 3 pressure transducer locations

Table provided lists sensor locations for extraction of pressure coefficient information.
Can also be found in provided tecplot data files of experimental data sets.
An ascii template will be provided for submission of data

Updated on next slide, February 10, 2012

Comparison Data Matrix

CONFIGURATION	REQUIRED CALCULATIONS			
	GRID CONVERGENCE STUDIES	TIME CONVERGENCE STUDIES	STEADY CALCULATIONS	DYNAMIC CALCULATIONS
Steady-Rigid Cases (RSW, BSCW)	C_L, C_D, C_M vs. $N^{-2/3}$	n/a	• Mean C_p vs. x/c • Means of C_L, C_D, C_M	n/a
Steady-Aeroelastic Cases (HIRENASD)	C_L, C_D, C_M vs. $N^{-2/3}$	n/a	• Mean C_p vs. x/c • Means of C_L, C_D, C_M • Vertical displacement vs. chord • Twist angle vs. span	n/a
Forced Oscillation Cases (all configurations)	• Magnitude and Phase of CL, CD, CM vs. $N^{-2/3}$ at excitation frequency	• Magnitude and Phase of C_L, C_D, C_M vs. Dt at excitation frequency	n/a	• Magnitude and Phase of C_p vs. x/c at span stations corresponding to transducer locations • Magnitude and Phase of C_L, C_D, C_M at excitation frequency • Time histories of C_p's at a selected span station for two upper- and two lower-surface transducer locations

Table provided lists sensor locations for extraction of pressure coefficient information.
Can also be found in provided tecplot data files of experimental data sets.
An ascii template will be provided for submission of data

Data extraction locations: station 1

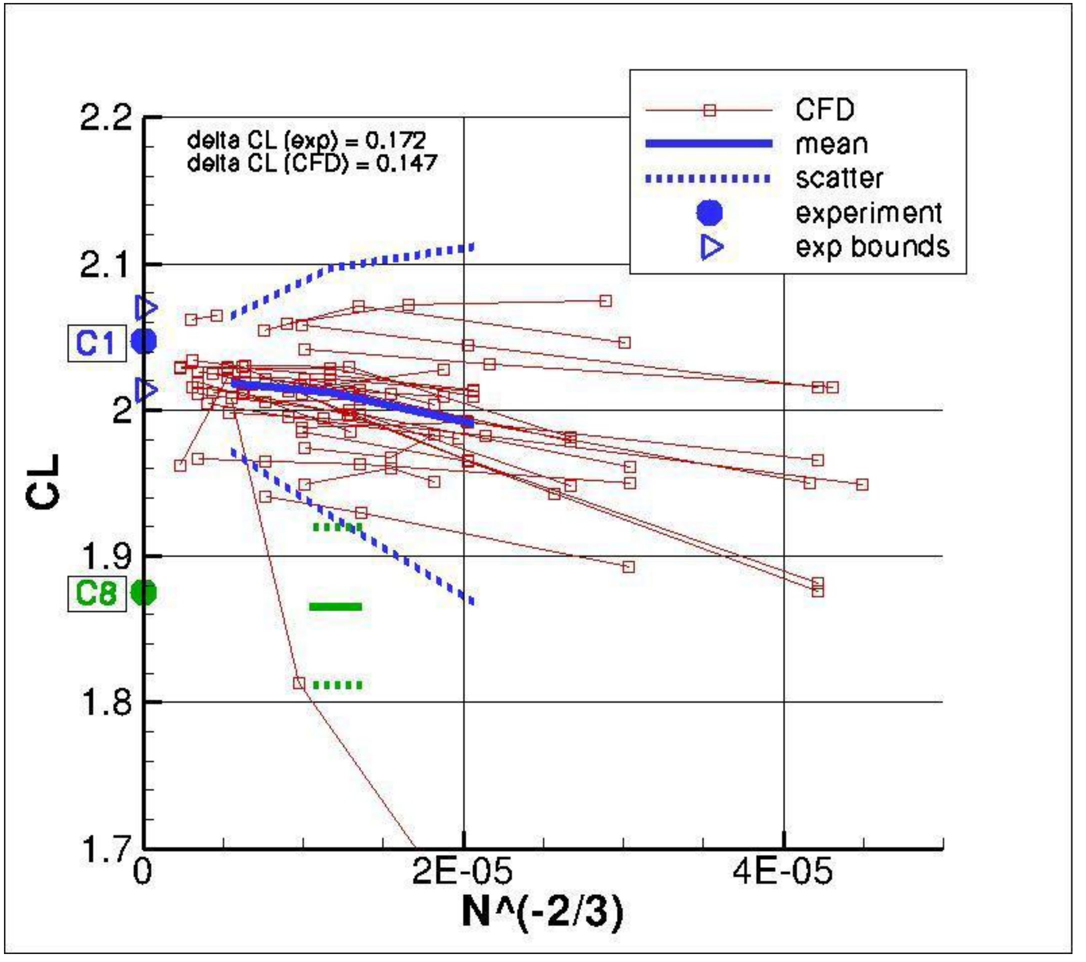
HIRENASD Data Information for the Aeroelastic Prediction Workshop					
2-Nov-11					
Pressure Sensor Locations					
Span Station	1.00000E+00				
eta	1.45000E-01				
Local chord length	4.43058E-01				
X leading edge	8.25758E-01				
upper surface					
Port Number	X	X_normalized	X_normalized_signed	Y	Z
16	1.25000E-01	6.86140E-04	6.86140E-04	1.86320E-01	1.00000E-04
17	1.28240E-01	7.99895E-03	7.99895E-03	1.83220E-01	7.83000E-03
18	1.36480E-01	2.65970E-02	2.65970E-02	1.83430E-01	1.16400E-02
19	1.45160E-01	4.61881E-02	4.61881E-02	1.83460E-01	1.40700E-02
20	1.66510E-01	9.43759E-02	9.43759E-02	1.83440E-01	1.84600E-02
21	2.17910E-01	2.10388E-01	2.10388E-01	1.83260E-01	2.49800E-02
22	2.82090E-01	3.55245E-01	3.55245E-01	1.83200E-01	2.88200E-02
23	3.59010E-01	5.28856E-01	5.28856E-01	1.83190E-01	2.84300E-02
24	3.71980E-01	5.58130E-01	5.58130E-01	1.83380E-01	2.77600E-02
25	3.97380E-01	6.15459E-01	6.15459E-01	1.83280E-01	2.58300E-02
26	4.23440E-01	6.74277E-01	6.74277E-01	1.83360E-01	2.31600E-02
27	4.48910E-01	7.31764E-01	7.31764E-01	1.83290E-01	1.98600E-02
28	4.74540E-01	7.89612E-01	7.89612E-01	1.83380E-01	1.60300E-02
29	5.00250E-01	8.47641E-01	8.47641E-01	1.83410E-01	1.18200E-02
lower surface					
Port Number	X	X_normalized	X_normalized_signed	Y	Z
1	5.26370E-01	9.06595E-01	-9.06595E-01	1.85420E-01	-3.39000E-03
2	4.96790E-01	8.39831E-01	-8.39831E-01	1.85630E-01	-5.64000E-03
3	4.66670E-01	7.71849E-01	-7.71849E-01	1.86340E-01	-8.46000E-03
4	4.36940E-01	7.04747E-01	-7.04747E-01	1.86330E-01	-1.18500E-02
5	4.07790E-01	6.38955E-01	-6.38955E-01	1.86140E-01	-1.56500E-02
6	3.77650E-01	5.70928E-01	-5.70928E-01	1.85990E-01	-1.97500E-02
7	3.47360E-01	5.02562E-01	-5.02562E-01	1.86370E-01	-2.35600E-02
8	3.17970E-01	4.36227E-01	-4.36227E-01	1.86010E-01	-2.62600E-02
9	2.88160E-01	3.68945E-01	-3.68945E-01	1.86010E-01	-2.73300E-02
10	2.27720E-01	2.32529E-01	-2.32529E-01	1.86100E-01	-2.42900E-02
11	1.97880E-01	1.65179E-01	-1.65179E-01	1.86150E-01	-2.04600E-02
12	1.68940E-01	9.98605E-02	-9.98605E-02	1.85610E-01	-1.62300E-02
13	1.51170E-01	5.97529E-02	-5.97529E-02	1.86110E-01	-1.40200E-02
14	1.38120E-01	3.02985E-02	-3.02985E-02	1.86290E-01	-1.23500E-02
15	1.30030E-01	1.20391E-02	-1.20391E-02	1.86500E-01	-9.76000E-03

