Wind Tunnel Verification of the Performance of a Smart Material Canard Actuator

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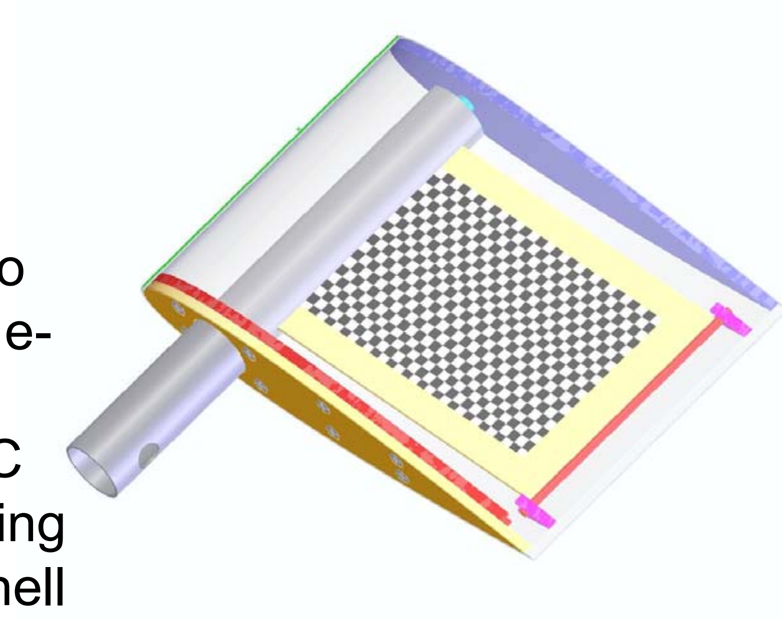
Smart Material Canard Actuator Design



Actuator Characteristics

• Hollow NACA 0018 aeroshell surrounds actuator mechanism.

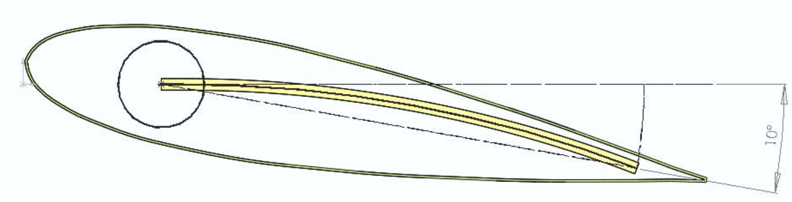
• Actuator Mechanism consists of two Macro Fiber Composite (MFC) patches bonded to e-glass plate.

  • Differential voltage applied to MFC patches produces deflection at trailing edge of plate and rotation of aeroshell

Benefits of actuator concept:

  • Minimizes volume intrusion of actuator into munition payload

  • Potential weight savings



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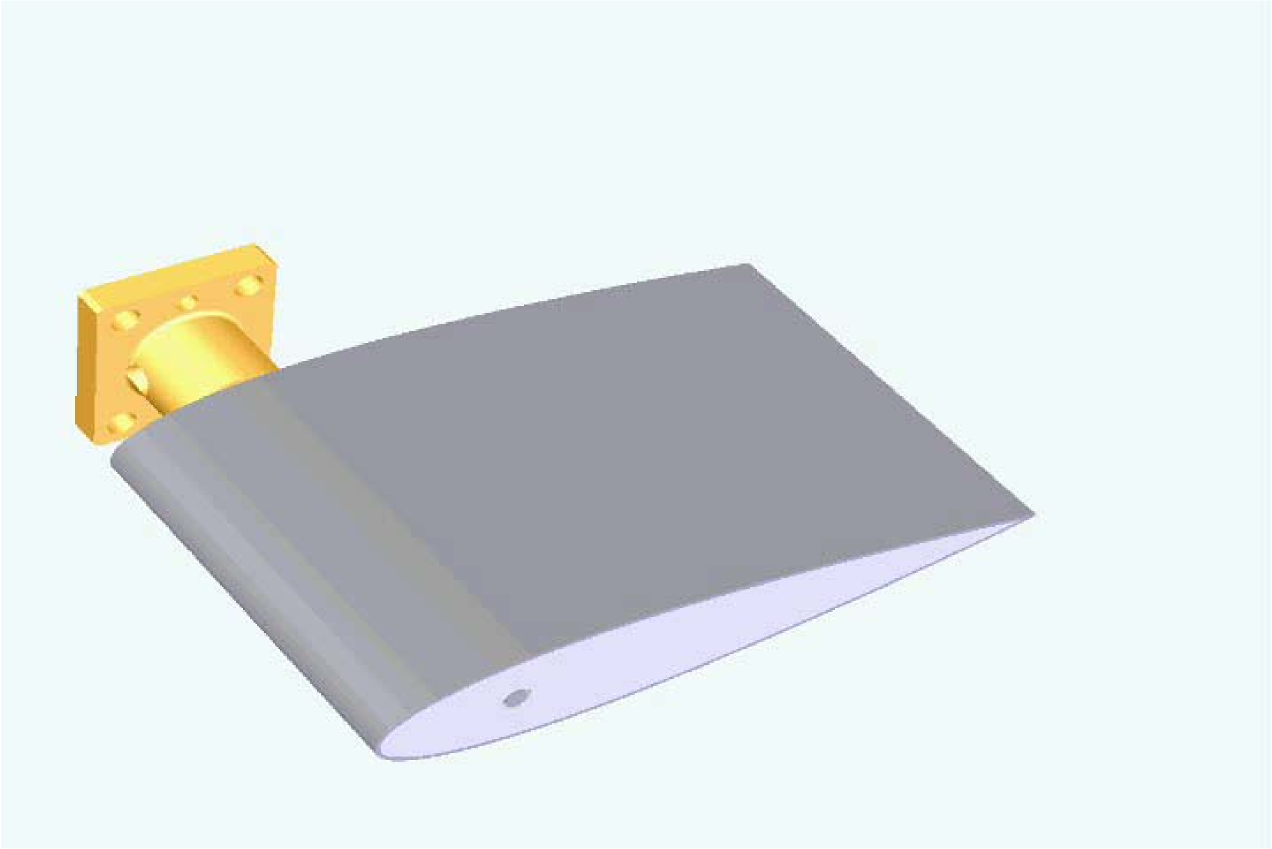
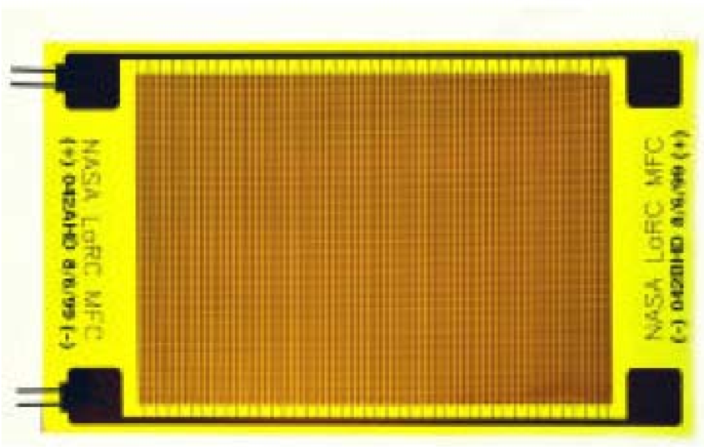
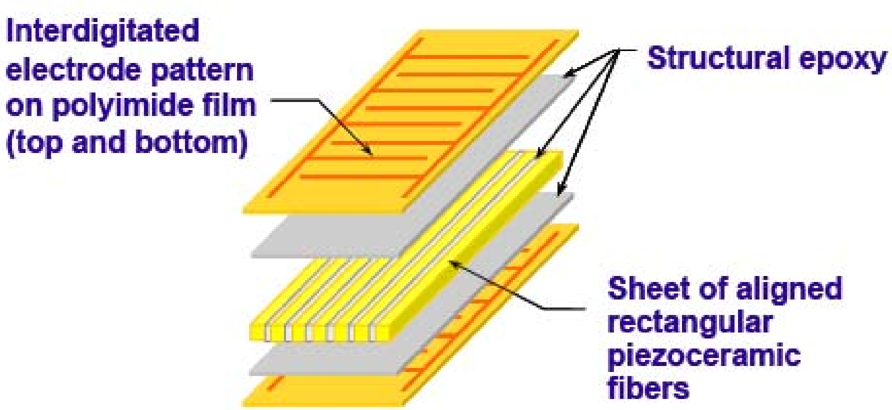
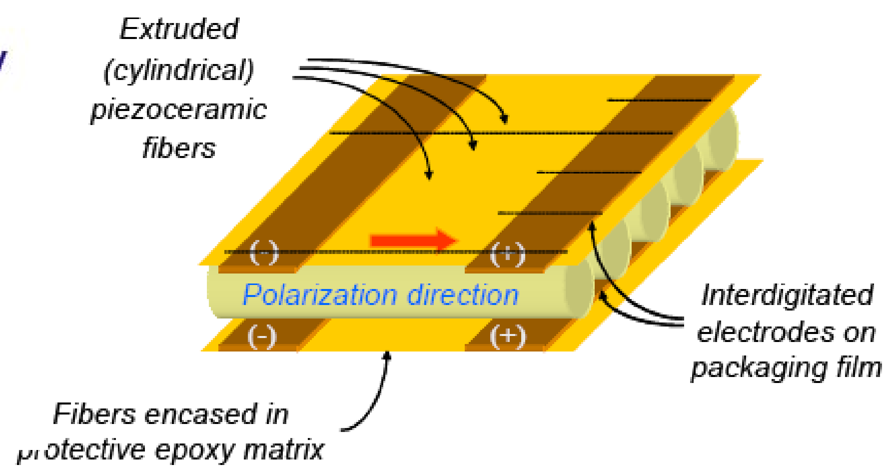


