



Progress on Transonic Flutter and Shock Buffet Computations in Support of the Third Aeroelastic Prediction Workshop

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AIAA SciTech Forum
3 – 7 January 2022
San Diego, CA & Online

Aeroelastic Prediction Workshop Series

(a building block approach to incremental validation of computational aeroelastic software)



AePW-1, 2012

The challenge selected for the first AePW was the accurate prediction of unsteady aerodynamic phenomena on essentially rigid, geometrically simple models, with an additional foray into systems with weak coupling between the fluid and the structure.

- **Forced-pitch oscillations**
- **Static aeroelastic with harmonic modal excitation**

Heeg, et al., "Overview and Lessons Learned from the Aeroelastic Prediction Workshop," AIAA Paper 2013-1798
Chwalowski, et al., "FUN3D Analyses in Support of the First Aeroelastic Prediction Workshop," AIAA Paper 2013-785

AePW-2, 2016

The AePW-1 challenge was expanded to BSCW flutter boundary prediction at two conditions: **Mach 0.74, AoA = 0°** with experimental data available and considered to be an easy case, and **Mach 0.85, AoA = 5°**, no experimental data, 'blind' case and considered to be more difficult.

- **Forced-pitch oscillations**
- **Unforced, rigid wing**
- **Flutter Predictions**

Heeg, et al., "Data Comparisons and Summary of the Second Aeroelastic Prediction Workshop," AIAA Paper 2016-3121
Chwalowski, et al., "FUN3D Analyses in Support of the Second Aeroelastic Prediction Workshop," AIAA Paper 2016-3122

Aeroelastic Prediction Workshop Series

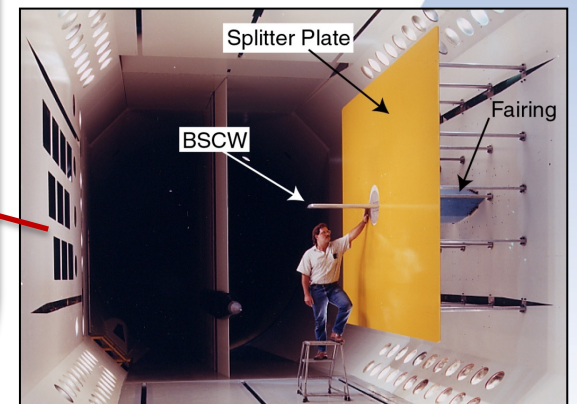
(a building block approach to incremental validation of computational aeroelastic software)



