Paper ID: 37491
oral
student

MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

Author: Mr. Jared Butler
Brigham Young University, United States, jaredbutler824@gmail.com

Dr. Aaron Parness
Caltech/JPL, United States, Aaron.Parness@jpl.nasa.gov
Mr. Stefano Mancini
Politecnico di Torino, Italy, mancini.stefano90@gmail.com
Dr. Spencer Magleby
Brigham Young University, United States, magleby@byu.edu
Dr. Larry Howell
Brigham Young University, United States, lhowell@byu.edu

HIGHLY COMPRESSIBLE ORIGAMI BELLOWS FOR MICROGRAVITY DRILLING-DEBRIS CONTAINMENT

Abstract

This paper describes the results of designing and evaluating origami-based bellows as a solution for dust containment during microgravity drilling. The potential benefits of an origami-based solution created an opportunity for application on NASA's Asteroid Redirect Mission (ARM) to protect sensitive parts from debris.

In space, bellows are frequently used to protect sensitive instruments and moving parts from dust and debris. Spacecraft have traditionally relied upon metal bellows for protection. Origami-based bellows offer an opportunities to reduce mass, improve compression to extension ratios, and lower parasitic reaction forces during compression. They also have the flexibility to rotate or bend to accommodate system motion. The manufacture of origami-based bellows is likely to be less expensive than metal bellows. Origami-based bellows are capable of compression ratios exceeding 1:30, compared to 1:8 for metal bellows, making them a strong candidate in bellows design for space mechanisms.

For application on the ARM, origami-based bellows were designed to fit spacial limitations and meet needed compression ratios. Designs have demonstrated high mass reductions, improved stroke length, greatly decreased stowed volume, improved flexibility, and reduced reaction forces in comparison with traditional metal bellows. Material and design testing demonstrated that a nylon-reinforced polyvinyl fluoride based bellows with an aramid fiber stitched seam is well suited for debris containment in space conditions. Various epoxies were able to maintain an adequate bond with polyvinyl fluoride below expected environmental temperature for bellows mounting to the ARM drill. Asymmetric compression of the bellows can occur at extreme low temperatures and is preventable by balancing stiffness within the structure.

Prototype bellows were mounted to the ARM drill for full-model drill testing at room temperature. After several months of drill testing, no observable failure has been identified. The bellows has demonstrated no signs of fatigue failure and remains fully intact. The stitched-seam has showed no signs of failure or propagation of perforations. Additionally, debris has been adequately contained as predicted.

Origami bellows can be adapted through material selection and crease design to suit a variety of design needs and show great promise in space applications such as shaft protection, deployment mechanisms, supports, or protective barriers.