Files containing this information for all stations:
Ascii format: Pressure_locations_asciifile
Excel worksheet: Pressure_locations.xls
Tecplot data file: Pressure_locations.dat
Tecplot layout files: Pressure_locations_nondim_plot.lay
Pressure_locations_dim_plot.lay

Example of grid convergence data:

Lift coefficient vs convergence parameter

CONFIGURATION	REQUIRED CALCULATIONS		
	GRID CONVERGENCE STUDIES	STEADY CALCULATIONS	DYNAMIC CALCULATIONS
Steady-Rigid Cases (RSW, BSCW)	C_L, C_D, C_M vs. N-2/3	Mean Cp vs. x/c Means of C_L, C_D, C_M	
Steady-Aeroelastic Cases (HIRENASD)	C_L, C_D, C_M vs. $N^{-2/3}$	Mean C_p vs. x/c Vertical displacement vs. chord Twist angle vs. span Means of C_L, C_D, C_M	
Forced Oscillation Cases (all configurations)	TBD		• Magnitude and Phase of C_p vs. x/c at span stations corresponding to transducer locations • Magnitude and Phase of C_L, C_D, C_M at excitation frequency • Time history of Cp at each span station for 3 pressure transducer locations

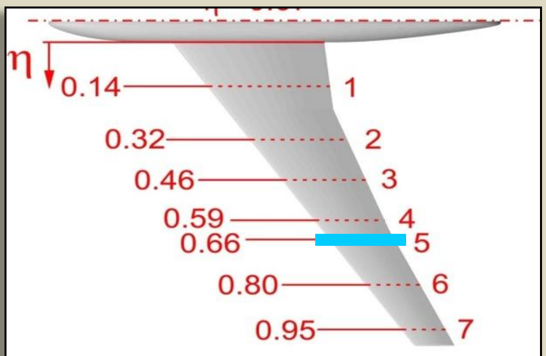


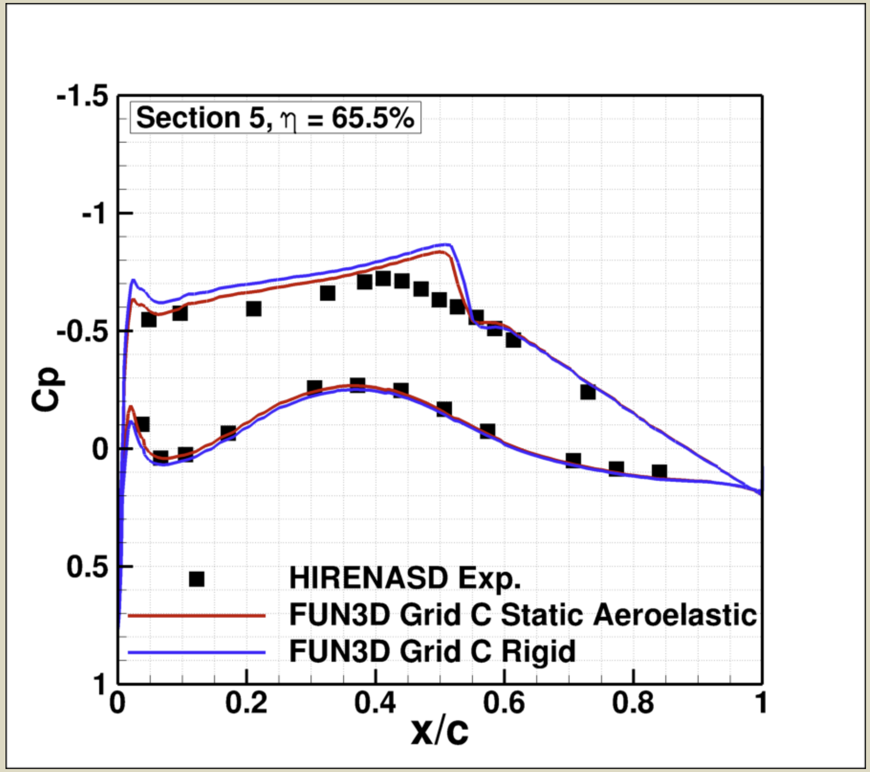
Ref High Lift Prediction Workshop, Rumsey & Slotnik

Example of steady data:

Steady pressure coefficient for HIRENASD

CONFIGURATION	REQUIRED CALCULATIONS: GRID CONVERGENCE STUDIES	STEADY CALCULATIONS	DYNAMIC CALCULATIONS
Steady-Rigid Cases (RSW, BSCW)	C_L, C_D, C_M vs. N-2/3	• Mean Cp vs. x/c • Means of C_L, C_D, C_M	
Steady-Aeroelastic Cases (HIRENASD)	C_L, C_D, C_M vs. $N^{-2/3}$	• Mean C_p vs. x/c • Vertical displacement vs. chord • Twist angle vs. span • Means of C_L, C_D, C_M	
Forced Oscillation Cases (all configurations)	TBD		• Magnitude and Phase of C_p vs. x/c at span stations corresponding to transducer locations • Magnitude and Phase of C_L, C_D, C_M at excitation frequency • Time history of Cp at each span station for 3 pressure transducer locations

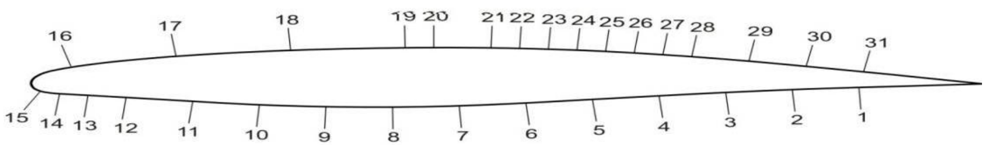




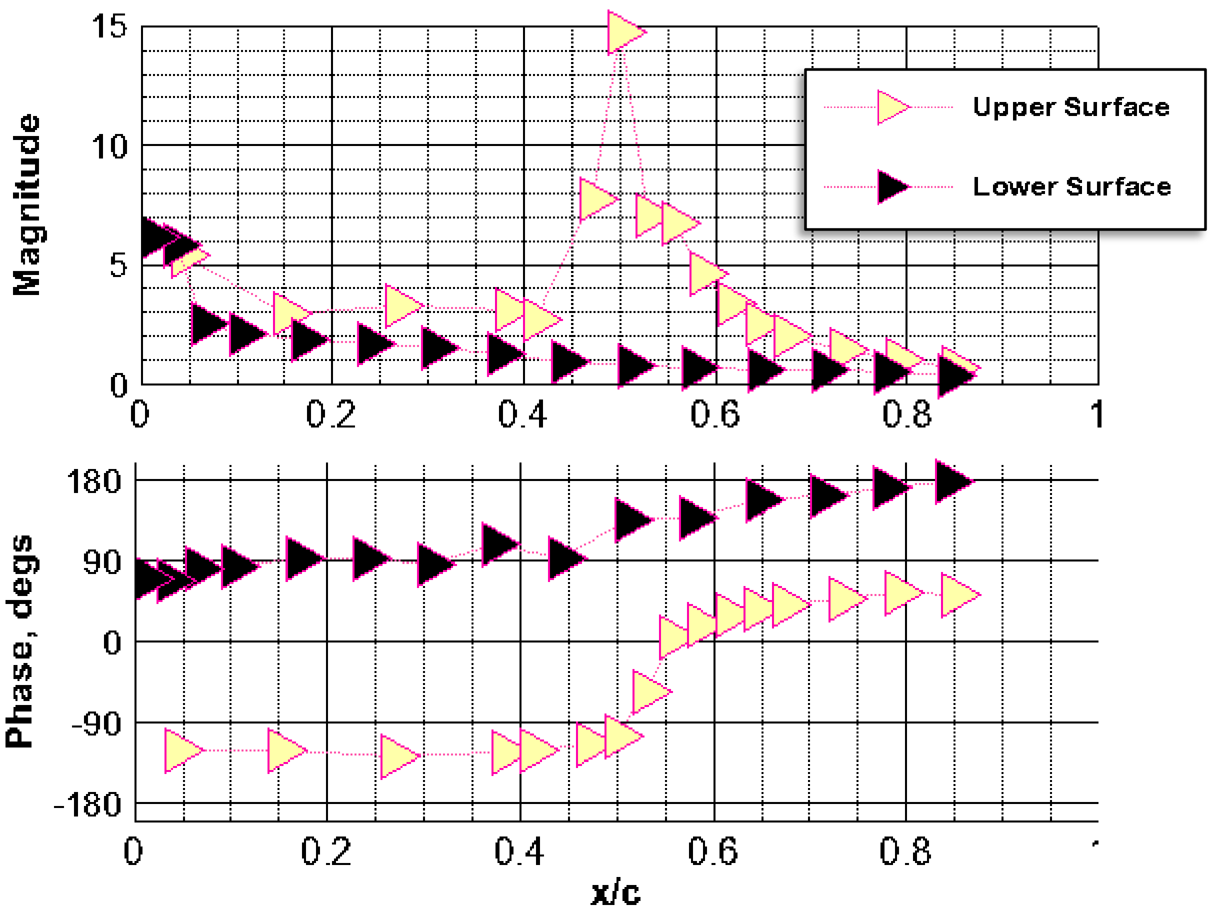
CONFIGURATION	REQUIRED CALCULATIONS: GRID CONVERGENCE STUDIES	STEADY CALCULATIONS	DYNAMIC CALCULATIONS
Steady-Rigid Cases (RSW, BSCW)	C_L, C_D, C_M vs. N-2/3	• Mean Cp vs. x/c • Means of C_L, C_D, C_M	
Steady-Aeroelastic Cases (HIRENASD)	C_L, C_D, C_M vs. $N^{-2/3}$	• Mean C_p vs. x/c • Vertical displacement vs. chord • Twist angle vs. span • Means of C_L, C_D, C_M	
Forced Oscillation Cases (all configurations)	TBD		• Magnitude and Phase of C_p vs. x/c at span stations corresponding to transducer locations • Magnitude and Phase of C_L, C_D, C_M at excitation frequency • Time history of Cp at each span station for 3 pressure transducer locations

