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Effect of joint flexibility on vibration characteristics of a composite box manipulator

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Flexibility of links and joints affects dynamic behavior of manipulators. In this work, the vibration characteristics of a one-link carbon-fiber box manipulator with a rectangular cross-section and a [0/90/0/90] lay-up are studied to examine the effects of the link and joint flexibility. The theoretical results supported with experimental studies are presented to realize the mentioned examinations. An experimental system, which consists of a composite box manipulator driven by a geared servo motor and a wireless measurement system, is introduced. Some parameters of the driver are manually set in the experiments. Vibration tests of the composite manipulator are realized for the stationary and nonstationary cases. Experimental vibration responses are both evaluated for auto and manual tune modes of the servo driver. Theoretical results obtained via the finite element vibration analysis compared with the experimental results. The changes of the natural frequencies and damping properties are presented for the stationary and nonstationary cases. The experimental vibration responses of the composite box manipulator with various payloads match well with the theoretical ones by tuning servo motor parameters manually.

Keywords: Composite box manipulator, vibration, joint flexibility, servo tuning.

1. Introduction

Engineers aim to produce manipulators having lighter arms and higher payload-to-weight ratio. Nowadays composite materials have been used for the requirements in the arms of industrial or manufactured manipulators. These requirements and joint flexibility caused from the motors and gears used in the manipulators affect dynamic properties of the structures.

Precision, repeatability, natural frequencies and mode shapes are the dynamic properties of manipulators affected by flexibility of links and joint flexibility. The two subjects of flexibility of links and joint flexibility are different cases. Flexible links cause unwanted vibrations at the tip due to the low stiffness. Joint flexibility may influence the mode shapes and natural frequencies Dwivedy et al. [1]. Mathematical modeling approaches and design considerations about link and joint flexibilities were examined in Book [2] and in Rahimi and Nazemizadeh [3]. These studies can be considered as good starting points to analyze the effect of these flexibilities in a theoretical manner.

In order to analyze the effect of joint flexibility, a manipulator model must include linear or torsional springs at the hub. A flexible joint with a linear spring for a single flexible link was modeled in Yang and Donath [4]. In Chen and Fu [5], the joints with torsional springs driven by DC motors was modeled to control the vibration. In Ulrich et al. [6], tracking performance of a two-link manipulator was improved by increasing robustness to modeling