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学 位 論 文 要 旨
Dissertation Summary

氏　名 (Name): Abdul Kadir Muhammad

論　文　名: Finite Element Analysis and Experiments on Vibration Control of Flexible
(Dissertation Title) Manipulators Using Piezoelectric Actuators

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Employment of flexible manipulators is recommended in the space and industrial applications in order to accomplish high performance requirements such as high-speed besides safe operation, increasing of positioning accuracy, and lower energy consumption, namely less weight. However, it is not usually easy to control a flexible manipulator because of its inheriting flexibility. Deformation of the flexible manipulator when it is operated must be considered by any control. Its controller system should be dealt with not only its motion but also vibration due to the flexibility of the link.

The main subjects of this research are modeling and designing of controllers to suppress vibration of flexible single-link and two-link manipulators. The manipulator systems with flexible links are continuous dynamical systems that have continuous distributions of mass and elasticity. Such systems are characterized by an infinite number of degrees of freedom. Therefore, finite element method was chosen in modeling and designing of controllers for the systems using one-dimensional and two-node element type.

The single-link flexible manipulator used in this research consists of an aluminum beam as a flexible link, a clamp-part, a servo motor to rotate the link, a piezoelectric actuator to control vibration and a base. Modeling of the system was prefaced by kinematics analysis in global and rotational coordinate frames. Equations of motion of the flexible single-link manipulator were derived using finite element method. Computational codes on time history responses, Fast Fourier Transform (FFT) processing and eigenvalues - eigenvectors analysis were developed to calculate the dynamic behavior of the link. An end-effector that treated as a concentrated mass was introduced to demonstrate a complete flexible single-link manipulator system. Furthermore, a control scheme using a piezoelectric actuator was designed to suppress the vibration of the system. A proportional (P), a proportional-derivative (PD) and an active-force (AF) controls strategies were designed and compared their performances through the calculations and experiments. Based on the calculated results, the effect of D-controller was very small compared to P-controller, therefore using a P-controller is sufficient for experiment. The calculated and experimental results show the superiority of the proposed AF- control compared to the P and PD ones to suppress the vibration of the flexible single-link manipulator.

The flexible two-link manipulator used in this research consists of two aluminum beams as flexible links, two clamp-parts, two servo motors to rotate the links, piezoelectric actuators to control vibration and a base. Modeling of the system was prefaced by kinematics analysis in global and rotational coordinate frames. Equations of motion of the flexible two-link manipulator were derived using finite element method. Computational codes on time history responses, FFT processing and eigenvalues - eigenvectors analysis were developed to calculate the dynamic behavior of the links. An end-effector that treated as a concentrated mass was introduced to demonstrate a complete flexible two-link manipulator system. Furthermore, a control scheme using one and two piezoelectric actuators was designed to suppress the vibration of the system. Two proportional, two proportional-derivative and two active-force controls strategies were designed and compared their performances through the calculations and experiments. Based on the calculated results, the effect of the second piezoelectric actuator was small compare to the first one. Therefore, using one piezoelectric actuator is sufficient for experiment. The calculated and experimental results have revealed that the proposed control scheme can effectively suppress the vibration of the flexible two-link manipulator even though using only one piezoelectric actuator as well as the effectiveness of the proposed PD-control compared to the P and AF ones to suppress the vibration of the system.