Mass Estimation Modeling of Stacked Tori Hypersonic Inflatable Aerodynamic Decelerators

Lin Li[1], Robert D. Braun[1], Michael C. Lindell[2]

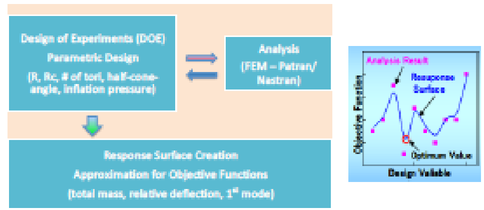
[1] Georgia Institute of Technology, [2] NASA Langley Research Center

Abstract

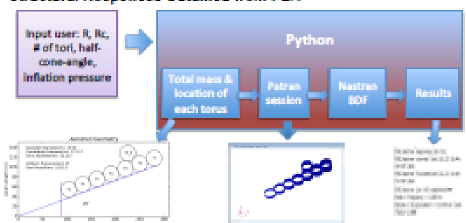
Many Entry, Descent and Landing (EDL) architectures are being developed to enable high mass, deep space exploration missions to planets with an atmosphere including Mars, Venus, Titan, and the gas giants. One such technology is the Hypersonic Inflatable Aerodynamic Decelerator (HIAD), which uses an inflatable aeroshell to slow down the payload upon hypersonic entry into an atmosphere. A particular HIAD design currently being developed is the stacked tori configuration, which assembles a series of tori of increasing diameter to form a cone shape. HIAD designs with different number of tori, major diameter, inflation pressure and cone angle have different structural and aerodynamic performance and mass characteristics. In order to determine the preferable HIAD configuration for a specific EDL mission, it is important to estimate the total mass of the aeroshell since it affects the ballistic coefficient and, in turn, the heating and deceleration. The deflection is also important since it influences the vehicle stability and aerodynamics. While the inflatable structural mass and deflection can be calculated knowing the diameter, number of tori, rigid centerbody nose radius, and half-cone-angle it is computational costly to analyze every single configuration for a given mission. Therefore, a Response Surface Methodology (RSM) was developed to calculate the total mass of the fabric and gas and the maximum deflection for a selected HIAD configuration. A design space was constructed by varying each input parameter within predetermined bounds. The calculations involve using Python to calculate the geometry as well as material, gas, and total mass of a HIAD with a given set of parameters defined by the user. The Python script then passes these parameters to Patran, which constructs the HIAD geometry. The geometry is used as an input into Nastran to solve for the maximum deflection and the first vibrational mode. The RSM was used to explore the relationship between the HIAD characteristics (diameter, cone angle and number of tori) and the response (total mass of the inflatable structure and its deflection). This project can be used to aid mission designers in the selection of the most efficient HIAD configuration for their mission based on the goal of minimizing total mass while meeting a maximum allowable deflection requirement.

Methodology

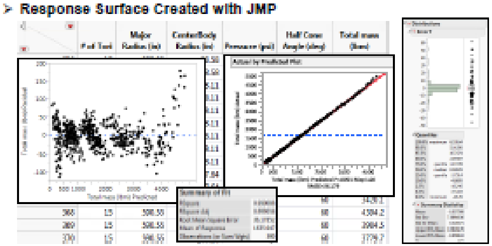
➢ **Design Parameters and Modeling**



➢ **Structural Responses Obtained from FEA**



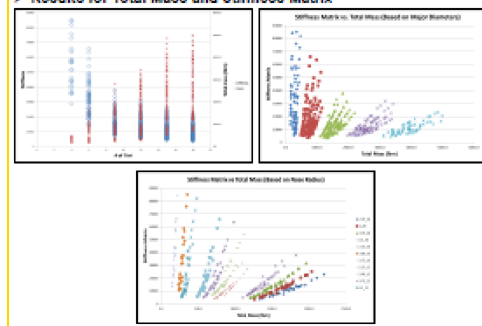
➢ **Response Surface Created with JMP**



Results

➢ **2nd Order Polynomial Approximation Function for Deflection**

➢ **Results for Total Mass and Stiffness Matrix**



Summary

- ➢ 2nd order response surface created for rapid deflection estimation
  - ➢ Similar method can be used to estimate the total structural mass and stiffness
- ➢ Major diameter and rigid nose radius dominate structural response
  - ➢ Generally, major diameter determined by aerodynamics, rigid nose radius determined by payload size
- ➢ Pareto frontier: min(structural mass) & max(stiffness)
  - ➢ Increasing cone angle — less stiff — less mass
  - ➢ Increasing inflation pressure — more stiff — more mass
  - ➢ Increasing number of tori — less stiff — less mass

Contact

Lin Li
Georgia Institute of Technology
lli313@gatech.edu

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