VIBRATION CONTROL FOR A GANTRY CRANE SYSTEM USING INPUT SHAPING

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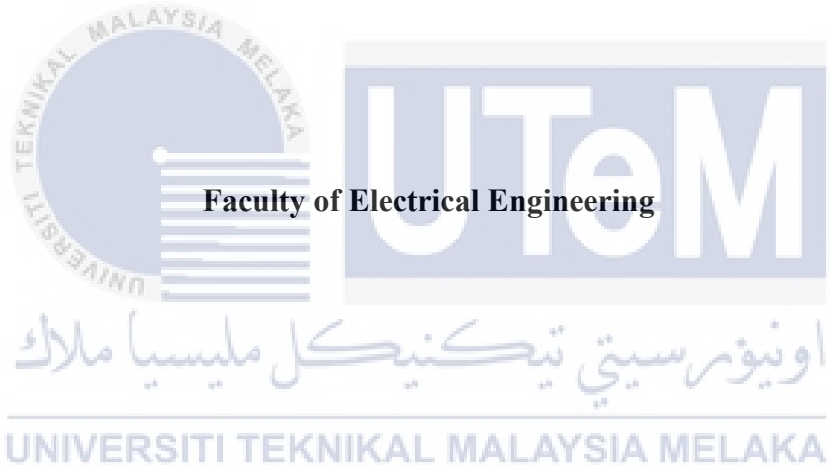
A report submitted
in partial fulfilment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours



Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this report entitle *"Vibration Control for a Gantry Crane System Using Input Shaping"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : SYAZWANI BINTI JAMIDAN

Date : 5 JULY 2021

APPROVAL

"I hereby declare that I have read through this report entitle *"Vibration Control for a Gantry Crane System Using Input Shaping"* and in my opinion, this thesis it complies the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering.

Signature : _____

Supervisor Name : TS. DR. HAZRIQ IZZUAN BIN JAAFAR

Date : 5 JULY 2021

DEDICATIONS

To my beloved mother and father

ACKNOWLEDGEMENTS

First and foremost, praises and thanks to the God for giving the strength and health to complete the project successfully. There are many people whom I acknowledge for their support and encouragement during the journey of making this project.

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ABSTRACT

This project proposes the implementation of vibration control using input shaping control schemes for a Gantry Crane System (GCS). Two types of input shaping controllers, which are Zero Vibration and Zero Vibration Derivatives are applied to control the vibration. The model of a nonlinear GCS is employed by using Lagrange technique. The effectiveness of the proposed control controllers are verified by using Simulink/Matlab to observe the controller and system performances. This project is divided into two stages, which are Stage 1 is to observe the behavior of the system. The behavior of the system is observed by varying the value for input voltage, payload mass and cable length. Meanwhile, Stage 2 is focused on implementation of input shaping control schemes namely ZV and ZVD for vibration control of the GCS. The behavior of the system implemented with input shaping is compared with an uncontrolled GCS. Then, the dynamic behaviour is observed by varying value for input voltage, payload mass and cable length.

ABSTRAK

Projek ini mencadangkan pelaksanaan kawalan getaran menggunakan kawalan pembentukan masukan untuk Sistem Kren Gantri (SKG). Terdapat dua jenis pengawal pembentukan data iaitu Getaran Sifar dan Pembezaan Getaran Sifar digunakan untuk mengawal getaran. SKG jenis tidak linear digunakan dengan menggunakan teknik *Lagrange*. Keberkesanan pengawal yang dicadangkan diuji dengan menggunakan *Simulink/Matlab* untuk memerhati prestasi pengawal dan sistem. Projek ini dibahagikan kepada dua tahap, iaitu Tahap 1 untuk memerhati tingkah laku sistem. Prestasi sistem diperhatikan dengan mempelbagaikan nilai pada voltan input, jisim muatan dan panjang kabel. Sementara itu, Tahap 2 memfokuskan pada penggunaan skema kawalan pembentukan data bagi mengawal getaran pada SKG. Prestasi sistem yang dilaksanakan dengan pengawal pembentukan data dibandingkan dengan SKG tanpa kawalan. Seterusnya, ia diperhatikan dengan mempelbagaikan nilai untuk voltan masukan, jisim muatan dan panjang kabel.