Data for Steady Rigid cases will be similar, but without Static Aeroelastic results

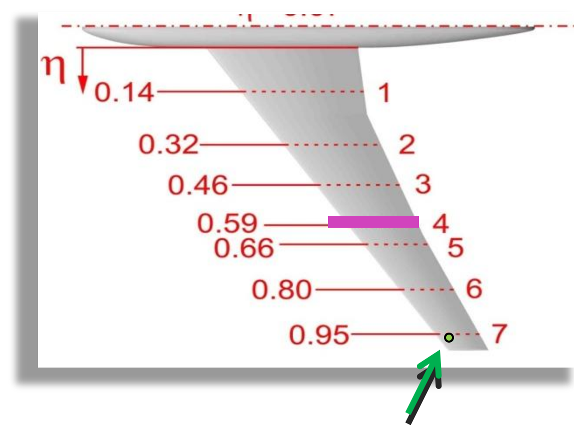
Example of dynamic comparison data: HIRENASD Frequency Responses at 2^{nd} Bending Mode Frequency (78.9 Hz)



Cp(x)/displacement



Pressure coefficients at span station 4 due to displacement at location (15,1)

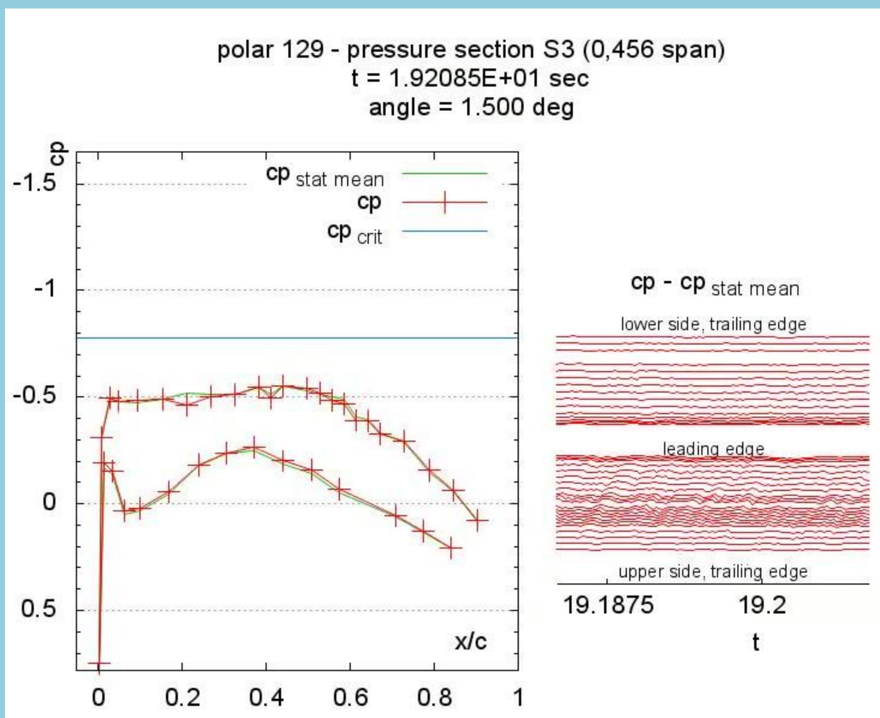


Reference quantity: Displacement at location (15,1)

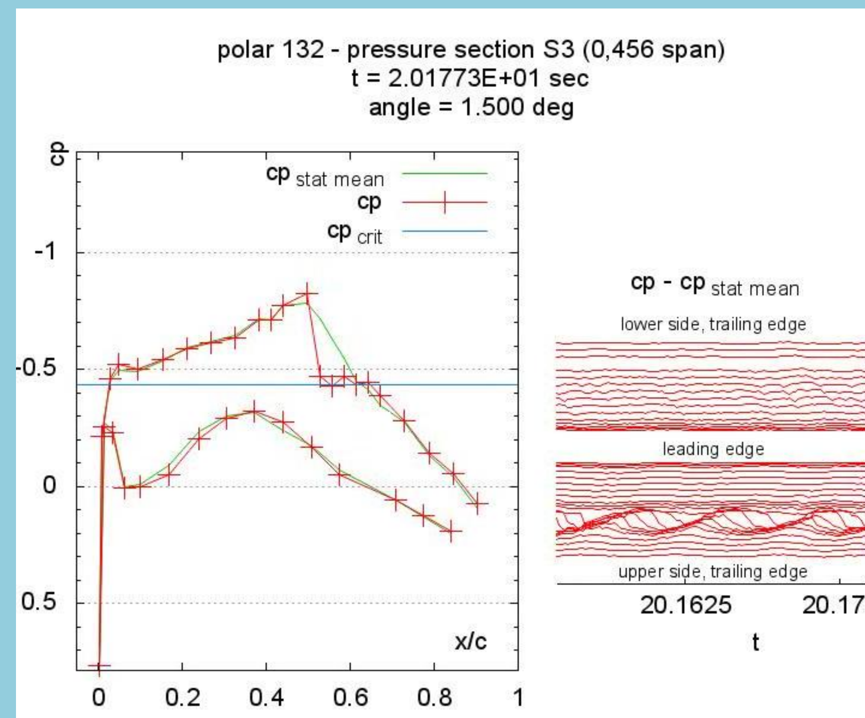
HIRENASD Experimental Data
Mach 0.7 vs Mach 0.8

