MODELING AND TESTING OF MOVING BASE MANIPULATORS WITH ELASTIC JOINTS

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Abstract— **In this paper, design and manufacturing of a manipulator with joint elasticity is described while different base positions are considered. First, the kinematics and dynamic equations of the mechanism with flexible joints for the three major axis of the mobile robot are derived and simulated. Next, computational technique for obtaining maximum load carrying capacity of robotic manipulators with joint elasticity is described while different base positions are considered. The maximum load carrying capacity that can be achieved by a robotic manipulator during a given trajectory is limited by number of factors. Probably the most important factors are the actuator limitations, joint elasticity (transmissions, reducers and servo drive system) and relative configuration of robot with respect to its base. Finally, the manipulator is tested for a given trajectory in order to find the characteristics of the designed manipulator. While the manipulator is designed to carry the maximum load, end-effector's speed, robot's compatibility with the operator's condition, and accuracy are the most important applicable points of the manipulator. Therefore, the manipulator in different trajectories with various speeds and loads are tested, and then the results are analyzed.**

Keywords— **Modeling and Simulation, Manipulator, Flexible Joints.**

I. INTRODUCTION

Today, one of the most important problems in the modern industrial companies is difficulties in the manufacturing for operators. In addition, in the automation, which needs operator's accuracy and swiftness, manipulating might cause errors in measurement especially in hard working situations. This hard work situation not only might hurt labor but also cause unqualified production. Efficiency is the main purpose in manipulators usage in industries and they are tremendously used in carrying pieces. The use of industrial mechanisms especially robotic manipulators in production industry has been very important worldwide. For many industrial applications, current robotic manipulators with flexible joint are relatively slow even when they are not fully loaded, so it is hard to justify their use economically. Their speed, load-carrying capacity, and hence their productivity, are limited by the deflection of the end-effector and the capability of their actuators. Increasing actuator size and power is largely self-defeating, because of increased cost and power consumption of the larger actuators as well as increased inertia of the actuators themselves. Consequently, a more successful approach should be to maximize the load-carrying capacity of the flexible manipulator, subject to the constraints imposed by actuator capacity and allowable end-effector deflection for a given dynamic trajectory.

Works on load-carrying-capacity problems for manipulators have applications in advanced trajectory planning, design and selection of robot manipulators. For instance, Wang and Ravani (1988) were shown the maximum allowable load of a fixed base manipulator on a given trajectory is primarily constrained by the joint actuator torque and its velocity characteristic. Thomas *et al.* (1985) used the load capacity as a criterion for sizing the actuator at the design stage of robotic manipulators. In their study, they considered the maximum load in the neighborhood of a robot configuration. A technique was also developed in Wang and Ravani (1988) to maximize the DLCC of an entire trajectory, rather than in the neighborhood of a configuration. In this work, piece-wise rigid links and joints were assumed. Korayem and Basu (1994a,b), by relaxing the rigid body assumption, presented an algorithm for computing the Dynamic Load Carrying Capacity (DLCC) of elastic manipulators. Yue and Tso (2001) used a finite-element method for describing the dynamics of a system and computed the maximum payload of kinematically redundant manipulators. Korayem and Ghariblu (2003) developed an algorithm for finding the DLCC of rigid mobile manipulators.

The main source of vibration in industrial robot manipulators is the presence of joint elasticity between the driving actuators and the drive links. The origin of elasticity is transmission parts, such as harmonic drives, belts, or long shafts, during high-speed motion or hard contact with the environment (Sweet and Good, 1985; Rivin, 1988). Ider and Ozgoren (2000) studied the inverse dynamic control of a manipulator with elastic joints. A computer modeling was applied to show the accuracy of the results based on a manipulator with 3 degrees of freedom with elastic joints. Gamrraado and Yuhara (1999) obtained interesting results by applying Newton-Euler method to computer modeling for an elastic robot with two arms and revolute joint. Usually, in computing the DLCC by assuming rigid joints and links, the actuator torque limits are considered (Wand and Ravani, 1985), but for the flexible robot, the difference between the allowable deflection and the magnitude of the deflection with added end-effector mass can