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REPORT

DYNAMIC MODELING OF A DOUBLE-PENDULUM GANTRY CRANE SYSTEM

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18th JUNE 2014

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Date : 18 June 2014

DYNAMIC MODELING OF A DOUBLE-PENDULUM GANTRY CRANE SYSTEM

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering

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2014

I declare that this report entitle "*Dynamic Modeling of a Double Pendulum Gantry Crane System*" 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 : .....

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To my beloved mother and father

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ABSTRACT

This project presents investigations of dynamic behavior of Double Pendulum Gantry Crane System (DPGCS). The dynamic model system is developed and derived using Lagrange equation. The effects of performances in term of movement of the trolley and payload oscillation of the system are analyzed and discussed. The dynamic model is developed and the extensive results based on derivation are presented in the frequency domains. Simulation results are presented within MATLAB environment to verify the response performances of the system. It shows that several factors may affecting the performance of the DPGCS in terms of hook and load length, input force, hook mass, payload mass and trolley mass.

ABSTRAK

Projek ini membentangkan tentang kajian terhadap tingkah laku dinamik *Double-Pendulum Gantry Sistem Crane* (DPGCS). Sistem model dinamik diperolehi dengan menggunakan persamaan Lagrange. Kesan perubahan dari segi pergerakan troli dan ayunan beban dianalisa dan dibincangkan. Model dinamik juga dikaji dan keputusan yang diperolehi dipersembahkan dalam bentuk frekuensi domain. Keputusan simulasiyang dihasilkan melalui MATLAB adalah untuk mengkaji prestasi sistem tersebut. Ia menunjukkan bahawa beberapa faktor boleh menjejaskan prestasi DPGCS dari segi perubahan pada panjang kabel cangkuk dan kabel beban, kuasa input, muatan cangkuk, muatan beban dan muatan troli.

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LIST OF ABBREVIATIONS

DPGCS	-	Double-Pendulum Gantry Crane System
GCS	-	Gantry Crane System

LIST OF SYMBOLS

m_1	-	Hook Mass
m_2	-	Payload Mass
m_3	-	Trolley Mass
L_1	-	Hook Pendulum Length
L_2	-	Load Pendulum Length
g	-	Gravity Acceleration
F	-	Bang-bang Force Input
x (m)	-	Trolley Displacement
θ_1	-	Hook Swing Angle
θ_2	-	Load Swing Angle
kg	-	Kilogram (Mass unit)
N	-	Newton (Force unit)
m	-	Meter (Distance unit)

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CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter will be discussed about the Gantry Crane System (GCS) dynamic analysis. The project objective, problem statement, scopes of work and methodology will also be presented in this chapter.

1.1 Gantry Crane System

By the centuries, humans have been facing a problem in lifting and handling heavy materials. There is no other way in solving the problem until the GCS has been introduced. The use of modern machine technology is a step to provide support in the construction, transportation and make daily life become more convenient. The industrial use of GCS are increasing with the demand for greater safety and faster transferring payloads. The uncontrolled payload motions that are suspended will become dangerous if accident occur along transferring payloads. Crane operators must be skilled in handling cranes and have

the appropriate training to control the crane with more secure. The operator have the responsibility to plan carefully and taken the inspection before controlling the crane.

Thus, GCS supports to hold the load at a fixed location to move left or right and high or low. It consists of two or more legs parallel to each other on the bridge as shown in Figure 1.1. The heights of loads are depending on the maximum hook height. Samson and the Goliath have built the largest GCS ever that could each lift up to 840 tons [16].

Figure 1.1: Industrial Gantry Crane System (GCS)

Many cranes facing the same problem of the inefficiency cause by payload oscillations. It is difficult to manipulate payload accurately, quickly and safely because of the natural sway of crane payload. The purpose of crane controlling is to transfer the load as fast as possible without increasing any excessive sway at the desired position. Moreover, the results in a sway motion gave the terrible response when payload stopped after desired motion. The problem is become more complicated when the payload use a Double-Pendulum Gantry Crane System (DPGCS). It motion is very complex and its dynamic behavior are definitely related to the noise level of whole structure [10]. If the

crane behaves like a single-pendulum, the crane operators can eliminate much of the residual motion by causing a deceleration oscillation that cancel the oscillation induced during acceleration. For the system that behaves like a double pendulum, manual method of eliminating residual vibration becomes very difficult even for the most experienced operators. It may cause an accident if the problem cannot be resolved.

1.2 Motivation

Safety issues are very important because the GCS involved the use of shipping heavy loads. Gantry crane accidents have the potential to cause a serious injury or death to employees and other person involved. Many cases have been reported involving an accident on the gantry crane. This accident occurred is due to failure in handling the crane and may cause load collapse. Even though the person that have been injured in accidents have the legal right to claim compensation for the losses if cause by the negligence of the employer but precaution is better to avoid the injury occurred.

This matter can be supported with incident occurred involving crane which is on May 21, 2013 (Tuesday) at the Gallatin, Tennessee where the crane (Terex/American 165) owned and operated by Mountain States Contractors. According to the inspection report, a construction worker died on previous works. During the incident happen, the crane was collapse and fall on to a moving car. In this accident, nobody was seriously hurt on Highway 109 in Gallatin when the crane was crashed down the car. Gallatin police reported that the strong winds at that time in the afternoon were caused of the accident.

