REEF SUBSONIC WIND TUNNEL ARTICULATING ROBOTIC ARM

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Abstract

The Aerodynamic Characterization Facility (ACF) of the Research and Engineering Education Facility (REEF) has requested a mounting device and an actuating mechanism in order to continue testing. This facility hosts an open subsonic wind tunnel with a maximum wind speed of 22 $^{m}/_{s}$. The design must be able to adjust pitch (-5° to +30°) and yaw (-10° to +10°) while the tunnel is in operation and maintain the specimen in the center of the air flow.

The design features an arc with a square shaped cross-section. This arc will be actuated through the use of a flexible gear track fixed to the underside and a turn table as its base. A sting mount will be utilized to hold specimens.

The procurement of the necessary components and materials for this design is underway and fabrication is expected to start at the beginning of Spring semester.

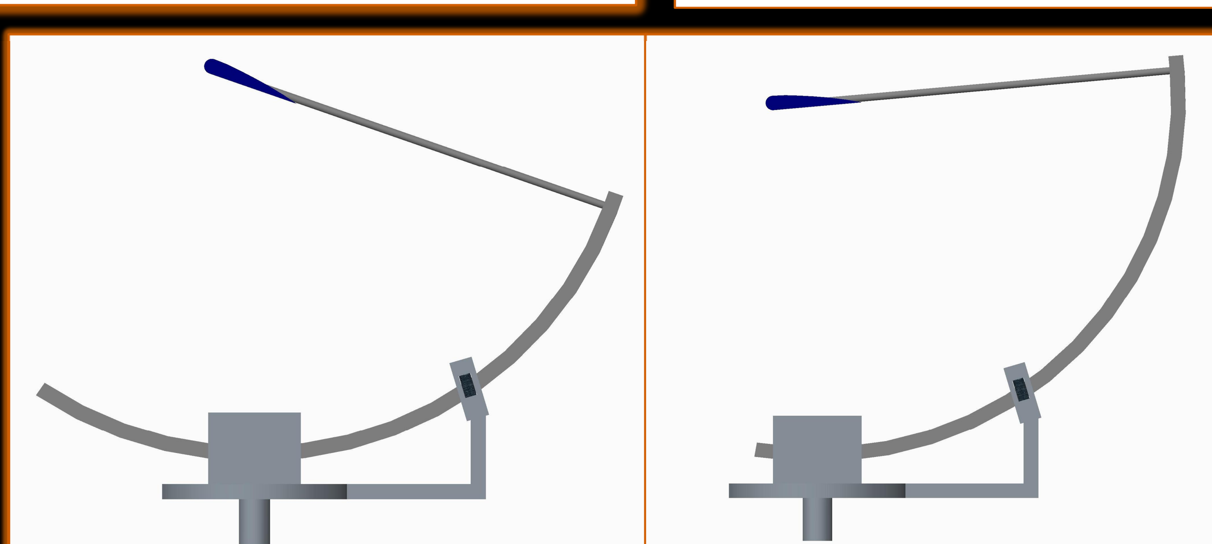
Design

The design is structured around an arc of 95° with a radius of $63.5cm$ ($25in.$) and a square shaped cross-section of approximately $6.45cm^2$ ($1in.^2$). The arc ensures that the specimen will remain in the center of the airflow throughout its actuation in the pitch direction. A flexible gear track will be fixed to the underside of the arc and will work in conjunction with a worm gear to actuate the arc.

This worm gear will have a module of 2 and an $8mm$ ($0.315in.$) face width. The arc will be seated on a turn table which will adjust the specimen in the yaw direction while also keeping the specimen centered. Actuation will be achieved through the use of stepper motors. These stepper motors will be equipped with encoders to improve resolution and prevent possible complications from slippage.

