NASA TECH BRIEF

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Hybrid Coordinate Formulation Used for the Design of Attitude Control Systems for Flexible Spacecraft

Interaction between spacecraft attitude control systems and flexible structures is receiving increasing attention because many appendages cannot reasonably be designed with sufficient rigidity to justify the traditional assumption that the dynamic response to attitude control devices can be uncoupled from vehicle vibrations; whenever coupling is present, the result may be control system instability. It has therefore become necessary to confront directly the coupled equations of vibration and attitude control. Analytical techniques developed for aircraft and missile applications employ coordinates representing the normal modes of (small) deformation of the vehicle. This *vehicle normal coordinate* approach has been successfully applied to space vehicles of a limited class, but for many modern spacecraft this method is inappropriate. Specifically, if the vehicle includes any rotating parts, discrete dampers, or nonlinearities, the traditional vehicle normal coordinate approach is generally inadequate. Various dynamical formalisms have been proposed for the direct simulation of a system of interconnected and actively controlled rigid bodies, but this *discrete coordinate* approach sacrifices the advantages afforded by distributed or modal coordinates when structural deformations can be assumed to remain small.

A *hybrid coordinate* method has been developed which combines certain of the advantages of discrete and distributed (modal) coordinates by using both simultaneously. In a report summarizing the method, theoretical development is extended as necessary for applications of practical interest. Explicit analyses are presented in sufficient detail to establish the utility in flexible space vehicle control system design of a hybrid coordinate formulation.

A three-stage process for the design of attitude control systems for flexible vehicles is described: (1) Preliminary design is based on root locus plots for single-axis response of linearized systems with truncated modal coordinate matrices; (2) Modifications are imposed as required by eigenvalue analyses of coupled linear systems; (3) Design confirmation is established by complex, nonlinear differential equation simulation using digital computer numerical integration.

These procedures are illustrated by application to two vehicle models. A very simple model is used to demonstrate in physically meaningful terms the potentially destabilizing influence of vehicle flexibility, and corresponding results are shown for a realistically complex model of the Thermoelectric Outer Planet Spacecraft.

Note:

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under contract to
NASA Pasadena Office
(NPO-11714)

Category 09