Low Speed Open Circuit Wind Tunnel Design

Wyatt Chapdelaine, Clint Dunn, Jeremy Helstrom
Chris Lambrecht, Randy Layton, Stephan Munari
Presentation Outline

• Overview of tunnel and project objectives
• Components of main tunnel and their design/construction
• Axial fan
• Instrumentation design
• Budget/FMEA
• Conclusion
Tunnel and Project Overview
Overview

• Tier One funds were designated for design of a new teaching laboratory wind tunnel
• Open circuit over closed circuit
• Four primary segments
Project Goals and Objectives Overview

- Maximum air speed of 60 mph
  - Ability to have variable speeds up to maximum desired speed
- Air flow quality
  - Minimal turbulence and experiments easily repeated
- Ability to be disassembled and stored
- Operation is easy and enjoyable for user
- Remain under set budget of $20,000
Meeting Goals and Objectives Overview

• Flow Quality and Pressure Losses
  – Utilize screens and a honeycomb to create laminar flow
  – Use favorable geometry in order to avoid flow separation and losses
  – Weather stripping to create seal between parts

• Disassembly
  – Disassembled into four parts
    • Settling chamber and nozzle, test section, diffuser, and fan
  – Test section sets into aluminum frame of nozzle and diffuser

• Support Stand
  – Stand to stabilize wind tunnel during operation

• Instrumentation
  – Test section and model mount design
  – Tunnel control software and instrumentation
Main Tunnel Components
Wind Tunnel Construction

• Arcon Inc.
  – Producing tunnel for a bid of not to exceed $9,000
• 3 Separate, Connectable Parts
  – Total Length 13’-1”
Settling Chamber

- Housing for screen inlays
  - Honeycomb Frame assembly or end
  - Increasingly fine mesh as heading toward test section
- 3’x3’ cross sectional area
- 2’-10” overall length
Mesh Screens

• Screens assembled according to porosity
  – Outermost is Honeycomb
    • 22,500 cells for ¼” cell diameter
  – 2\textsuperscript{nd} screen is a 4 mesh screen
    • 0.0470 inches spacing for porosity of 0.59
  – Final screen is an 8 mesh screen
    • 0.0170 inches for porosity of 0.71
Nozzle

- Nozzle utilizes a fifth-order polynomial profile to increase velocity without introducing turbulent conditions
- 9:1 Area ratio between inlet and outlet
- Nozzle frame out of wood inlayed with ABS plastic

\[ \xi = \frac{X}{L} \]  

\[ \dot{h} = \left[ -10(\xi)^3 + 15(\xi)^4 - 6(\xi)^5 \right] \left( H_i - H_o \right) + H_i \]
Test Section

• One main test section
  – Used for lift-drag assembly
  – Mounts securely to diffuser and nozzle
  – Permits entry of model mount for experimentation
Diffuser

- 4:1 area ratio allows 60 mph incoming air to leave the section at 15mph
- Shallow angle (5°) prevents separation of flow
- Section made of half inch plywood with 2”x2” supports to maintain its shape
Axial Fan
Square To Round Duct

- Whole duct made from 14 gauge (0.080”) sheet metal
- Square cross section of 24” by 24”
- Round cross section of 30” diameter
- Length of 30.5”
- Length made to match angle of diffuser
Fan

• VirTau 30" Belt Drive Tube Axial Duct Fan
  – Operate at 2.0 inches of water static pressure within test section

• Rated at 5000 CFM at 7200’
  – Operates at 3 HP, 230 V
  – Includes mounting legs and will be mounted to a cart

• Cart rated at 1200 lb load capacity with locking wheels
Instrumentation
Tunnel Control Loop

• Main control loop
  – MC DAQ reports wind tunnel airspeed from pressure transducer/Pitot tube to central LabVIEW program
  – The LabVIEW program then adjusts fan speed with a VFD according to the user specified air speed
Lift/Drag Model Mount

- Used to determine aerodynamic characteristics of models
- Capable of determining both lift and drag forces simultaneously
- Load cells were selected based on maximum drag and lift forces expected (25 lb)
- Lift and Drag are recorded and displayed by central LabVIEW program
Model Mount

Flow Direction

Test Section Boundary

Lift Load Cell

Linear Bearings

Drag Load Cell
Budget and FMEA
Budget Consideration

• Tier One fund of $20,000
• Budget considerations were a priority
• Itemized list of critical item prices here

<table>
<thead>
<tr>
<th>Item(s)</th>
<th>Price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Frequency Drive</td>
<td>655</td>
</tr>
<tr>
<td>Data Acquisition Unit</td>
<td>718</td>
</tr>
<tr>
<td>Fan</td>
<td>4934</td>
</tr>
<tr>
<td>Wind Tunnel Construction</td>
<td>9000</td>
</tr>
<tr>
<td>Square to round duct</td>
<td>849</td>
</tr>
<tr>
<td>Model mount</td>
<td>491</td>
</tr>
<tr>
<td>Total</td>
<td>17924</td>
</tr>
</tbody>
</table>
# FMEA (Failure Mode Effect Analysis)

<table>
<thead>
<tr>
<th>Process/Item</th>
<th>Failure mode</th>
<th>Potential Effect(s)</th>
<th>Severity (1-5)</th>
<th>Potential Cause(s)</th>
<th>Occurrence (1-5)</th>
<th>Current controls</th>
<th>Detection (1-5)</th>
<th>Recommended Action(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Incorrectly mated</td>
<td>Creates turbulence</td>
<td>1</td>
<td>Warped wood</td>
<td>3</td>
<td>Locking joints</td>
<td>3</td>
<td>Channels for connections</td>
</tr>
<tr>
<td>Connections</td>
<td>Tunnel separates in operation</td>
<td>1</td>
<td>2</td>
<td>Mounted</td>
<td>2</td>
<td>2</td>
<td>Check clamps</td>
<td></td>
</tr>
<tr>
<td>Flow straighteners</td>
<td>Wire mesh comes loose</td>
<td>Creates turbulence</td>
<td>1</td>
<td>Incorrectly mounted</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lift/Drag Measurements</td>
<td>Rust/parts come loose</td>
<td>Incorrect measurements</td>
<td>2</td>
<td>Over usage</td>
<td>3</td>
<td>1</td>
<td>Use rust resistant materials</td>
<td></td>
</tr>
<tr>
<td>Load cells fail</td>
<td>Incorrect measurements</td>
<td>1</td>
<td>Over usage</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diffuser</td>
<td>Flow separates from wall</td>
<td>Lower pressure</td>
<td>2</td>
<td>Incorrect</td>
<td>1</td>
<td>Low angle for</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>difference across</td>
<td></td>
<td>design of the</td>
<td></td>
<td>diffuser</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the fan</td>
<td></td>
<td>diffuser</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- FMEA is a process to identify possible failures of a system
- FMEA preformed on aspects that would affect testing
Conclusion
Thank You

• Dr. Kilty
• Dr. Naughton
  – Marlin Holmes
  – Eric DeMillard
• Dr. Belmont

• Questions?