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LIST OF ABBREVIATIONS

DFS	-	Delay Feedback Signal
GCS	-	Gantry Crane System
LQR	-	Linear Quadratic Controller
PD	-	Proportional and Derivative Controller
PFS	-	Priority-based Fitness Scheme
PID	-	Proportional, Integral and Derivative Controller
PSO	-	Particle Swarm Optimization
SMC	-	Sliding Mode Controller
ZV	-	Zero Vibration
ZVD	-	Zero Vibration Derivatives
ZVDD	-	Zero Vibration Derivatives-Derivatives

LIST OF SYMBOLS

x	-	Trolley Position
θ_1	-	Payload Oscillation
m_1	-	Payload Mass
m_2	-	Trolley Mass
L	-	Cable Length
g	-	Gravity Acceleration
F	-	Force Input
kg	-	Kilogram (Mass unit)
m	-	Meter (Distance unit)
V	-	Velocity
T	-	Kinetic Energy
P	-	Potential Energy
B	-	Damping Coefficient
K_T	-	Torque Constant
K_E	-	Electric Constant
z	-	Gear Ratio
rp	-	Radius of Pulley
ω_n	-	Natural Frequency
ζ	-	Damping Ratio
ω_d	-	Damped Natural Frequency
K	-	Stiffness Constant
A_i	-	Amplitudes
T_i	-	Time Locations

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CHAPTER 1

INTRODUCTION

1.0 Overview

This section provides a short explanation of the project. Descriptions and introductions about Gantry Crane System (GCS) is explained. This chapter will clearly explain the problem statements, objectives, scopes, motivation, and the project outlines for the overall project.

1.1 Introduction

A crane system has been a part of the laboring background since its creation back in time during ancient Greece. It is still counted as a crucial part of equipment for heavy production work and lifting loads chores. The crane is equipped with cables and pulleys. Based on the application of basic mechanical rules, it is stated that a crane can raise and drop weights well enough beyond the capabilities of the construction laborers. The purpose of monitoring a crane is to move the weights quickly with no producing too much sway at the desired point. Nevertheless, nearly all crane produces a sway movement when payload is immediately stopped after a rapid movement.

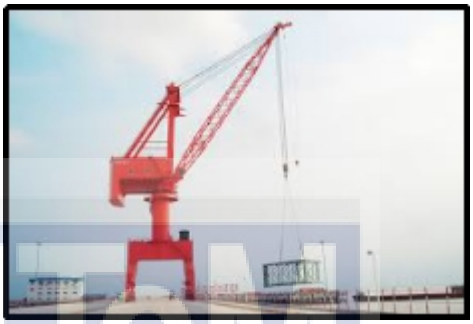
The crane model has established to meet the requirement of a variety of manufacturing requests to accomplish complex lifting tasks. Various categories of cranes are used in construction and manufacturing are tower crane, mobile crane, telescopic crane, giant cantilever crane, level-luffing crane, crawler crane, aerial crane, and gantry crane.

a) Tower Crane

b) Mobile Crane

c) Telescopic Crane

d) Giant Cantilever Crane



e) Level-Luffing Crane

f) Crawler Crane

g) Aerial Crane

h) Gantry Crane

Figure 1.1: Types of Cranes

Most of the crane types are operated by electric motors, hydraulic power, or an inner combustion engine. However, we can look ahead to see improvements in how cranes are operated in the future because of rapid modifications in technology. To work effectively and retain its vital stability, each form of crane should fulfil the laws of physics. Two main things that need to be considered in this aspect are that the crane must not transfer loads which beyond its own capability, and that every stressful motion going on exceed the machine's designated plane of operation should be extinguish wherever possible. A crane is considered running and capable to raise weights as the weight is balanced by counterbalances which stabilize the crane, letting crane to raise and shift its burdens. Various forms of crane nowadays have a variety of various features and capabilities. Some of the familiar elements in crane are usually considered when buying, are lifting capacity, lifting angle, swing angle, working radius, mobility, weight, dimensions, and setup time.

1.1.1 Gantry Crane System (GCS)

In our everyday life, the capability of person is very restricted and cause troubles in managing with massive supplies. To overcome this issue, heavy equipment is required to accomplish the chore. These days, complex technology make up GCS as some of the best heavy machinery in the construction, manufacturing, or shipping as shown in Figure 1.2. GCS are normally operated in loads carrying system in construction, manufacturing, shipping and nuclear resources where heavy weights must be transferred with great accuracy. The trolley is constructed on the upper section of GCS to shift and lift weights either to the right or to the left alongside the horizontal bridge rail by using the hoist. While the bridge is firmly stand by two or more legs shifting on permanent rails or any path.

