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Conference Paper · July 2003

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OPTIMUM JOINT PROFILE FOR CONSTRAINED MOTION OF A PLANAR RIGID-FLEXIBLE MANIPULATOR

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Dynamic system performance of a constrained rigid-flexible manipulator in contact with a circular surface is considered here. A dynamic model with zero tip deformation constraint is derived using extended Hamilton's principle. An analytical approach for vibration of the flexible link using the assumed modes technique is presented. The effect the force exerted at the end-effector and the required joint torque is investigated through the solution of the inverse dynamics problem. Optimum system performance is suggested for the circular contact surfaces considered in this study using the minimum energy criteria for three joint motion profiles.

1. Introduction

In the last two decades, the dynamics and control of the flexible manipulator constrained by the task environment have received considerable research attention. The control objectives, in this case, are trajectory tracking by the end-effector and force regulation between the end-effector and the environment. Typical examples of such constrained motion of the manipulator include grinding, deburring, cutting, polishing, drilling, fastening, and the list continues. Despite the voluminous research done in the last decade, the study of dynamics and control of the constrained motion of the flexible manipulators remains open for further investigations.

Raibert and Craig (1981) applied hybrid position / force control for rigid manipulator. The work by Su et al. (1990) represents one of the earliest studies in force control of constrained maneuver of the rigid/flexible manipulator. Ulsoy and Hu (1994) developed a low-order model, suitable for controller design, of a constrained rigid-flexible robot. Schutter et al. (1996) introduced a new method for the hybrid force / position control, which is equipped with an internal, high bandwidth velocity controller and with a compliant end-effector during constrained motion. This method combines force control with results from active control of flexible robots. Rocco et al. (1996) presented a general and systemic model of a flexible robot interacting with rigid environment using a two-time scale force/position controller. In the work presented by Shi et al. (1999), a multivariable controller was designed for the simultaneous motion and force control along the desired trajectory for constrained motion of a rigid-flexible manipulator. Siciliano and Villani (2000) proposed a parallel force and position control of flexible manipulators. Using singular perturbation theory, the system is decomposed into a slow subsystem associated with rigid motion and a fast subsystem associated with link flexible dynamics. Hu et al. (2001) developed a position and force control scheme for a class of flexible joint robots during constrained motion tasks with model