Implementation and Validation of Aeroelastic Functionality during Wing Design

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Sep 11th-Sep 13th , Moscow

1.Background

2. Aeroelastic method

3. HIRENASD

4. Conclusion

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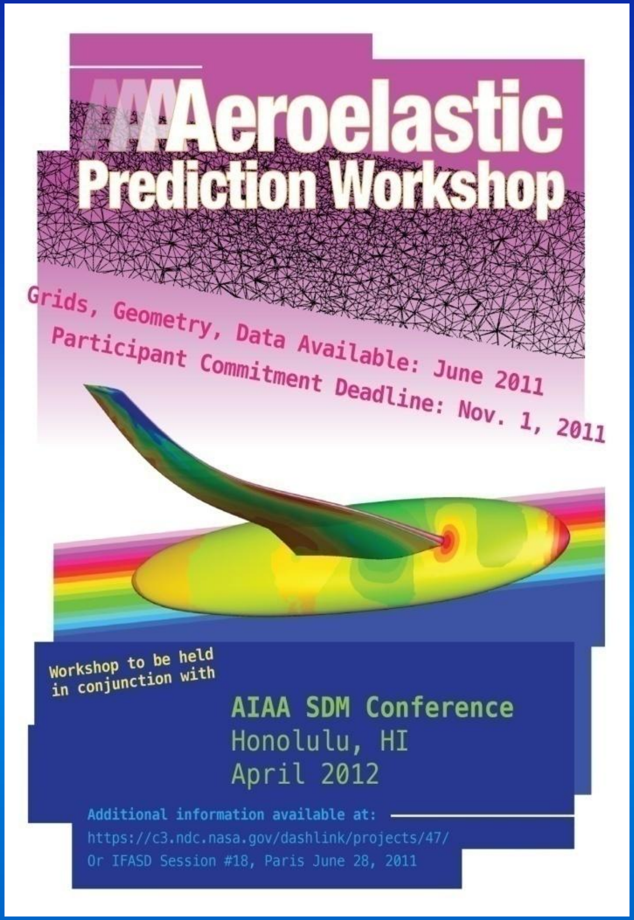
Background

AePW(Aeroelastic Prediction Workshop)

Website https://c3.ndc.nasa.gov/dashlink/projects/47/

- ✈Rectangular Supercritical Wing
- ✈Benchmark Supercritical Wing
- ✈**HIRENASD Wing**



Background

AePW(Aeroelastic Prediction Workshop)

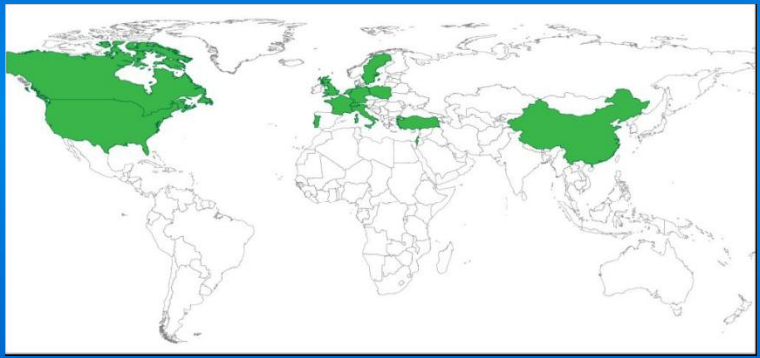
- 16 analysis teams providing data for workshop

Industry	University	Government
5	6	5

- 25 total analyses committed for workshop

RSW	BSCW	HIRENASD
6	6	13

- 9 nations represented



from Mar 10th, 2011.

updated April 16th, 2012.

Background

HIRENASD **AePW-1(April 21th,2012 — April 22th,2012)**

—High Reynolds Number Aerostructural Dynamics

HIRENASD Talks

1. Daniel Steiling; RUAG
2. Bart Eussen; NLR
3. Dimitri Mavriplis; University of Wyoming
4. Markus Ritter; DLR
5. Thorsten Hansen; Ansys
6. Mats Dalenbring; FOI
7. Pawel Chwalowski; NASA Langley
8. Jean Pierre Grisval; ONERA

BREAK

1. Daniella Raveh, Technion University
2. Melike Nikbay/Z. Zhang, Istanbul TU/Zona
3. Sergio Ricci, Politecnico di Milano
4. Singh and Castro; CFD++/MSC Nastran
5. Alan Mueller/Sergey Zhelzov, CD Adapco
6. Larry Brase, Boeing

Background

AePW-1 Organizing Committee Roster

Organizing Committee Roster

Name	Affiliation
Bhatia, Kumar	Boeing Commercial Aircraft
Ballmann, Josef	Aachen University
Blades, Eric	ATA Engineering, Inc.
Boucke, Alexander	Aachen University
Chwalowski, Pawel	NASA
Dietz, Guido	European Transonic Windtunnel (ETW)
Dowell, Earl	Duke University
Florance, Jennifer	NASA
Hansen, Thorsten	ANSYS Germany GmbH
Heeg, Jennifer	NASA
Mani, Mori	Boeing Research & Technology
Mavriplis, Dimitri	University of Wyoming
Perry, Boyd	NASA
Ritter, Markus	Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Schuster, David	NASA
Smith, Marilyn	Georgia Institute of Technology
Taylor, Paul	Gulfstream Aerospace
Whiting, Brent	Boeing Research & Technology
Wieseman, Carol	NASA

Acknowledgments

Workshop sponsorship and organization

AIAA Structural Dynamics Technical Committee

AIAA Structural Dynamics Conference Team

Product managers

K.C Niedermeyr and Elizabeth Carter

Event planner Cathy Chenevey

NASA Engineering & Safety Center

Funding of NASA participation, geometry generation & workshop organization

NASA Subsonic Fixed Wing Program

HIRENASD Research Project

Aachen University

HIRENASD Project Funding

German Research Foundation (DFG)

