Chapter 5

Computation of the Output Torque, Power and Work of the Driving Motor for a Redundant Parallel Manipulator

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ABSTRACT

Inverse dynamic analysis of the 8-PSS redundant parallel manipulator is carried out in the exhaustive decoupled way. The required output of the torque, the power and the work of the driving motor are achieved. The whole actuating torque is divided into four terms which are caused by the acceleration, the velocity, the gravity, and the external force. It is also decoupled into the components contributed by the moving platform, the strut, the slider, the lead screw, the motor rotor-coupler, and the external force. The required powers contributed by the component of torque caused by the acceleration term, the velocity term, the gravity term, the external force term, and the powers contributed by the moving platform, the strut, the slider, the lead screw, and the motor rotor-coupler are computed respectively. For a prescribed trajectory, the required output work generated by the ith driving motor is obtained by the presented numerical integration method. Simulation for the computation of the driving motor’s output torque, power and work is illustrated.

INTRODUCTION

There are mainly two different types of redundancy for the parallel manipulators: a) kinematic redundancy and b) actuation redundancy. A parallel manipulator is said to be kinematically redundant manipulator when its mobility of the mechanism is greater than the required degrees of freedom of the moving platform. On the other hand, a parallel manipulator is called redundantly actuated manipulator when the number of actuators is greater than the mobility of the mechanism. It is believed that redundancy can improve the ability and performance of parallel manipulator (Kim, 2001; Merlet, 1996; Nokleby, 2005; Wang, 2004; Cheng, 2003; Müller, 2005; Mohamed, 2005;
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Ebrahimi, 2007; Zhao, 2009). There are some advantages for the redundant parallel manipulator such as avoiding kinematic singularities, increasing workspace, improving dexterity, enlarging load capability and so on. It is shown that the redundantly actuated parallel manipulator has a better dynamic characteristic than its non-redundant counterpart considering the presented dynamic index (Zhao, 2009). Redundant actuation in a parallel manipulator can be implemented by the following approaches. The first one is to actuate some of the passive joints within the branches of parallel manipulator. The second one is to add some additional branches beyond the minimum necessary to actuate the parallel manipulator. The last one can be the hybrid of the above two approaches.

The dynamics of the manipulator are of importance in the areas of simulation, control and dynamic optimum design. Many works have been done on the dynamics of parallel manipulators. Several approaches, including the Newton-Euler formulation (Carvalho, 2001; Dasgupta, 1998), the Lagrangian formulation (Lee, 1988; Miller, 1992), the Kane formulation (Ben-Horin, 1998; Liu, 2000) and the virtual work principle (Li, 2005; Sokolov, 2007; Wang, 1998; Tsai, 2000; Zhu, 2005; Staicu, 2009) have been applied to the dynamics analysis of parallel manipulators. In fact, the inverse dynamics of parallel manipulators involve almost all of the mechanics principles. Along with these mechanics principles, many mathematic methods such as screw theory (Gallardo, 2003), Lie algebra (Muller, 2003), natural orthogonal complement (Khan, 2005), motor algebra (Sugimoto, 1987), group theory (Geike, 2003), symbolic programming (Geike, 2003; McPhee, 2002), geometric approach (Selig, 1999), parallel computational algorithms (Gosselin, 1996) and system identification (Wiens, 2002) have also been adopted to the dynamics of parallel manipulators. However, the results computed by different methods have been shown to be equivalent.

Though much attention has been paid to the dynamics of the parallel manipulator, little work has been done on the dynamics of the redundant parallel manipulator (Cheng, 2003), especially in the exhaustive decoupled way. Furthermore, maybe no paper has dealt with the required output power and work of the driving motor when the redundant parallel manipulator moves on a prescribed trajectory. It is one of the motivations for this work. By taking the 8-PSS redundant parallel manipulator as an object of study, this paper presents the inverse dynamic analysis in the exhaustive decoupled way. The actuating torques caused by the following term: acceleration, velocity, gravity, external force, moving platform, strut, slider, lead screw and motor rotor-coupler are computed respectively. The required output powers generated by the motor corresponding to the above terms of torque are achieved. For a prescribed trajectory, the computation of the required output work generated by the ith driving motor is implemented by the numerical integration. The paper is organized as follows: the description and the dynamic model of the redundant parallel manipulator are presented in section two. The rigid dynamic model is decoupled in the exhaustive decoupled way. The computation of the required output power and work of the driving motor are given in section three. Investigations of the system dynamic characteristics through simulation and conclusions are presented in section four and section five, respectively.

SYSTEM DESCRIPTION AND DYNAMIC MODEL

System Description

As shown in Figure 1 and Figure 2, the 8-PSS redundant parallel manipulator consists of a moving platform and eight sliders. In each kinematic chain, the platform and the slider are connected via spherical ball bearing joints by a strut of fixed