Dimensionless Parameters for Estimating Mass of Inflatable Aerodynamic Decelerators

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Abstract

This paper provides an overview of a mass estimating technique for inflatable aerodynamic decelerators. The technique uses dimensional analysis to identify a set of dimensionless parameters for inflation pressure, inflation gas mass, and flexible material mass. The dimensionless parameters are similar to drag coefficient, and these parameters allow scaling of an inflatable concept with geometry sizing parameters (e.g., diameter), environmental conditions (e.g., dynamic pressure), inflation gas properties (e.g., temperature), and mass growth allowance. This technique is suitable for estimating the mass of attached (tension cone, hypercone and stacked toroid) and trailing inflatable aerodynamic decelerators.

The technique relies on simple engineering approaches developed by NASA in the 1960s, 1970s, and some recent developments. The technique was recently used for NASA's Mars Entry and Descent Landing System Analysis (EDL-SA) project. The EDL-SA results were validated with two separate sets of finite element analyses. A typical inflatable concept consists of following components: toroid(s), radial straps, gores, rigid heatshield, and thermal protection system. The last two components will not be included in the final paper.

The structural concept for toroids can be either film, coated fabric, or a combination of thin bladder covered with reinforced fabric material. The latter concept will also include axial straps to counter in-plane and out-plane buckling. The dimensionless parameter for minimum inflation pressure is a critical parameter for toroid mass, and this parameter is shown to be only dependent on the geometry of inflatable concept. The mass of the inflation system is based on a user-defined mass fraction. The gores are used as gas barrier layers that also carry loads produced by the dynamic pressure. The radial straps are used to connect the toroid(s) to the rigid heatshield and are made of high performance fabric.

The results indicate that the dimensionless parameter for gas mass depends on only geometry parameters and gas properties. Similarly, the dimensionless parameter for mass of flexible material depends on only geometry and material properties.