Grid Generation

Ansys, ATA, Georgia Tech, Technion University, ISCFDC, NASA

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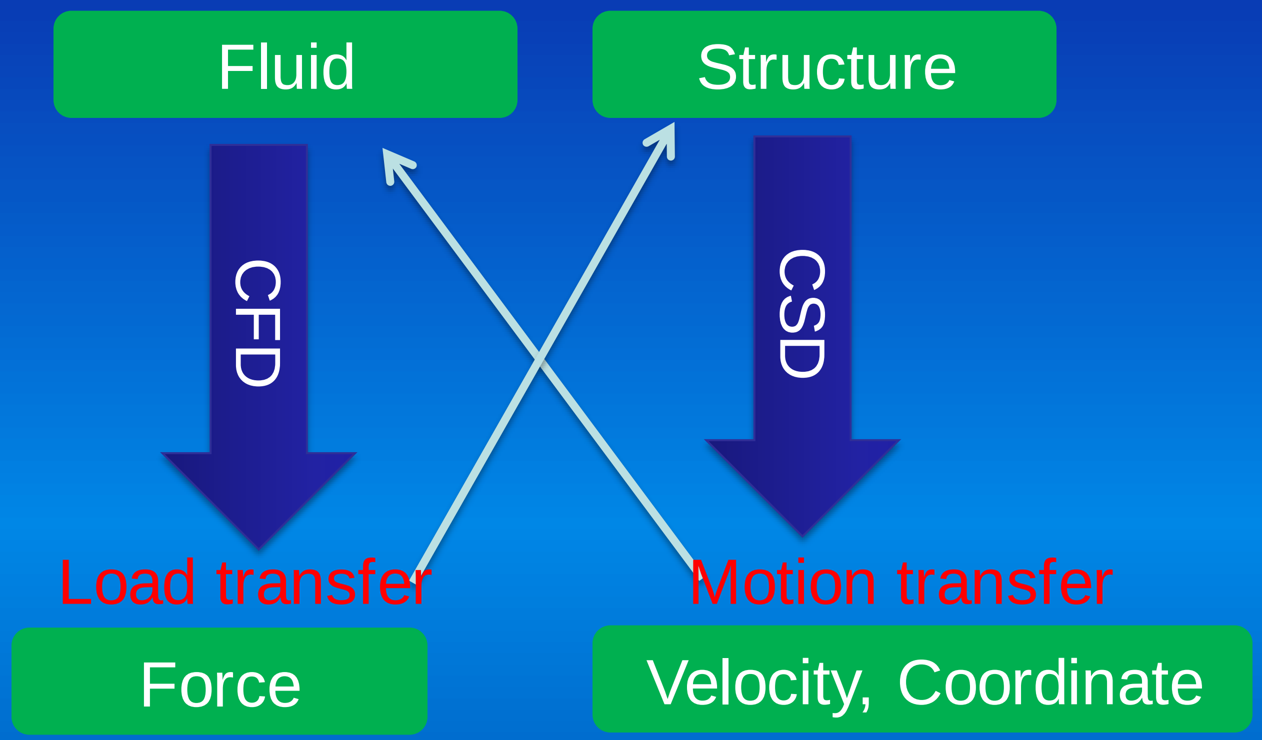
Aeroelastic method

CFD/CSD Coupling Method

AVICFD-X Solver（via an exchange of instantaneous load and displacement data）

- **Fluid**
- **Structure**
- **Coupling**
- **Moving grid**



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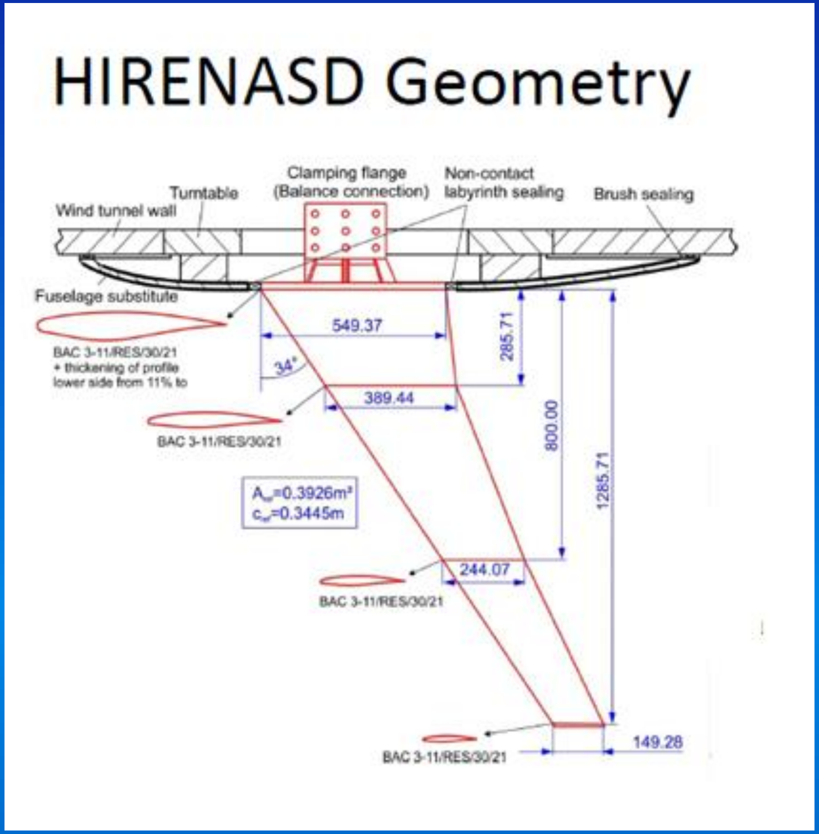
HIRENASD

3-D aeroelastic wing with generic fuselage model

Only excited at natural frequencies

- Grid
- Test Case
- Result



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)

Grid

- Node based
- Cell-centered

- Coarse
- Medium
- Fine

- ✓ VGRID
- ✓ Centaur

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	√	√	√	√	√	√	√	√	√	√	√	√	√	○	○	√	⊙	⊙

