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Non-linear response of a magneto-elastic translating beam with prismatic joint for higher resonance conditions

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ABSTRACT

The non-linear response of a magneto-elastic translating beam having prismatic joint for higher resonance conditions is studied. A periodically varying transverse magnetic field is applied to the system. Two frequencies of prismatic motion and oscillating transverse magnetic field are implemented to the system. The method of multiple scales as one of the perturbation techniques is used to derive two first order ordinary differential equations that govern the time variation of the amplitude and phase of the response. Then a stability analysis is conducted for subharmonic resonance and simultaneous resonance conditions. A parametric study is performed to investigate the effect of magnetic field strength, amplitude of prismatic motion, damping and payload mass on the frequency response curves for both the resonance conditions. The catastrophic failure of the system may occur due to the presence of saddle-node and pitchfork bifurcations. The results obtained by method of multiple scales are compared with those obtained by numerically integrating the reduced equations and are found to be in good agreement. The developed results can be applied to control the vibration of a beam with prismatic joint subjected to magnetic field for third order subharmonic resonance and simultaneous resonance conditions.

1. Introduction

Owing to the demand for the improvement of productivity and quality in industry, modeling of lightweight links in robot system has received significant attentions for their low energy consumption, high operating speed, better maneuverability and better transportability. But the use of lightweight link experiences a penalty due to elastic deformation and vibration typically associated with the structural flexibility and the high-speed motion of the long reach slender link. As a result an inaccurate positioning and material failure of the link will take place. This undesirable vibration of the link can successfully be suppressed by improving the dynamic models and incorporating different control strategies. Here to suppress this undesirable vibration, a harmonically varying transverse magnetic field is applied to the system. A single link flexible robotic manipulator can be modeled as a translating flexible beam having a prismatic joint. However, the intention of the present work is to study the non-linear response of a magneto-elastic translating flexible beam with prismatic joint subjected to transverse magnetic field. A brief literature related to the dynamics and control of flexible beam with prismatic joint is cited in the following paragraph.

Tabarrok et al. [1] derived the equation of motion of an axially moving beam whose length changes with the time. Authors have used Newton's second law to derive the equation of motion of the system. While Coleman [2] determined the natural frequencies of a single-link flexible Cartesian manipulator, Coleman and McSweeney [3] derived the eigenfunction and investigated the eigenspectrum of a single-link flexible Cartesian manipulator. Theodore and Ghosal [4] investigated the dynamic behavior of flexible-link manipulators with prismatic joints. Here, the translating flexible link manipulator has been modeled as an axially moving Euler–Bernoulli beam. Basher [5,6] studied the dynamic modeling of a single-link flexible robot arm with both the rotational and translation motions. In these work, an analytical model of the manipulator has been developed using Euler–Bernoulli beam equation and modal expansion method. Al-Bedoor and Khulief [7] determined the approximate analytical solutions of an axially moving elastic beam with different end conditions. Tadikonda and Baruh [8] proposed different control strategies to minimize the vibration problem of a single-link flexible Cartesian manipulator. Wang and Wei [9] investigated the effect of elastic and translational motions of the beam on each other using Lagrangian method where a flexible robot arm was modeled by a moving slender beam having prismatic joint. Liu [10] investigated the effect of geometric non-linearities on the dynamic behavior of

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