"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the award of degree of Bachelor of Engineering (Electrical & Electronics – Control & Instrumentation)"

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Date : 24 November 2009

THE DEVELOPMENT OF BAND-STOP FILTER FOR VIBRATION CONTROL OF A FLEXIBLE MANIPULATOR USING PIC MICROCONTROLLER

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A thesis submitted in partial fulfilment of the requirements for the award of the Bachelor's degree of Engineering (Electrical & Electronics – Control & Instrumentation)

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NOVEMBER 2009

I declare that this thesis entitled "*The Development of Band-stop Filter for Vibration Control of a Flexible Manipulator Using PIC Microcontroller*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my Loving Dad, Mom and Sister

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ABSTRACT

This thesis presents the development of band-stop filter for vibration control of a flexible manipulator using PIC microcontroller. The simulation work is designed in Matlab based environment with sampling frequency of 1 kHz and the responses are presented in time and frequency domains. In this work, a single link flexible manipulator that moves in a horizontal plane is considered. Modelling is done using the assumed mode method where two modal displacements are considered in characterizing the dynamic behavior of the manipulator incorporating structural damping in this project. The band-stop filter is used to reduce vibrations in the system. This method reduce vibrations by filtering the natural frequencies that cause the system vibration. This can improve vibration control done by bang-bang torque input control technique. It is then written into C code language, together with the bang-bang torque input, and compiled into .hex file to be programmed into a PIC microcontroller, PIC18LFK50. The band-stop filter that has been embedded into the PIC shows a similar result compared to the band-stop filter in Matlab. However, the PIC has its limitations, that is, it can only give output values which have two decimal places or below. This limitation has caused the hub angle of the flexible manipulator to increase throughout the end. The embedded filter in PIC also increases the processing time.

ABSTRAK

Tesis ini membincangkan perkembangan penapis band-stop untuk kawalan getaran terhadap pengolah lentur dengan menggunakan pengawal mikro PIC. Kerja simulasi dicipta dalam keadaan berasaskan Matlab dengan sampel frekuensi 1 kHz dan tindak balasnya ditunjukkan dalam domain masa dan frekuensi. Satu cabang pengolah yang bergerak pada satah mendatar dipertimbangkan dalam kajian ini. Teknik penganggaran mode telah digunakan dalam pemodalan di mana dua sesaran modal telah diambil kira dalam menyifatkan perangai dinamik pengolah yang menggabungkan struktur redaman dalam projek ini. Penapis band-stop digunakan untuk mengurangkan getaran dalam sistem. Cara ini mengurangkan getaran dengan menapis frekuensi yang menyebabkan getaran. Ini boleh memperbaiki kawalan getaran yang dilakukan oleh teknik kawalan bang-bang. Kemudian, ia dituliskan ke dalam bahasa kod C, bersama dengan input bang-bang, dan digabungkan menjadi fail .hex untuk diprogramkan ke dalam sebuah kawalan mikro PIC, PIC18LFK50. Penapis band-stop yang telah diprogramkan ke dalam PIC menunjukkan hasil yang hampir sama dengan penapis yang dicipta dengan Matlab. Tapi PIC ada kekurangannya, iaitu, ia hanya boleh memberi nilai yang mempunyai dua titik perpuluhan atau ke bawah. Ini menyebabkan sudut hub pengolah lentur terus meningkat. Tambahan pula, penapis filter yang diprogramkan ke dalam PIC mengambil masa yang lebih lama dalam tempoh pemprosesan.

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LIST OF SYMBOLS

N	-	Newton
m	-	Meter
τ	-	Torque
t	-	Time
s	-	Second
E	-	Young Modulus
I	-	Area moment of inertia
A	-	Cross sectional area
ρ	-	Mass density per volume
I_h	-	Hub inertia
I_b	-	Beam rotation inertia
M	-	Global mass matrix
D	-	Damping matrix
K	-	Stifness matrix
n	-	Number of element
l	-	Length of element
$\boldsymbol{F}$	-	Vector of external force
$\boldsymbol{Q}$	-	Nodal displacement vector

θ	-	Angular displacement
x	-	Distance from hub
ω	-	Natural frequency
FE	-	Final Element method

CHAPTER 1

INTRODUCTION

The title of this proposed project is The Development of Band-stop Filter for Vibration Control of a Flexible Manipulator Using PIC Microcontroller. The contents of this thesis are organized into six sections namely: (1) introduction, (2) literature review, (3) methodology, (4) results and discussion, (5) conclusion, and (6) list of references and appendices. In addition, the format used throughout the entire thesis is based on the University Technology Malaysia's Thesis Manual, January 2004.

1.1 Background and motivation

In today's world of modern technology and fast-paced lifestyle, industries need to be able to achieve high productivity in order to survive in the market. The increasing demand for high speed performance and lower energy consumption in robot systems make the design of light-weight manipulators a necessity. Flexible manipulator systems offer several advantages over traditional rigid robotic arms, lighter in weight, require less material, have higher manipulation speed, lower power consumption, require small actuators, more manoeuvrable and transportable and safer operation, in general, less overall cost.

The increase in demand of flexible manipulator systems is the reason why more studies and development should be done in this field. In this project, the

development of band-stop filter will be used to control the vibration of the flexible manipulator. In the beginning, using MATLAB SIMULINK an unshaped bang-bang torque input will be filtered by the Butterworth band-stop filter developed to control the vibration of the flexible manipulator. After finding the most appropriate parameters of the Butterworth band-stop filter, the transfer function of the filter is programmed into a PIC microcontroller, that is, the hardware of this project.

1.2 Problem Statement

Due to the flexible nature of the manipulator, the light manipulators may possess significant flexibility. When the flexible manipulator of a system vibrates, it might cause inaccuracy in the system. Accuracy is often an essential requirement in a particular system. For example, in the field of neurosurgery, pinpoint accuracy is required.

Safety is also a main concern while using the flexible manipulator. If the fluctuations of the flexible manipulator cannot be controlled, it might cause damage to the equipment or endanger anyone who is near the equipment.

1.3 Project objective

The objective of this project is to:

i. Reduce and control the vibration of the flexible manipulator using band-stop filter.
ii. Choose the best parameters of the Butterworth band-stop filter to filter the bang-bang torque input.
iii. Implement an embedded band-stop filter using PIC microcontroller.

1.4 Scope of project

Based on the aim and objectives of this project, it is expected that this study will produce the following outcomes:

i. The development of band-stop filter for vibration control.
ii. The Butterworth filter is analyzed. (Different order, range of cut-off frequency)
iii. The appropriate parameters of the Butterworth band-stop filter will be chosen.
iv. An embedded band-stop filter is implemented using PIC microcontroller.
v. The results are then compared to the results gained from MATLAB SIMULINK.

1.5 Significance of the project

Flexible manipulators are used in a variety of fields, including medical field, space structures, flexible aircraft wings, robotic manipulators etc. The development of Butterworth band-stop filter will improve the vibration control of the flexible manipulator. Vibration is reduced after the bang-bang shaped input torque is filtered by the band-stop filter. Reduced vibration helps to improve the accuracy of flexible manipulator systems. Safety can be achieved through vibration control of the flexible manipulator. By eliminating the challenge of vibration of flexible manipulators, the choice of flexible manipulator will be favoured compared to rigid robot arms due to cheaper materials and faster response.

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