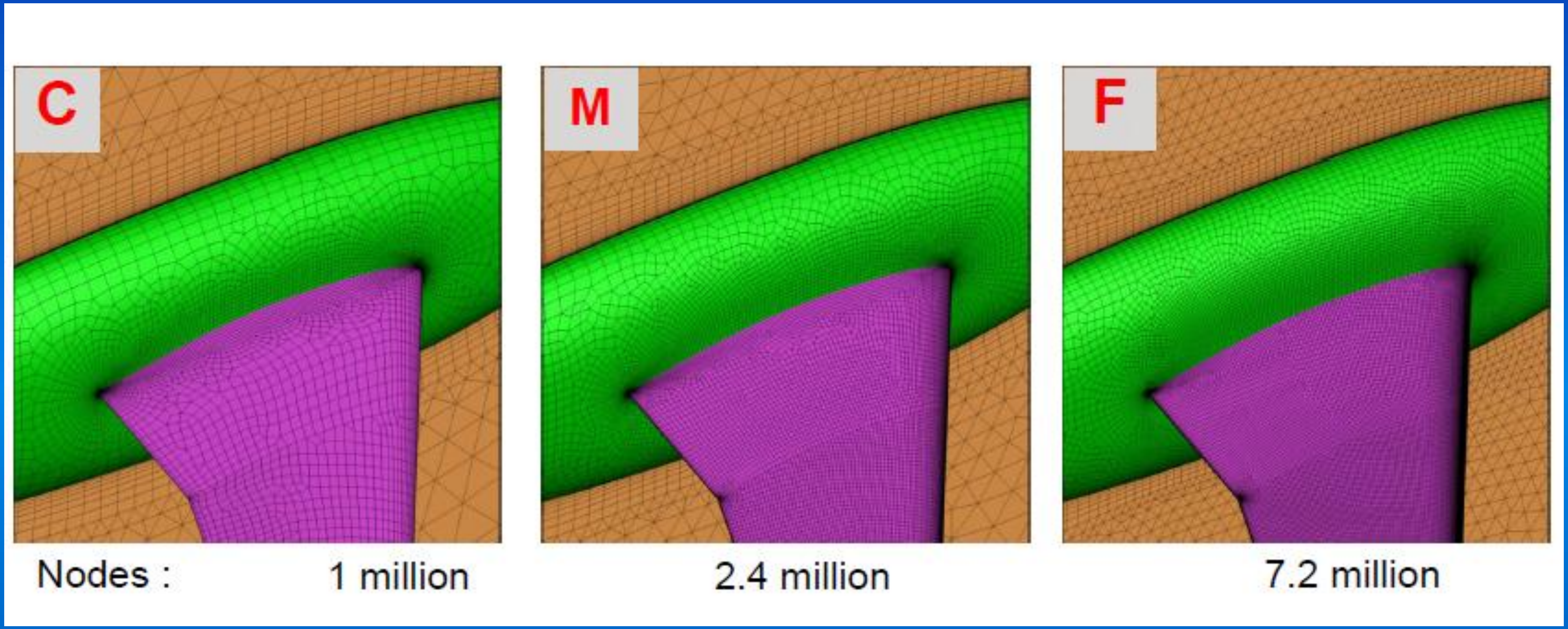
√ = Complete
⊙ = In process
○ = Desired

HIRENASD

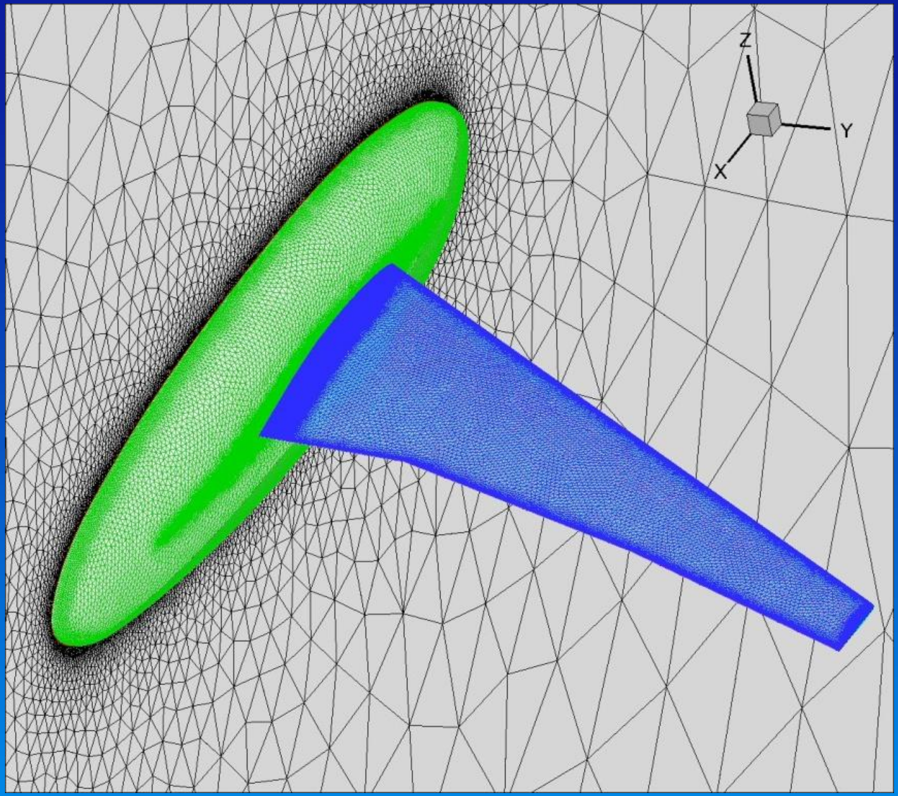
Grid

initial spacing normal to all walls (Re_c = 23.5M based on c_{ref} = 0.3445 m)

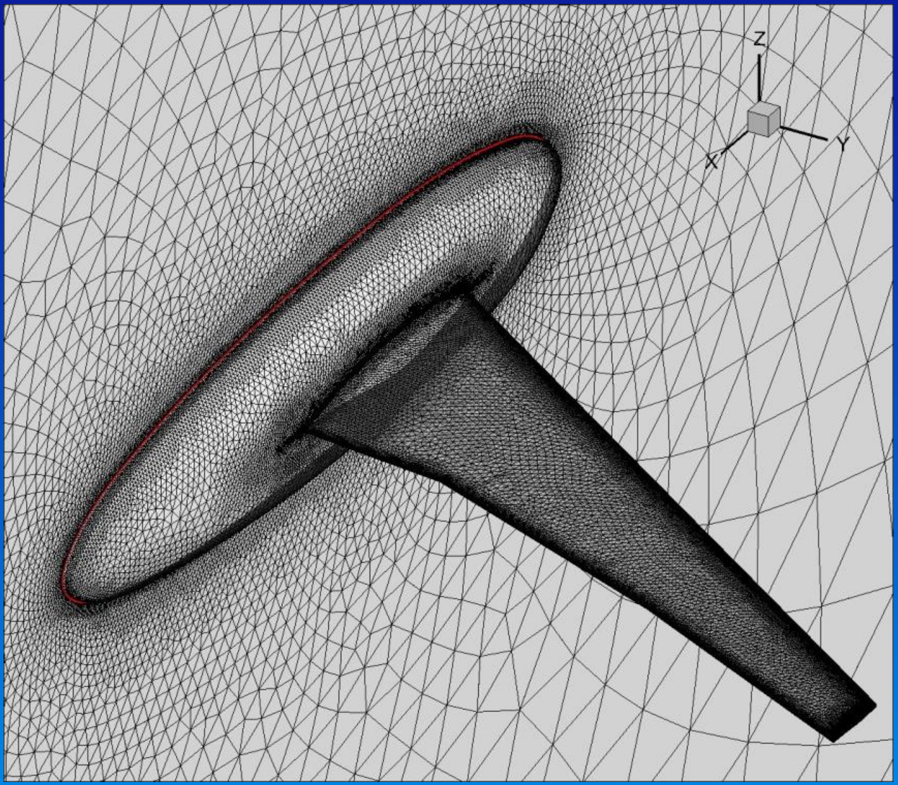
	Coarse	Medium	Fine
y^+	1.0	2/3	4/9
dy	4.40961e-7	2.93973e-7	1.95982e-7