AePW-3, 2023

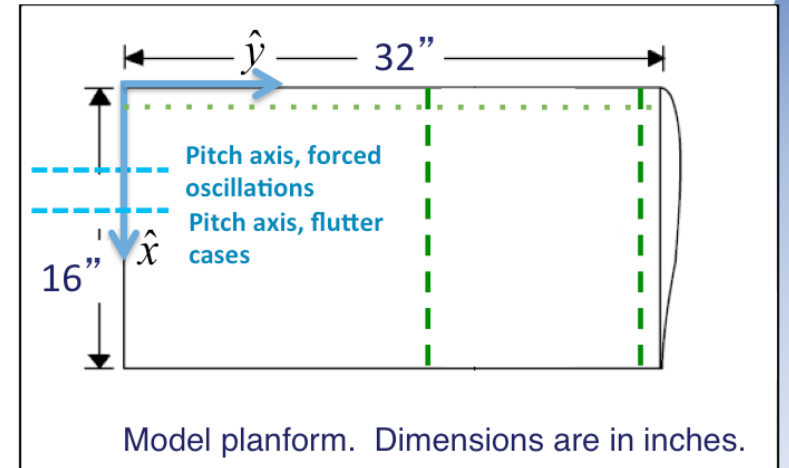
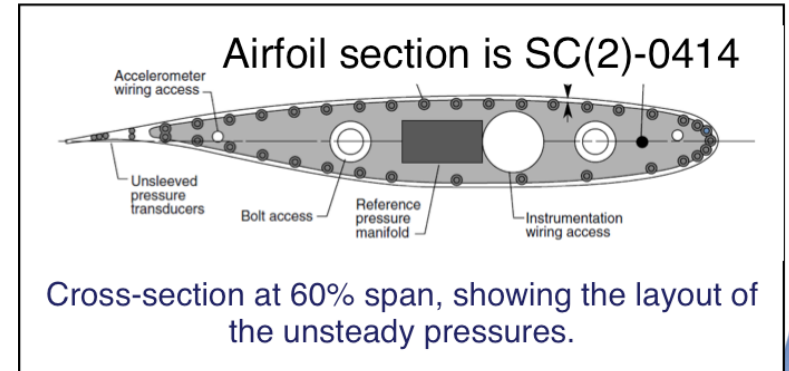
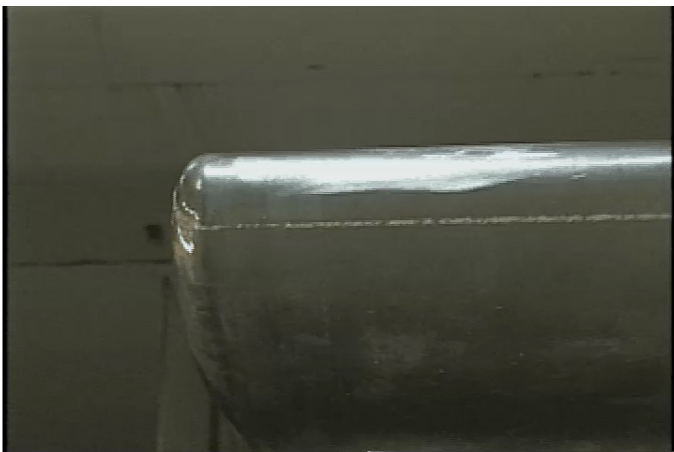
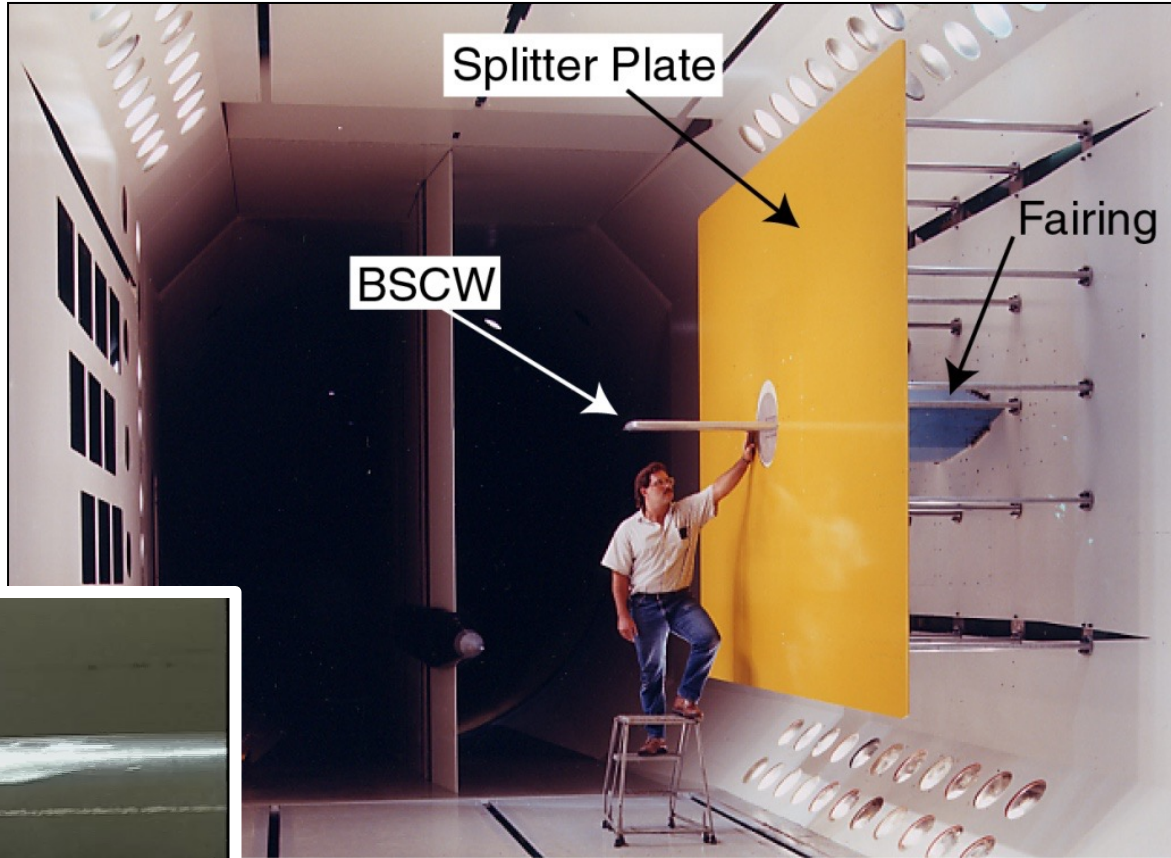
The computational aeroelasticity community decided to split into four working groups:

