Dynamic Behavior of Parachute Canopy Fabrics and Seams

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Abstract

Parachute canopy fabrics and seams are designed and qualified under loading conditions that are far from what they undergo during the deployment. The current design paradigm for parachutes generally rely only on ultimate strength measured in uniaxial stress conditions, and ignore anisotropy, nonlinearity, temperature sensitivity, stress bi-axiality, and visco-plastic behavior of fabrics. Furthermore, the effect of seams and other stress concentrators are usually only considered through knock down factors not thoroughly studied. While a parachute failure is critical and should be avoided at all costs, it is also not desirable to use high safety factors given the significant cost of adding unnecessary mass in aerospace systems. With the significant expansion of the capabilities of fluid-structure interaction (FSI), development of accurate constitutive models of textiles under deployment conditions has become increasingly necessary. In this work two methods of dynamic extension of fabrics at intermediate rates, comparable with those occurring during deployment, are presented. A drop tower apparatus and a modified gas-gun driven direct impact setup were employed to simulate the rapid deployment of a parachute, closely mimicking the high-amplitude impulse forces encountered during actual parachute deployment. These tests provide critical insights into the fabric's tensile properties. Additionally, large-scale biaxial testing was employed to simulate realistic loading conditions on fabrics by pulling them along the warp and weft directions at the same time. The biaxial machine enables testing of larger fabric samples, thereby reducing boundary effects and providing more accurate data compared to previous work focusing on small swatch-scale biaxial tests. Both biaxial and fast-rate tests aim to emulate the conditions the fabric experiences during deployment. The combined results from these tests provide a better understanding of parachute fabric behavior, contributing to the development of more reliable and safer parachutes. Finally, seam tests were conducted to evaluate the integrity and performance of the French fell seam method, commonly used to connect gores in parachutes. It indicated significant additional compliances normal to the seam, but minimal loss of strength, at least in quasi-static testing. Dynamic testing is planned and expected to also include the localization of strain due to additional mass. This study underscores the necessity of multi-faceted testing approaches to ensure the optimal performance and safety of parachute fabrics in diverse environmental conditions.

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