Chapter 5
Active Vibration Control of a Flexible Manipulator With Velocity Feedback

Şahin Yavuz
https://orcid.org/0000-0001-9007-772X
Dokuz Eylül University, Turkey

Doğukan Akgöl
Dokuz Eylül University, Turkey

Gökçe Naz Biricik
Dokuz Eylül University, Turkey

ABSTRACT

In this study, active vibration control of a single-link flexible manipulator has been performed. Residual vibrations affect the end-point positioning accuracy of the manipulator. To control residual vibration amplitudes, closed loop control scheme has been effectuated. Velocity feedback of the desired endpoint has been carried out and traditional proportional-integral (PI) Control has been applied. The mathematical model of the flexible manipulator has been established by the finite element method (FEM). The FEM results in modal analysis have been verified by the experimental results and then, the transient analysis has been realized by the Newmark method. Different velocity profiles have been applied to the manipulator to demonstrate the effect of PI controller on vibration amplitudes. The root mean square values and steady-state time have been calculated presented for different cases. It is observed from the results that the residual vibration amplitudes of the manipulators are successfully suppressed by the proportional-integral control gains.

DOI: 10.4018/978-1-6684-5381-0.ch005

INTRODUCTION

Robot manipulators with rigid links have been widely used on industrial applications. These links are generally heavy to achieve high accuracy and repeatability during high-speed operations. Developments in the field of materials science and manufacturing technologies, flexible manipulator concepts have started to drawn attention and have attracted the interest of many researchers.

The most common usage example of flexible manipulators is robot manipulators. Flexible and light-weighted manipulators show many advantages over rigid and bulky ones. Flexible manipulators can be driven by smaller driving actuators and accordingly have less energy consumption levels. However, these and similar advantages reveal disadvantages in their advantages due to lightness. Residual vibrations occur due to high flexibility. Residual vibrations due to flexibility affects the settling time and end point accuracy of the robot manipulators while operating with high speeds. Robot manipulator action time increases accordingly residual vibrations as the flexible manipulator need to be allowed to settle at the end of the application.

Developing dynamic models of flexible manipulators can be constructed by the finite element method or analytical methods (Benosman & LeVey, 2004). The governing differential equations of a dynamic system can be solved by different numerical methods (Fung, 1997; Haido et al., 2010; Owren & Simonsen, 1995; Zhang et al., 1999). However, developing a proper dynamic model plays an important role in the controlling or suppression of the residual vibrations of flexible manipulators. Conspicuously, since the model-based control system performance depends on the dynamic model accuracy highly.

Elimination of residual vibrations at the end of the manipulation action by using different control strategies is a challenging problem for many researchers (Dwivedy & Eberhard, 2006; Oguamanam et al., 2006; Vakil et al., 2011). It is well known that flexible manipulators can be deformed easily due to their high flexibility. Thus, suppression of the residual vibrations come into prominence, which have destructive consequences on effectiveness and accuracy.

Residual vibration amplitudes can be eliminated by using two main strategies, passive and active control schemes. One of them is the passive control strategy stated in other words feed-forward control, which deals with the open loop system can be achieved by using techniques like motion input command shaping methods or trajectory planning methods (Conker et al., 2016). In addition, several studies can be found about different vibration control approaches with counter springs to eliminate residual vibrations of the flexible manipulators (Tang et al., 2021). This method aims to eliminate residual vibrations under favour of additional spring elements which have been attached to a flexible manipulator with opposite angles to each other to suppress or reduce the vibration amplitudes in both directions.

In trajectory planning methods, specifying the trajectory of the joint angle is the main target by using a combination of polynomial and cycloidal functions. The coefficients of the trajectory function can be adjusted by using different algorithms such as genetic algorithm (Kojima & Hiruma, 2006).

However, among these feed-forward control (passive control) strategies, motion command shaping or in other words input shaping methods take an important place in the field of vibration control of flexible manipulators and have drawn attention of many researchers (Blackburn et al., 2010; Chan et al., 2003; Dharne & Jayasuriya, 2007; Gürleyük & Cinal, 2007; Kim & Singhose, 2010; Singhose & Pao, 1997; Singhose et al., 2000).

Active control strategy (feed-back control) is the other method which is used to eliminate vibrations. Active control requires sensors to be equipped with thus, can be expensive or difficult to implement. Besides that, to achieve active control properly it can require sufficient computing power to evaluate the