- **Large Deflection:** coupled aeroelastic problems associated with large deflections of a relatively flexible high-aspect wing subjected to low-speed aerodynamics (DLR)
- **Flight Test:** body freedom flutter analysis of NASA's experimental flight vehicle X-56A (NASA Armstrong)
- **High Speed:** fluid-structure-interaction analysis at supersonic to hypersonic speeds (ATA Engineering, AFRL, University of South Wales, Australia)
- **High Angle:** BSCW flutter analysis at Mach 0.8 and shock-buffet environment (NASA Langley – Aeroelasticity Branch)



High Angle Working Group:

BSCW flutter analysis at Mach 0.8 and shock-buffet environment



High Angle Working Group:

BSCW flutter analysis at Mach 0.8 and shock-buffet environment



Dansberry, B., et al., "Experimental Unsteady Pressures at Flutter on the Supercritical Wing Benchmark Model," AIAA Paper 93-1592-CP

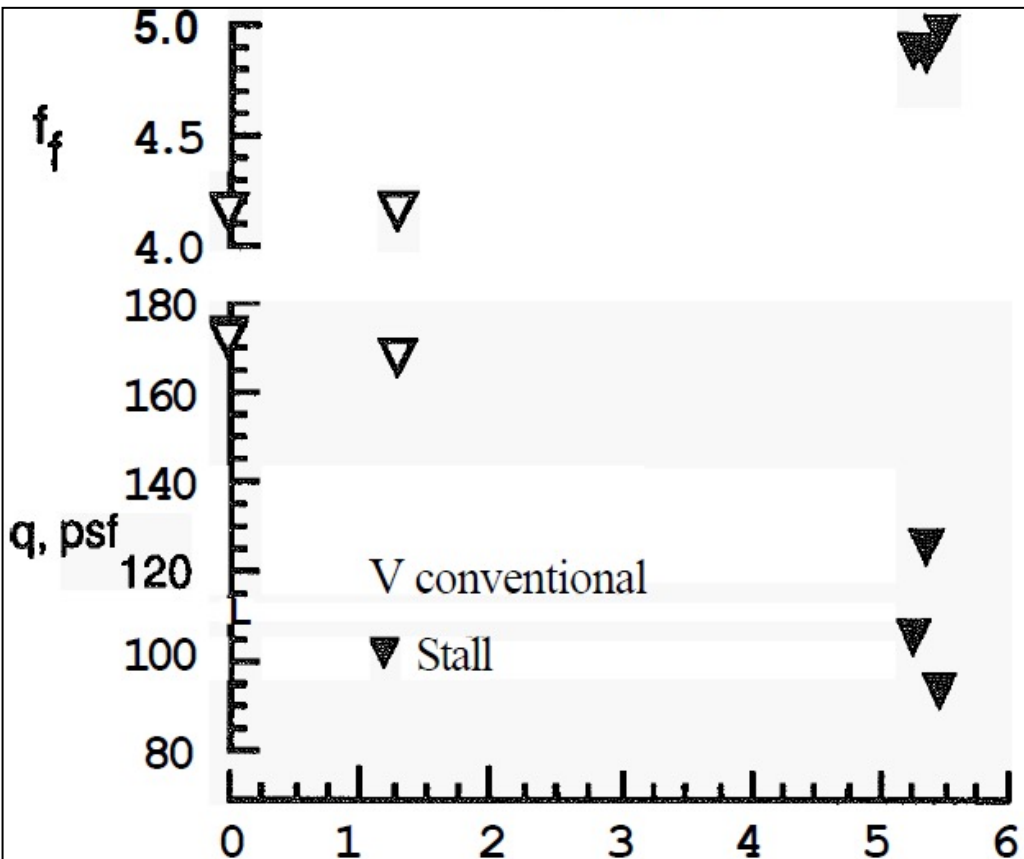


Figure 9. Stall flutter boundary in R-12 at $M = 0.80$.

Table 2. AePW-3 Workshop Test Cases.

	Case #1	Case #2
Mach	0.8	0.8
AoA	5°	5°
Dynamic Data Type	Flutter Unsteady	Unforced Unsteady
Notes	- Attached / Separated - PAPA exp. data - R-134a	- Shock buffet (?) - OTT exp. data - R-134a

High Angle Working Group: FUN3D BSCW flutter analysis at Mach 0.8



Time-Domain Analysis

- Unforced-wing **steady state** solution
- **Static aeroelastic solution:** coupled unsteady solution with large structural damping ratio value
- **Dynamic aeroelastic solution** (flutter): coupled unsteady solution with small structural damping value and initial '**kick**'
- Analysis are repeated at **many q values** to find stable and unstable wing response
- Matrix-pencil method is used to compute **damping values** from the modal response
- Dynamic pressure at '**zero**' **damping is flutter** dynamic pressure

<https://fun3d.larc.nasa.gov>

Kiviaho, et al., "Flutter Boundary Identification from Time-Domain Simulations Using the Matrix Pencil Method," <https://doi.org/10.2514/1.J058072>

Linearized Frequency Domain (LFD) w/Mesh Adaptation

- Unforced-wing **steady state** solution using FUN3D/SFE at a given AoA and BSCW mesh
- **LFD equations** are solved where aerodynamic response to **harmonic motion of structural modes** linearized about the steady state solution is computed
- Resulting **GAFs** are processed through a p-k solver to compute **flutter- q**
- **Refine** is used to create a new mesh with its adaptation mechanics
- AoA is updated based on pitch rotation needed to bring the system into pitch equilibrium
- Process is repeated with new AoA and new mesh

