BOTANY
Research Journal
MEDWELL PUBLICATIONS SINCE 2000

Portable Gantry Cranepayload Angle Limitation Control with the Presence of Trolley Position Vibration using Optimal Control

Mustefa Jibril, Messay Tadese and Reta Degefa
School of Electrical and Computer Engineering, Dire Dawa Institute of Technology, Dire Dawa, Ethiopia

Key words: Portable gantry crane, H2 synthesis controller, μ-synthesis controller, payload, technique

Corresponding Author:
Mustefa Jibril
School of Electrical and Computer Engineering, Dire Dawa Institute of Technology, Dire Dawa, Ethiopia

Page No.: 25-28
Volume: 13, Issue 4, 2020
ISSN: 1995-4751
Botany Research Journal

Abstract: In this study, a portable gantry crane is designed and controlled with the presence of trolley vibration disturbance using robust control technique. In the open loop system, the payload angle is not stable in both the impulse and step input force signals. Comparison of the system with H2 and μ-synthesis controllers have been done for a step and impulse input force signal and a promising results have been analyzed.

INTRODUCTION

Portable gantry cranes are used to lift and move smaller items, usually >5 tons. They are widely used in vehicle motor installation, machinery installation in industries. Some portable gantry cranes are equipped with a trolley moving track while others utility an I-beam or other extruded shapes for the movable surface. Most portable gantry cranes are intended to be stationary when loaded and mobile when unloaded. Portable Gantry Cranes can be outfitted with either a cord rope hoist or a lower capacity chain hoist[1].

MATERIALS AND METHODS

Mathematical modeling of portable gantry crane: The portable gantry crane with trolley vibration disturbance model is shown in Fig. 1. The differential equation describing the motion of the crane is:

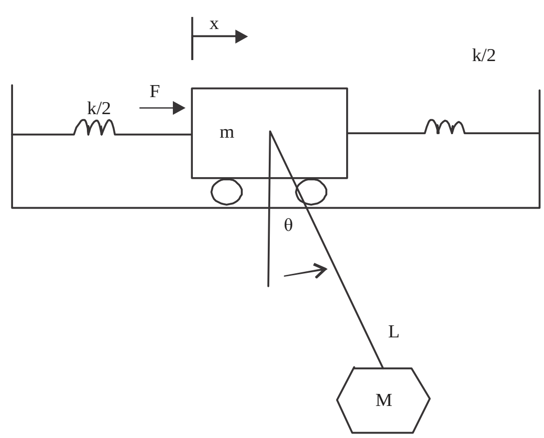

Fig. 1: Portable gantry crane with trolley vibration disturbance model

$$(M+m)\ddot{x}+Kx+ML\ddot{\theta}\cos\theta-ML\dot{\theta}^2\sin\theta = F \quad (1)$$

$$L\ddot{\theta}+\ddot{x}\cos\theta+g\sin\theta = 0 \quad (2)$$

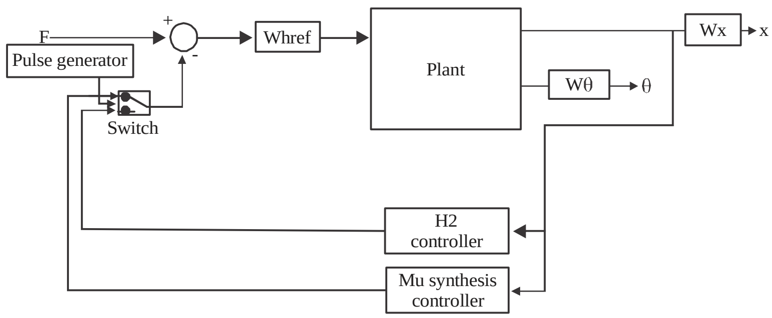

Fig. 2: Portable gantry crane system with H2 and μ-synthesis controller's system interconnections block diagram

Table 1: Parameters

Parameter	Symbols	Values
Trolley mass	m	120 kg
Payload mass	M	122 kg
Spring stiffness	K	8 N/m
Rod length	L	2 m
Gravity constant	g	9.8 m sec^{-2}

Assuming θ is small angle (Eq. 1 and 2) becomes:

$$(M+m)\ddot{x}+Kx+ML\ddot{\theta}=F \tag{3}$$

$$L\ddot{\theta}+\ddot{x}+g\theta=0 \tag{4}$$

Let:

$$x_1=x,\ x_2=\dot{x},\ x_3=\theta,\ x_4=\dot{\theta}\ \text{and}\ u=F$$

So, the state space representation becomes:

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_1\\ \dot{x}_1\\ \dot{x}_1\end{bmatrix}=\begin{pmatrix}0 & 1 & 0 & 0\\ -\frac{K}{m} & 0 & \frac{M}{m}g & 0\\ 0 & 0 & 0 & 1\\ \frac{K}{mL} & 0 & -\frac{(M+m)}{mL}g & 0\end{pmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\\ x_4\end{bmatrix}+\begin{bmatrix}0\\ \frac{1}{m}\\ 0\\ -\frac{1}{mL}\end{bmatrix}u$$

$$y=\begin{pmatrix}1 & 0 & 0 & 0\\ 0 & 0 & 1 & 0\end{pmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\\ x_4\end{bmatrix}$$

The parameter of the portable gantry crane is shown in Table 1. The portable gantry crane state space description is shown:

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_1\\ \dot{x}_1\\ \dot{x}_1\end{bmatrix}=\begin{pmatrix}0 & 1 & 0 & 0\\ -0.006 & 0 & 98 & 0\\ 0 & 0 & 0 & 1\\ 0.033 & 0 & -54 & 0\end{pmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\\ x_4\end{bmatrix}+\begin{bmatrix}0\\ 0.8\\ 0\\ -0.4\end{bmatrix}u\times 10^2$$

$$y=\begin{pmatrix}1 & 0 & 0 & 0\\ 0 & 0 & 1 & 0\end{pmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\\ x_4\end{bmatrix}$$

The proposed controller design: The design of portable gantry crane system to provide payload control is evolved the use of H2 and μ-synthesis controllers design. In the portable gantry cranesystem, the proposed controllers design to control the payload angle and to analyze the effect of trolley vibration on the payload angle[2, 3]. The predominant purpose of the controller design is to decrease the payload angle even with the presence of trolley vibration. Synthesis method is used to design the proposed controllers through reaching the overall performance objective through minimizing the payload angle. The portable gantry cranesystem with H2 and μ-synthesis controller's system interconnections block is shown in Fig. 2.

A μ -synthesis controller is synthesized with the usage of D-K iteration. The D-K iteration method is an approximation to synthesis that tries to synthesize the controller. There is one manipulate input the desired payload angle. The controller's acts on the y signal to produce the feedback trolley position signal. The Wx block modelled the disturbance inside the channel. Wx is given a disturbance noise of 0.09 m[4]:

$$W_x=0.09$$

The magnitude of the force disturbance is scaled using the weight W_{href}. Let us assume the maximum force disturbance is 0.2 N which means:

$$W_{href}=0.2$$

RESULTS AND DISCUSSION

Portable gantry crane open loop impulse response: The open loop impulse response of the trolley position

