Numerous types of spacecraft exist for exploring the surface of planetary bodies. Planetary hoppers are one type that traverse surfaces by making multiple launches and landings. To date, the only successful landers have been wheeled rovers or fixed landers. These land a single time and rely on one-time use mechanisms such as crushable aluminum honeycomb shock absorbers or inflatable airbags to reduce shock loading to the spacecraft. A hopper requires a mechanism that can operate reliably multiple times in harsh environments.

Most terrestrial shock absorbers use hydraulic fluid pressurized with gas or springs. Because the hydraulic fluid is incompressible it allows for compact and inexpensive devices. Hydraulics have been used in space applications but require thermal controls to maintain the proper liquid viscosity. They also require dynamic seals which in the case of a leak can degrade performance, shorten mission life, and contaminate sensitive science equipment. Leakage is also a concern in pressurized systems in space because missions to planetary bodies can take decades from when a system is installed to when it actually is used.

To address these issues a pneumatic metal bellows shock absorber is proposed. This shock absorber could operate at any expected spacecraft environment. Metal bellows are designed to operate from cryogenic temperatures to several hundred degrees Celsius. A hermetically sealed system eliminates the risks of a system with dynamic seals. Metal bellows are in common use for terrestrial harsh environments and vacuum applications. Small metal bellows are used as dampers in pressure control systems with small displacements.

Models for the dynamics of this device are developed and presented here. Starting from the ideal gas law, polytropic compression, and compressible flow through an orifice, differential equations of motion and pressure are derived. These equations are nonlinear for the displacements under consideration and are nondimensionalized to provide insight. Equations for the steady state solution, limits for maximum stroke, and estimated natural frequency are presented. Finally a method is developed to estimate a linear damping ratio that is used as the objective function for optimization.

Metal bellows actuators can operate as a passive damper with a simple orifice between control volumes. Performance can be improved by adding controls. The first control strategy is adding a check valve so the effective orifice size varies between compression and extension. The next control strategy replaces the orifice with a control valve and by timing the opening and closing of the valve optimal performance can be achieved. Finally the concept of compressing the gas in the second volume is proposed so that in combination with the control valve the actuator can be used to help launch the hopper. The results of this research show that such a device holds promise as both as passive and active shock absorber for use in planetary hopper and other harsh environments.

Major: Mechanical Engineering

Educational Career:
Bachelor’s of Mechanical Engineering, BS, 1996, Rutgers University
Bachelor’s of Computer Science, BS, 2004, Florida State University

Committee in Charge:
Jeffrey Kauffman, Chair, Mechanical and Aerospace Engineering
Shawn Putnum, Mechanical and Aerospace Engineering
Seetha Raghavan, Mechanical and Aerospace Engineering

Approved for distribution by Jeffrey Kauffman, Committee Chair, on November 4, 2015.

The public is welcome to attend.