Macro Fiber Composite Patches

- Active layer consists of Macro Fiber Composites (FMC) produced by Smart Material Corp.
- FMCs utilize uniaxially aligned fibers surrounded by a polymeric matrix.
- Interdigitated electrode pattern is used to deliver an electric field along the length of the fiber.







Design Approach

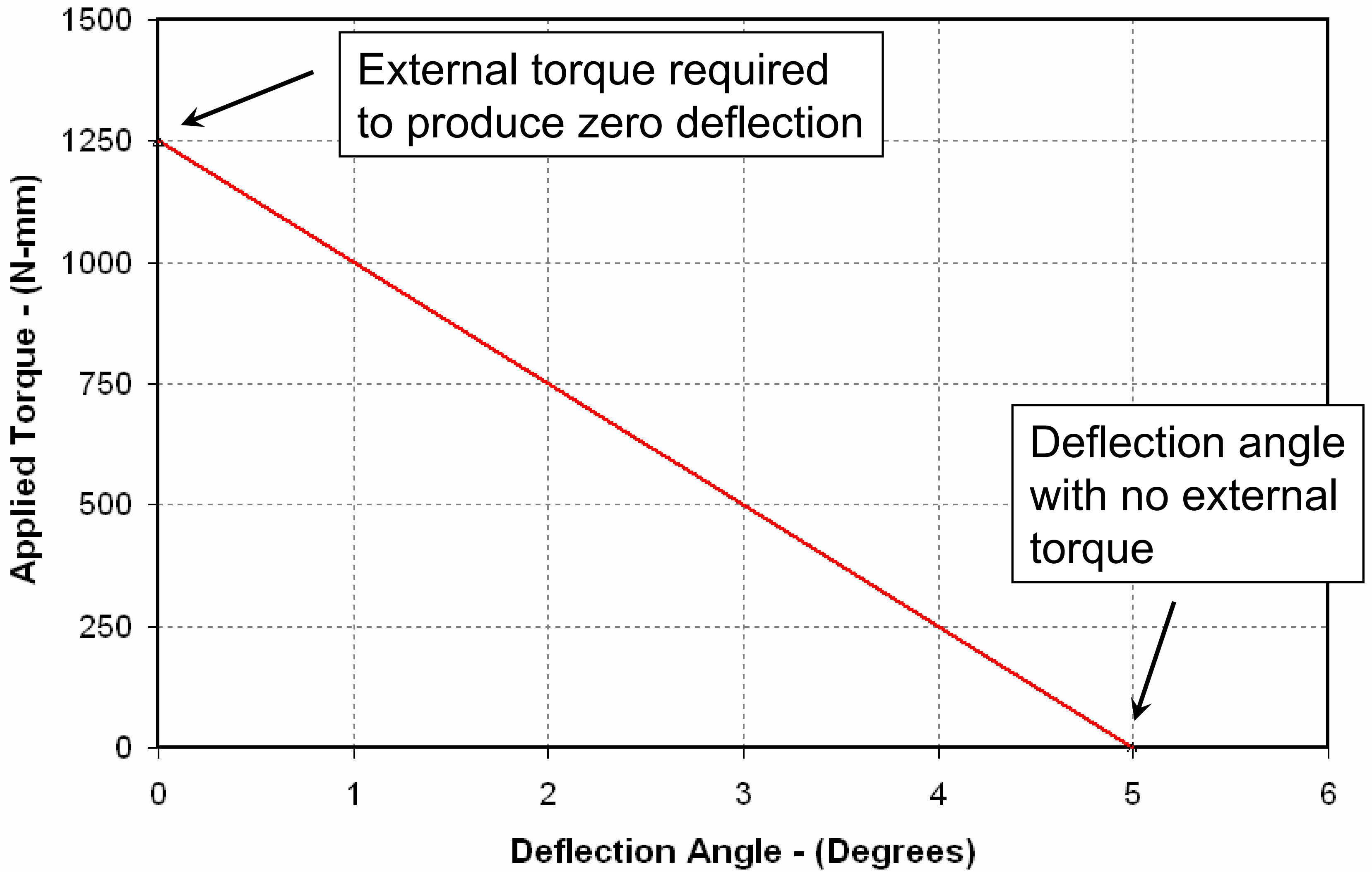
• Multi-disciplinary design approach - coupled structures and aerodynamics.

• In general, there is a trade-off between fin deflection angle and available torque to overcome aerodynamic hinge moment.

