

DYNAMIC MODELLING OF A TWO-LINK FLEXIBLE ROBOT MANIPULATOR

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ABSTRACT

This paper presents dynamic modelling of a two-link flexible manipulator system. The kinematic model is based on standard frame transformation matrices describing both rigid rotation and modal displacement, under small deflection assumption. A two-link flexible manipulator incorporating structural damping, hub inertia and payload is considered. An explicit, complete, and accurate nonlinear dynamic model of the system is developed using assumed mode method. Moreover, the effects of payload on the response of a two-link flexible manipulator are studied.

Keywords: *Assumed mode, modelling, two-link flexible manipulator*

INTRODUCTION

Flexible robot manipulators exhibit many advantages over rigid robots. They require smaller actuator, consume less power, require less material, are lighter in weight, have less overall cost, are more manoeuvrable and transportable and higher payload to robot weight ratio. In order to control the two-link flexible manipulators to achieve and maintain accurate positioning is challenging. Due to the flexible nature of the system, the dynamics are significantly more complex. Moreover, flexible link causes significant technical problems. The problem increases dramatically for a two-link flexible manipulator with varying payload. In order to achieve high-speed and accurate positioning, it is necessary to control the manipulator's response in a cost effective manner. Control algorithms are required to compensate for both the vibration and the static deflection of the system.

The main goal on the modelling of a two-link flexible manipulator is to achieve an accurate model representing the actual system behaviour. Each flexible link can be modelled as distributed parameter system where the motion is described by a coupled system of ordinary and partial differential equations (PDE). Various approaches have been developed which can mainly be divided into two categories: the numerical analysis approach and the assumed mode method (AMM). The numerical analysis methods that are utilised include finite difference and finite element methods. Both approaches have been used in obtaining the dynamic characterisation of a single-link flexible manipulator system incorporating damping, hub inertia and payload [1,2]. Subudhi and Morris [3] have used a combined Euler-Lagrange formulation and AMM approach to model the planar motion of a manipulator consisting of two flexible links and joints. The conventional Lagrangian modeling of flexible link robots does not fully incorporate the bending mechanism of flexible link as it allows free link elongation in addition to link deflection. De Luca and Siciliano [4] have utilised the AMM to derive a dynamic model of multilink flexible robot arms limiting to the case of planar manipulators with no torsional effects. The equations of motion that can be arranged in a computationally efficient closed form with respect to a suitable set of constant mechanical parameters have been obtained [5].

This paper presents modelling of a two-link flexible manipulator using Lagrangian technique in conjunction with the AMM. The links are modelled as Euler-Bernoulli beams satisfying proper mass boundary conditions. A payload is added to the tip of the outer link, while hub inertias are included at the actuator joints. Simulation of the dynamic model is performed using Matlab and Simulink. Angular position and modal displacement responses of the system responses are investigated. The effects of payload on the dynamic characteristics of the system are also studied.

A TWO-LINK FLEXIBLE MANIPULATOR

Figure 1 shows the schematic diagram of a two-link flexible manipulator system considered in this study. The links are cascaded in serial fashion and are actuated by rotors and hubs with individual motors. An inertial payload of mass M_p and inertia I_p is connected to the distal link. The proximal link is clamped and connected to the rotor with a hub. The i th link has length l_i and uniform mass density per unit length ρ_i . E and I represent