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The 5th International Symposium on Material, Mechatronics and Energy The 5th ISMME 2018

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The 5th International Symposium on Material, Mechatronics and Energy
The 5th ISMME 2018

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Foreword

First, we would like to thank all researcher who are already send the results of scientific research papers and participated in the 5th International Symposium on Material, Mechatronics and Energy 2018. All papers in this volume has presented at ISMME 2018 by oral presentation. The papers have been peer reviewed through processes administered by the proceedings Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

Our theme is Challenges and Opportunities of Materials Engineering, Mechatronics and Energy towards independence of independent and sustainable technology products. Themes have been given an important role of Indonesian Development of Industrial Manufacture strategic plan, where the Indonesian people are still in desperate need of technology in these areas, material, mechatronics and energy.

Today Issues is still on Industry 4.0, they are five items should be considered:
1. Scalability; The automation principle of Industry 4.0 could help to facilitate improved scalability among companies in the manufacturing sector.
2. Security; One of the foremost concerns about Industry 4.0 among manufacturers is the possibility of mishaps due to glitches in cognitive computing.
3. Control and Visibility; As manufacturing networks globalize, it is crucial to make digital processes visible to all points of a system. When fully implemented, the principles of Industry 4.0 support responsiveness by making information available worldwide within a fraction of a second.
4. Customer Satisfaction; The process will be fully transparent along all stops on the manufacturing chain, from the moment someone places an order or submits a design until the moment when shipments arrive. Industry 4.0 will facilitate co-creation capabilities between manufacturers and related entities on a global scale.
5. Customization; Industry 4.0 could take customization to new levels with the use of commercial 3-D printers, which there are 23,000 of in use worldwide.

We hope many researchers play on such conditions. Finally, thanks to all of my college in Faculty of Engineering Hasanuddin University, Okayama University, Graduate School of Unhas, Research and Community Services Institute of Unhas and Polytechnik State of Ujung Pandang.

Makassar-Gowa, November , 2018
Yours

Dr. Ir. Muhammad Arsyad Thaha, MT
Dean of Engineering Faculty of Hasanuddin University

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Peer Review Statement

All papers published in this volume of Journal of Physics: Conference Series have been peer reviewed through processes administered by the proceedings Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

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Experiments on Motion and Oscillation Controls of a Gantry Crane System Using Parallel Proportional Controllers

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Experiments on Motion and Oscillation Controls of a Gantry Crane System Using Parallel Proportional Controllers

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Abstract. The purposes of this research are to formulate the mathematical model of the system, to propose an effective control scheme and to perform experiments on a laboratory scale. The system used in this paper consists of a trolley, a pendulum as load and a dc motor to drive the trolley. Mathematical model of trolley position and load angle were formulated considering voltage of the motor and damping constant of the air calculated specifically using energy balance. Two proportional (*P*) controllers were designed in parallel in such a way to drive the trolley and to reduce oscillation of the load. The system and the proposed control scheme were confirmed through experiments. The experimental results revealed that the motion and oscillation of the system can be controlled effectively.

1. Introduction

The use of gantry crane systems for transporting payload is very common in engineering constructions, industrial applications and trading. For instance, a gantry crane is used for lifting containers from a ship onto a truck. The crane should move the load as fast as possible without having any excessive payload motion at the final position. However, moving the load using the crane is not an easy task. Most of the common gantry cranes result in a swing motion when payload is suddenly stopped after a fast motion [1]. So, the gantry crane needs a skillful operator to manually control it and to immediately stop the swing at the right position. Furthermore to unload, the operator has to wait until the load stops swinging [2]. It is often time consuming process which eventually affects the productivity in transporting payload. These problems can be solved using a controlled gantry crane system. Its controller system should deal with not only its motion but also oscillation of the payload.

The purposes of this research are to formulate the mathematical model of the system, to propose an effective control scheme and to perform experiments on a laboratory scale. The system used in this paper consists of a trolley, a load and a dc motor to drive the trolley. Mathematical model of trolley position and load angle were formulated considering voltage of the motor and damping constant of the air calculated specifically using energy balance. Two proportional (*P*) controllers were designed in parallel in such a way to drive the trolley and to reduce oscillation of the load.

