Progress Report: CFD of the thermal performance of a Titan Montgolfiere

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Objectives (SURF 2009)

• Previous work shows that qualitative behavior of laminar regime similar to turbulent regime
• Extend laminar balloon simulations to consider transient behavior
• Control vent controls altitude
  – Need to predict transient timescales upon venting
• Previous simulations used closed balloon
  – Add realism by opening bottom
Progress

• Familiarized with the IBFS code for laminar flow
• Reproduced selected previous data
• Wrote a new Matlab script to post-process simulation results
• Generated data for a hole at the bottom
• Presently examining cases with a hole at the top.
Dimensional Analysis

Minimize the number of computations and obtain functional groups

Scaled temperature or non-dimensional net buoyancy

\[ \tilde{B} = \frac{6F_b}{\pi \rho_\infty \nu^2} \]

Non-dimensional heat input

\[ \tilde{Q} = \frac{gD^2 \dot{Q}}{\rho_\infty c_p T_\infty \nu^3} \]

\[ \tilde{B} = \text{fun} \left( \tilde{Q}, \text{balloon geometry} \right) \]
Cases Examined for a Single walled-balloon

- Non Dimensional Heat input values selected:
  - \( Q^\sim = 8000 \)
  - \( Q^\sim = 16000 \)
  - \( Q^\sim = 125000 \)
  - \( Q^\sim = 625000 \)
  - \( Q^\sim = 1.25e6 \)
  - \( Q^\sim = 1e7 \)
  - \( Q^\sim = 1.35e8 \)

- Hole Sizes:
  1. No hole
  2. Bottom hole of diameter = 10\%D
  3. Bottom hole of diameter = 15\%D, 20\%D
  4. Bottom hole of diameter = 10\%D and top hole of diameter = 1\%D (currently examining)
Single-walled Montgolfiere

\[0.75 \tilde{Q}^{0.8}\]
Temperature Contours (Varying hole size)

Hole dia = 0.087D

Hole dia = 0.20D

Hole dia = 0.15D

$Q^\sim = 16000$
Velocity Plots (Varying Hole size)

Hole dia = 0.087D

Hole dia = 0.15D

Hole dia = 0.20D

Q~ = 16000
Single-walled Montgolfiere

- Correlation
- Old Data
- Single wall
- Bottom hole: D=0.1

\[ 0.75 \tilde{Q}^{0.8} \]
Single-walled Montgolfiere

Correlation

- Old Data
- Single wall
- Bottom hole: D=0.1

(Zoomed in)
Temperature Contours: High heat input values, hole dia = 0.1

$Q^\sim=625000$

$Q^\sim=1e7$

$Q^\sim=1.35e8$
Velocity Plots: High heat input values, hole dia = 0.1

$Q^\sim=625000$  $Q^\sim=1e7$  $Q^\sim=1.35e8$
Goals for the future

- Run simulations with different vent hole sizes from time $t=0$ to steady state.

- Predict transient time scales for venting by starting from a particular steady state condition.

- Run similar cases for double walled balloons