Figure 1.2: Example of GCS

However, the crane acceleration necessary for mobility and continuously causes unwanted swing motion. This inescapable often swing motion leads to effectiveness reduction, overload damages and yet crashes. It is preferable to relocate the trolley to a desired spot quicker with reduce swing motion [1]. At greater acceleration, these swing angles turn out to be bigger, causes the payload unable to unload. Hence, to unload until the payload stop from swaying, a longer time is needed [3].

To shift the GCS to the desired location, a control mechanism that practically useful for trolley position and payload oscillation is needed. Due to this, specialists and skillful operators need to prevent the swing and shift the trolley to the desired spot manually. The vibration in the trolley and payload would be hazardous if heavy burdens are increasing. Therefore, load swing should be reduced in vibration and stop as fast as possible to maximize the operations [6]. Hence, Simulink is used for simulation to observe the output response of input shaping to the vibration control for the GCS.

1.2 Motivation

Construction of high-rise structures, huge scale apartment blocks, or construction in city are highly needed usage of cranes. In the construction industry, the usage of crane is common and very crucial regardless of the scope of the project. Cranes normally use cable and pulley to transport a mechanical gain when it is needed to lift heavy burdens. The crane operator is in charge person for monitoring the crane and obey the protection procedures. Life loss, injury, and property damage are the consequences that will happen if the crane maintenance requirements and operations are not properly performed. As the results, crane accident happened annually.

The latest incident happened on 22nd March 2021, at Alam Damai. Three foreign workers dead and one road user has been injured after a construction crane fell along the Sungai Besi-Ulu Kelang Elevated Expressway (SUKE) [18].

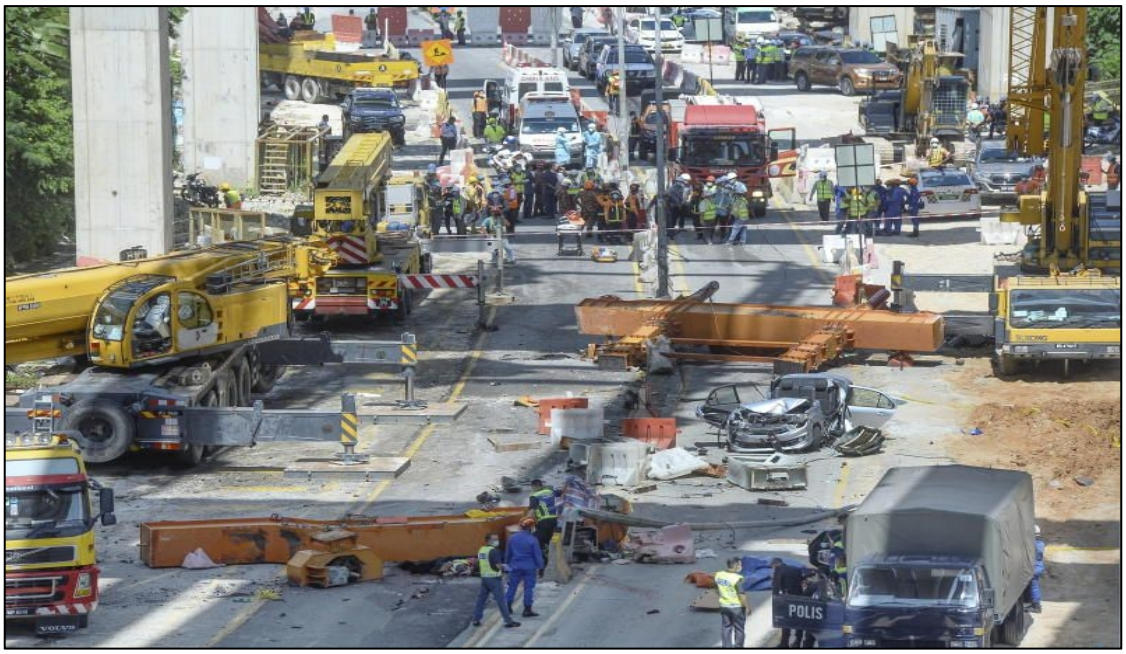


Figure 1.3: An accident involving crane [18]

Previous incidents that happened in Malaysia:

September 19, 2020: A woman had a nearly-death experience when a part of the tower crane knocked into two telephone poles, causing them to collapse onto the road and hit her car at Jalan SS2/24 in Petaling Jaya [19].

August 5, 2020: A crane driver, 28, endured a fracture after being stuck under a crane that had fallen over in Alam Damai, Cheras [20].

July 20, 2020: A foreign employee, 35, was buried alive at a construction site in Kota Damansara [21].

March 5, 2020: Two foreign labors were murdered when they were buried by mounds of falling earth at a construction site in Temerloh, Pahang [22].