Static Data
Shown in Figures
Pressure section 3

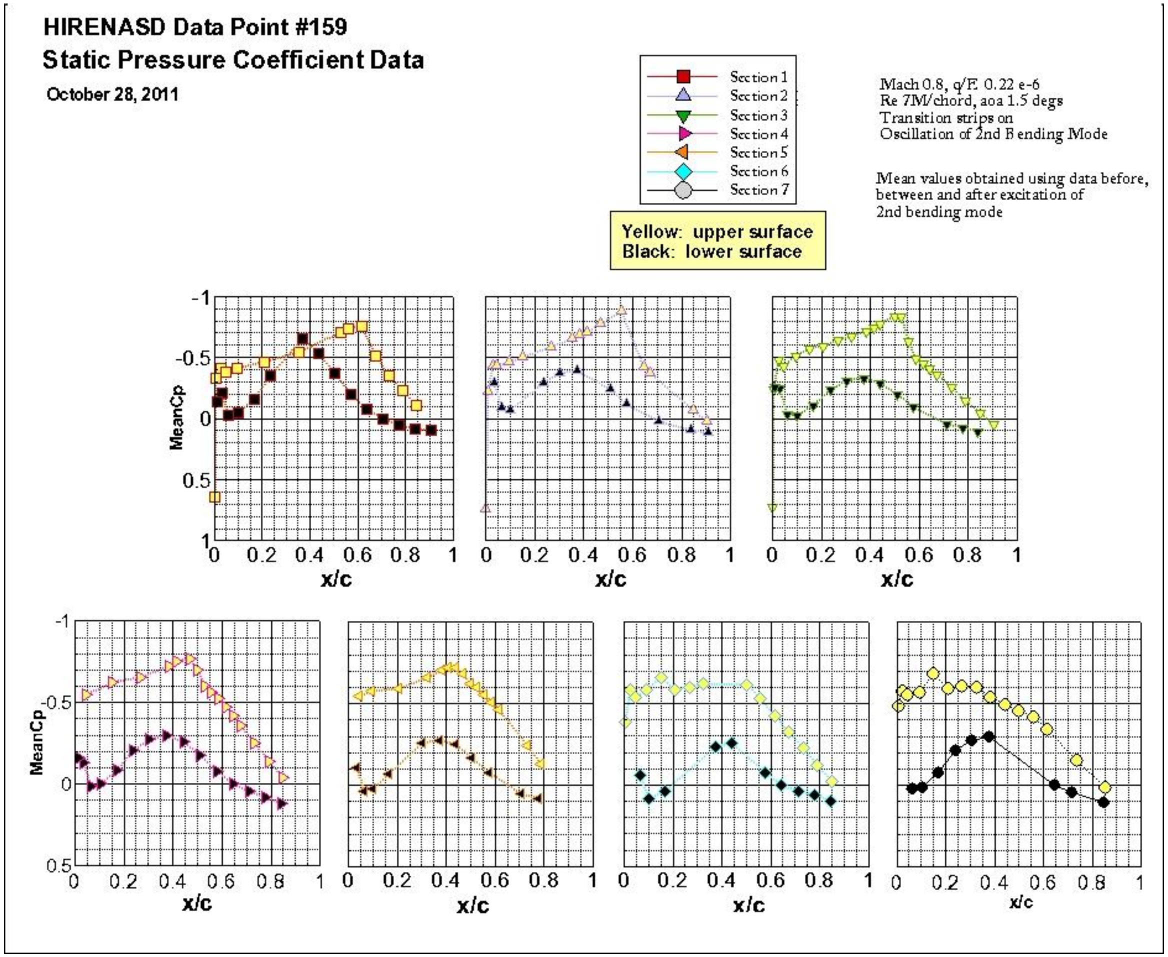
Mach 0.7
(Test Point # 129)
No non-stationary supersonic regions



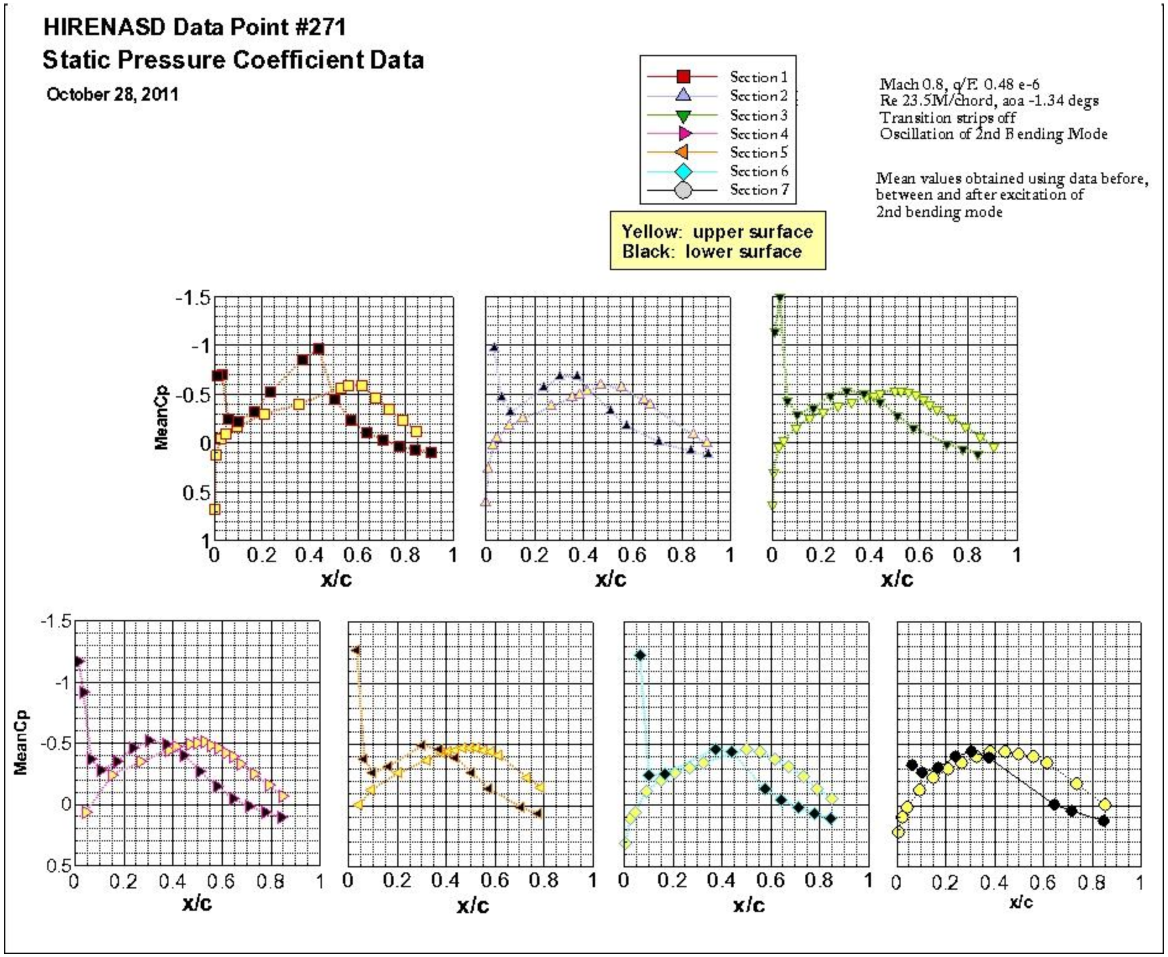
Mach 0.8
(Test Point #132)



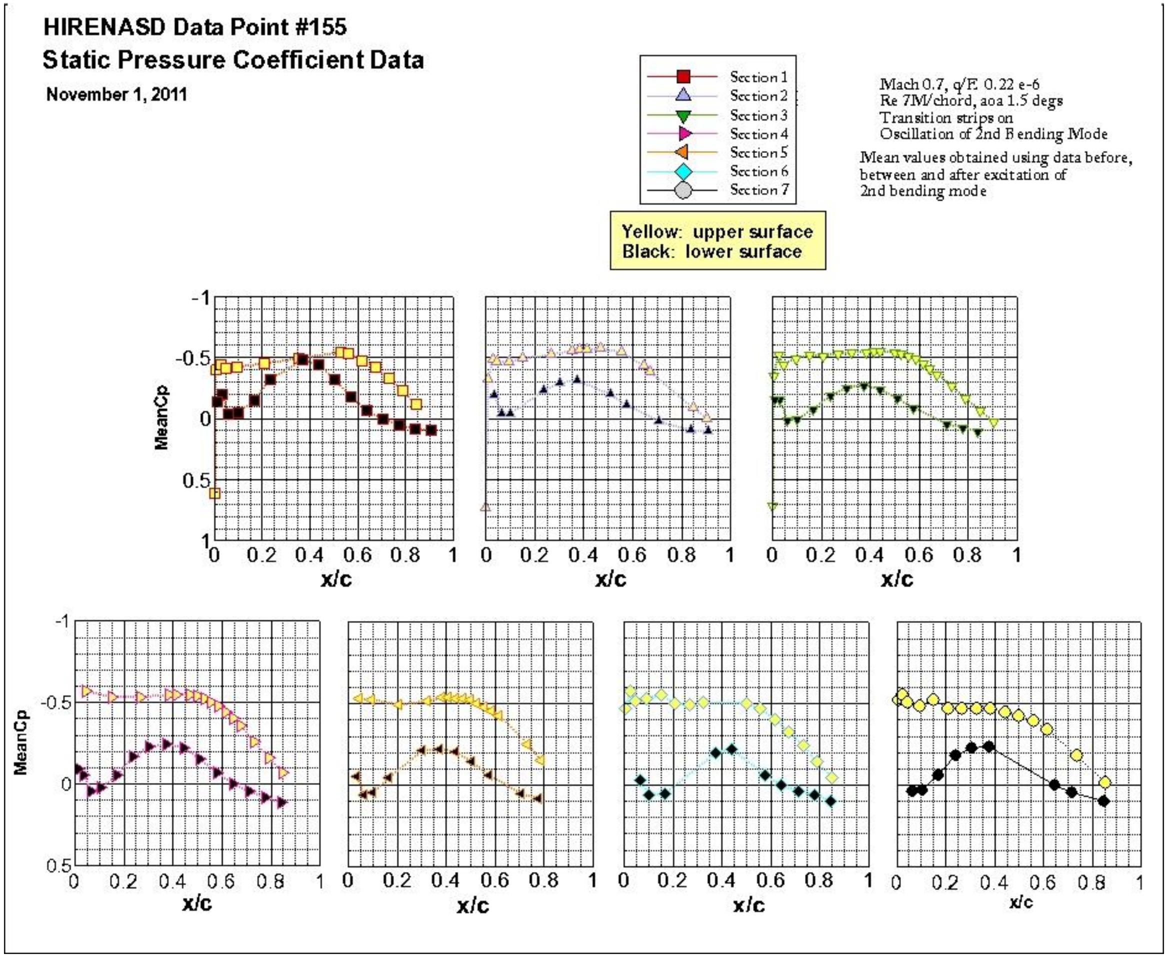
Experimental comparison data: Static pressures (M 0.8, Re 7M)