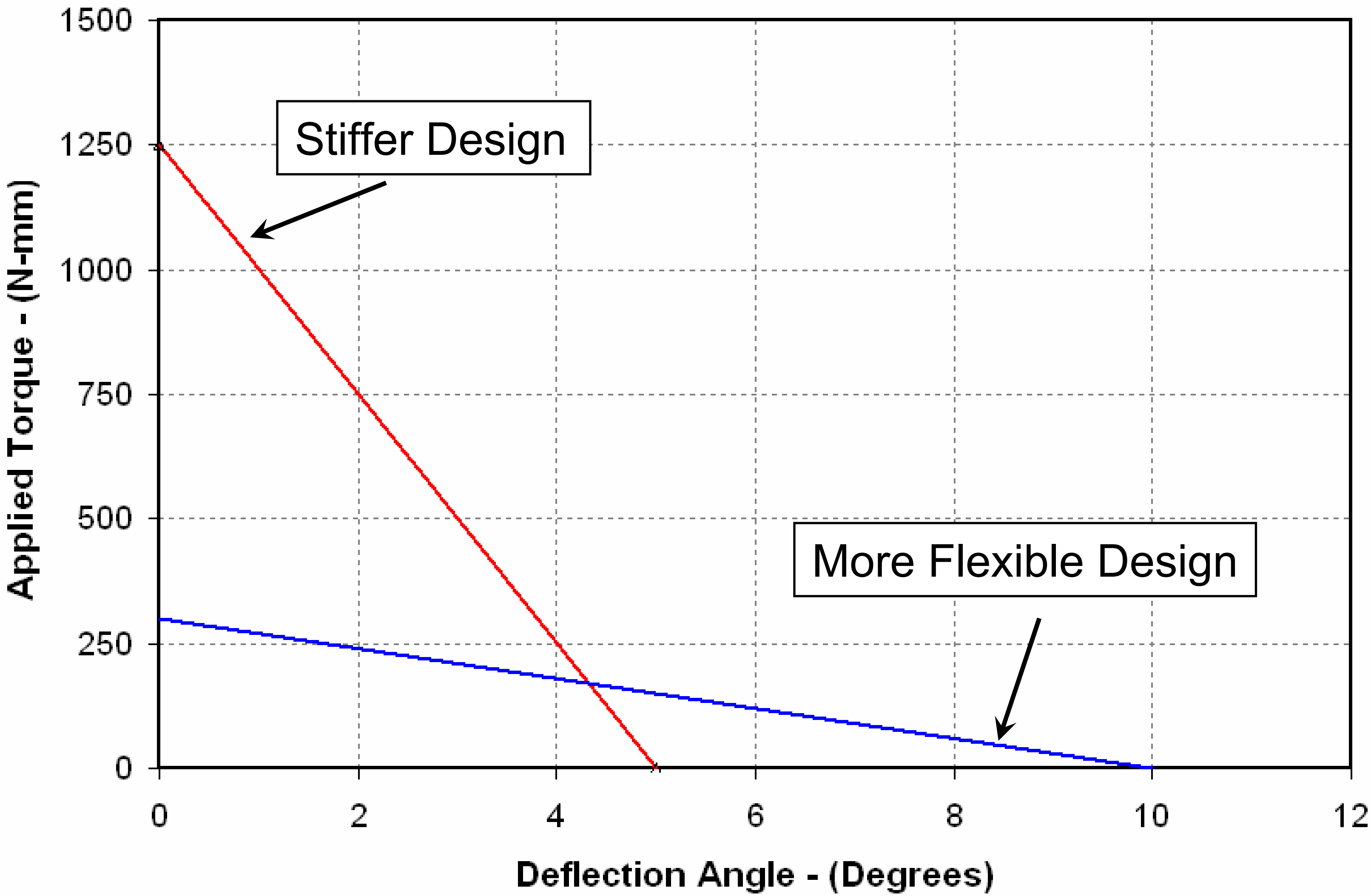
• ARL/University of Delaware design - maximize fin deflection angle ~ Mach 0.3-0.5.

• It is possible to obtain more deflection if aerodynamic torque is ignored.

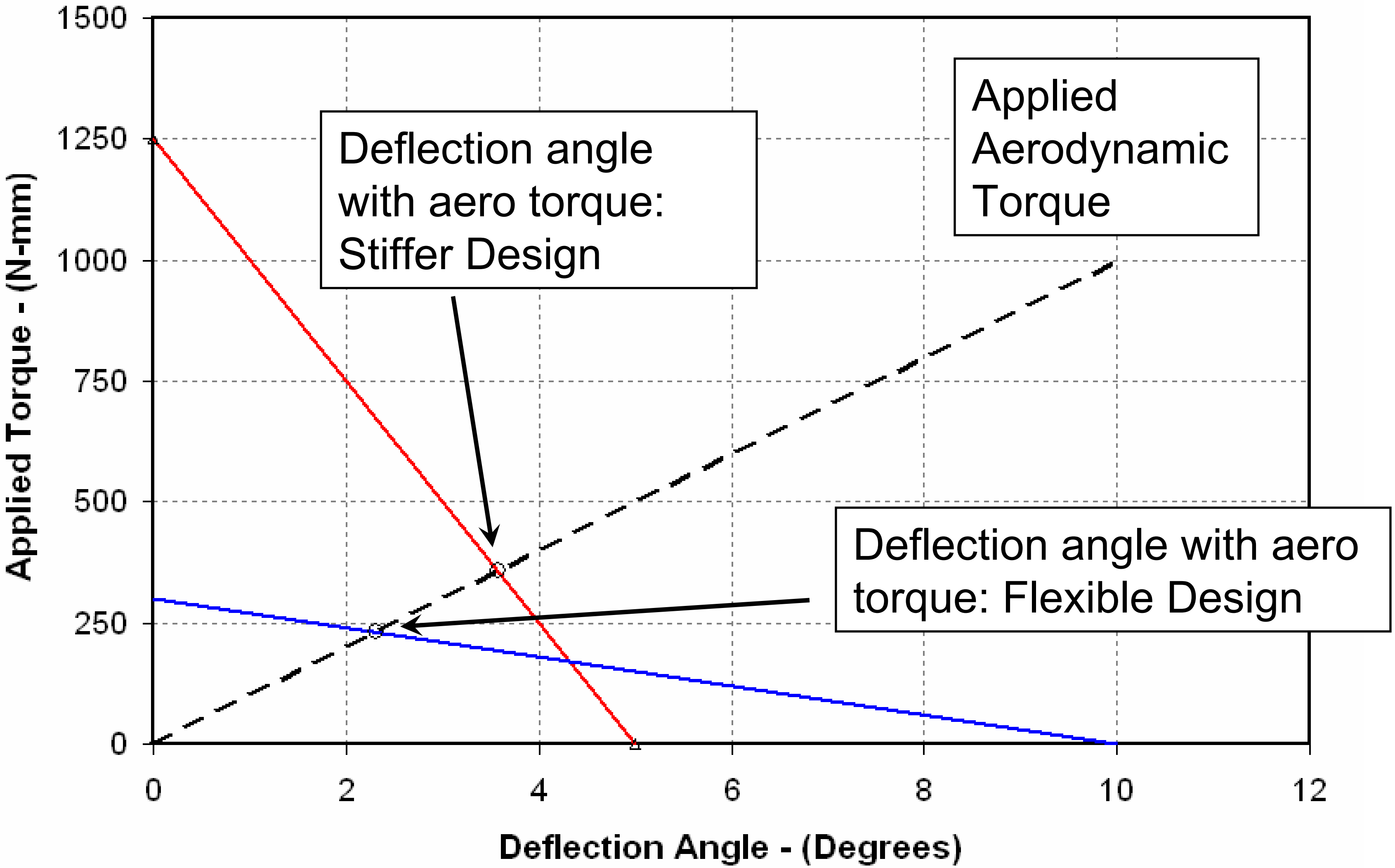
Design Approach (Cont.)