2. Modeling

2.1. Mathematical Model

Figure 1 shows the dc motor used in this study. Electrical part of the motor consists of resistor, *R* and conductor, L. Voltage of *V* is the source of power. Inverse voltage of the motor and its constant are denoted by *e* and *K* respectively. Torque constant of the motor is denoted by K_t. Mechanical part of the motor has mass moment of inertia, *J* , viscous damping constant, *b* and motor torque *T*. Radius of gear, angular position and velocity of the motor are denoted by *r*, θ and $\dot{\theta}$. Transfer function of voltage of the motor to position of the trolley *X* and is expressed by [3]

$$\frac{X(s)}{V(s)} = \frac{r.K_t}{s\left((Ls+R)(Js+b)+KK_t\right)} \tag{1}$$

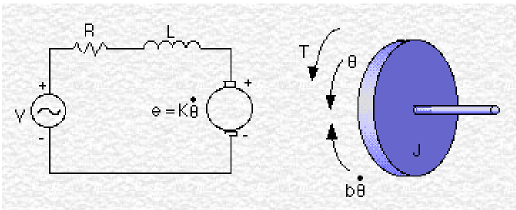

Figure 1. DC Motor

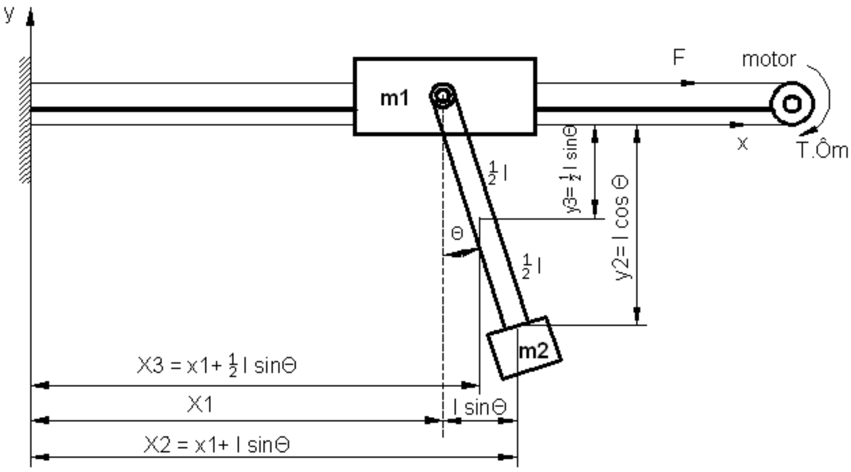

Figure 2. Design of the gantry crane system

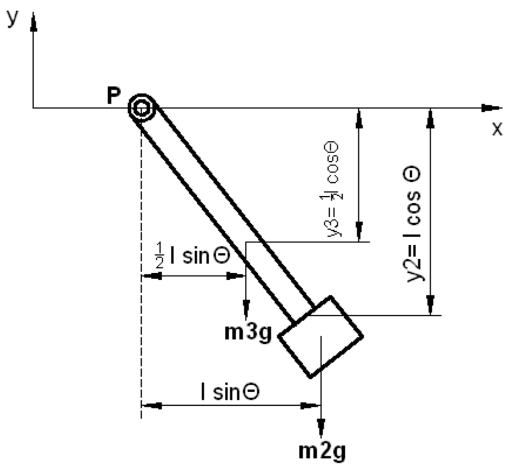

Figure 3. Free body diagram of the load

Figure 2 and figure 3 show the gantry crane system and free body diagram of the load. Based the figures, transfer function of position of the trolley *to* angle of the load α and is expressed by [3]

$$\frac{\theta(s)}{X_1(s)} = \frac{2.22.s^2}{s^2 + 1.25D_f.s + 21.8} \tag{2}$$

where D_f is damping constant of the air calculated specifically using energy balance.