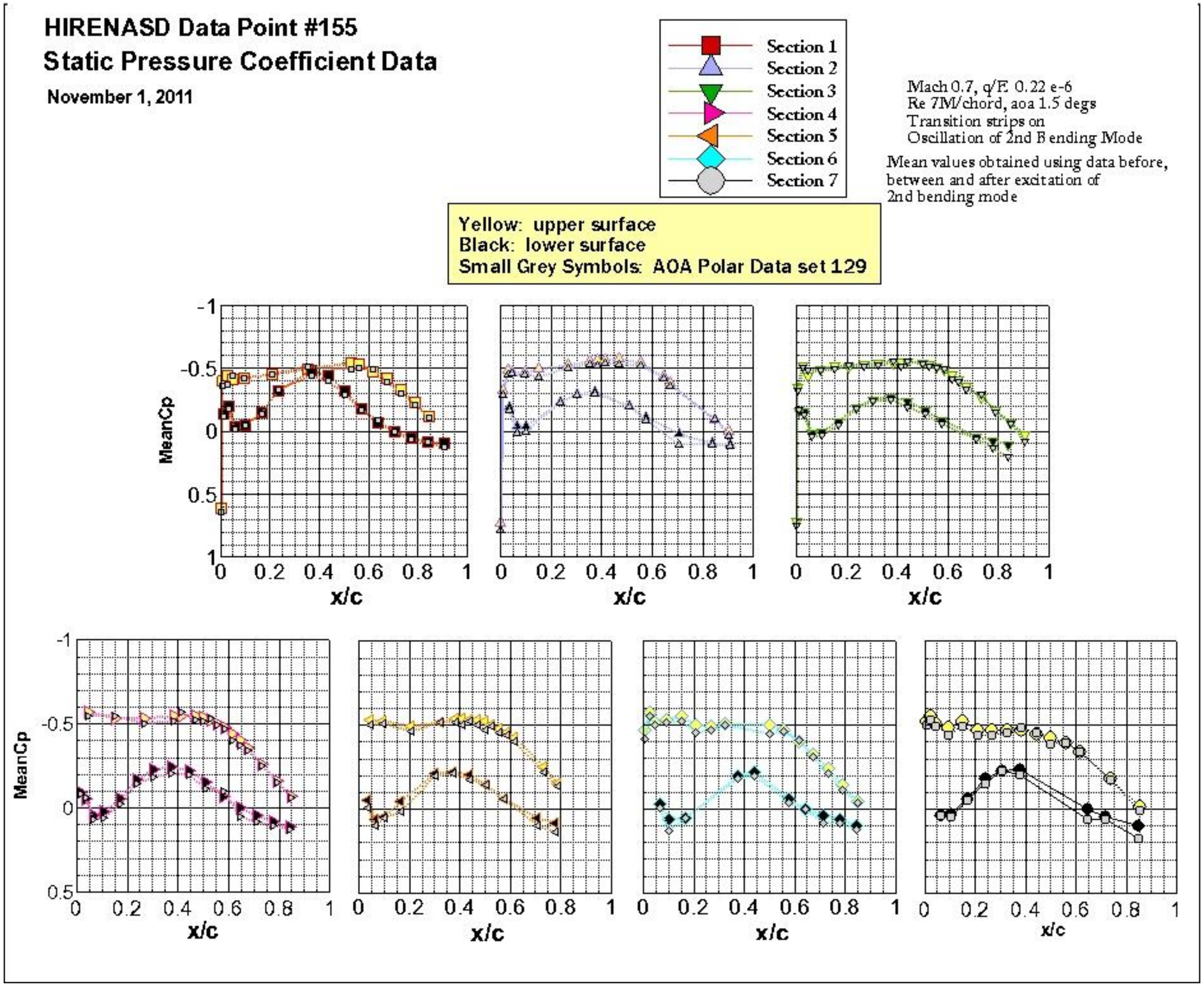
Experimental comparison data: Static pressures (M 0.8, Re 23.5M)



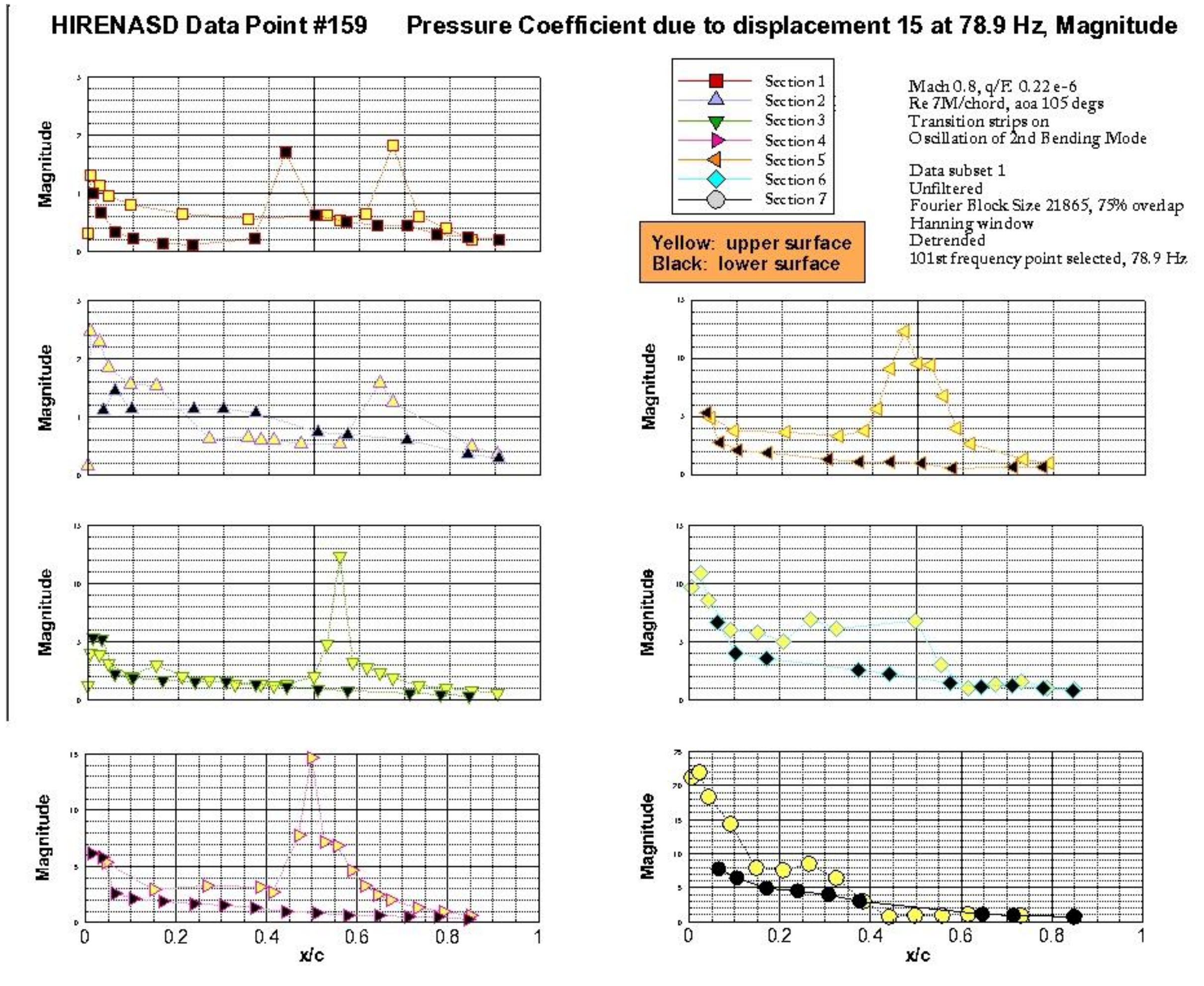
Experimental comparison data: Static pressures (M 0.7, Re 7M)



