UNIVERSITI TEKNOLOGI MARA

REAL-TIME DIGITAL TRACKING CONTROL OF ELECTRO-HYDRAULIC ACTUATOR USING TRAJECTORY ZERO PHASE ERROR TRACKING CONTROLLER

NORLELA BINTI ISHAK

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Electrical Engineering

August 2017

AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student	:	Norlela Binti ishak
Student I.D. No.	:	2009469308
Programme	:	Doctor of Philosophy in Electrical Engineering (EE990)
Faculty	:	Electrical Engineering
Thesis Title	:	Real-Time Digital Tracking Control of Electro-Hydraulic Actuator Using Trajectory Zero Phase Error Tracking Controller
Signature of Student	:	Norlelaishak ....
Date	:	August 2017

ABSTRACT

The experimental equipment Quarter Car System was used in the studies of comfort riding. This system consists of a metal framework with hydraulic absorber attached to a tyre assembly. In comfort riding studies, the tyre will move up and down and the absorber has to sustain and stabilize the movements. For comfort riding, a control system was designed to control the movement of absorber and stabilized in shortest possible time. The movement of tyre up and down represents the road profile to test the robustness of the absorber controller. The tyre movements to represent the road profile can be done by a position control electro-hydraulic actuator (EHA) system which was placed in vertical position. The control movement of cylinder rod will represent the required road profile for comfort riding studies. By implementing conventional Zero Phase Error Tracking Control (ZPETC) to control the cylinder rod movement will only accurate for slow movement but not for fast movement. This is due to low frequencies and small bandwidth limitation. High frequency operation is not applicable. Thus, this research work proposed a new development and implementation of digital tracking control using feedforward trajectory ZPETC to the EHA system that will provide better control of cylinder rod to emulate road profile for low and high frequency movements. The plant model was represented by ARX331 structure and identified from the open-loop test experimental data. The proposed controller was designed using three different controllers based on three separated methods such as RLS method, comparing coefficients method and Laurent series method. Simulation results showed that the RLS method was capable to produce satisfactory tracking performance even with small filter-order. High filter-order was required to produce the same satisfactory tracking performance using the comparing coefficients method and Laurent series method. Using the same filter-order, Laurent series method produced better tracking performance than comparing coefficients method. The simulation results were validated using the real-time control of the EHA system using Matlab and Simulink environment.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Good riding performance and driving comfort depend on the vehicle suspension system which usually isolated the vehicle body from road irregularities and accelerations [1]. Passenger ride comfort is considered to be of utmost importance in designing any suspension system. The primary objective of any suspension system in automobiles is to isolate the road disturbances experienced by the tires from being transmitted to the passengers. ISO-2631-1:1997(E) [2][3] has provided certain guidelines to analyze ride comfort and also indicates the degree to which the vibration exposure will be acceptable. Hence active suspension systems are becoming crucial to improve ride quality and passenger comfort, in view of the established superiority over conventional systems.

Passive suspension system has failed in providing the aspect of comfort due to ride comfort which is directly proportional to the accelerations experienced [3]. In passive suspension system, the design has to compromise between the ride comfort and the stability of vehicle. The ride comfort and vehicle stability can be properly balanced through control in active suspension systems. Thus, active suspension systems have attracted much interest in both the academics and industrial researchers [4]. The active suspension systems have been gradually applied in cars to improve riding comfort when going through bumping roads or any other disturbances. In active suspension systems studies, nonlinear electro-hydraulic actuators (EHA) have been used in a quarter cars active suspension model [5][6].

Active car hydraulic suspensions are widely used since the fluid power produces accurate active force to improve the ride quality of automobiles [5]. The fluid power is the prominent feature and main advantage of the EHA system. It has good ratio between forces delivered by the actuator over the weight and its size [7]. Light in weight and small compact structure of the EHA system makes this actuator very suitable to be used in automotive and industrial applications. Moreover, the