ADAPTIVE INPUT SHAPING FOR CONTROL OF A FLEXIBLE MANIPULATOR SYSTEM

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Dedicated to my beloved family

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ABSTRACT

Input shaping is a simple method for reducing the residual vibration in positioning lightly damped systems. Although several input shaping techniques have been derived to control a flexible manipulator system without payload, theoretical results are hard to be traced for their application to control a flexible manipulator system with payload. This thesis is concerned with Adaptive Input Shaping for Control of a Flexible Manipulator System with payload. To increase the performance of the manipulators, it is essential to control the system well. The control problem of this system consists of obtaining the physical dynamic model and specifying the corresponding control strategy so that it tracks a predefined desired trajectory as closely as possible at all times. The simulation can be repeated for different payload of the system varying from 0 to 100 g. In this work, a single link flexible robot manipulator that moves in horizontal plane is considered. Modeling is done using finite element method where the system is divided into 10 elements. The input shaping technique is used to reduce vibrations in the system. It is noted that the input shaping control technique is a better control technique compared to the bang-bang torque input control technique. It is useful to use when payload is zero compare with unshaped bang-bang torque. But when payload is considered input shaping has to adapt. This method requires calculating or finding the value of natural frequency and damping ratio to adapt time and amplitude of impulse sequences. The results prove that the controller has successfully provided the necessary position tracking control for the flexible robot manipulator system.

ABSTRAK

Pembentukan input adalah satu kaedah mudah untuk mengurangkan getaran sisa dalam kedudukan sistem teredam ringan. Walaupun beberapa pembentukan input teknik telah dirumuskan untuk mengawal sistem manipulator fleksibel tanpa payload, secara teorinya keputusan untuk aplikasi adalah sukar untuk dikenal pasti dan diperolehi untuk mengawal sistem manipulator fleksibel dengan payload. Tesis ini adalah berkaitan dengan Pembentuk Adaptive Input untuk sistem manipulator fleksibel dengan payload. Untuk meningkatkan prestasi manipulator,ia adalah sangat penting untuk mengawal sistem dengan baik. Masalah kawalan sistem ini, adalah dalam mendapatkan model dinamik fizikal dan menentukan strategi pengendalian yang sesuai sehingga trek laluan yang sudah ditetapkan adalah sentiasa tepat dan persis. Simulasi boleh diulangi mengunakan sistem dengan payload yang berlainan dalam julat 0 hingga100 g. Dalam kajian ini, anggapan telah dibuat hanya satu perhubungan fleksibel robot manipulator yang bergerak dengan mendatar. Modeling dilakukan dengan menggunakan kaedah elemen d i mana sistem ini dibahagi kepada 10 elemen. Teknik pembentukan input ini digunakan untuk mengurangkan getaran dalam sistem. Adalah jelas bahawa pembentukan input teknik kawalan adalah teknik kawalan yang lebih baik berbanding dengan teknik bang-bang torque kawalan input. Teknik ini lebih berkesan untuk digunakan ketika payload adalah sifar berbanding dengan bang-bang torque . Tetapi ketika payload dianggap membentuk input harus untuk diapdaptasikan. Kaedah ini memerlukan untuk menghitung atau mencari nilai natural frekuensi dan nisbah redaman untuk menyesuaikan dengan masa dan urutan amplitud impulse. Hasil keputusan akhir daripada kajian ini membuktikan bahawa pengawal telah berjaya memberikan posisi yang diperlukan dalam kawalan untuk sistem manipulator robot fleksibel.

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ω_n	-	Natural frequency
ξ	-	Damping ratio
K	-	Stiffness
α	-	Speed motion
β	-	Relationship between and
m	-	Payload mass
l	-	Length of the hoisting rope
F_x	-	Input force
g	-	Gravitational acceleration = $9.81 ms^{-2}$
θ	-	Sway angle
$\dot{\theta}$	-	Angular velocity
$\ddot{\theta}$	-	Angular acceleration
M_n	-	Mass matrix
K_n	-	Stiffness matrix
M_p	-	Payload
N_i	-	Number of impulse
A_i	-	Amplitude of impulse
t_i	-	Time of impulse
ρ	-	Mass density per unit volume

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Many manufacturing situations such as lithography for microelectronics require rapid high precision positioning of machinery, and load positioning is achieved by simple open-loop control. In the case where structural flexibility is significant, and the load is lightly damped, the vibration may be unacceptable. Many solutions have been proposed to reduce vibration using input shaping technique.