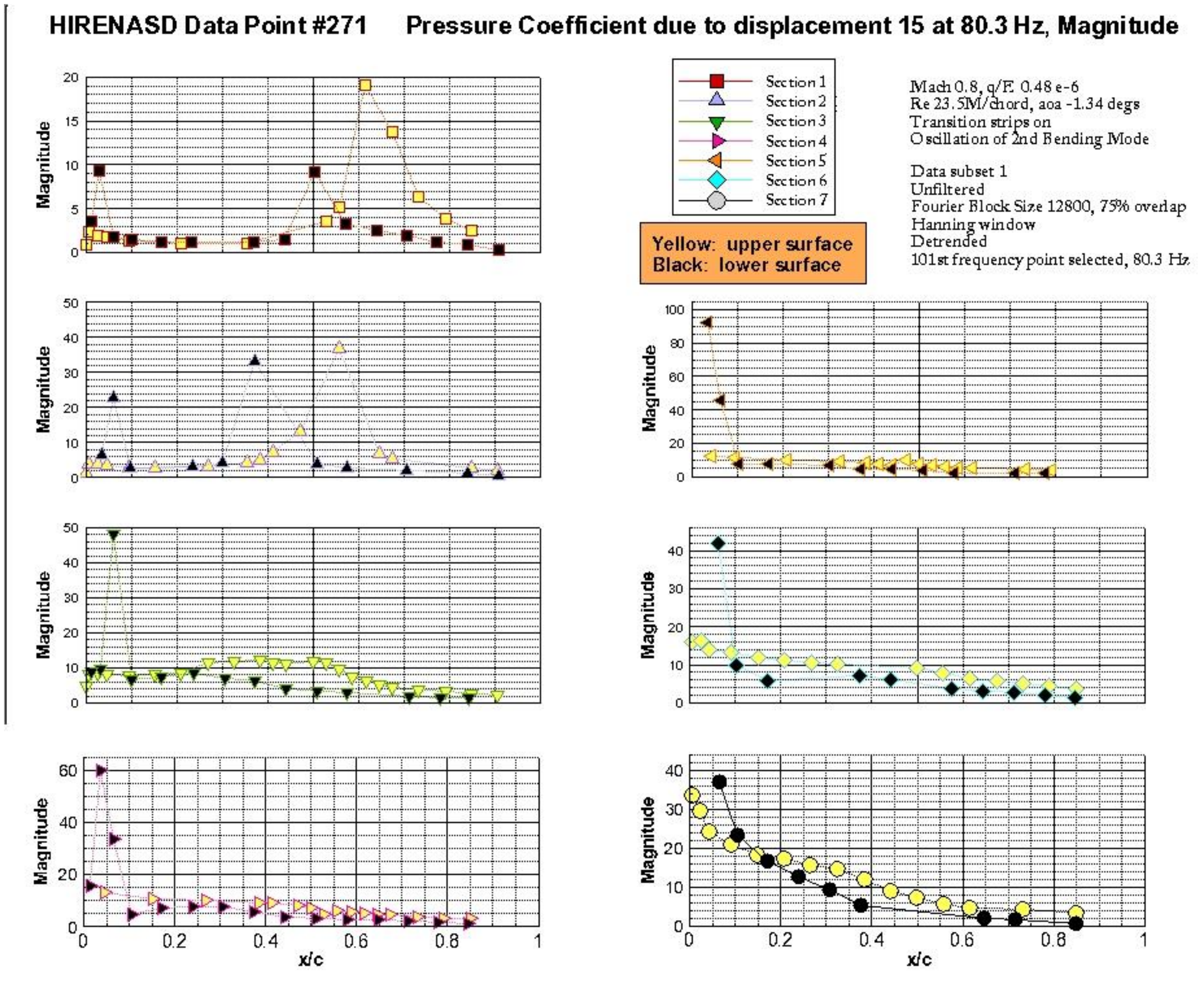
Experimental comparison data: **Static** pressures (M 0.7, Re 7M) Comparison of Polar Data Results and Dynamic Data Results



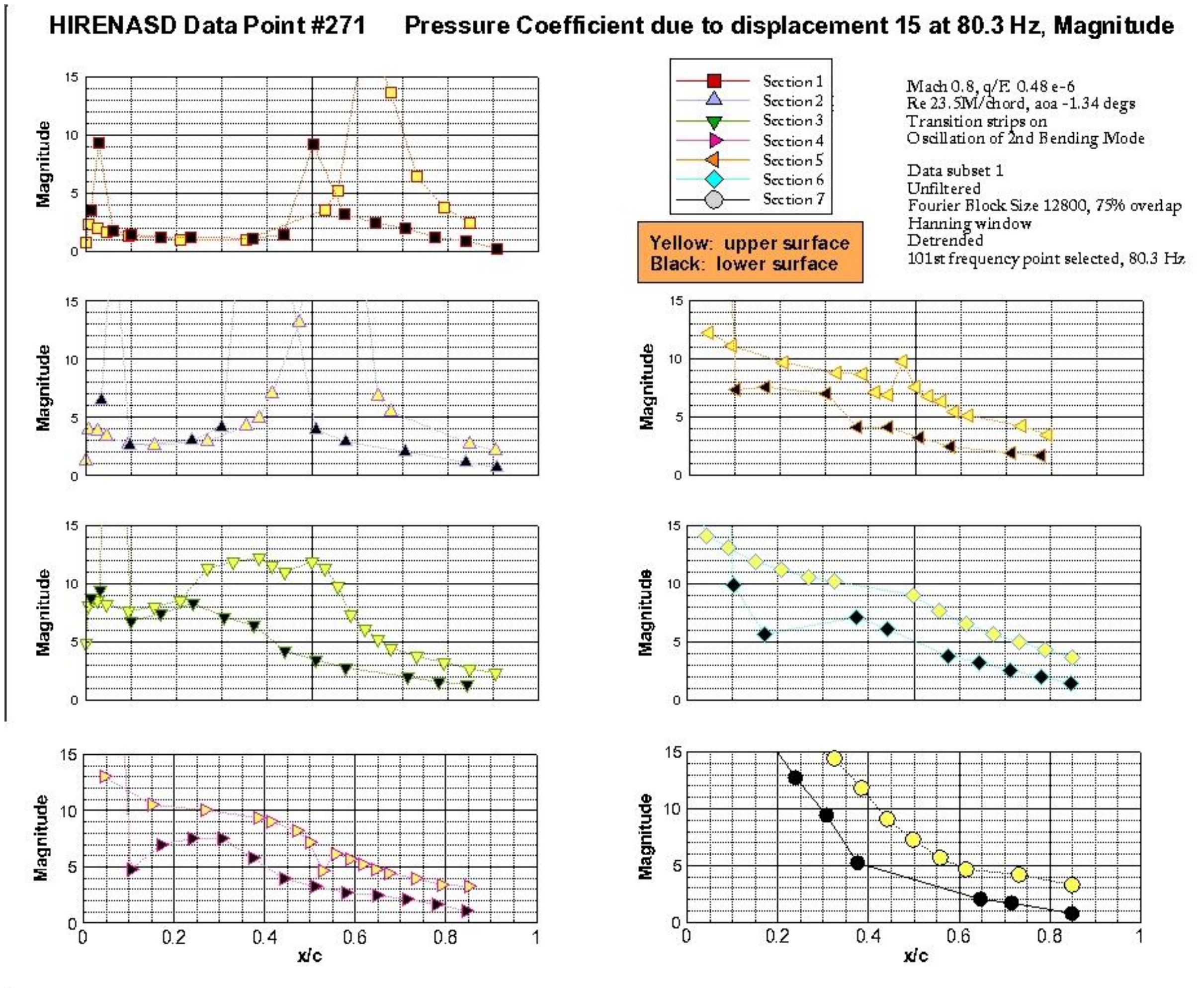
Experimental comparison data: Magnitude of Forced Oscillation Data (M 0.8, Re 7M)