February 14, 2020: The condominium project in Taman Desa, Kuala Lumpur partially collapsed after heavy rain [23].

December 13, 2019: A chain construction crane collapsed at a condominium construction site in Bandar Baru Sentul, Kuala Lumpur [24].

1.3 Problem Statement

Problem statements are listed as below:

i. Difficult in controlling the payload oscillation for a GCS.
ii. At greater speed, the sway angle become bigger. Hence, a long duration is required to unload until the oscillation stop.
iii. Need an experience and expert operator.

1.4 Objectives

Objectives for this proposed study are:

i. To study the dynamic GCS with various input voltage, payload mass, and cable length.
ii. To design and evaluate the system by using input shaping control schemes to reduce the payload oscillation.
iii. To analyse and verify the effectiveness of Zero Vibration (ZV) and Zero Vibration Derivative (ZVD) control schemes.

1.5 Scopes

To achieve the objectives, the scopes of the projects are:

i. Modelling mathematical expressions of the GCS by using Lagrange technique.
ii. Simulink/Matlab is used for simulation executions.
iii. Implement ZV and ZVD as the input shapers.
iv. The input voltage used for this project are 5 V, 10 V, and 15 V.
v. The payload mass used are 1 kg, 5 kg, and 15 kg.
vi. The cable length used for this project are 0.75 m, 1.75 m, and 2.75 m.

1.6 Report Outlines

The report outlines are stated as below:

Chapter 1 Introduction

It consists of introduction regarding the GCS, motivation, purpose, scopes, and problem statement of project.

Chapter 2 Literature Review

Contain summary about the GCS based on some journal paper and thesis from researcher.

Chapter 3 Methodology

Detail explanation for the project taken from another researcher model. The derivation for mathematical expression is shown. Brief explanation of the methodology for this project also are well stated in this chapter.

Chapter 4 Results and Discussions

Display results of the project. Proves that the project either produced the desired outcomes or not based on the methodology and technique proposed earlier.

Chapter 5 Conclusion and Recommendation

This last section makes a conclusion and summarize the result of the project and make a recommendation for the improvisation purpose.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This section reviews the study on the innovation of the GCS such as the field of study and modes of controller used for this system. In order to develop the controller for vibration control for the GCS, the proposed tuning method has been investigated. Some research for an approached method for input shaping control schemes such as ZV and ZVD are discussed in this chapter. Outline for this entire section is displayed in the Figure 2.1.

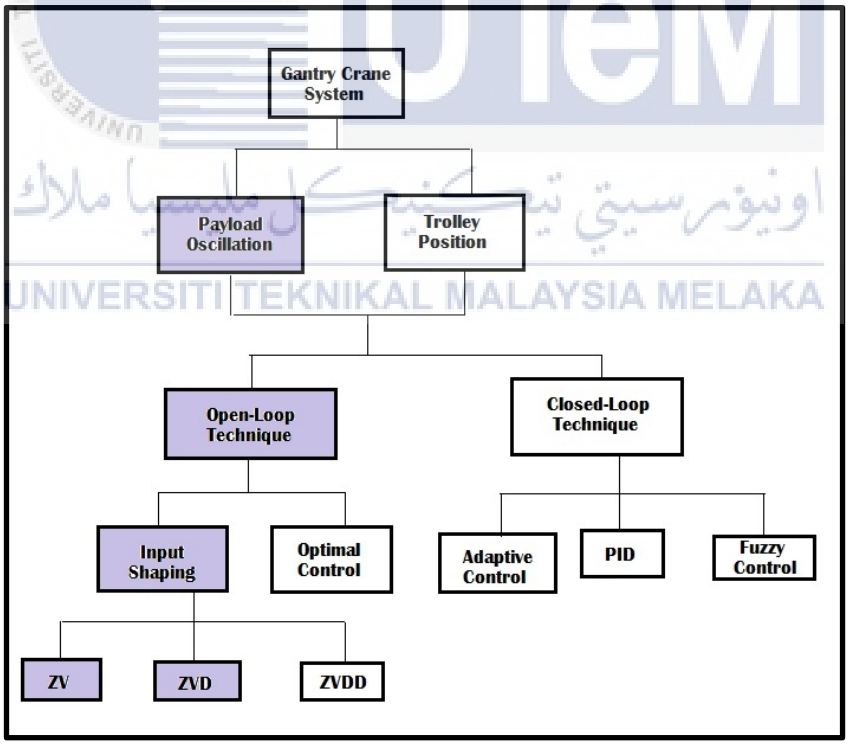


Figure 2.1: Scopes of literature review