A Study of the Nonlinear and Linear Behavior of a Gantry Crane System

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Abstract— **This work presents a study of the nonlinear and linear behavior of a gantry crane system. The Lagrange equation was used to derive the model of the nonlinear system, and the Taylor series approximation was used to get the linearized model. The system was simulated using MATLAB. PID and PD controllers were used to control the oscillation of the load during the movement of the trolley within the specified displacement. The MATLAB simulation results were presented to demonstrate the effect of model parameters such as cable length, mass of trolley and payload on the trolley displacement and payload oscillation, as well as the effect of the controllers on system response.**

Keywords - Nonlinear model, gantry crane, Lagrange, simulation, PID controller.

I. Introduction

The growing need for large items and equipment necessitates the employment of modern, rapid, effective, and dependable cranes for transporting, loading and unloading heavy goods from one place to another. In industries, warehouses, seaports, building sites mining sites, and power plants, among others, a gantry crane system is a straightforward solution for transporting, loading, and unloading various types of products [1].

Two or more legs usually support the gantry crane, and the trolley is designed to move and deliver large goods right or left along the crane's horizontal bridge rail until they reach their destination [2].

During normal operation or in the presence of external disturbance such as high wind, gantry crane system (GCS) are susceptible to vibration and payload deflection. This resulted in incorrect load positioning, task delays, and perhaps system or operational environment damage [3]. In addition, the oscillation of the payload increases with the speed of movement of the crane [2]. However, the speed of movement is required because it affects productivity. Therefore, many researchers have been working on constructing a mathematical model of the system for exact dynamic analysis and effective control to improve system Productivity, ensure environmental safety, and reduce maintenance costs due to system breakdown [1,3,4].

In order to control the trolley position and the oscillation of payload, many researchers have been applied various control strategies such as Fuzzy Logic, Linear Quadratic Regulator and PID controllers [3,5]. PID controllers are frequently employed in industrial control systems because of its simple form, ease of adjustment, and outstanding stability [6].

In this work, the behaviour of linear and non-linear for the crane system will be analyzed and studied when changing the system parameters as well as the effect of using PID and PD controllers on the response of the system.

II. Gantry Crane System Description

The gantry crane system (GCS) shown in Fig.1, the trolley moves horizontally along the jib. A pair of legs hold the jib in place. A payload is hung from a trolley by a suspension cable. The schematic diagram of the gantry crane system in Fig.2 shows that the force required to move the trolley is denoted by (F). The trolley mass is (m_2), the payload mass is (m_1), the payload oscillation angle is (θ), the trolley displacement is (x), and the payload cable length is (l). The force supplied to the trolley (F) is the GCS's input, while the desired outputs are the displacement (x) and the payload oscillation angle (θ) [1].

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displacement and payload oscillation. The controllers were manually tuned to show the effect of the controller on the response of the system.

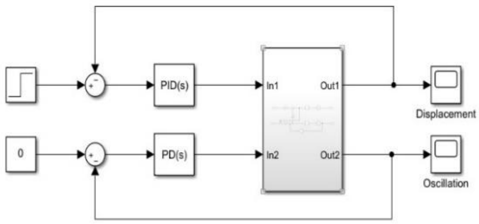

Figure 15. Simulink diagram of the system with controllers.

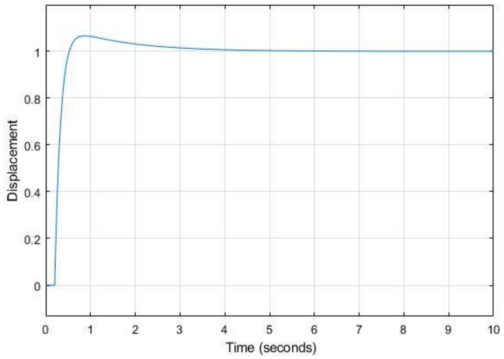

Figure 16. Trolley displacement with controller.

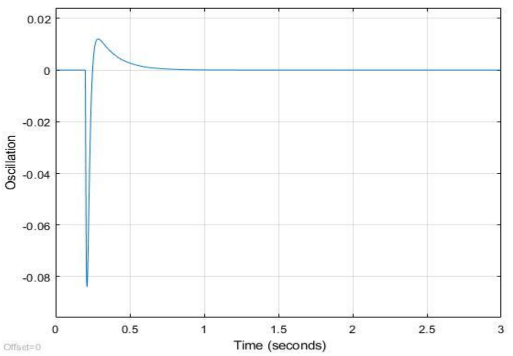

Figure 17. Payload oscillation with controller.

VI. CONCLUSION

In this work, a dynamic model of the gantry crane system has been studied and analyzed. The Lagrange equation have been used to derive the system's nonlinear differential equations. The responses of the system, such as trolley displacement and payload oscillation, have been studied. Various GCS system parameters have been investigated. The performance response of GCS is particularly sensitive to parameter setting adjustment, according to simulation results. PID and PD controllers have been applied to the system with manual tuning to show their effect on the system response. The study and analysis of systems is very useful in developing control mechanisms for gantry crane systems.

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