Figure 3: Example of a flexible gear track, known as "flexirack".
Source: https://sdp-si.com/eStore/Catalog/Group/764

Figure 4: Worm gear options
Source: https://sdp-si.com/eStore/Catalog/Group/764



A sting mount will protrude on a rod from the top of the arc with a length of $63.5cm$ ($25in.$) and a diameter of $19.05mm$ ($0.75in.$). This will hold specimens at the center of the arc structure. A block will be used to mount the arc to the turn table. The block will encase 4 roller bearings to account for forces in the Y-direction and 4 roller bearings to account for forces in the Z-direction. This will constrain the arc. A follower will be attached to the back of the table to help support the arc. It will have 2 roller bearings so as not to impede the actuation of the arc. Both the arc and sting mount will be made from AL6061.

Background

Wind tunnels offer a cost effective way to test aerodynamic designs in a controlled environment. When a properly scaled model is placed in a wind tunnel, dimensionless numbers can be utilized to generate flows that are dynamically similar to conditions that would been felt by the full-sized design. The data accumulated from testing would allow for modification and improvement before starting full-scale production.

The facility utilizing team 12's design is an open test section subsonic wind tunnel. In an open test section wind tunnel there are no walls bounding the flow immediately after the inlet contraction. This means that as the flow moves away from the inlet, the boundary layer of the flow will expand outward. This type of wind tunnel orientation is most often used for acoustic testing purposes.

