Sliding Mode Control of a Novel 6-DOF Parallel Manipulator with Rotary Actuators

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***Abstract*—A novel six-DOF parallel manipulator is introduced. Kinematics analysis is discussed and using Lagrange equations for constrained systems the full dynamic modeling is performed. Sliding mode control as a class of very special nonlinear control is proposed to control the position of the manipulator in the presence of parametric uncertainties. Stability of the system is guaranteed via Lyapunov approach. An intensive series of simulation studies has been fulfilled to show the abilities of the proposed controller for trajectory tracking even in the case of large parameter variations.**

I. Introduction

Nowadays the parallel manipulators have found a variety of applications due to their advantages over the serial ones such as, better accuracy, higher rigidity and higher load-to-weight ratio. One of the most popular parallel manipulator is the Gough Stewart mechanism introduced in 1965 by D. Stewart [1]. This kind of the Stewart platform is activated by hydraulic actuators. Hence practical usage of this kind has been generally in the area of low speed and high load conditions such as motion base of vehicle and flight simulators, motion bed for machine tool and such like. In the case of the manipulator high speed reactions, it is needed that the electrical actuators can be used instead of hydraulic ones. In the last two decades most of the research has been particularly aimed at Gough Stewart platform with prismatic hydraulic actuators and the rotary type is less studied.

The 6-DOF parallel manipulator with rotary actuators was initially introduced by Hunt [2] in 1983. Thereafter several species of this kind of Parallel manipulator are suggested such as the prototypes constructed by Sarkissian [3], Zamanov [4] and Mimura [5], where they have a few differences in linkage and joint configurations. A more recent and commercial design has been introduced by Servos & Simulation Inc. [6].

It is well-known that the Stewart platform, due to its inclusion of several closed loop structures, is highly complicated mechanism to make kinematic and dynamic analysis. In addition, the rotary type of the Stewart platform has a more complex dynamic system than the typical one. Moreover, the Stewart platform usually suffers from matched and unmatched uncertainties and also external disturbances due to its various applications. All these issues make the control of the 6-DOF parallel manipulator with rotary actuators a challenging problem.

To the best of the authors' knowledge the control of a 6-DOF parallel manipulator with rotary actuators has not been studied yet. Though, pending the span of last two decades several control strategies have been developed to control the parallel robots and specially the typical Stewart platform. An adaptive control scheme [7,8] in which the controller gains are regulated by the adaptation law was proposed in 1993. Lee [9] used inverse dynamics with approximate dynamics to control a Stewart platform in 2003. Sliding mode controller with sliding perturbation observer is suggested by Sung [10] in 2004. Some important properties of dynamics of the Stewart platform are derived and exploited to develop a sliding mode controller by Huang [11] in 2005. Iqbal [12] used the mass uncertainties to calculate the upper bounds of perturbation in order to design a robust sliding mode controller. In 2008 Qiang [13] transformed the dynamic model by means of defining one operation point for the manipulator and designed a sliding mode controller based on the simplified dynamics.

In this paper, first, we introduce a novel 6-DOF parallel manipulator with rotary actuators which has some differences in linkage and joint configurations with respect to the conventional designs. Then, due to the several attractive superior properties of SMC, such as good control performance even in the case of nonlinear systems, applicability to MIMO systems, fast transient response and insensitivity to parameter changes and external disturbances without the need for system identification, a sliding mode controller is employed to control the position of the 6-DOF parallel manipulator.

The reminder of this article is organized as follows. Section II introduces the mechanism of the manipulator. Dynamics modeling of the system is presented in Section III. Section IV deals with the design of sliding mode controller. Simulation study has been carried out and the results are discussed in Section V. Finally, some

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