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Current Contact Information

Current Email Address: kaitlin.spak@gmail.com

Street Address (line 1): 916 OAK AVE

Street Address (line 2):

City: REDWOOD CITY State/Province: CA Daytime Phone: 530 277 3073

Country: USA Postal Code: 94061 Evening Phone:

Permanent Contact Information

Permanent Email Address: kaitlin.spak@gmail.com

Street Address (line 1): 7405 BALDWIN DAM RD

Street Address (line 2):

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Modeling Cable Harness Effects on Spacecraft Structures

Kaitlin S. Spak

Dissertation submitted to the faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Mechanical Engineering

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Jeff T. Borggaard
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Modeling Cable Harness Effects on Spacecraft Structures

Kaitlin S. Spak

ABSTRACT

Due to the high mass ratio of cables on lightweight spacecraft, the dynamic response of cabled structures must be understood and modeled for accurate spacecraft control. Models of cable behavior are reviewed and categorized into three major classes consisting of thin rod models, semi-continuous models, and beam models. A shear beam model can predict natural frequencies, frequency response, and mode shapes for a cable if effective homogenous cable parameters are used as inputs. Thus, a method for determining these parameters from straightforward cable measurements is developed. Upper and lower bounds for cable properties of area, density, bending stiffness, shear rigidity, and attachment stiffness are calculated and shown to be effective in cable models for natural frequency prediction. Although the cables investigated are spaceflight cables, the method can be applied to any stranded cable for which the constituent material properties can be determined.

One aspect unique to spaceflight cables is the bakeout requirement, a heat and vacuum treatment required for flight hardware. The effect of bakeout on spaceflight cable dynamic response was investigated by experimentally identifying natural frequencies and damping values of spaceflight cables before and after the bakeout process. After bakeout, spaceflight cables showed reduced natural frequencies and increased damping, so a bakeout correction factor is recommended for bending stiffness calculations.

The cable model is developed using the distributed transfer function method (DTFM) by adding shear, tension, and damping terms to existing Euler-Bernoulli models. The cable model is then extended to model a cabled structure. Both the cable and cabled beam models include attachment points that can incorporate linear and rotational stiffness and damping. Cable damping mechanisms are explored and time hysteretic damping predicts amplitude response for more cable modes than viscous or structural damping. The DTFM models are combined with the determined cable parameters and damping expressions to yield frequency ranges that agree with experimental data. The developed cabled beam model matches experimental data more closely than the currently used distributed mass model. This work extends the understanding of cable dynamics and presents methods and models to aid in the analysis of stranded cables and cabled structures.