Ain Shams University
Faculty of Engineering

Design and Implementation of a Parallel Robot-Based Machining Center

A Thesis
By

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"Design and Implementation of a Parallel Robot-Based Machining Center"

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Abstract

A Hybrid parallel robot is investigated. The manipulator has four degrees of freedom and the moving platform is constrained to three rotational motions about cartesian axes *X*, *Y*, and *Z*, in addition to one translational motion along Z-direction. The point of interest is the motion control of the moving table using PID control. The motion planning control for the parallel robot requires inverse kinematic model, and the workspace. The workspace is important to be verified if a given trajectory lies completely within the robot workspace. The Forward kinematic has been deduced to determine the workspace.

Keywords: HPR, R(3-RPS), Inverse Kinematic, Direct Kinematic, ADAMS, PID Control.

Summary of Master Thesis

"Design and Implementation of a Parallel Robot-Based Machining Center"

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Over the last few years, parallel robots have been under increasing developments from a theoretical point of view as well as for practical applications. Parallel robots are used in several applications like machining operations and are called in this case as parallel kinematic machines (PKM). They have features such as high payload, high stiffness and high accuracy compared to conventional machine tools. However, a great disadvantage is their limited workspace.

In design and control of a PKM, it is important to completely understand the kinematics, in forward and reverse directions for the end-effector. Also, the design and control methods to improve accuracy are the key technologies for the development of a machine tool.

The objectives of this work are:

1- Implementing the PKM concept in the design of a machining center based on parallel robotics techniques.
2- Solving the motion tracking problems in the proposed machine (point to point, and path trajectory).
3- Practical implementation of the motion planning methods applied to some case studies.

In order to achieve this, an inverse kinematics, direct kinematics, and workspace is deduced. A four DOF Hybrid parallel manipulator was investigated and test rig is prepared with suitable sensors. Three DOF are constrained to only rotational motion, and the fourth DOF is a translational motion. For this HPR analytical equations for the forward and inverse kinematics have been deduced. The forward and inverse kinematics are transformed to a closed-form. A numerical simulation is presented for the inverse kinematics model to verify this model by the use of ADAMS software package. The most significant disadvantage is a limited moving table workspace relative to serial manipulators of comparable size.

The closed-form solutions are deduced for the inverse kinematic problem, where the closed-form solution in this case is just a unique solution. For the forward kinematic problem, the closed-form solutions consist of a system of three fourth-degree polynomials having up to 64 solutions. It has been found out that 48 of these solutions are imaginary and repeated. The other 16 solutions are mirror to each other, where 8 of them form all assembly modes of the HPR; whereas only one of these 8 modes represents the correct assembly mode of the model.

The numerical simulation software (ADAMS) is used to check and verify the obtained inverse kinematic model. It is shown that the error in the trajectory between the analytical model and the numerical software is small due to the different computation techniques. The workspace of the manipulator is obtained by direct kinematic simulation using ADAMS software. The workspace is small due to the geometry and physical constraints. The robot might be used in drilling or space telescopic applications where rotational degrees of freedom are needed.

A HPR is prepared with suitable equipment like sensors, drivers, and actuators. The HPR sensors and actuators are connected to the computer through data acquisition card, which is connected to PCI slot.

A linear mathematical model of the system is presented and all the parameters values are identified by using an identification toolbox.

Practical implementation of the motion planning is applied to the following paths helical, spiral, inverted spiral, spherical path, and straight line. A PID controller is used for the closed loop control of the manipulator and tested on the robot. The results obtained showed that the error in the paths is acceptable for the sensors used.

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