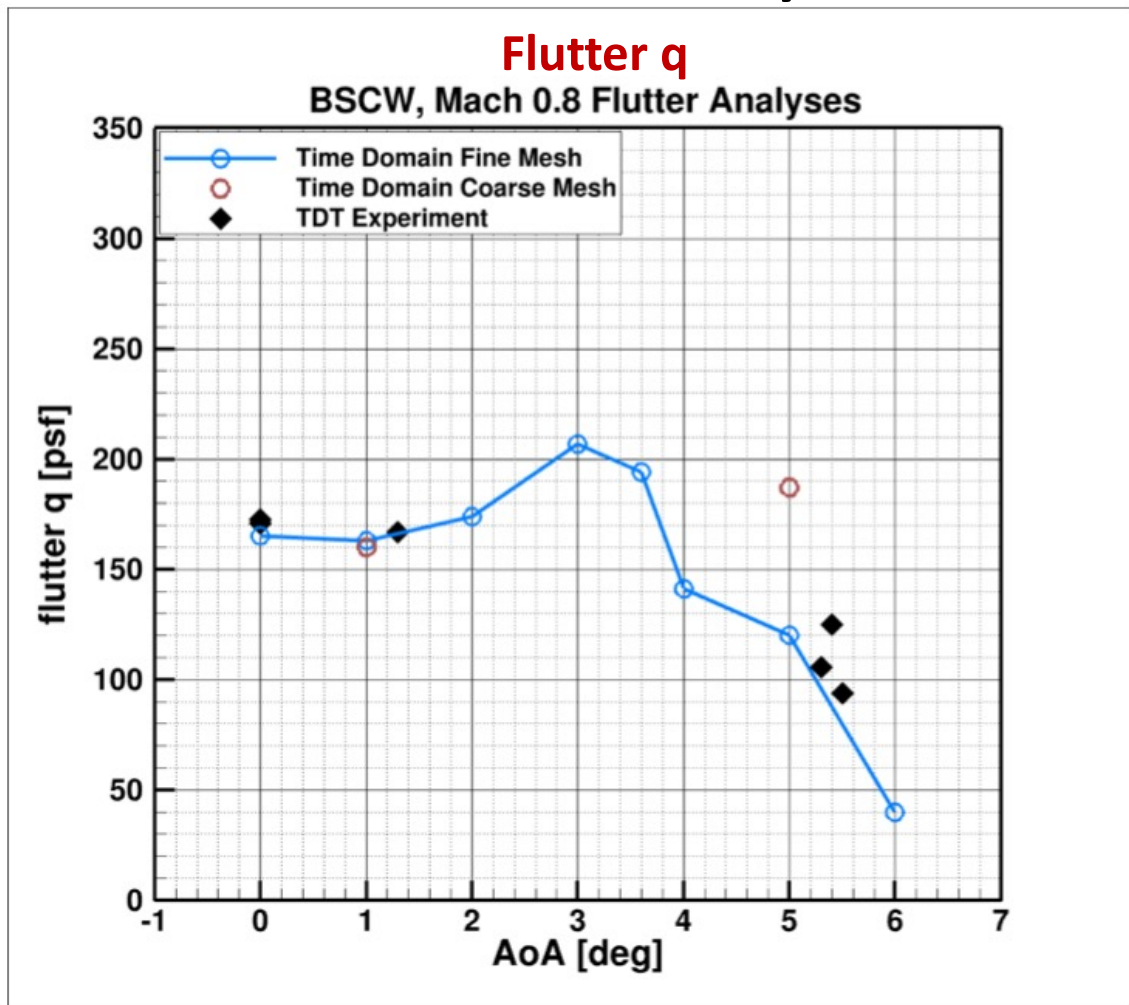
Stanford, et al., "Ongoing Aeroelastic Prediction and Validation Activities at NASA Langley Research Center, AIAA Paper, TBD.

Jacobson, et al., "Flutter Analysis with Stabilized Finite Elements based on the Linearized Frequency-domain Approach," AIAA Paper 2020-0403

