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Dynamic Analysis of Flexible Space Shuttle Remote Manipulator System with Large Payloads

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Abstract

This paper presents a new approach for determination of vibration response of the triply articulated Space Shuttle Remote Manipulator System (SRMS) with large rigid overhanging payloads. In contrast to other researchers dynamic modelling is based on the exact eigenvalue analysis of the two main flexible links with a rigid end effector and payload, including the effect of interaction of the Shuttle. A wide range of SRMS configurations and payloads with joints free and locked is examined for bang-bang slews and with all joints locked for payload positioning using Shuttle thruster firing.

Introduction

In recent years considerable interest has been shown in the vibration and control of flexible beams subject to rotational manoeuvres due to torque motors, producing acceleration / deceleration sequences. Of particular interest is the effect of flexibility in robot arms, for example the Space Station Mobile Manipulator System (MMS) and the Shuttle Remote Manipulator System (SRMS) shown in figure 1.

Dynamic analysis of such systems has generally been carried out by assuming approximate mode shapes for the separate links, taken as mode shapes for uniform beams without end masses or rotary inertias. A literature search shows that this approach has not been verified by comparison with the exact solution based on the classical Bernoulli beam theory. Many authors have studied the effect of concentrated masses and springs on single beam natural frequencies with approximate or exact analytical methods but have rarely included the mode shapes. However, some authors have studied the problem of a ground based single link flexible robot, but with one end inertially pinned. An approximate solution to a two-link Hermes Space Shuttle was studied in [1] for torsion spring restrained joints and fixed link configurations, for the first four natural frequencies of the Shuttle-payload system.

As a prelude to the present study the authors have considered the mode shapes and natural frequencies of a single beam with large end masses [2]. This paper presents an exact solution for the natural frequencies and mode shapes, of the lower modes, of a double flexible link system with rigid end effector and overhanging end masses and rotary inertias, such as the SRMS in Figure 1. The analysis includes torsion springs to simulate joint flexibility when the revolute joints at O_1, O_2 and O_3 are locked. The vibration response of the SRMS / payload system is considered for rotation of the