Grid

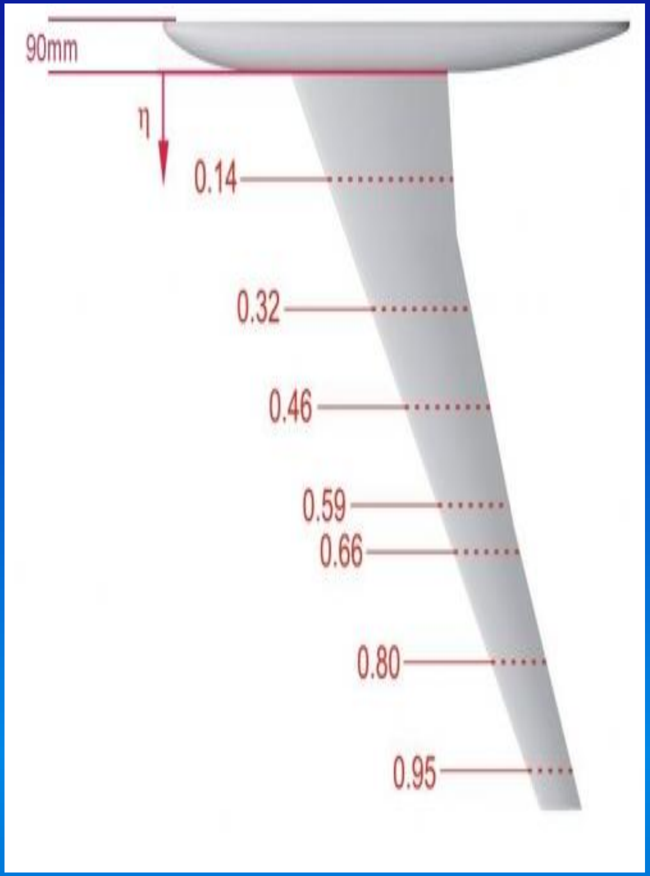


Centaur-Coarse



VGRID-Coarse

Test Case



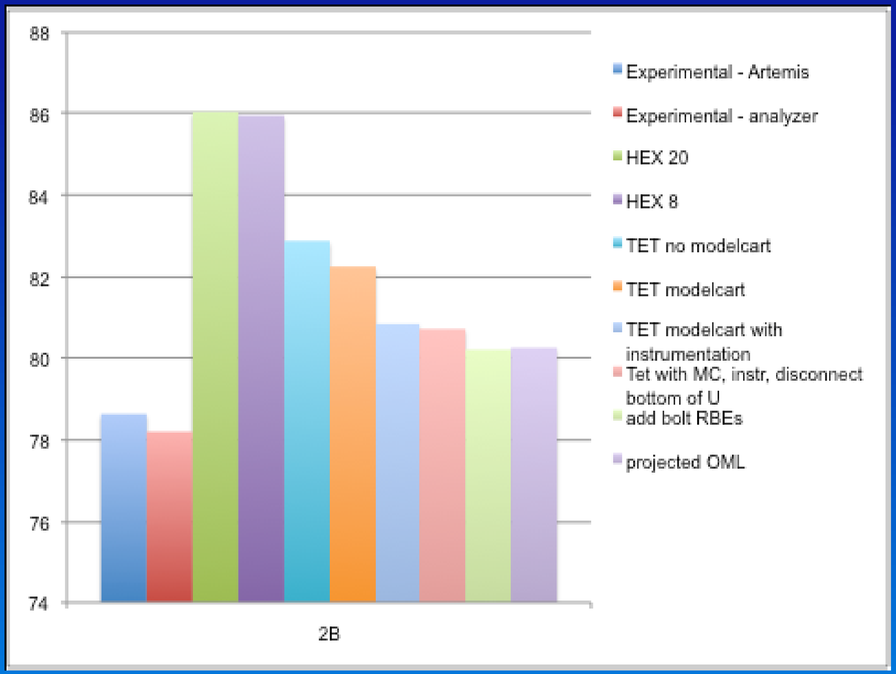
HIRENASD

Test Case

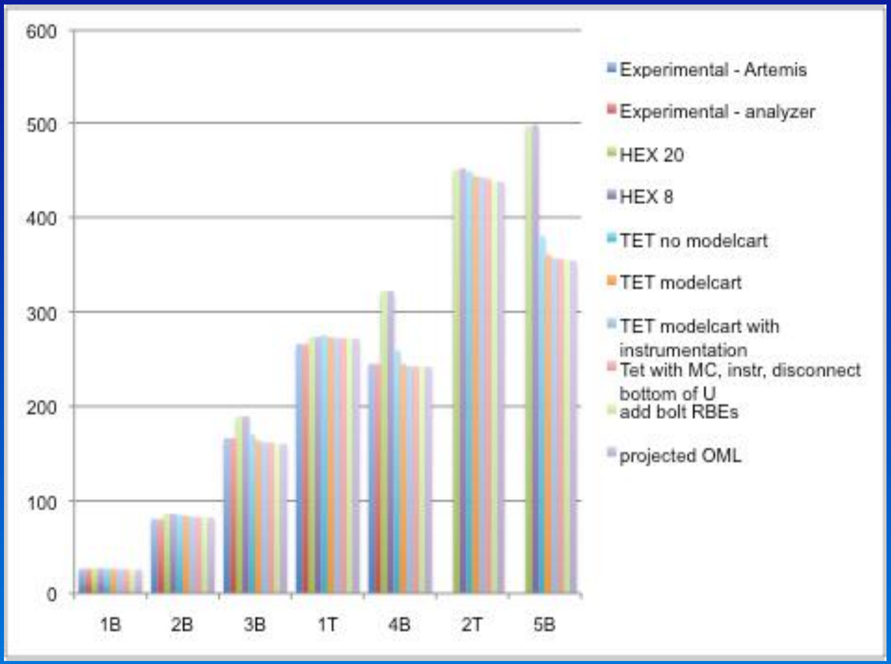
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
	Experimental - Artemis	Experimental - analyzer	HEX 20	HEX 8	TET no modelcart	TET modelcart	TET modelcart with instrumentation	Tet with MC, instr, disconnect bottom of U	add bolt RBEs	projected OML
1B	26.015	26.250	26.541	26.534	26.249	26.217	25.618	25.604	25.542	25.550
2B	78.635	78.203	86.019	85.932	82.881	82.257	80.812	80.688	80.199	80.245
1FA			156.938	157.237	117.465	110.904	108.626	106.998	106.242	106.193
3B	166.250	166.250	189.311	189.434	170.083	163.745	161.770	161.441	160.381	160.349
4B	245.002	245.000	321.774	321.985	259.317	244.899	242.520	242.364	241.942	241.995
1T	265.855	265.781	272.859	273.443	275.120	273.055	272.295	272.182	271.718	271.844
2T			450.506	451.811	448.517	443.496	442.291	441.178	437.122	437.830
5B			496.680	497.795	380.224	360.338	356.863	356.332	354.341	354.155
2FA			422.976	423.259	280.260	256.158	252.790	252.651	252.361	252.225
3T			622.407	625.227						569.737
3FA					499.387	454.750	450.171	446.396	444.318	443.805
6B										497.802
3T										569.737
7TB										643.234

HIRENASD

Test Case



Comparison of 2B frequencies



Comparison of Modal frequencies

The first 2 columns show the experimental data; the last column shows the current finite element model frequency

Test Case

Amplitude of excitations for 2nd bending modes for each of the 3 unsteady cases are extracted from the experimental data

