Flexible Optimization and Uncertainty-Enabled Design of Helical Compression Springs in Nonlinear Spring-Mass-Damper Systems

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Many mechanical devices operate via a combination of constant and position and velocity-dependent forces, and their behavior can be modeled by traditional spring-mass-damper differential equations. The constant and position-dependent forces often are manifested by spring-like mechanisms. In particular, helical compression springs are designed to provide these forces by controlling the spring geometry and constituent spring materials. A previous IMSM project team developed a nonlinear spring-mass-damper model to simulate the behavior of a rocket-mounted acceleration switch. The team accounted for spring forces, but they did not consider the design of the spring. Nevertheless, the team determined that the spring forces are critical to performance, ascertained that variations and uncertainties in the design could have adverse effects, and ultimately optimized spring forces to improve switch performance under uncertainty. Given the importance of the spring forces, optimized spring designs that meet a variety of performance goals and that take into account uncertainty effects are sought. Multiple spring performance objectives and constraints must be considered, including ones that address spring force relaxation. This project aims to develop an efficient, flexible method to optimize helical compression springs based on various performance measures and to quantify how spring design can lead to a switch whose operation is insensitive to variation and uncertainty. The project's approach is to develop a modeling capability and subsequently to study spring and switch behavior for varying design parameters. In support of project development, switch and spring data, and specifiable design parameters and constraints will be provided.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

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