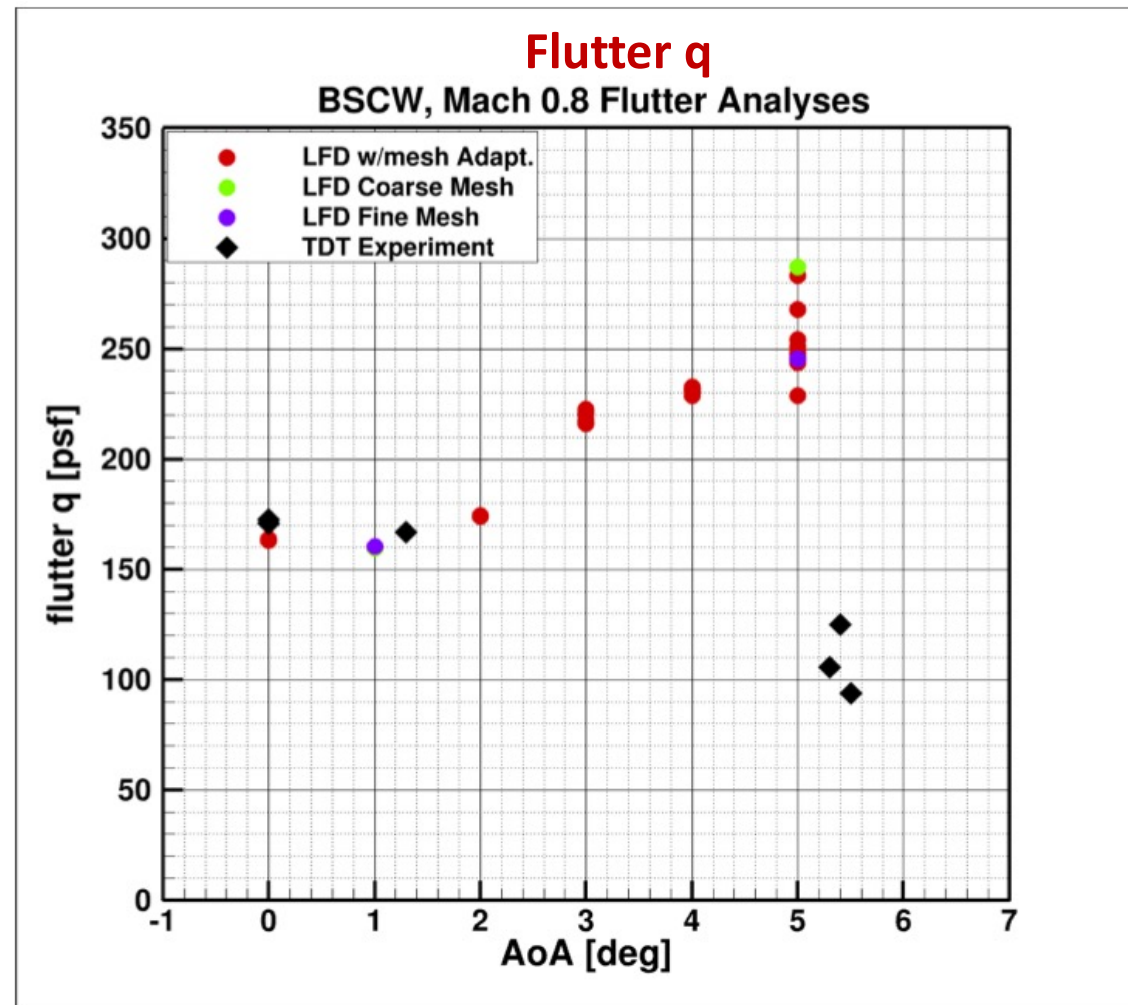
High Angle Working Group: FUN3D BSCW flutter analysis at Mach 0.8



