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A cascade load force control of a hydraulically driven 6-DOF parallel robot manipulator based on input-output linearization

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***Abstract** - In this paper, we consider the problem of tracking control of a hydraulically driven 6-DOF parallel robot manipulator. To drive the upper moving platform, hydraulic systems composed of the six valve-controlled asymmetric pistons are used as actuators. In order to realize the trajectory tracking control of the parallel robot manipulator, a cascade control algorithm based on input-output linearization in the legspace is proposed. We applied the cascade controller, which consists of an inner loop and an outer loop, in order to separate the hydraulic dynamics from the mechanical part. Thus, the inner-loop control has the objective of controlling the actuator load force using the input–output linearization, independent of the resulting motions of the load. The outer–loop control is aimed at controlling the actuator load and rejecting external disturbance of the system. To facilitate the realization of the proposed cascade control concept, the MATLAB/Simulink model is devised. In order to show the effectiveness of the proposed cascade control algorithm, the comparative simulation results are made between proposed concept and the classical control strategy for this kind of manipulator.*

***Key words**: robot manipulator, valve-controlled asymmetric pistons, cascade control, input-output linearization*

I. INTRODUCTION

The hydraulically driven parallel robot manipulator is obtained through a generalization of the mechanism proposed by Stewart [1] as a flight simulator. As shown in Fig. 1, this spatial platform mechanism consists of a fixed base platform and an upper moving platform. The six extendable legs connect these platforms. Besides greater stiffness and accuracy, these manipulators have high payload-weight ratio due to parallel linkage. Parallel linkage enables the payload distribution and averaging of the positioning error. The payload and positioning errors would be accumulated without parallel linkage. Accordingly, these types of parallel manipulators are attractive for certain applications, such as flight simulators, machine tools and force–torque sensors.

The parallel robot control strategy may be designed from two frameworks. One is to design a controller based on the legspace coordinates and the other is based on the workspace coordinates. The control strategy based on the workspace coordinates has a limitation to the real-time application due to difficultly in obtaining information on the upper moving platform. However, the upper moving platform of a parallel manipulator can move with the six desired degrees of freedom (DOF) if the lengths of the all legs are well controlled. Bearing this in mind, the control strategy study of the parallel robot manipulator rather is based on the legspace coordinates. A classical PID control technologies has been applied in practice for the control of a 6-DOF parallel robot manipulator. However, linear control techniques do not always guarantee the desired high performance of a parallel manipulator. Hence, a high-level control strategy is required to increase the control performance of the different types of actuators that are used to drive the upper moving platform, [2-3].

Hydraulic servo-system is used in a wide variety of industrial fields because of its advantages, which include rapid response, high power-to-weight ratio and compact size [4]. Thus, for the purpose of controlling the hydraulically driven parallel robot manipulator presented in this paper, we will use a hydraulic servo system. Dynamics of the hydraulically driven 6-DOF parallel robot manipulator consist of two parts. One is mechanical dynamics and the other is hydraulic dynamics, see [5]. Therefore, the designed controller should take into account not only the mechanical dynamics, but also the hydraulic dynamics using the cascade control method, see [5-8]. We decided to implement the feedback linearization for controlling the actuator load force, independent of the resulting motions of the load. Feedback linearization has attracted great research interest in the last two decades, [9]. The general idea of the approach is to transform non-linear system dynamics algebraically into a linear one, so that linear control techniques can be applied. This differs entirely from conventional linearization, in that feedback linearization is achieved by exact state transformations and feedback, rather then by linear approximations of the dynamics. MATLAB / Simulink model is devised to facilitate the realization of the proposed method. The simulation results for the robot manipulator are presented to show the effectiveness of the approach.

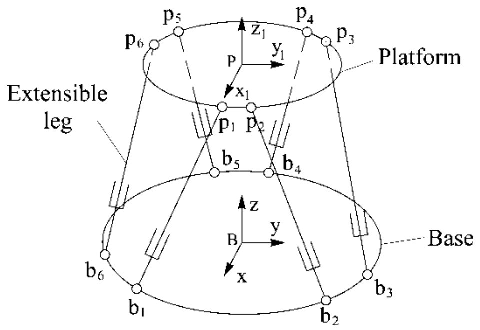

Fig.1. Schematic diagram of a 6-DOF parallel robot manipulator (modified from [8])