Based on the above issues, another way to curb and prevent this problem from continuing to happens is to study the behavior of cranes system in order to analyze the response performance of the system.

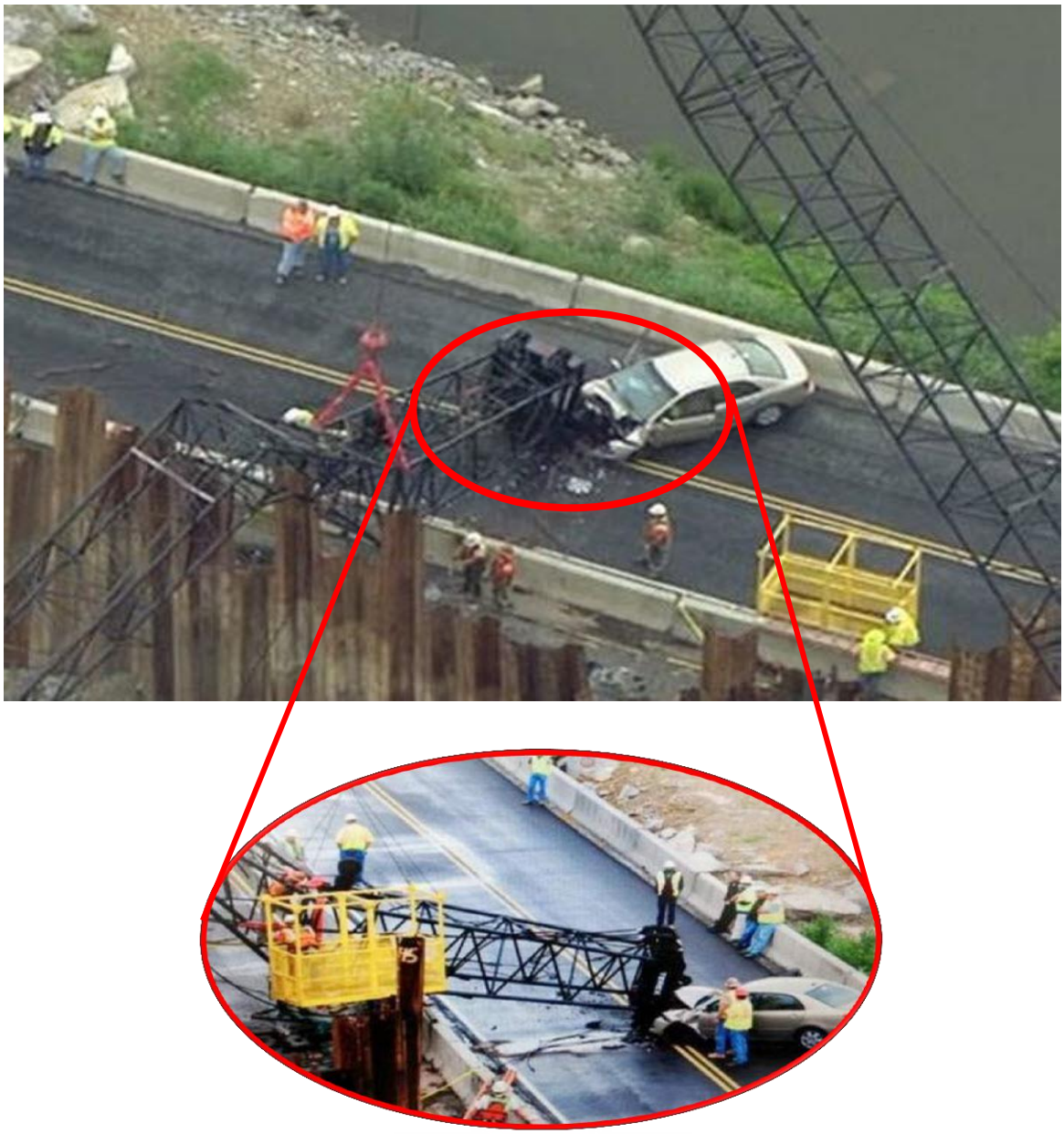

Figure 1.2: The overview of crane accident.

1.3 Problem Statement

i. Gantry crane has been developed to transfer heavy load as fast as possible or in a short period of time without causing any excessive swing at the desired position. However, the trolley acceleration always induces unwanted load swing. If the mass of trolley were increased, swing angle becomes larger. It requires more time to minimize the swing angle.

ii. Most of the gantry crane is manually controlled by the skillful and experience operators in handling cranes in order to make sure the payload stop swaying at correct position. A manual control is one of the factors that cause an accident in case of carelessness in handling the cranes. If the load becomes larger, it may cause accident and also harm people surrounding.

1.4 Significant of Project

i. According to previous researches, a lot of controllers have been designed in order to find the good performance of DPGCS. Most of controllers are used to control the trolley position and payload oscillation. However, the expected result still cannot be solved.

ii. Most industries are used general controller such as PID, Fuzzy Logic, and Input Shaping to overcome and improve the performance response. By development and investigations of dynamic modeling, it will lead us to better understand the behavior DPGCS in terms of performance response.