Time-Domain Analysis



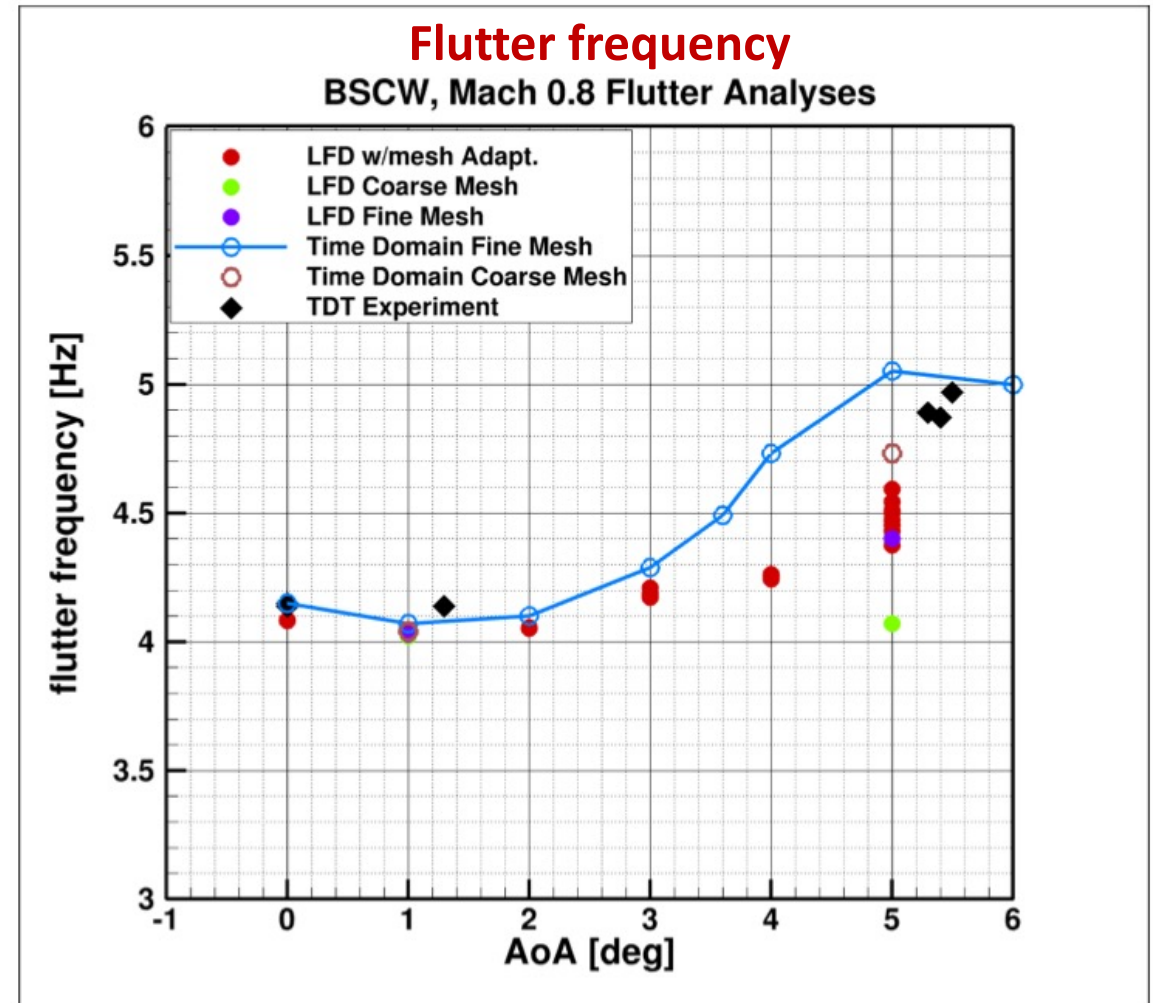
