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Transient response of a disk with discrete impedances from its decelerating boundary

Michael El-Raheb

Satellite Consulting Inc., 1000 Oakforest Lane, Pasadena, CA 91107, USA

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ABSTRACT

Analyzed is transient response of an elastic disk from its decelerating boundary. Eigenfunctions of the bear disk are used as Galerkin trial functions to the disk with discrete masses and impedances in the form of a one-degree-of-freedom (1-dof) oscillator. The oscillator mass models a module connected to the disk and the spring models the connecting isolation stiffness. For a fixed oscillator mass, except for very weak springs, stiffness mostly raises transmissibility of deceleration from disk to mass.

1. Introduction

Un-manned cost effective missions for space exploration rely on low-cost modules that hard-land on planet soil to avoid the expense of soft-landing equipment such as retro-jets. One future mission to Venus will drop a pressurized orbital module aided by parachutes up to some altitude from the planet surface then release it to free-fall till it strikes the soil. Predicted speed at impact does not exceed 10 m/s. One challenge is to insure that sensitive instruments housed in the spherically capped cylindrical module will be protected from the high deceleration or "g" level reached during impact that can attain 150 g's. Although the module is cushioned by energy absorbing material like metal foam, nevertheless the deceleration transmitted to disk shelves carrying measuring equipment are magnified due to shelf inertia. Since temperature on Venus is of the order of 500 °C, polymers, rubbers and liquid operated shock absorbers cannot be used to passively attenuate deceleration response. Therefore the only means adaptable to such harsh environment is a simple one-degree-of-freedom (1-dof) oscillator that interferes destructively with disk motion reducing its response.

Most recent references on disk dynamics concern thin rotating disks simulating a computer hard drive as in Heo et al. (2003), Ramachandra and Simha (2004), Sinha (1988). Asymmetric response of a disk was analyzed by El-Raheb and Wagner (2001) to study the effect on transient response of foot-print eccentricity. El-Raheb (2002) investigated the coupling of asymmetric dynamic motions affecting disk stability from axisymmetric impact. El-Raheb (2004) analyzed a complex geometry of a capsule formed by a thin cylinder and two disks connected to its boundaries simulating elastic confinement of comminuted material exerting non-uniform transient pressure on the capsule walls. El-Raheb (2007) treated the effect of disk perforation from a penetrator on transient strain histories, thus identifying damage of the disk from impact. El-Raheb (2008) simulated transient deceleration signatures of a disk striking a base of metallic foam at small obliquity, as a means of decelerating the disk to rest from an initial velocity. No references were found that address disks carrying discrete masses and impedances.

This work treats the asymmetric transient response of a homogeneous disk carrying discrete masses and impedances on its surface, and subjected to a decelerating profile at its boundary. The analysis adopts a Galerkin method where eigenfunctions of the bear disk are used as trial functions in solving the eigenproblem and transient response of the disk with discrete masses. A similar method was adopted by El-Raheb and Wagner (1989) in computing transient response of a thin cylinder with discrete masses attached to its surface.

Section 1.1 derives the eigenproblem of the bear disk followed by the Galerkin method of the disk coupled to discrete masses. For the case of a central mass, eigenfrequencies from the Galerkin method are compared to those of a segmented disk with varying properties for each segment (see Appendix B). Section 1.2 extends the analysis to a disk carrying discrete 1-dof oscillators. Section 2 presents histories for both central and non-central masses with emphasis on magnification of deceleration response from inertia of disk and discrete impedances.

E-mail address: mertrident@earthlink.net

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