Trade-Off Between Maximum Deflection Angle and Torsional Stiffness

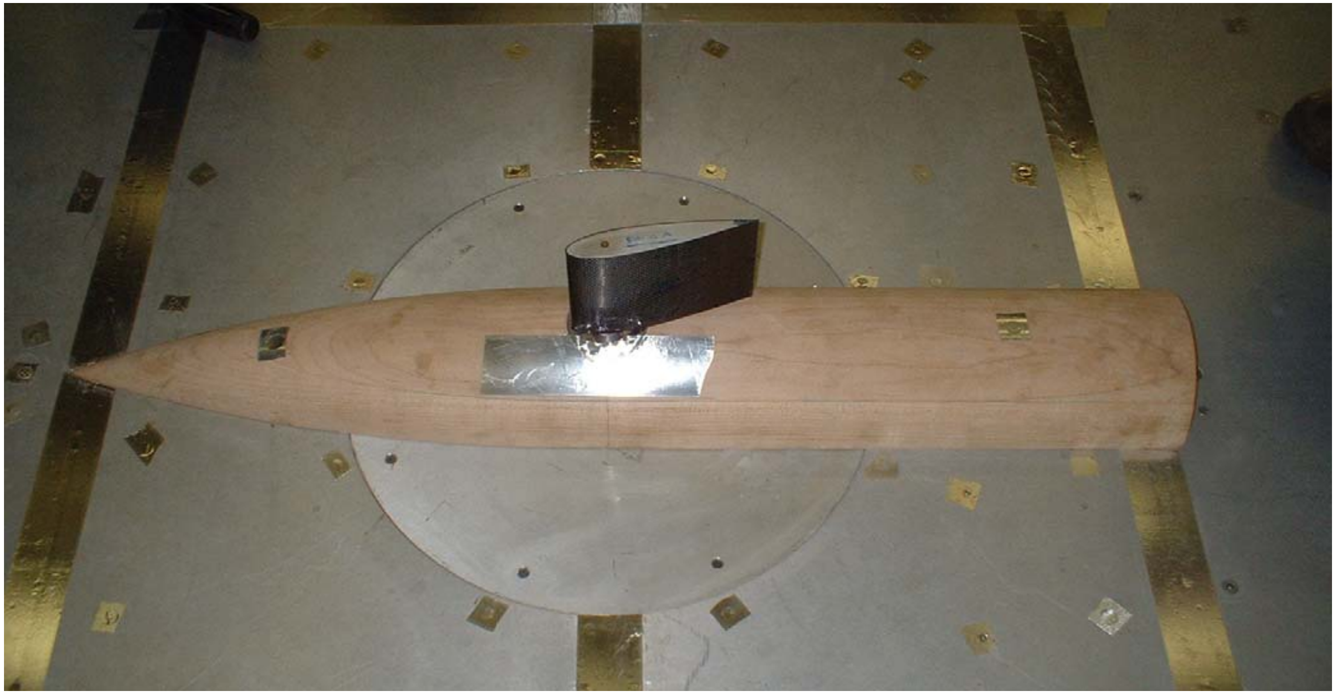


Deflection Angles in Presence of Aerodynamic Torque



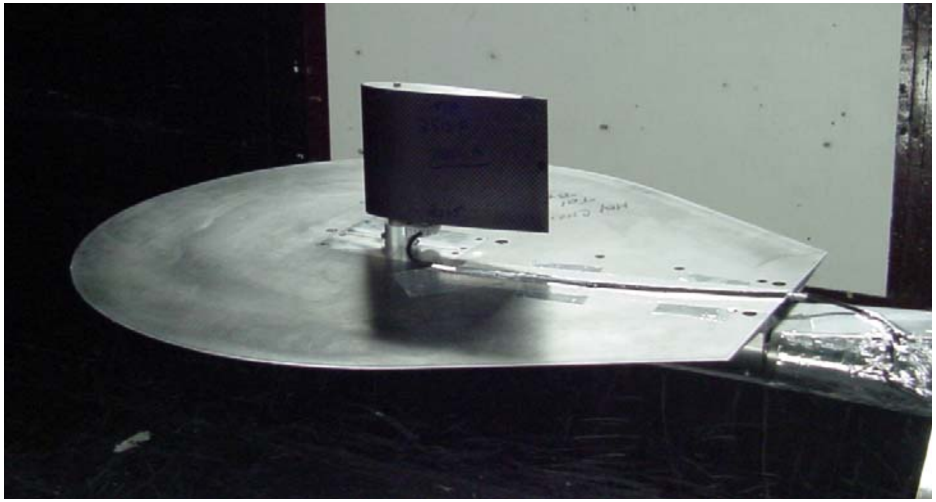
Wind Tunnel Testing at U. of Maryland

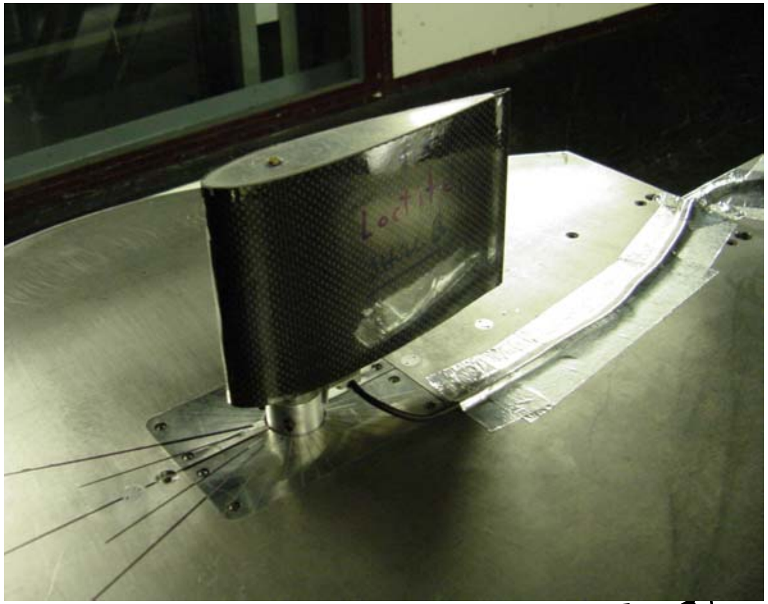
- Sponsored by ARL, U. Delaware
- Fin mounted to balance on tunnel floor – half missile body fairing used.
- Purpose of Wind Tunnel Test:
    - Determine response of fin in presence of aerodynamic load.
    - Measure and quantify aerodynamic loads.
    - Determine whether flutter is an issue.



Wind Tunnel Testing at Texas A&M

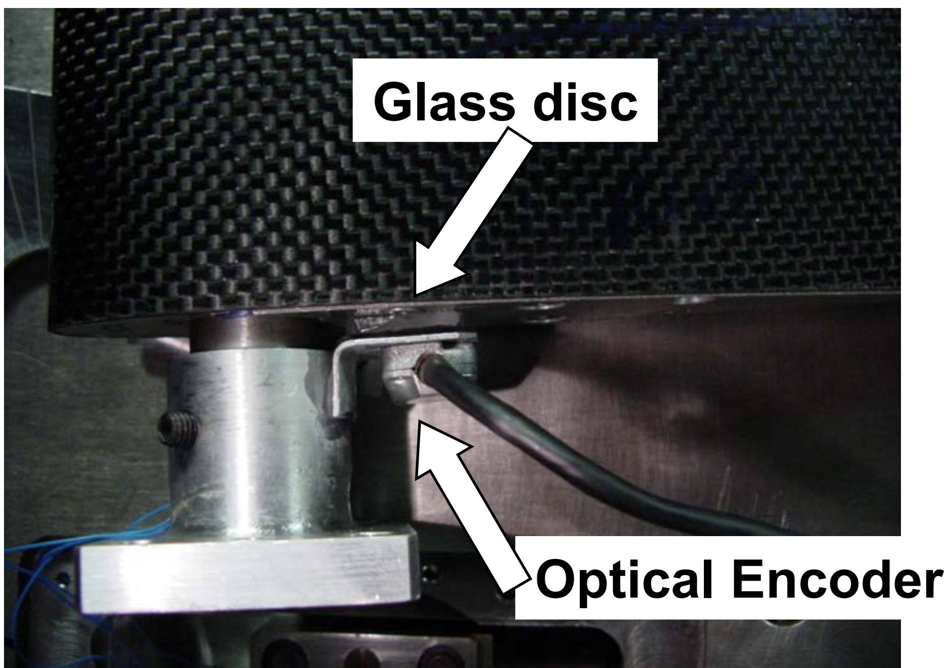
- Collaboration between AMRDEC Aero. Branch, ARL, U. Delaware
- Testing at Texas A&M University
- AMRDEC provided splitter plate, force/moment balance, testing time.
- Purpose of Wind Tunnel Test:
    - Determine response of fin in presence of aerodynamic load
    - Measure and quantify aerodynamic loads
    - Determine whether flutter is an issue.