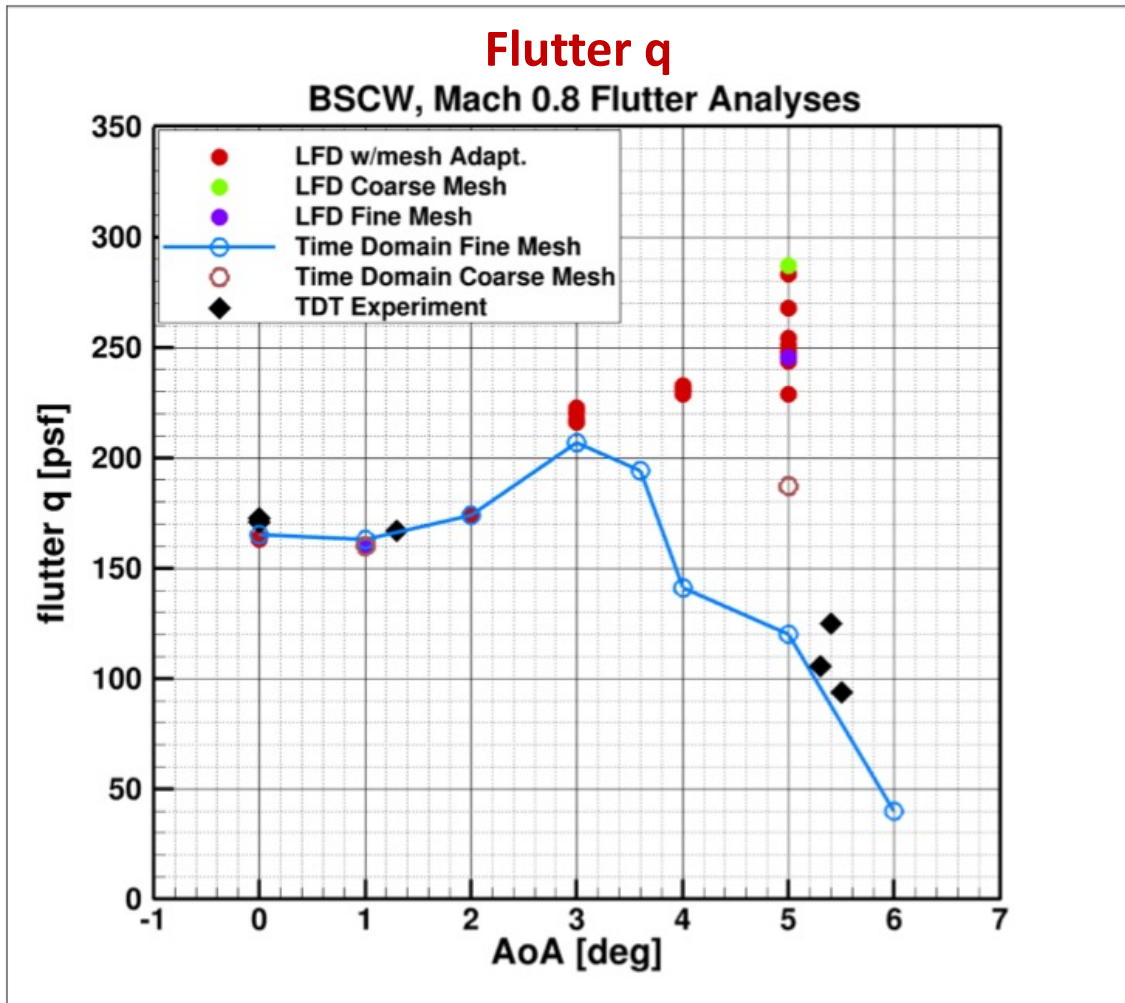
Linearized Frequency Domain (LFD) w/Mesh Adaptation