2.2. *Experimental Model*

Figure 4 shows the experimental model of the gantry crane system. The gantry crane consists of the frame, the trolley, the load, the dc motor and the base. The motor is fixed in one side of the frame. The trolley is connected to the motor through a belt transmission system. An encoder is attached in the other side of the motor. IMU (inertia measurement unit) sensor is attached to the load. The frame is mounted to the base.

Figure 4. Experimental model of the gantry crane system

3. Control Scheme

A control scheme to drive the trolley and to reduce oscillation of the load was designed for the dc motor. Two *P*-controllers were designed in parallel for the system. The controlled torque of the motor are defined as follows

$$\tau = k_{p1}(x_d - x) + k_{p2}(\theta_d - \theta) \tag{3}$$

where k_{p1} and k_{p2} are proportional gains for position and angle of the load, respectively. Desired and actual positions of the trolley are denoted by x_d and x, respectively.

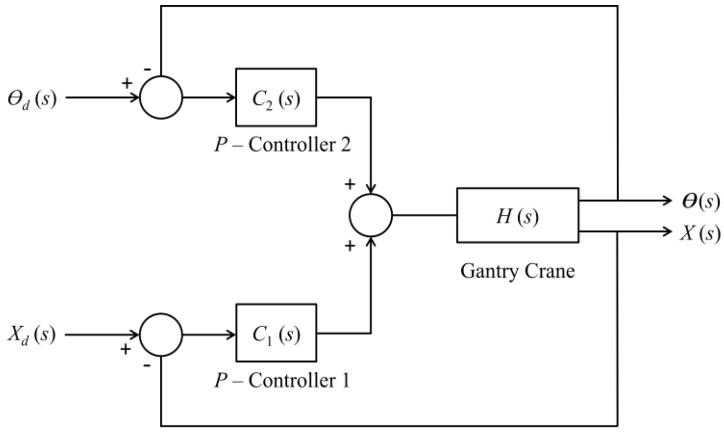

Figure 5. Block diagram of the proposed control scheme for the gantry crane system

Desired and actual angles of the load are denoted by θ_d and θ, respectively. θ_d is set to zero. The block diagram of the controlled system is shown in figure 5.

4. Experiment

4.1. Experimental Set-up
In order to investigate the validity of the proposed control scheme, an experimental set-up was designed. The set-up is shown in figure 6.

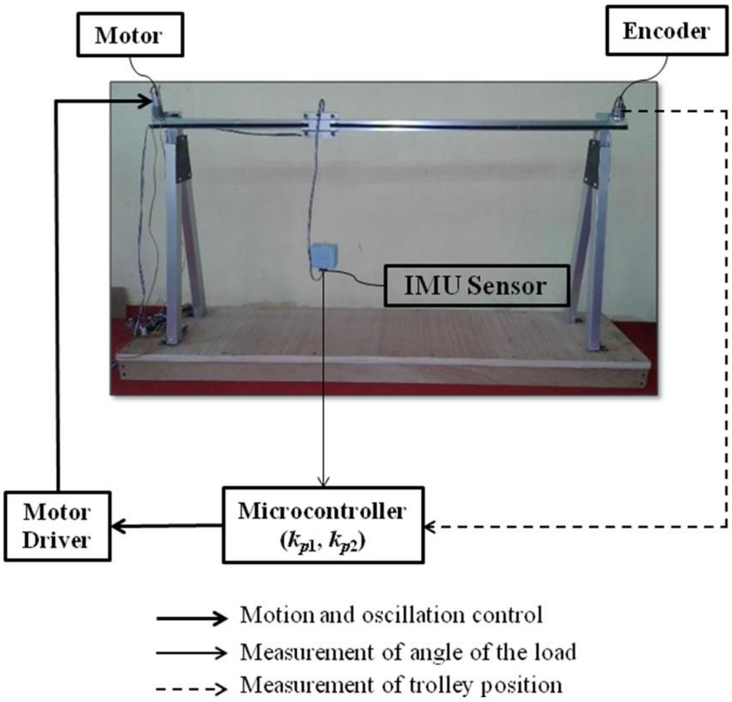

Figure 6. Schematics of measurement and control systems

The gantry crane system consists of the frame, the trolley, the load, the dc motor, the encoder, the IMU sensor and the base. The encoder and the IMU sensor provide information of trolley position and angle of the load. The both information were processed by a microcontroller using two *P*-controllers. The actuating signal sent to a motor driver to drive the motor and control oscillation of the load in the motor voltage range.