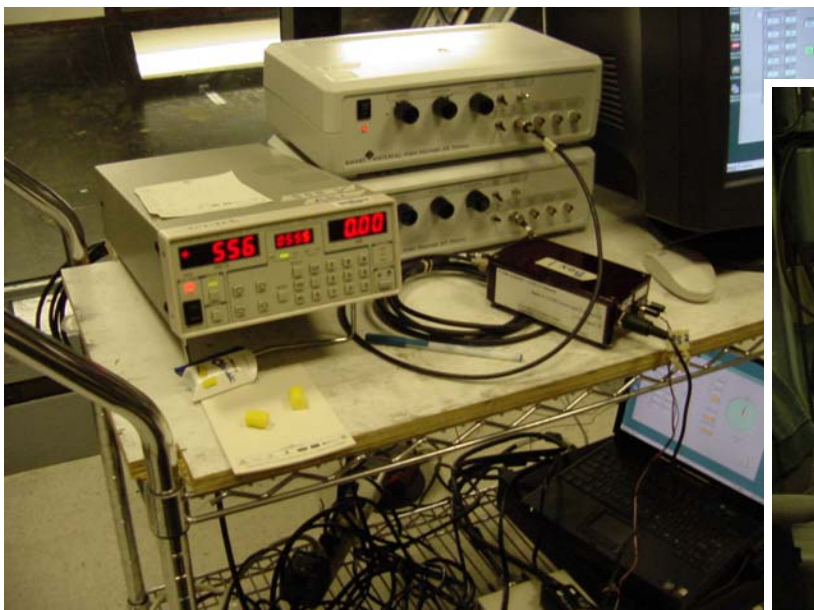
Optical Encoder

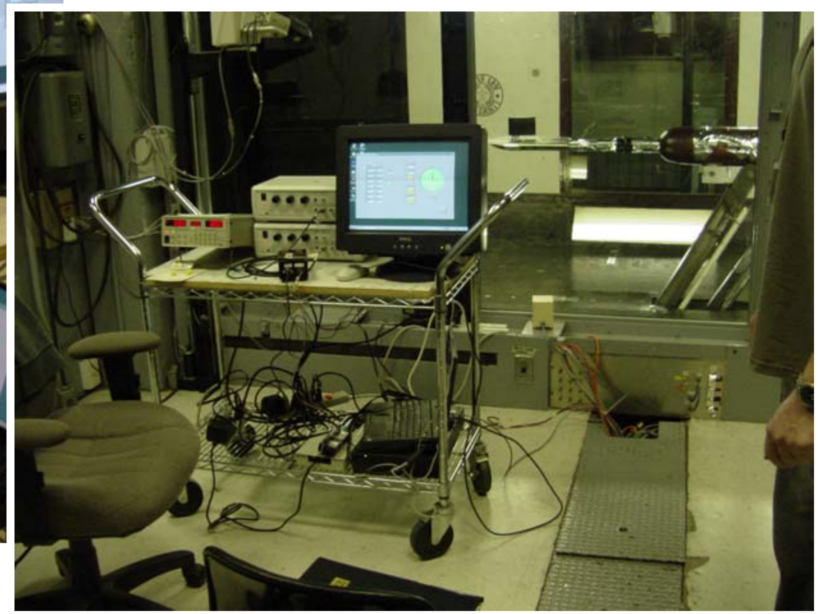
- Measures fin deflection angle
- Sensor mounted on fin base
- Sensor reads deflection from graduated glass disc glued to bottom of fin
- Time-dependent sensor output acquired on laptop



Fin Power Sources

- Three power sources provide voltage to both smart material patches
- Power controlled through laptop
- Continuous range of voltage available -500V to +1500V





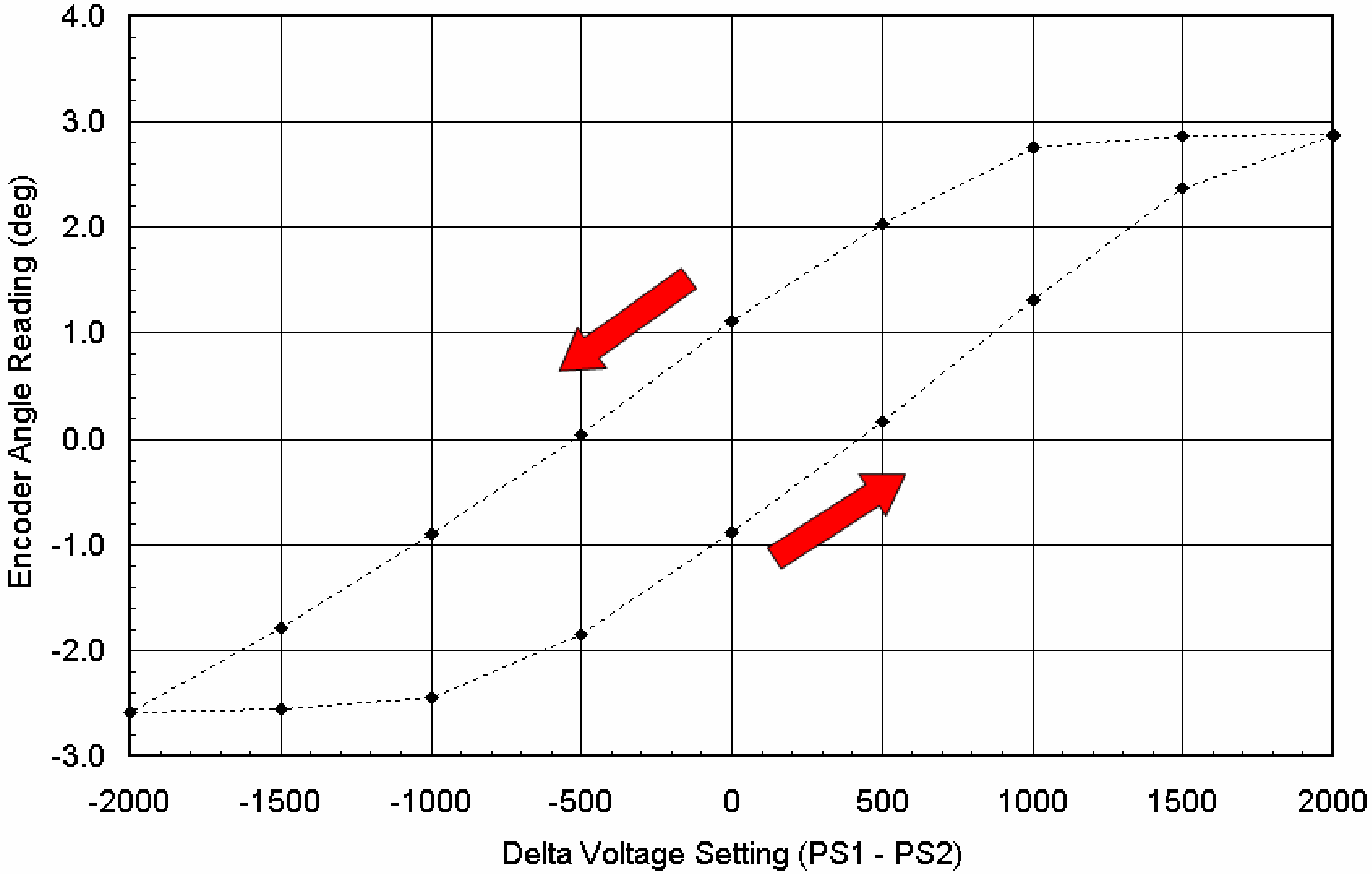
Wind-Off Response

- Several wind-off tests were run to obtain the response of the fin without aerodynamic load
- Results have some bearing on experimental approach and interpretation of results
- Static Deflection Tests