High Angle Working Group: FUN3D BSCW flutter analysis at Mach 0.8



Time-Domain Analysis (Fixed Mesh) + LFD w/Mesh Adaptation and Fixed Mesh

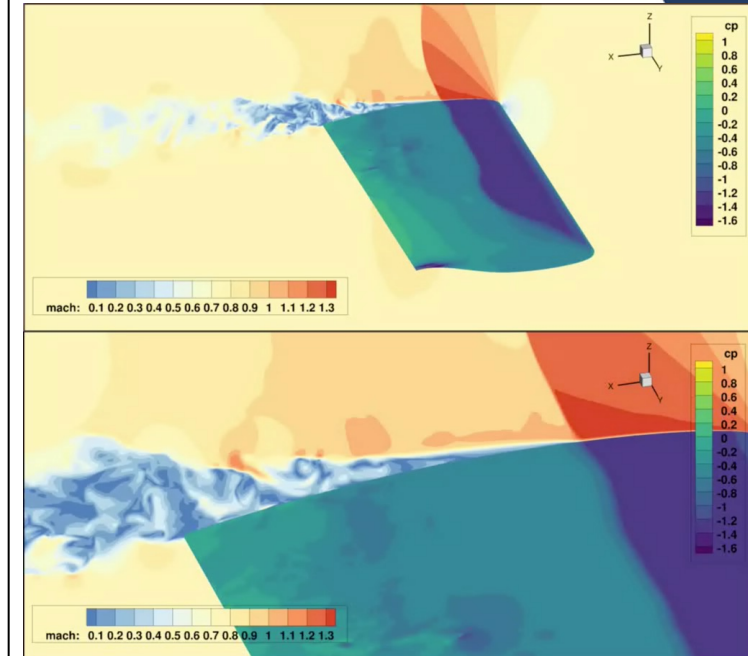


High Angle Working Group: Summary



Table 2. AePW-3 Workshop Test Cases.

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Thank you!

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Acknowledgments: This work is supported by the Transformational Tools and Technologies (TTT) project.
Computational Resources: K cluster and NAS.



Backup

High Angle Working Group: FUN3D BSCW flutter analysis at Mach 0.8



Time-Domain Analysis

