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Tilte of the Thesis : Analysis of Parallel Manipulators using Flexible Joints

ABSTRACT

This thesis investigates the development and analysis of parallel manipulators using flexible joints. The conventional six degree of freedom parallel manipulators called Stewart platform is chosen as the base mechanism for designing the passive isolator due to its high load carrying capacity and robust kinematic and dynamic behavior. The Stewart platform consists of two rigid plates connected by six legs. Preferably, the connections of the rigid plates to legs are through twelve numbers of frictionless spherical joints which would be replaced in the actual model by suitable flexible joints, as the spherical joints require lubrication and are vulnerable to develop backlash errors with time.

In this work, an initial geometrical model is considered with attachment points on the two rigid plates i.e. top plate and base plate. The kinematic analysis includes the derivation of closed-form expressions for the inverse Jacobian matrix of the mechanism and its time derivative. A Matlab program is used to solve the inverse position, velocity, and acceleration kinematics. The solution of inverse position kinematic gives the leg length, unit vector along the leg axis and model visualization. The use of Newton Raphson method for the solution of the forward kinematic problem is also presented, convinced the validity of the Cartesian pose assumed for the top plate.

The Computer Aided Design (CAD) modeling software (Solid Works) is used to generate the different parts of the Stewart platform and model is also assembled using this software. In this model, two components (spring and flexible joint) provide the added flexibility and required to finite element analysis. A hyperbolic profile is selected among the different profiles available in the literature. The conceptual design of the leg is presented which contains the following: base connector, spring holder, spring, spring adaptor, spring cover, stinger, flexible joint and top connector.

The fabrication of all the parts of the Stewart platform is completed after selecting a suitable material and different machining operations are used to manufacture the parts with fine accuracy. An experimental set-up is established with required equipment's to perform the vibration isolation test in longitudinal and lateral direction. The mathematical dynamic model is developed to evaluate the axial forces, spring forces and torque in the legs using Matlab. The developed finite element model is used for static, modal and harmonic analysis using ANSYS software.

The vibration isolation and control of the model is achieved by MSC ADAMS software. There is a close agreement between the natural frequencies obtained by ANSYS and MSC ADAMS software. The vertical transmissibility is also obtained for each natural frequency and the model performance using PID controller with suitable integral feedback gain is satisfactory with a minimum 32dB reduction in transmissibility. The corner frequency and amplitude obtained by the experiment is the same as the frequency predicted by the harmonic analysis using ANSYS.

Keywords: Parallel manipulators, Stewart platform, Flexible joints, Kinematics, Dynamics, Finite element analysis, Vibration, Control.