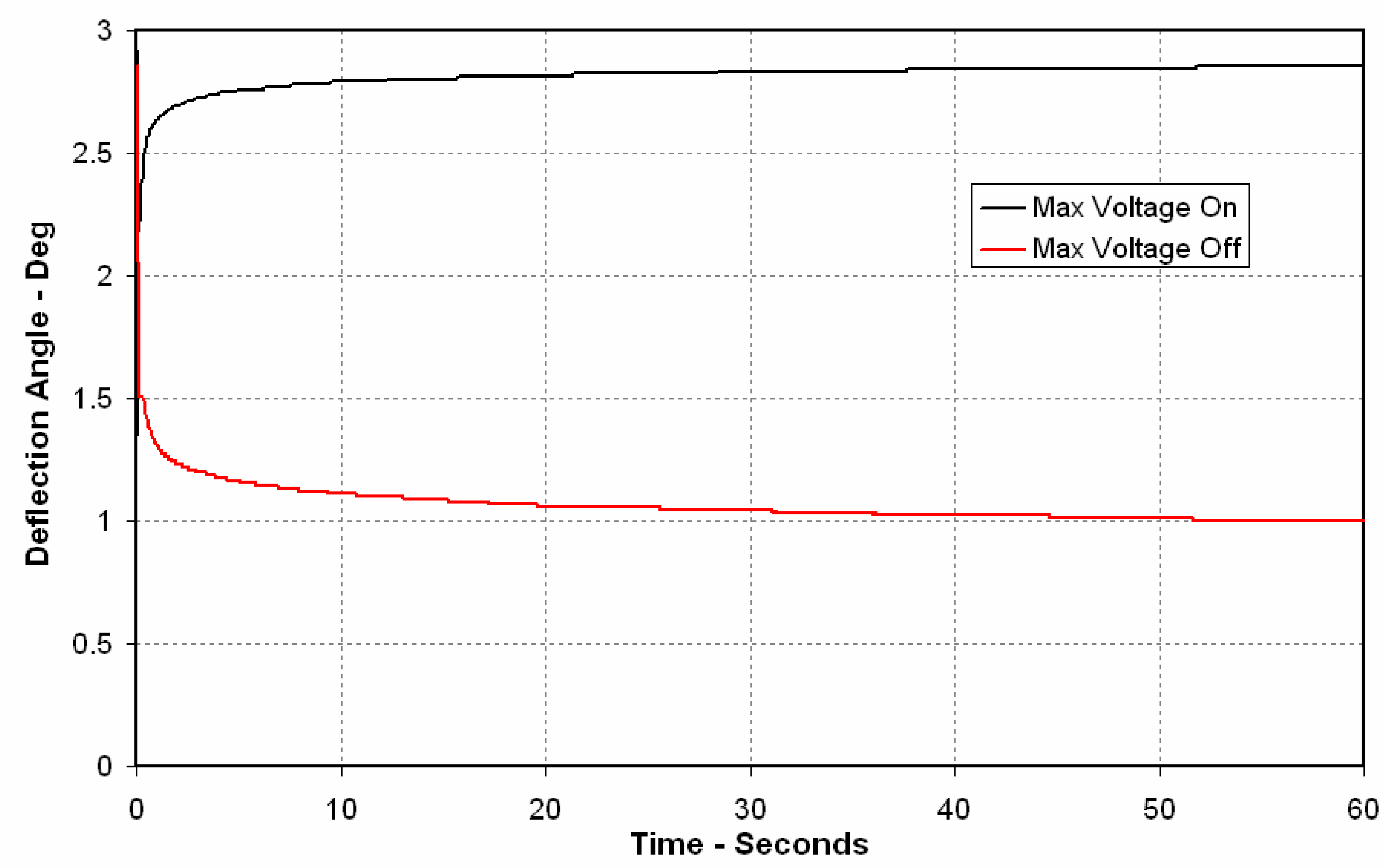
	Peak-to-Peak Deflection	Torsional Stiffness
250^{o}F Fin	5.3 deg	179 N-mm/deg
Loctite Fin	5.5 deg	279 N-mm/deg

- Hysteresis
- Time-Dependent Response

Wind-Off Hysteresis



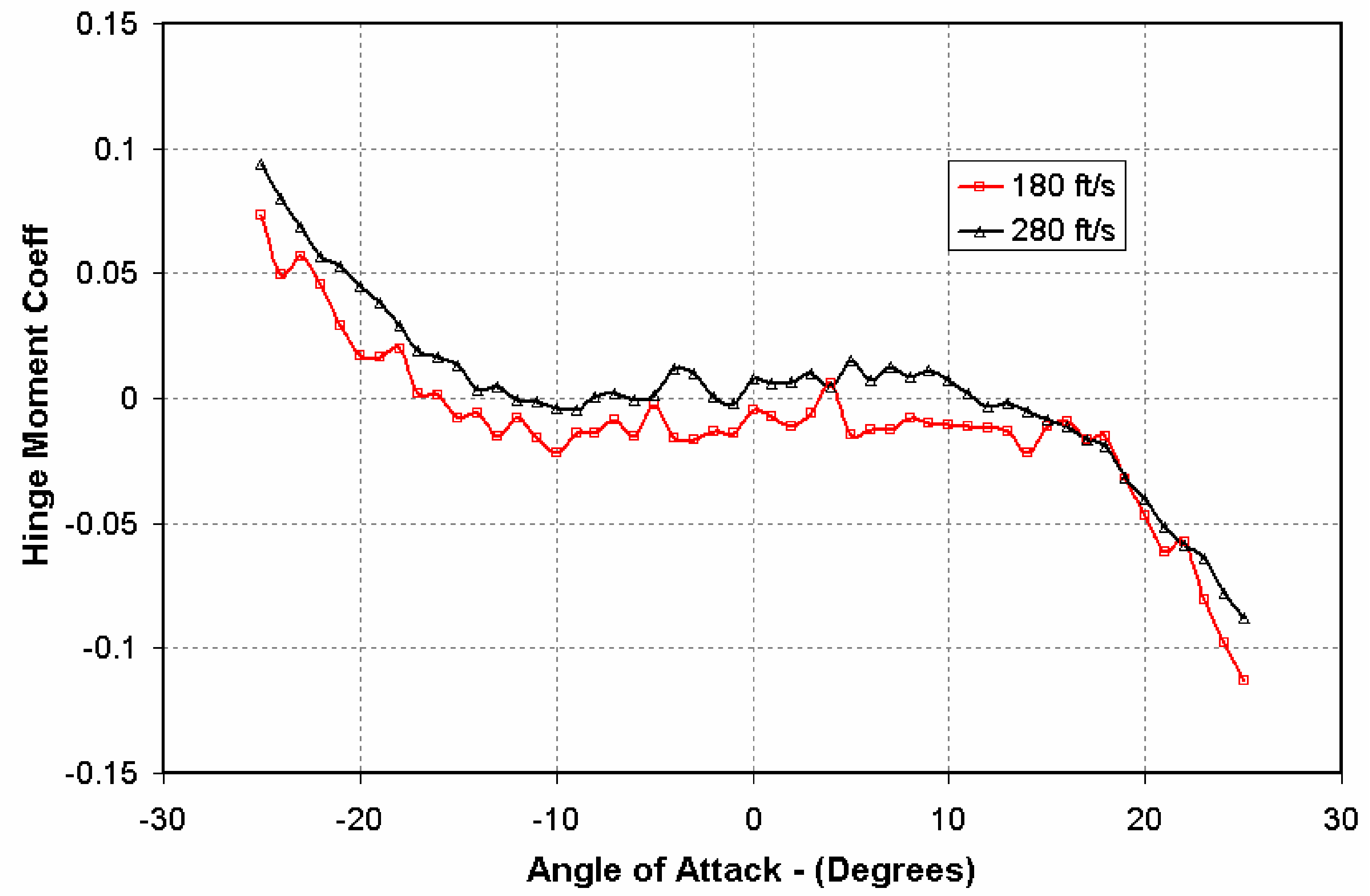
Time-Dependent Response



Rigid Fin Tests

- The pure aerodynamic response of the fin was examined using a rigid fin (no actuator):
- Aerodynamic forces and moments measured to ±25 deg angle of attack (AoA).
- "Hinge" line located at 20% of chord length from leading edge.
- Small difference between rigid fin and fins with acutator
  - Fin was mounted ¼" inch higher off splitter plate than for fins with actuator.
  - No optical encoder mounted.
- Considered two velocities 180 ft/s and 280 ft/s
- Measured six force/moment components