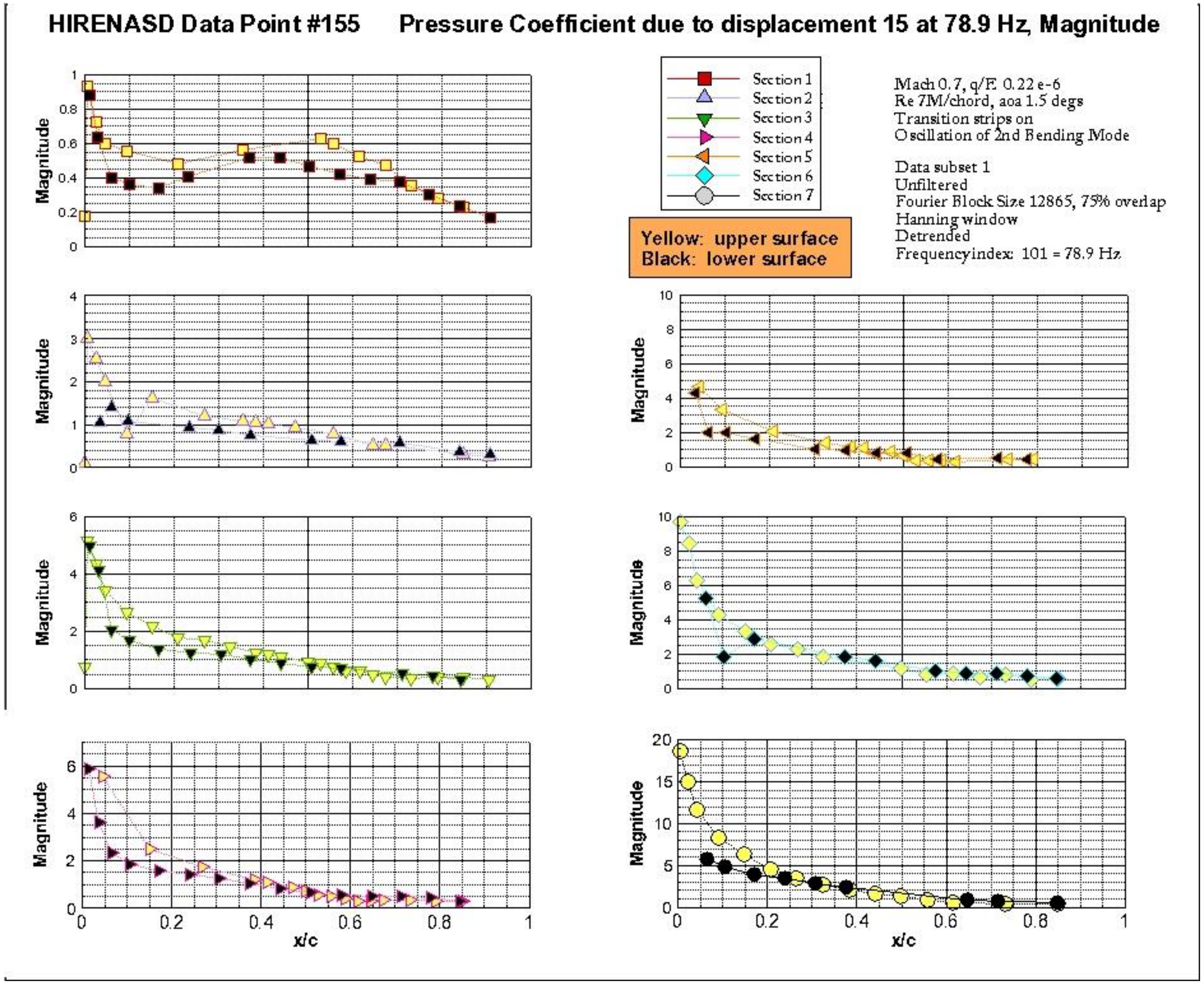
Experimental comparison data: Magnitude of Forced Oscillation Data (M 0.8, Re 23.5M)



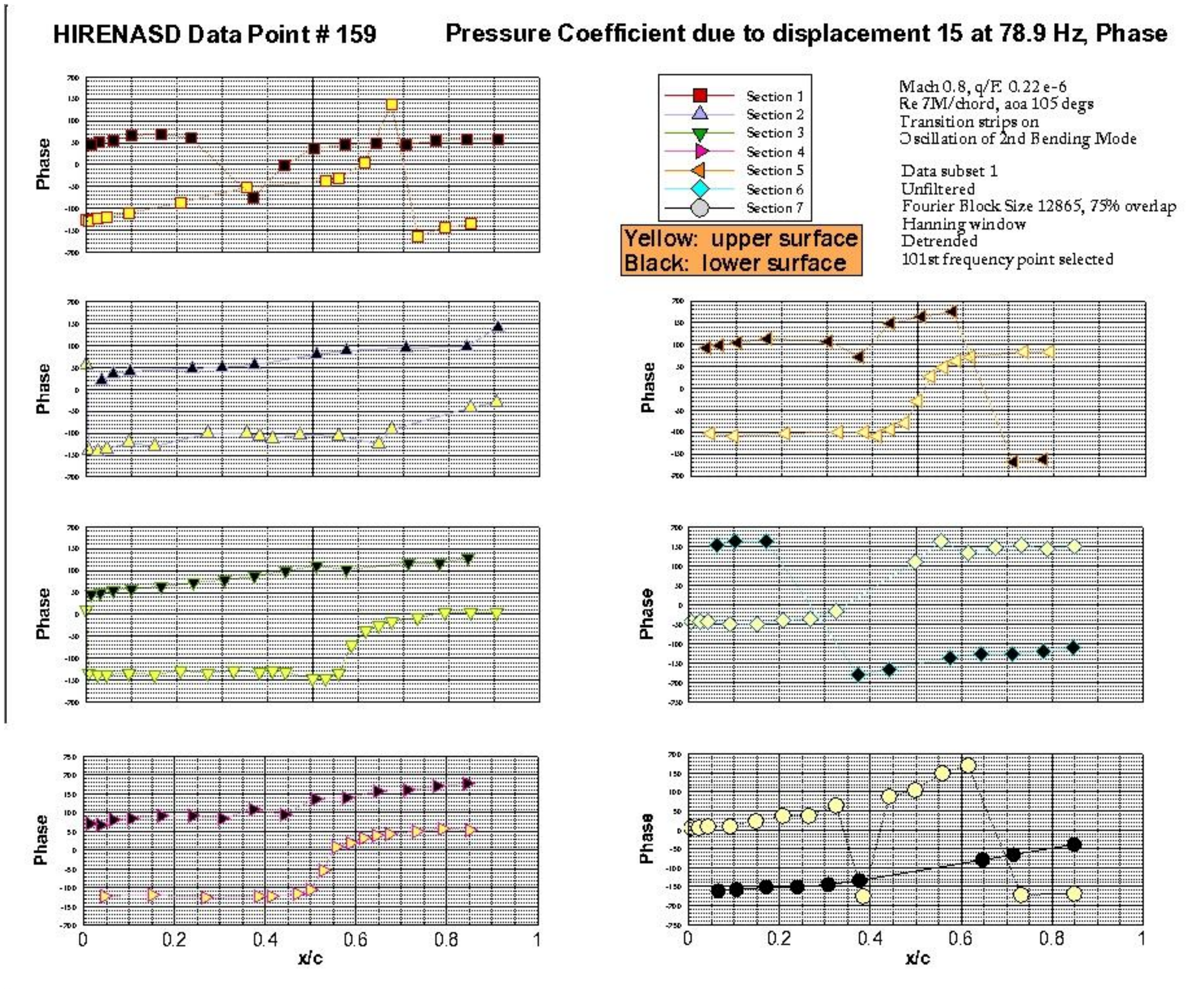
Experimental comparison data: Magnitude of Forced Oscillation Data (M 0.8, Re 23.5M) **RESCALED PLOT**