	Case1	Case2	Case3
EXP Test Points	159	271	155
Mach	0.8	0.8	0.7
Re	7M	23.5M	7M
Attack angle	1.5	-1.34	1.5
Amplitude (mm)	2.4	0.90	2.0
Excitation Frequency(Hz)	78.9	80.4	79.3

Test Case

AePW Analysis Parameters

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

Computational Method

AVICFD-X

Dual time step

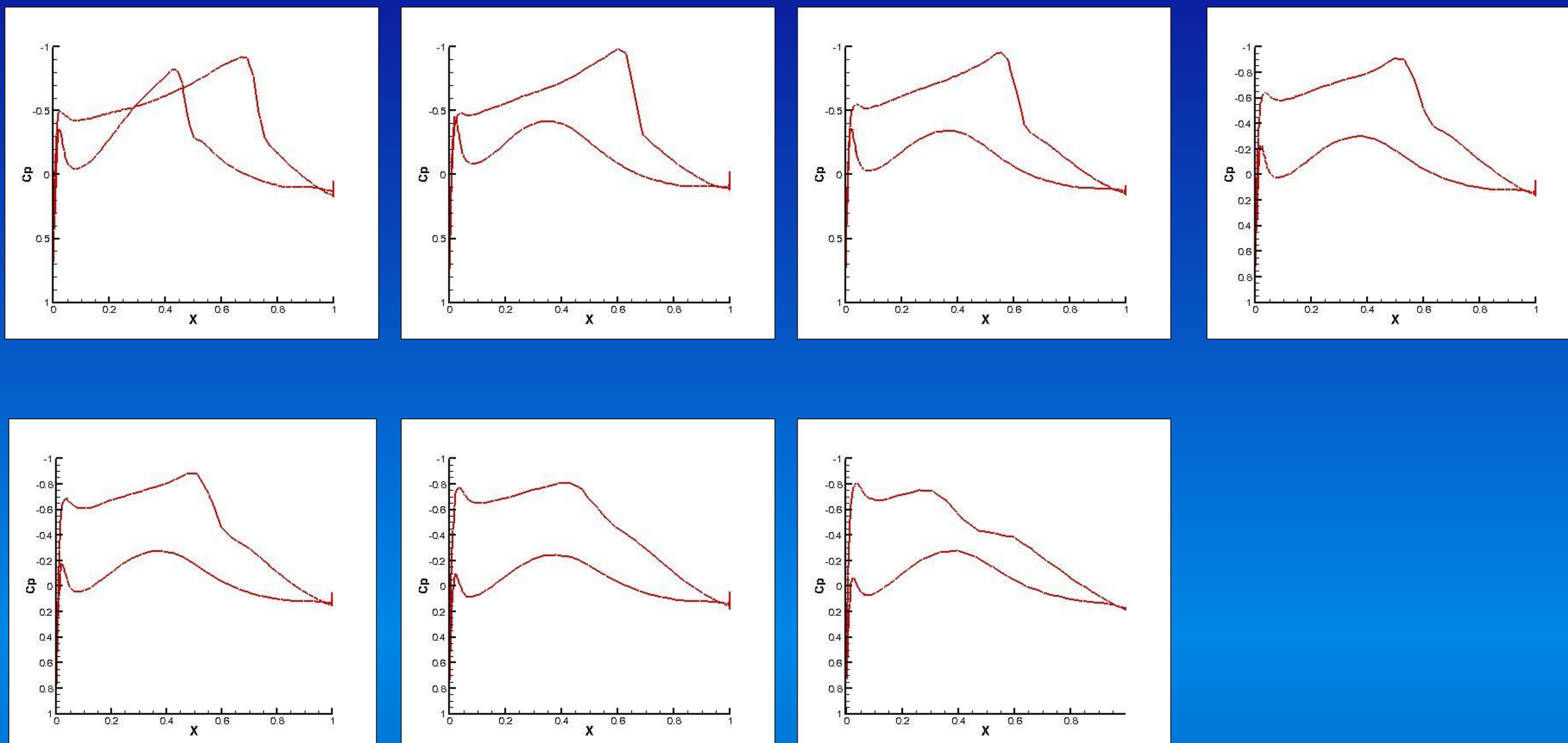
Δt=0.0001980355s, Frequency=78.9Hz 64 steps/T

RANS

Spalart-Allmaras one-eq model

HIRENASD

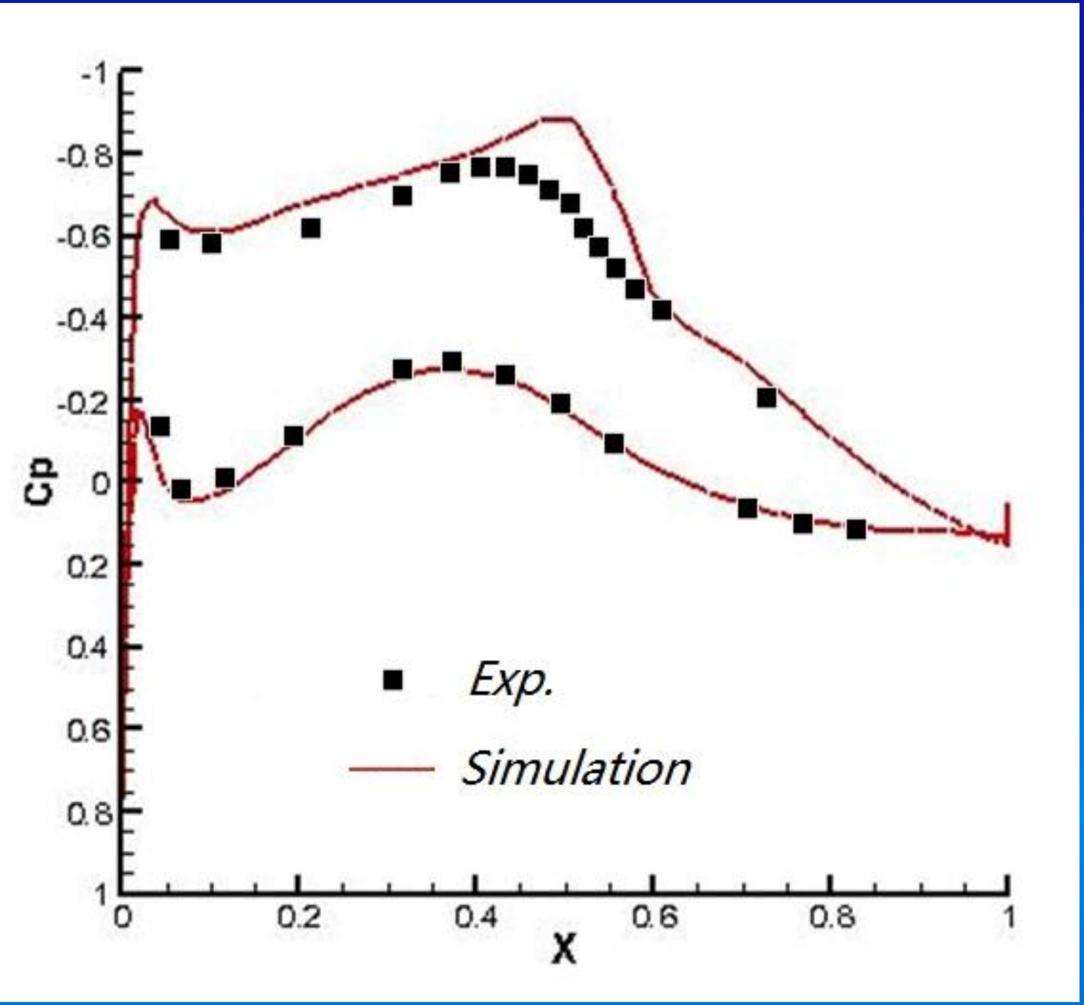
Pressure Coefficient (Case1)