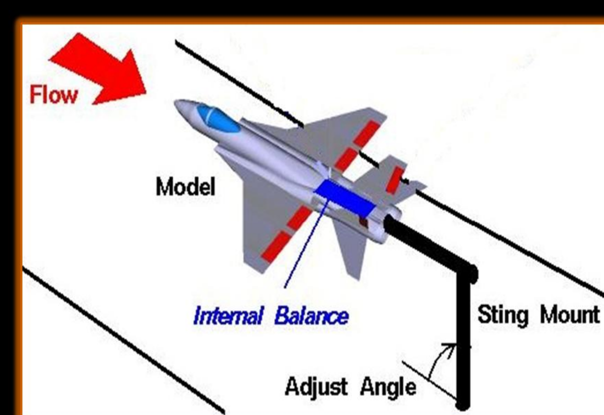


Figure 1: Sting mount example.
Source: http://www.grc.nasa.gov/WWW/

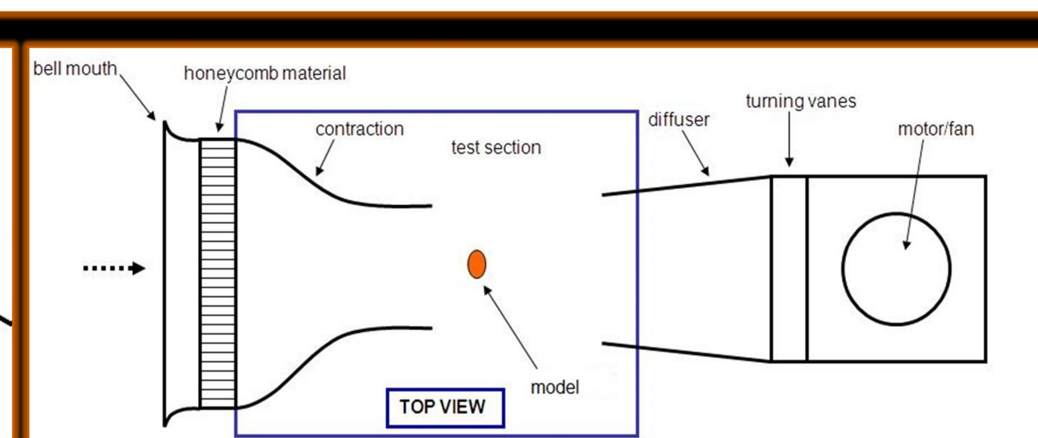


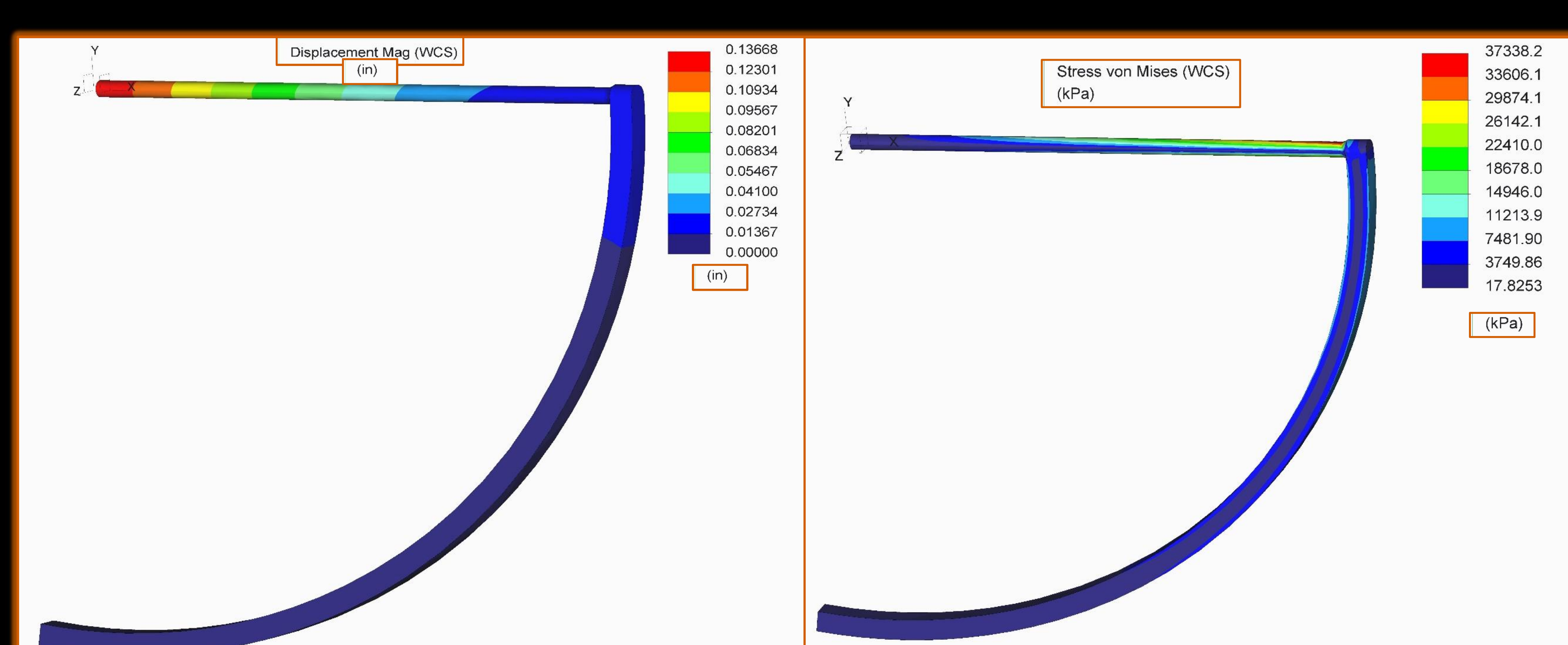
Figure 2: Example of an open test section wind tunnel.
Source: http://www.rtri.or.jp/rd/maibara-wt/English/ID3.HTML

To achieve ideal results from testing, it is imperative that the model mounting system be minimally invasive. This is especially true for subsonic wind tunnels, as the upstream adjusts to downstream objects and blockages. A common model attachment is the sting mount. This type of mount attaches to the rear of the model and provides minimal interference to the flow approaching the model.

Analysis

Assumptions:

- Maximum coefficient of drag and lift on arc are $C_D = 1$, $C_L = 2$
- Maximum flow blockage of tunnel is 10% * $Area_{tunnel}$
- Multiplier of 1.5 to applied forces for unsteady loading
- Loads applied to end of sting



Results:

- Assuming maximum drag, lift, and area blockage
  F_D= 12N and F_L= 60N
- These calculated drag and lift forces were used to perform FEA analysis on the arc structure
- Factor of safety with Aluminum 6061 (at most stressed area)
  N = 10
- Analysis showed stress concentrations and deflection

Future Work

- Check specifications of sponsor provided components against design requirements
- Selection of appropriate stepper motor (responsible for pitch)
- Completion of procurement for all components and materials required for design
- Design the circuitry for electrical components
- Programming of user interface using LabView

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http://eng.fsu.edu/me/senior_design/2015/team12/