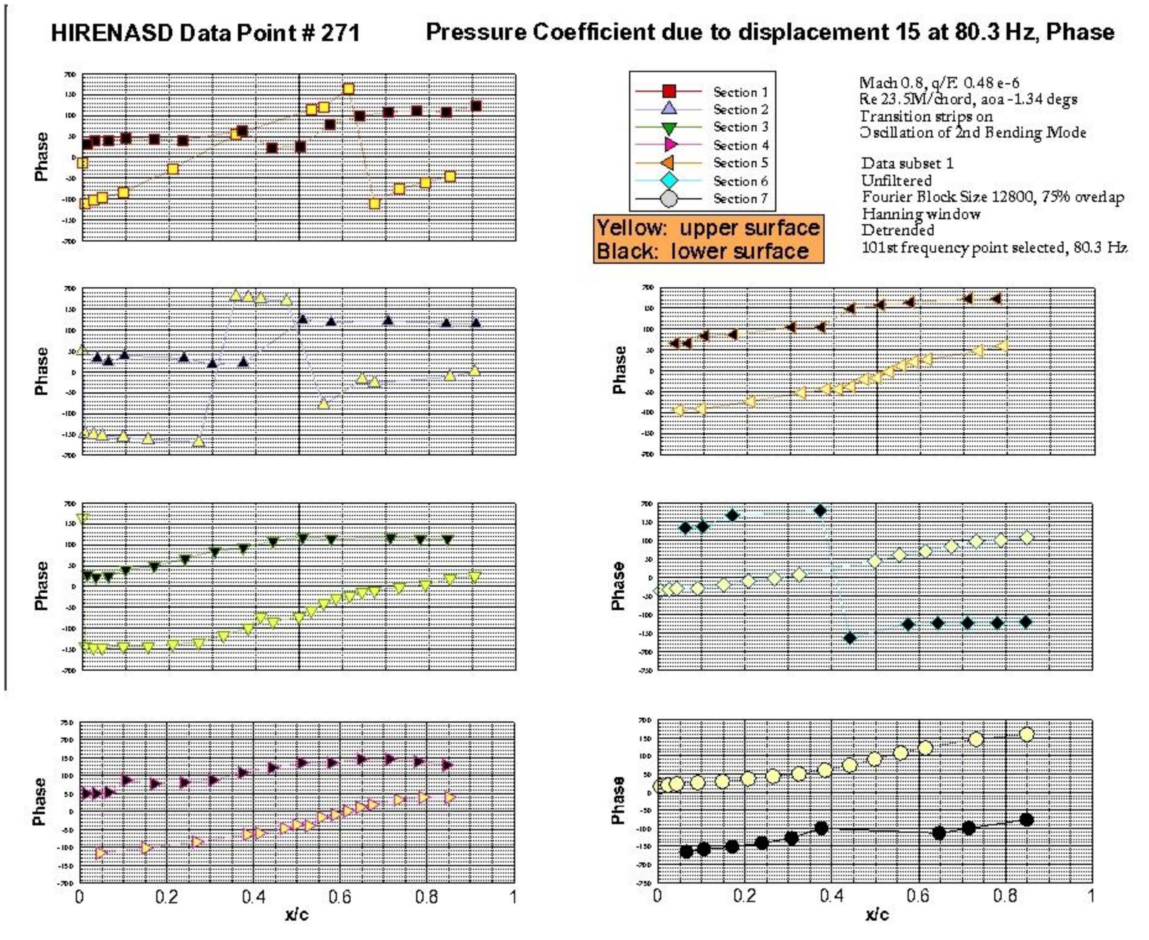
Experimental comparison data: Magnitude of Forced Oscillation Data (M 0.7, Re 7M)



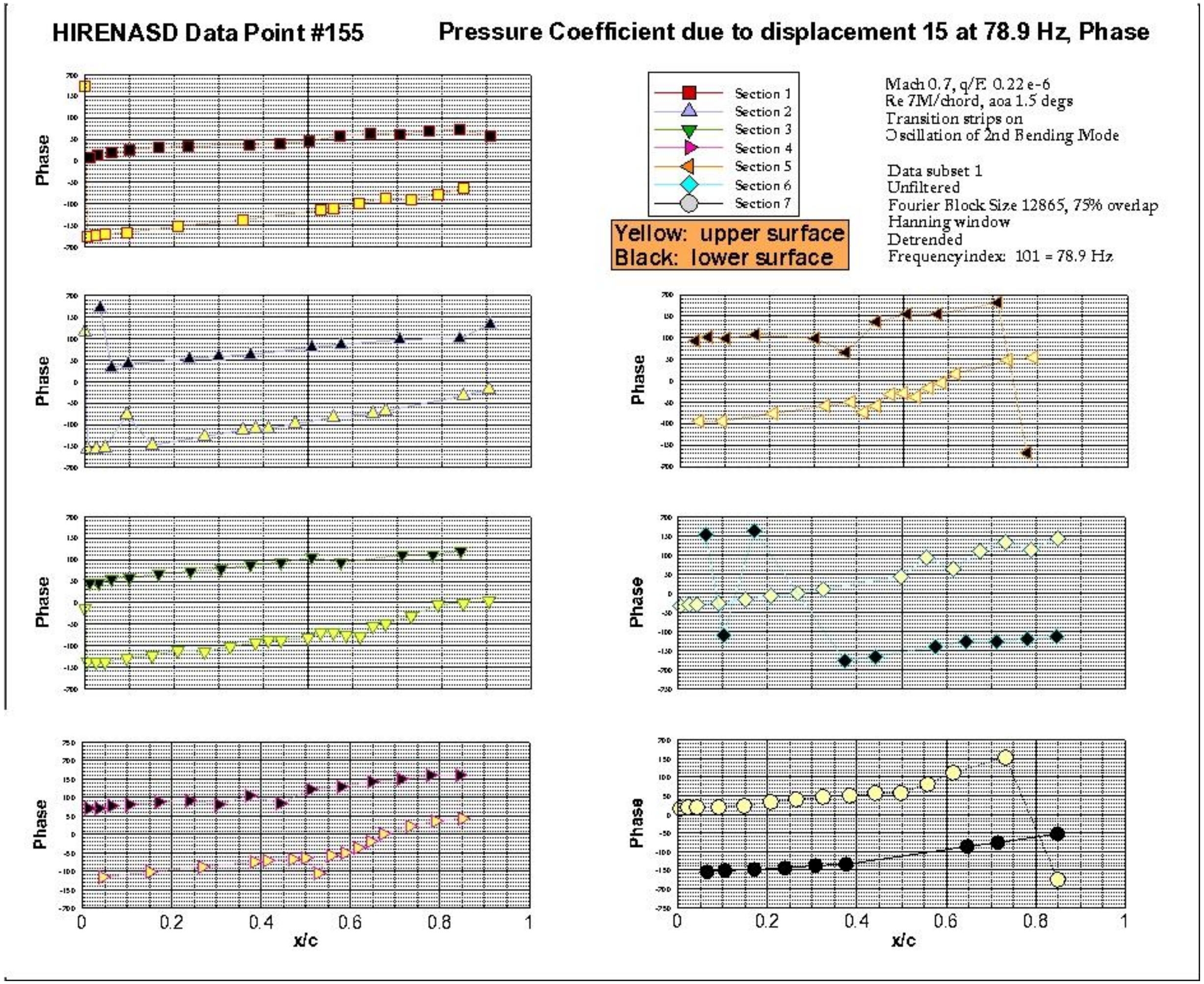
Experimental comparison data: Phase of Forced Oscillation Data (M 0.8, Re 7M)



Experimental comparison data: Phase of Forced Oscillation Data (M 0.8, Re 23.5M)



Experimental comparison data: Phase of Forced Oscillation Data (M 0.7, Re 7M)



Dynamic Analysis Details

- To extract the information at a frequency close to the excitation frequency, the following method was used to determine the Fourier block size and the index for extracting the information
- f* = (j-1)/(nfft*dt), where
  - f* is the excitation frequency
  - j is the index of the frequency to be chosen from the vector of computed frequencies
  - nfft is the analysis block size
- nfft = (j-1)/(f* x dt)

Dynamic Processing details

- Pt 155: use the 101^{st} frequency index
  - nfft = (101-1)/(78.9 Hz * 9.8518e-5 sec) = **12865** samples
- Pt 159: use the 101^{st} frequency index
  - Nfft= (101-1)/(78.9 Hz * 9.90177e-5 sec) = **12800** samples
- Pt 271:
  - Nfft = (101-1) / (80.3 * 9.72914e-5 sec) = **12800** samples

Dynamic Data process files

- Proc_t155_subset1_Nov2011.m
- Proc_t159_subset1_Nov2011.m
- Proc_T271_subset1_Nov2011.m

- Follow each by running: write_tecplot_DynamicData.m
- Move the tecplot file from directory C:\Matlab2008a\bin\Benchmarking\tec to C:\Matlab2008a\bin\Benchmarking\POSTEDtoWEB