Structural Mechanics Computation of the Orion Spacecraft Drogue Parachute in Compressible-Flow Regime

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Background
- Orion Drogue Parachute

- Field Tests
  - Drop test
  - Cost is about a million dollar for each test.
  - Wind-tunnel test
  - Scaling challenge due to coupling between the canopy deformation and the airflow.

Computational analysis can serve as a practical alternative.

Objective
- Study the pressure dependence and effect of time-step size, and damping coefficient.

Methods and Conditions
- Governing Equations
  - Structural mechanics equations
- Spatial Discretization
  - Finite element method

Base conditions
- Mach number: 0.5
- Altitude (ft): 35,000

Parachute configuration

Base Computation (Case 0)

<table>
<thead>
<tr>
<th>Pressure (Pa)</th>
<th>(\Delta t(s))</th>
<th>(\eta (s^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,500</td>
<td>0.001</td>
<td>0</td>
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</tbody>
</table>

Case 0 results look reasonable. We test:
- different pressures
- different time-step sizes \(\Delta t\)
- different structural damping coefficients \(\eta\)
to see how the settled parachute shape changes.

Pressure Dependence

- Case 1
  
<table>
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- Parachute canopy in Case 1 is positioned lower than it was in Case 0.
- Parachute diameter in Case 1 is smaller than it was in Case 0.
- Parachute canopy in Case 2 is positioned higher than it was in Case 0.
- Parachute diameter in Case 2 is larger than it was in Case 0.

- Case 2
  
<table>
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<tr>
<th>Pressure (Pa)</th>
<th>(\Delta t(s))</th>
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<tbody>
<tr>
<td>3,000</td>
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Conclusions
- How the solution and the solution process vary
  - Pressure : Parachute diameter and vertical position change.
  - \(\Delta t\) : Computing time can be reduced by increasing \(\Delta t\).
  - \(\eta\) : The settled shapes are close, but \(\eta=140\ s^{-1}\) leaves out movement details, which are actually not needed.
- Larger time-step size?
  - With larger \(\Delta t\), we can reach the settled shape sooner, with almost the same shape as in Case 0, but with less computing time.

Future Directions
- Mesh resolution effect
- Fluid computations with the deformed shape

References

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