4.2. Experimental Method
Position of the trolley was set to 20 [cm]. Actuation signal were obtained from the first *P*-controller based on error of the trolley position and by the second one based on angle of the load. The proportional control scheme was implemented using arduino nano.

4.3. Experimental Results
Experimental time history responses of the trolley position and angle of the load on the controlled system were measured under the control scheme as shown in figure 7 and figure 8. Examining several gains of the *P*-controllers leaded to $k_{p1} = 3$ and $k_{p2} = 4$ as the better ones for the system. Figure 7 shows the uncontrolled and controlled time history responses of trolley position. The trolley position of 20 [cm] was achieved for 33 [s] and 20 [s] for uncontrolled and controlled system. Figure 8 shows the uncontrolled and controlled time history responses of angle of the load. Maximum angle of the load was

11 [degrees] for the uncontrolled system and could be reduced after 50 [s]. Maximum angle of the load was 4 [degrees] for the controlled one and could be reduced after 25 [s].

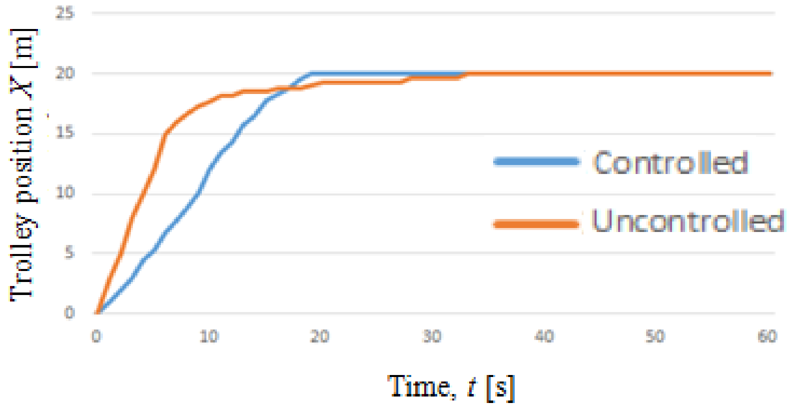

Figure 7. Time history responses of the trolley position

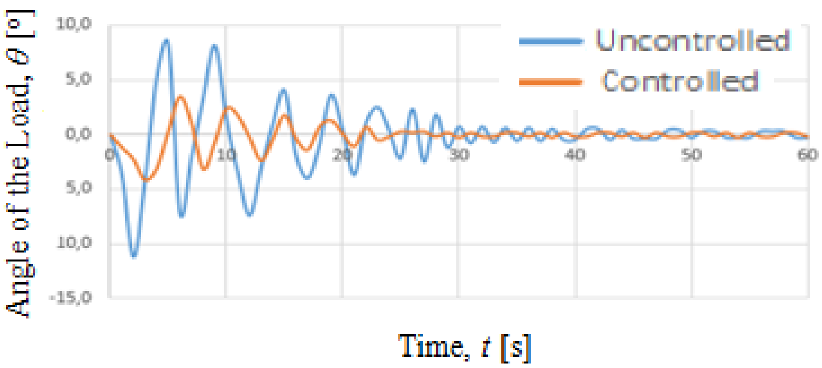

Figure 8. Time history responses of the load angle

5. Conclusion

The Mathematical model of the gantry crane system had been formulated considering voltage of the motor and damping constant of the air calculated specifically using energy balance. Two proportional (P) controllers were designed in parallel in such a way to drive the trolley and to reduce oscillation of the load. The proposed control scheme was examined through the experiments. The experimental results have been revealed that the position of the trolley and oscillation of the load can be controlled effectively.

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