Optimal Sizing and Placement of Inflatable Stiffeners in High Altitude Airships using Finite Element and Asymptotic Modeling

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ABSTRACT

High Altitude Airships (HAA) are lighter-than-air platforms deployed at around 20km altitude above sea level, currently gaining widespread attention for their potential as cheap substitutes for satellites. Non-rigid airships are the only choice for HAA due to their low-density requirement. They are characterized by the lack of metal frames, which in turn restricts payload capacity as well as rigidity of the airship envelope [2].

Variational Asymptotic Method (VAM) is a computational tool used to develop asymptotic models for composite structures like beams and shells [1]. This has advantages such as elimination of *ad hoc* assumptions as well as dimensional reduction in the models without compromising on accuracy. Hence, according to the nature of the problem, a theory can be derived with the desired orders of accuracy.

This work is an attempt to propose a system of stiffeners to the airship envelope using inflatable membranous toroids, the advantages being prevention of kinks on the envelope, reduction in overall structural weight in comparison to both metal-stiffened and thicker unstiffened cases, and in turn an increase in the payload capacity for a given volume.

3-D nonlinear static finite element analysis (FEA) is performed on the model to determine the stress distribution using commercial FEA packages. Geometric nonlinearity due to large displacements and material nonlinearity due to large strains are simultaneously taken into consideration during FEA. Hence, a benchmark problem is set up for initial validation. The reduction in the required design thickness of envelope due to introduction of these novel stiffeners is investigated. Optimal inflation pressures in the stiffeners and the envelope, membrane thickness of stiffeners, as well as their positioning and spacing within the airship envelope are found out. Next, first-order solution using VAM is used where constitutive law is generated. This will be inverted into a design module for the whole structure, where the optimal configuration is generated in iterative runs of the VAM-based code. An attempt is made to quantify the enormous computational ease VAM provides, compared to performing FEA of model.

REFERENCES

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