Hinge Moment

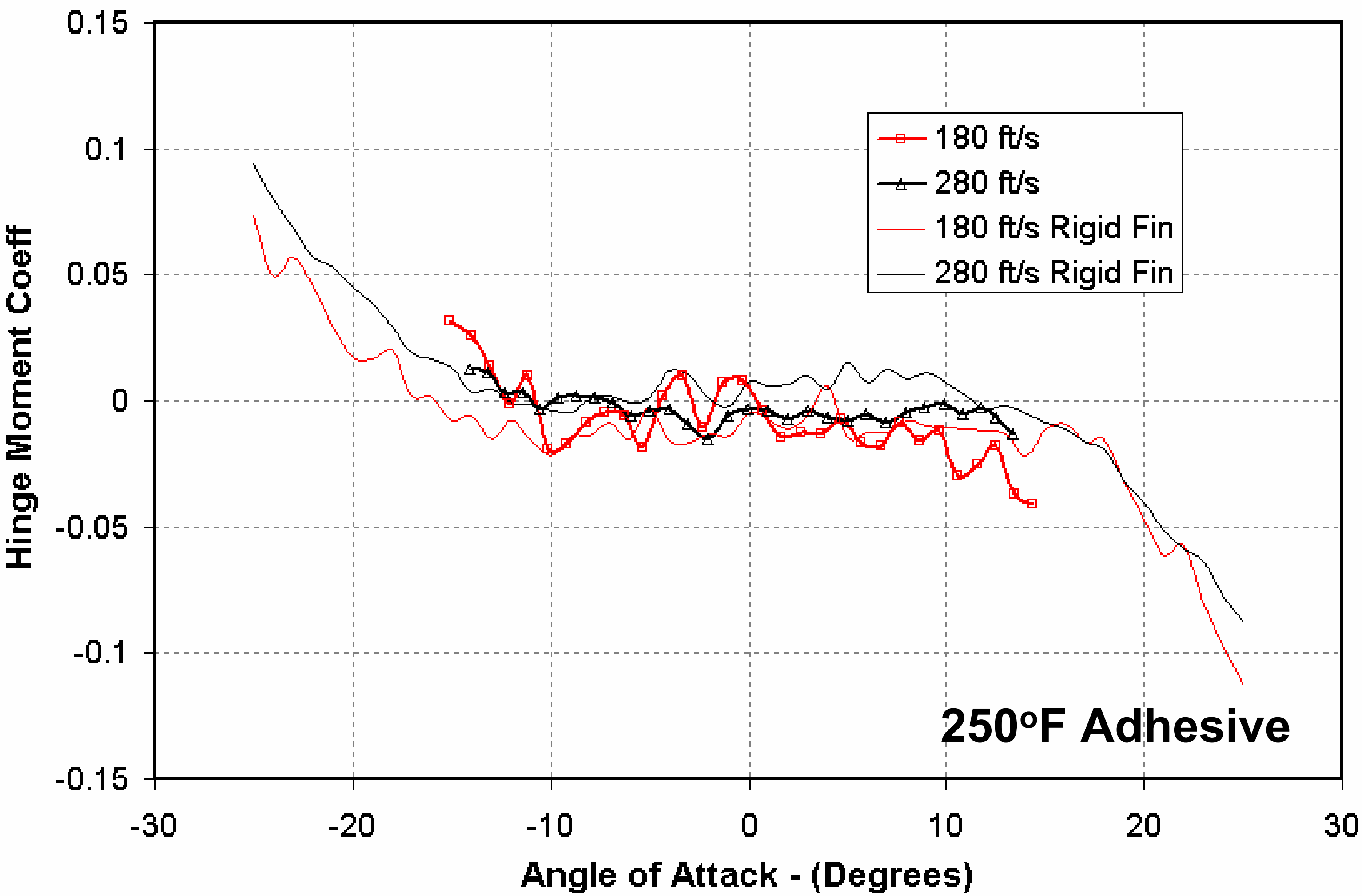


Aerodynamics Branch

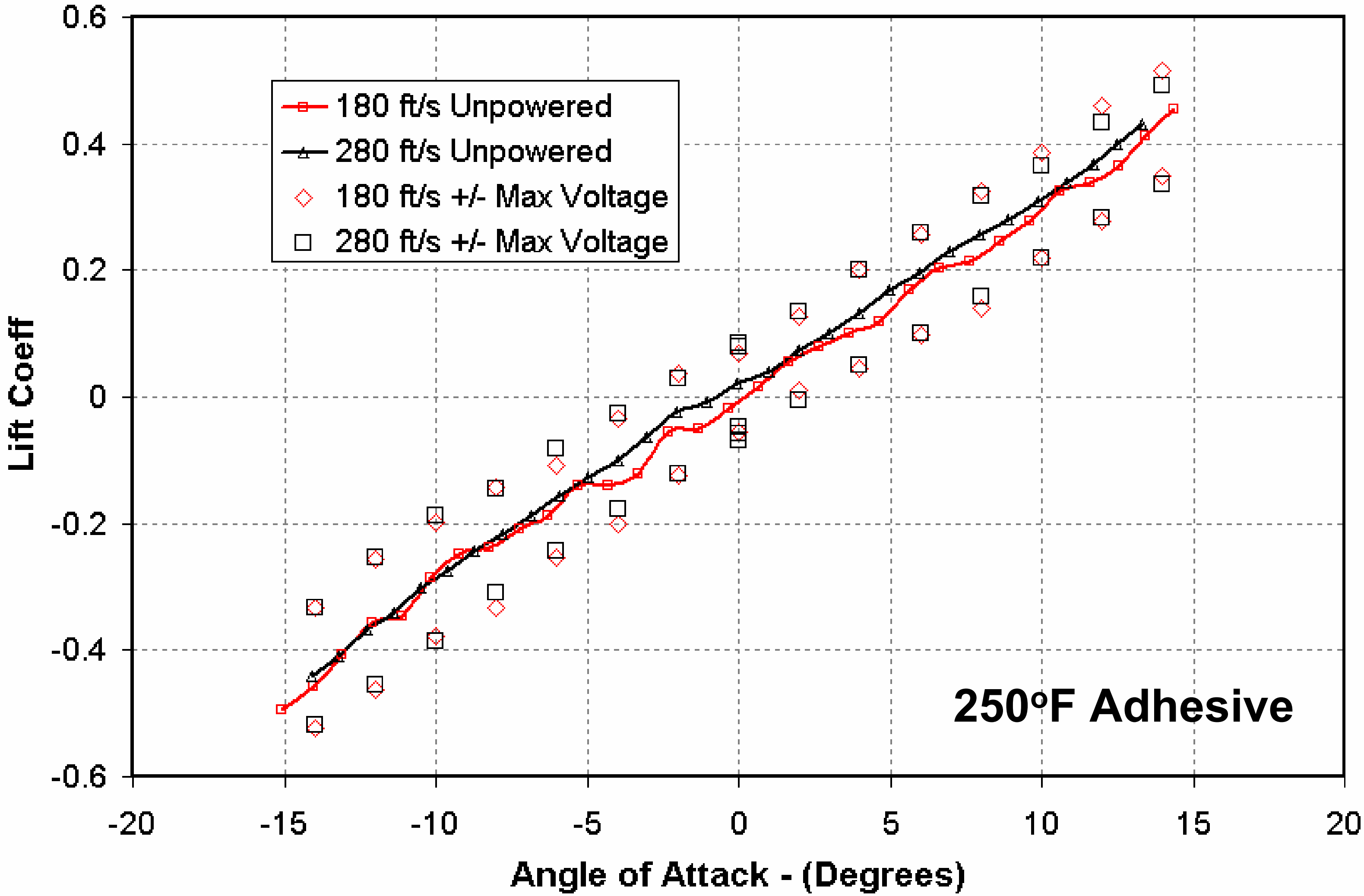
Smart Material Actuator Fin Tests

- The smart material actuator fin was tested in number of modes:
  - Unpowered (No applied voltage)
  - ± Maximum Voltage
  - Varying Voltage
  - Tests performed at 180ft/s, 280ft/s
  - AoA -14^o to 14^o
- Two versions of actuator tested
  - Differ only by adhesive used to bond patch to host
    - 250^{o}F epoxy
    - Loctite epoxy
- Force/moment balance measurements taken.
- Fin deflection measured with optical encoder.