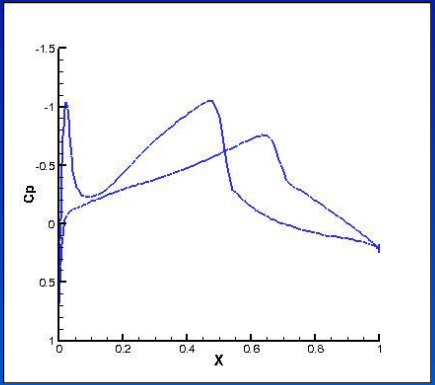
HIRENASD

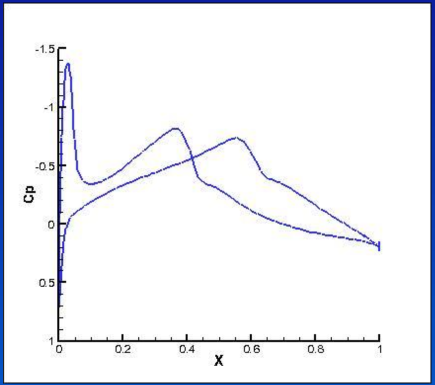
Pressure Coefficient (Case1)

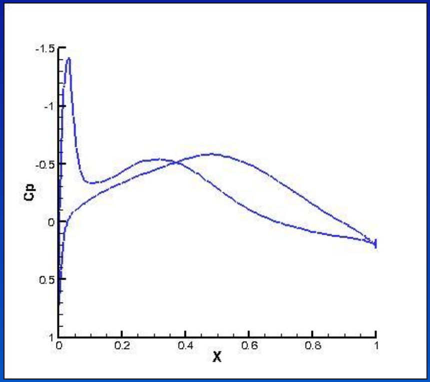
Eta=0.66

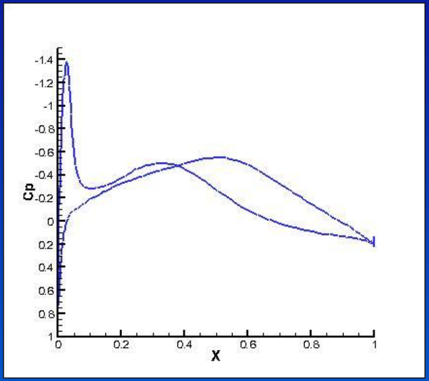


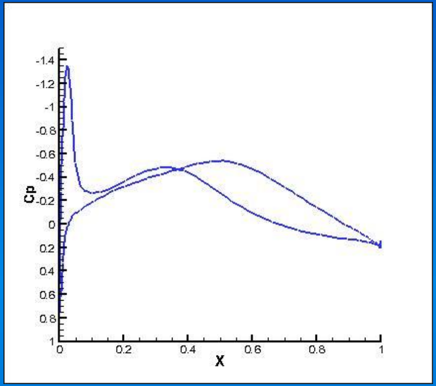
Pressure Coefficient (Case2)

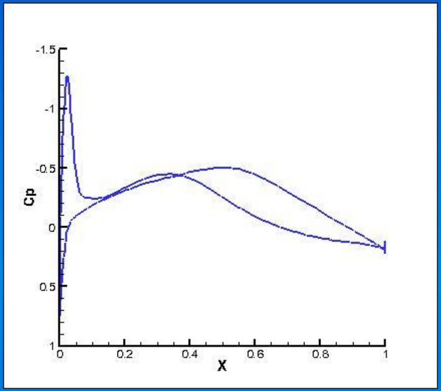


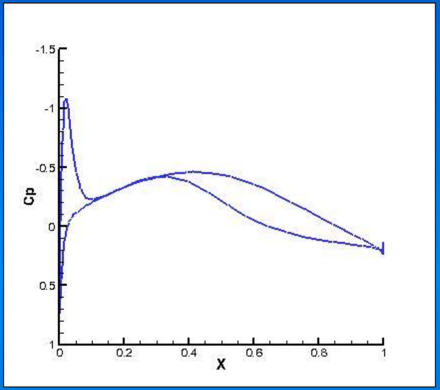




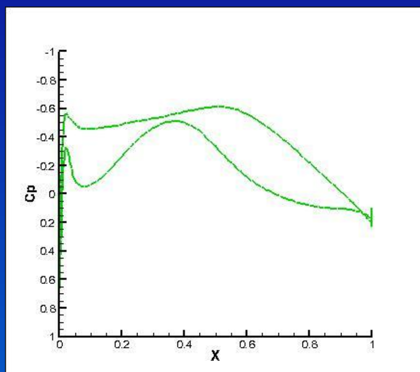


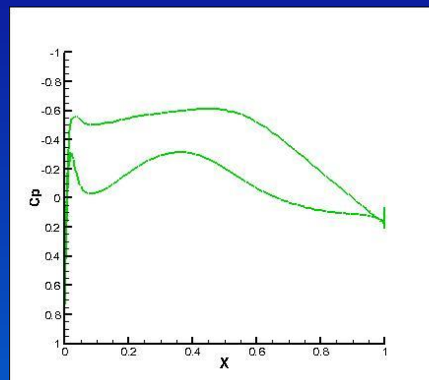


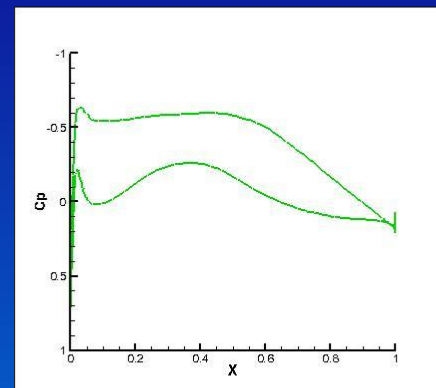


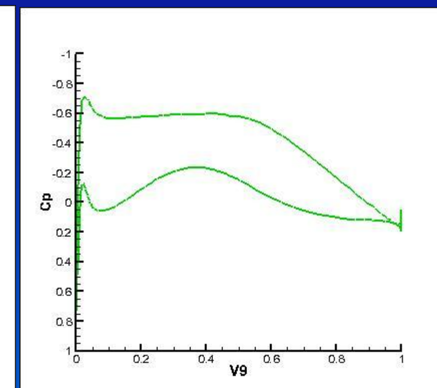


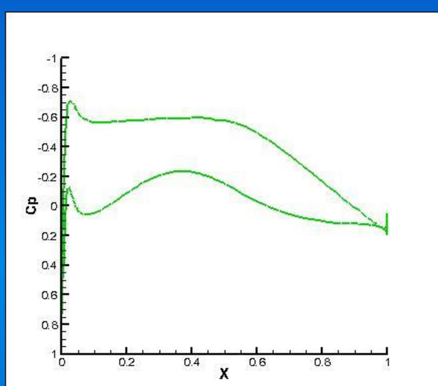
Pressure Coefficient (Case3)