Many robotic manipulators are used in industrial and space applications. Traditionally, robotic manipulators have been designed and built heavy and bulky for high structural stiffness; hence some drawbacks such as high power consumption, low motion speed, high manufacturing cost, and high capacity actuators may appear. Conversely, a lightweight manipulator decreases these considerably. However, a consequence of making lighter links is that the manipulator becomes more flexible and more difficult to control. There exists a residual vibration in flexible robot manipulator systems, in which the end effect or keeps vibrating even though nominal motion is already completed.

Vibration is a serious problem in mechanical systems that are required to perform precise motion in the presence of structural flexibility. Examples of such systems range from the positioning of disk drives head to large space structures, flexible manipulators and container cranes. In most cases, the residual vibration at the end of a move is the most detrimental and the extent of the residual vibration limits the performance of the system. The effective use of such systems can only be achieved when such vibration can be properly handled. As a result, there is active research interest in finding methods that will eliminate vibration for a variety of mechanical and structural systems.

Research on the control methods that will eliminate vibration from wide range of physical systems has found a great deal of interest for many years. The methods used to solve the problems arising due to unwanted structural vibrations include passive and active control. The passive control method consists of mounting passive material on the structure in order to change its dynamic characteristics such as stiffness and damping coefficient. This method is efficient at high frequencies but expensive and bulky at low frequencies. Active vibration control consists of artificially generating sources that absorb the energy caused by the unwanted vibrations in order to cancel or reduce their effect on the overall system. Lueg (1930) is among the first who used active vibration control in order to cancel noise vibration.

The control strategies for flexible manipulator systems can be classified as feedforward and feedback control. A number of techniques have been proposed as feed-forward control strategies for control of vibration. Traditional closed-loop feedback can be used to reduce end-point vibration. The closed-loop system will then benefit from the inherent advantages of feedback, such as insensitivity to parameter variations, noise attenuation and disturbance rejection. However, such a feedback system can be difficult to implement in practice, as it requires reliable sensor information for feedback. Such sensor information may not be so easily available. Another approach is input shaping is a feed-forward technique used to eliminate system vibration, where the input is typically convolved with a sequence of impulses (an input shaper) to yield a shaped input. These methods are popular in industry because they are relatively simple to implement the preshaped input together with closed-loop feedback strategies to enjoy the benefits of both systems.

1.2 Background of the Problems

Manipulator arms have traditionally been modelled as being rigid links to ensure stable and reliable control. In order for the arms to remain rigid while carrying an assigned payload, they must typically be made large and massive. With the designers' attempt to push the state-of-the-art with faster and lighter machines, the control of system that exhibit flexibility becomes important. Due to all these facts, much attention has been given to flexible-link manipulators applications.

Many researches have examined different controller configurations in order to control machines without exciting resonances. The input commands to the closed-loop system are desired that the controller treats as disturbances. Often these desired are step inputs that the machine cannot rigidly follow (Singer and Seering, 1989).

Flexible robot structures vibration problems when commanded to perform rapid motion. Because at low speed these vibrations are not important and can be ignored. However, in moderate high speed system these vibrations become larger and important. Here cause various parts of the structure no longer move the way they were intended to move and the system performance will be affected when vibration occurs during the movement of a flexible manipulator. This is a serious problem especially for the application that needs high accuracy. Moreover, the behavior of the system is significantly affected by payload variations.

1.3 Problem statement

As the behavior of a flexible manipulator changes with payload, if is desirable to develop an adaptive input shaping for effective vibration control.

1.4 Objective of the Study

- To study the dynamic characteristic of the flexible manipulator with payload in order to construct the controlling method to reduce the vibration.

- To develop an adaptive input shaping for vibration control of a flexible manipulator with payload.

- To study the effects of an adaptive input shaping in suppressing the residual vibration of a flexible manipulator system.

1.5 Scope of Study

The scope of study is divided into three main parts:

The first part is to study the previous research regarding the existing methods in vibration reduction for flexible robot manipulators. The flexible manipulator system considered in this work is a single-link flexible manipulator that moves in a horizontal plane.

The second part of the project is to study the dynamic characteristics of the flexible manipulator with payload. The study is done to understand the dynamic behaviors of the flexible manipulator system. This is very important part of the research in order to design a good controller for the system.

The third part of study is to design an adaptive input shaper to control the flexible manipulator system. An adaptive input shaping will be used in this work for reduction in vibration for flexible manipulator system with payload. This work will be carried out through simulation and investigate the continuity of previous research.

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