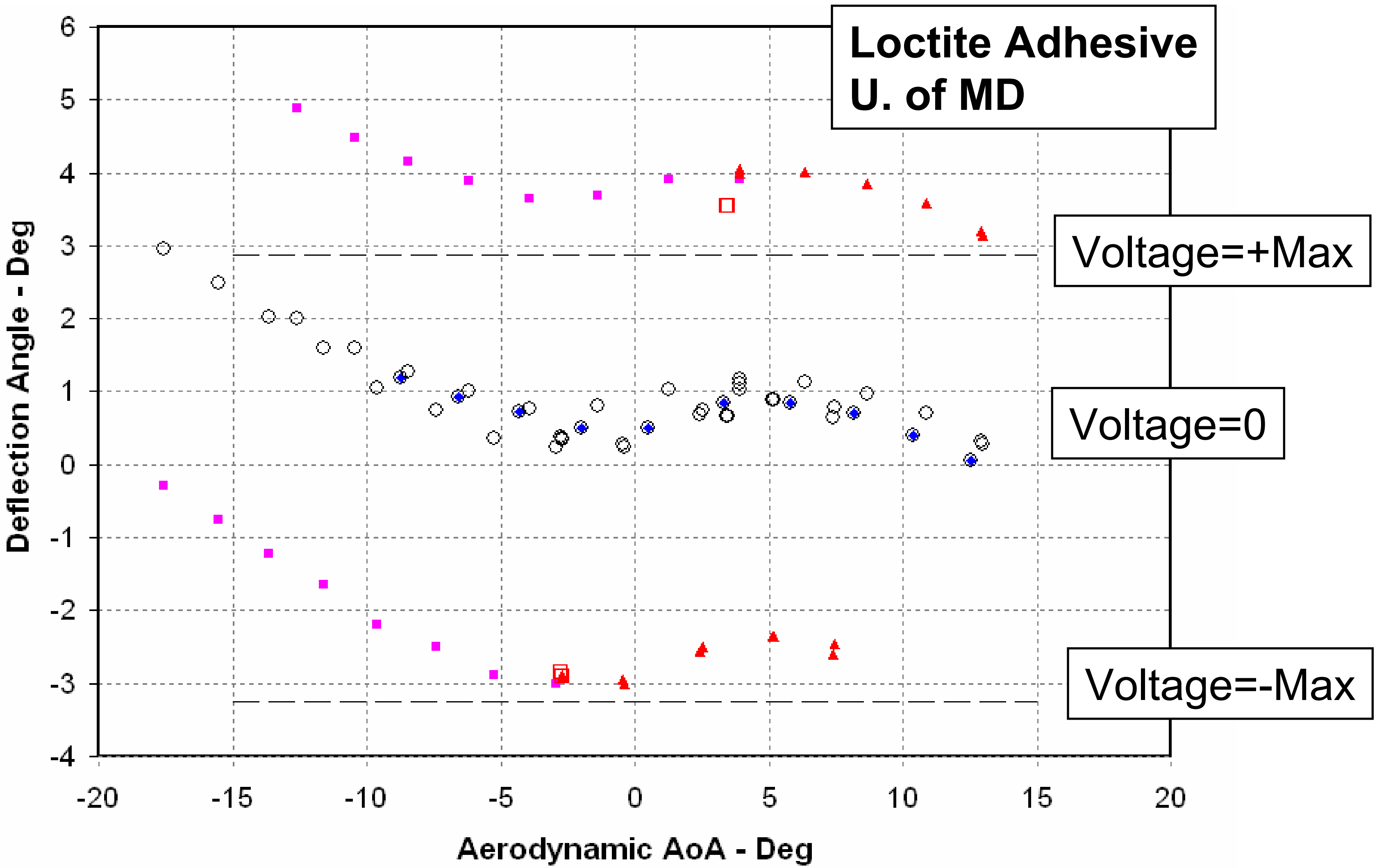
Hinge Moments



Lift Force Generated by Deflection



Fin Deflection Angle vs. Angle of Attack



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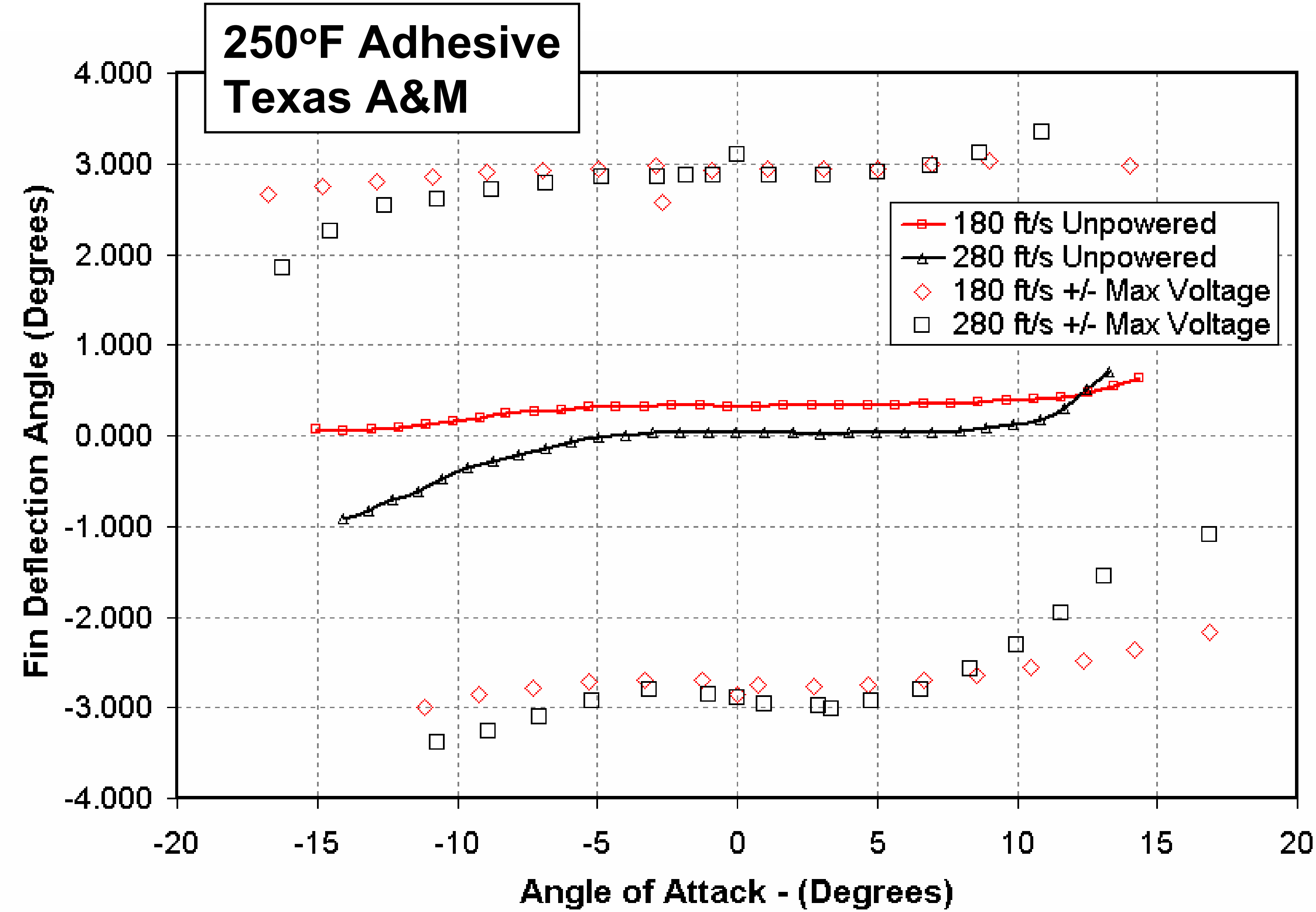

Conclusions

- Within one year, a canard actuator based on smart materials was designed, constructed and wind-tunnel tested.
- Design shows promise for application to munition systems.
    - Coupled structural/aerodynamic analysis required for the design of these flexible structures.
    - MFC actuators: rugged and robust – a requirement for gun-launched munitions.
    - Flutter not an issue for velocity range tested.
- Improved performance possible with existing design using better manufacturing techniques.
- Alternative designs, improved MFC patches being investigated.