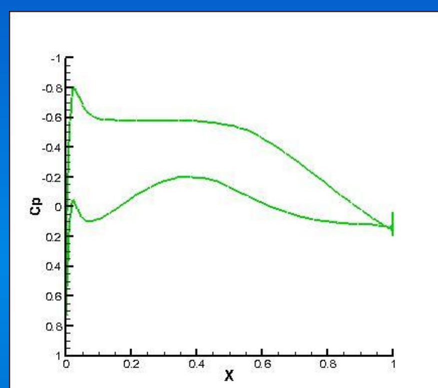


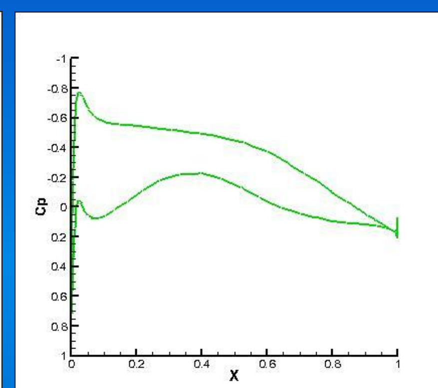






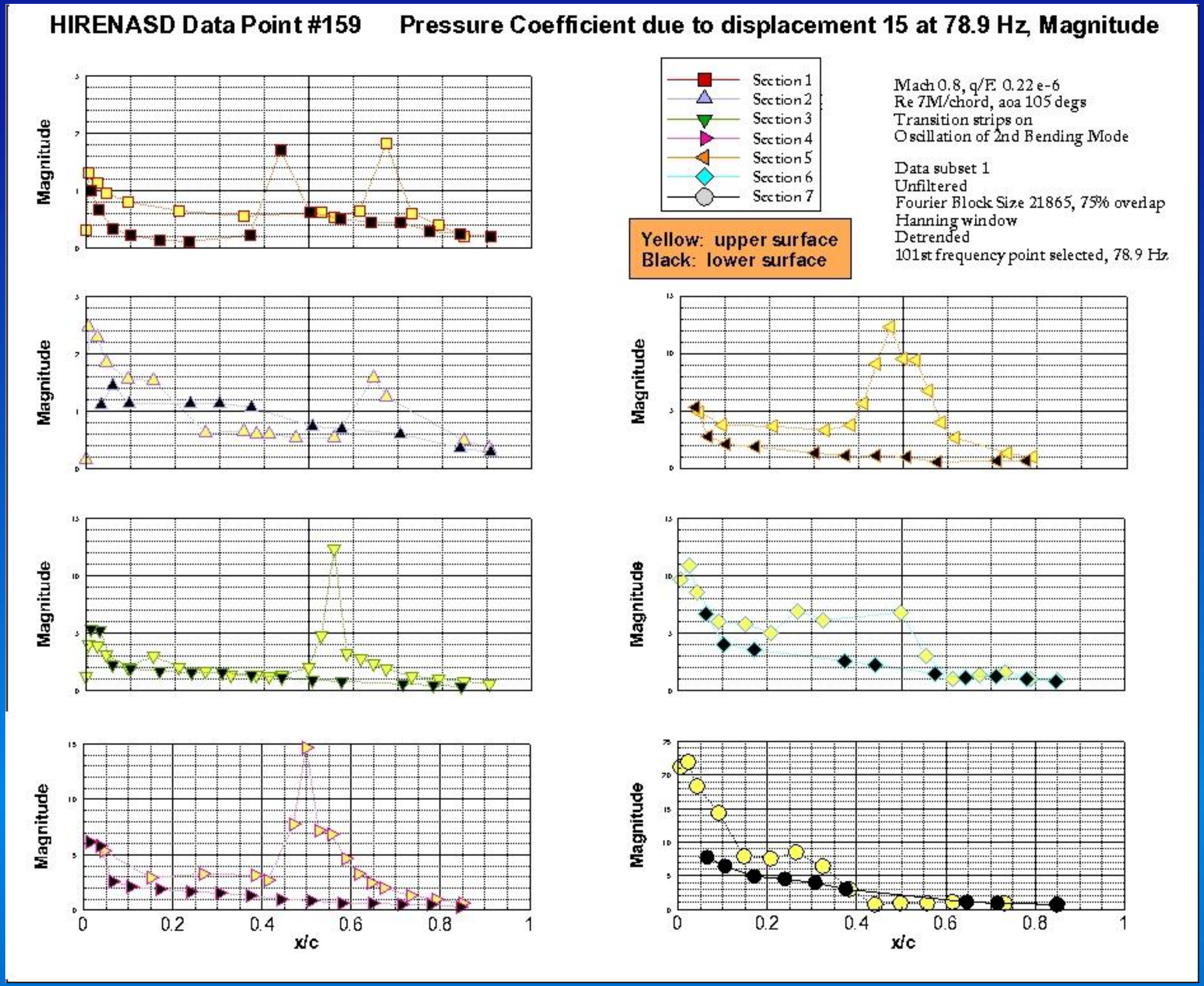






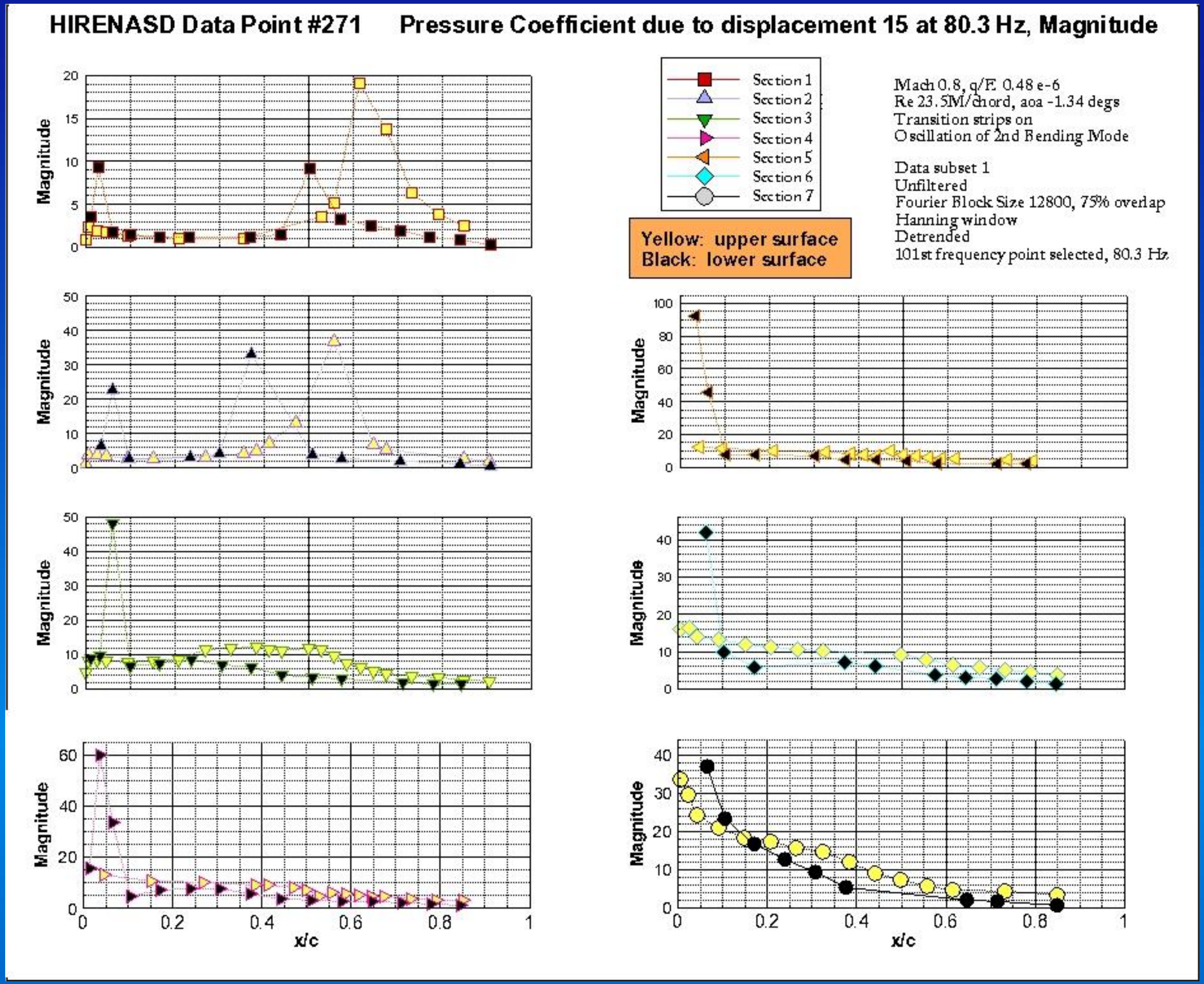
HIRENASD

Pressure Coefficient (Case1) (to be continued)



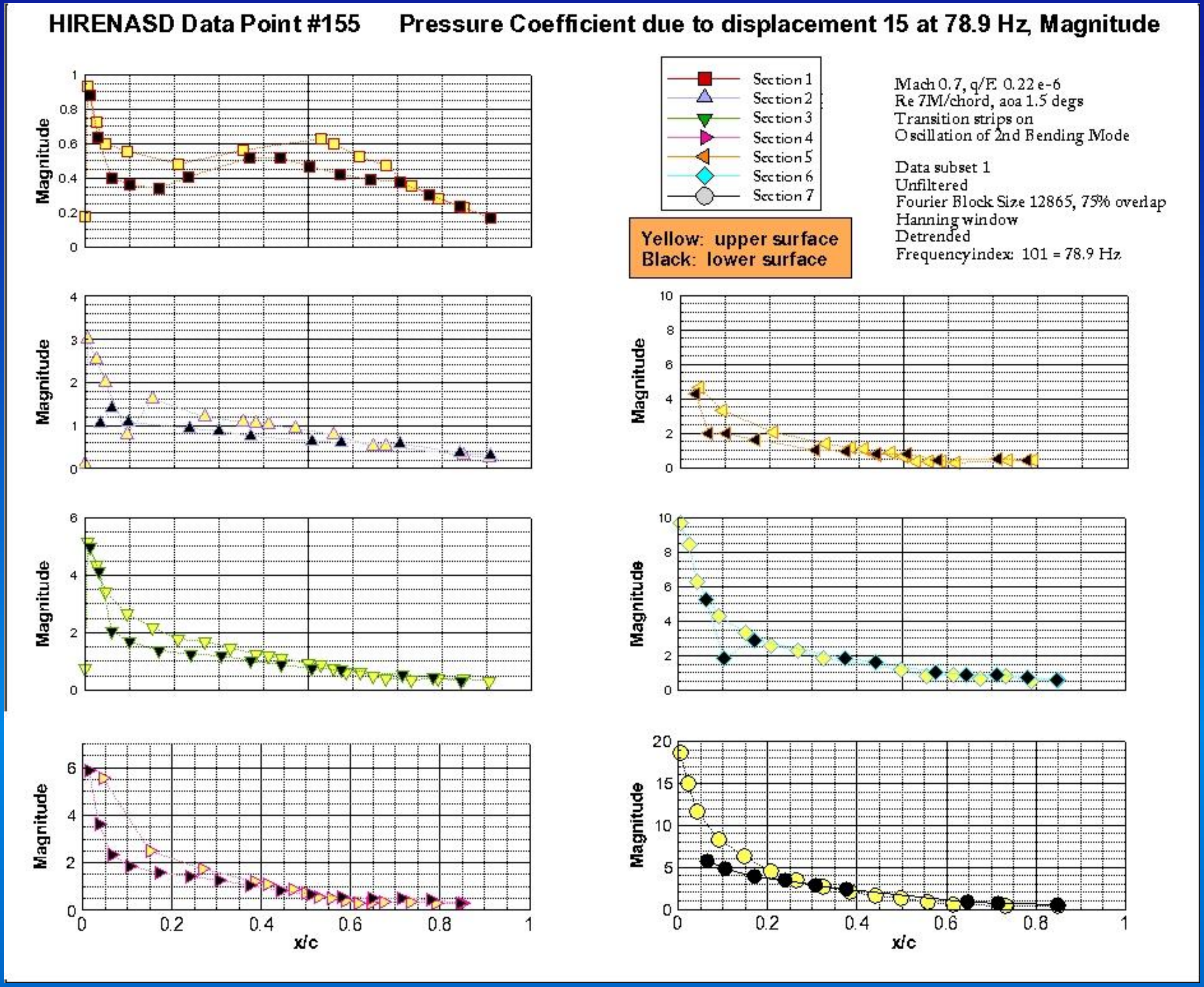
HIRENASD

Pressure Coefficient (Case2) (to be continued)



HIRENASD

Pressure Coefficient (Case3) (to be continued)



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Conclusion

Results of the steady simulations agree with experimental data

More work should be done in the future

- Mesh quality will be improved to reach more accurate results
- More cases at different Mach number should be tested
- The unsteady aeroelastic analyses of HIRENASD wing should be performed in the future

THANKS