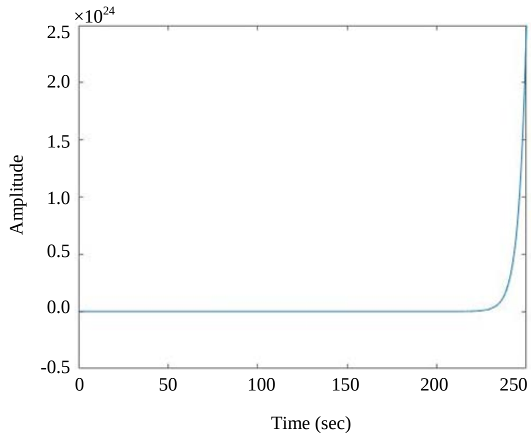

Fig. 3: Trolley open loop impulse response

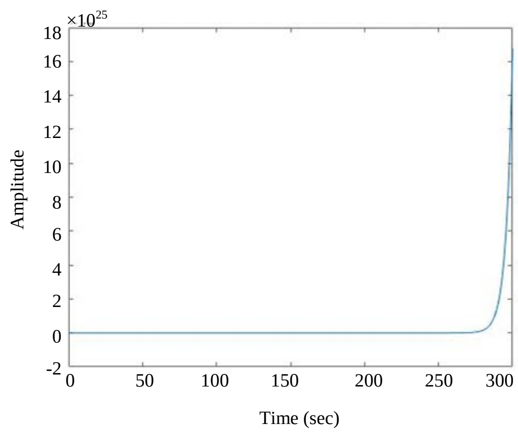

Fig. 4: Payload open loop impulse response

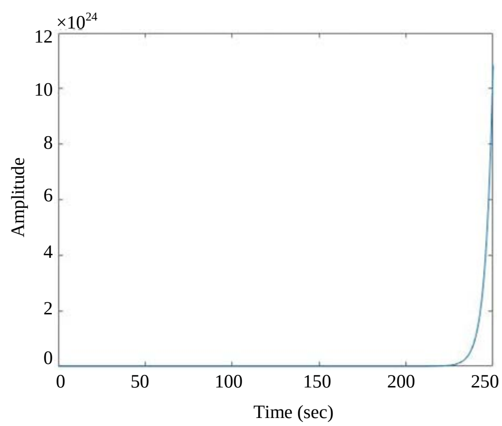

Fig. 5: Trolley open loop step response

and payload angle for a 100 N input is shown in Fig. 3 and 4, respectively. The impulse response simulation results show that both the trolley position and the payload angle are not stable[5].

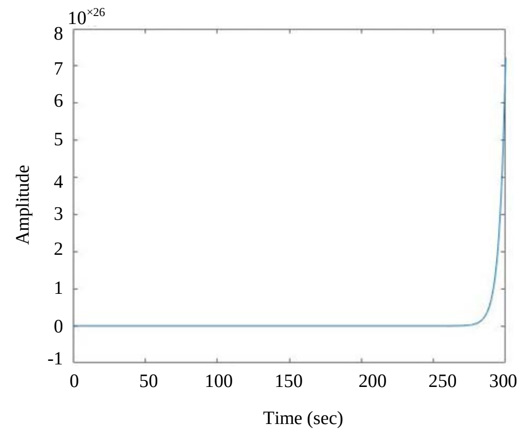

Fig. 6: Payload open loop step response

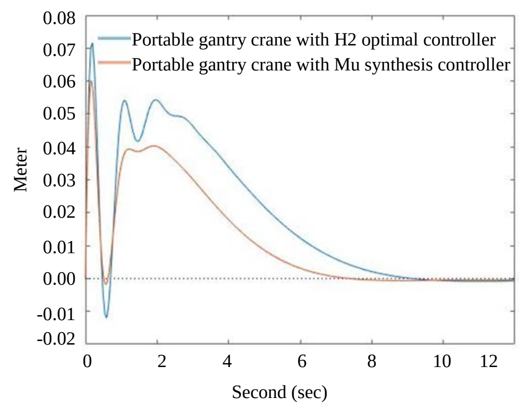

Fig. 7: Comparison simulation result of the impulse response of the trolley position; Trolley position impulse response comparison

Portable gantry crane open loop step response: The open loop step response of the trolley position and payload angle for a 100N input is shown in Fig. 5 and 6, respectively. The open loop step response simulation results show that both the trolley position and the payload angle are not stable[6].

Comparison of the portable gantry crane with the proposed controllers for an impulse force signal: The comparison simulation result of the impulse response of the trolley position and payload angle for a 100 N input force are shown in Fig. 7 and 8, respectively.

The impulse response comparison simulation result shows that the portable gantry crane with μ-synthesis controller improves the payload and trolley vibration (overshoot) and settling time.

Comparison of the portable gantry crane with the proposed controllers for a step force signal: The comparison simulation result of the step response of the trolley position and payload angle for a 100 N input force are shown in Fig. 9 and 10, respectively.

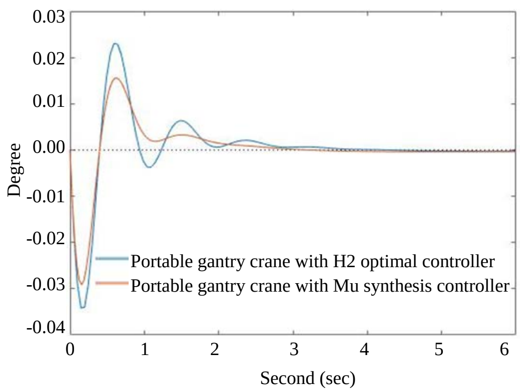

Fig. 8: Comparison simulation result of the impulse response of the payload angle; Payload angle impulse response comparison

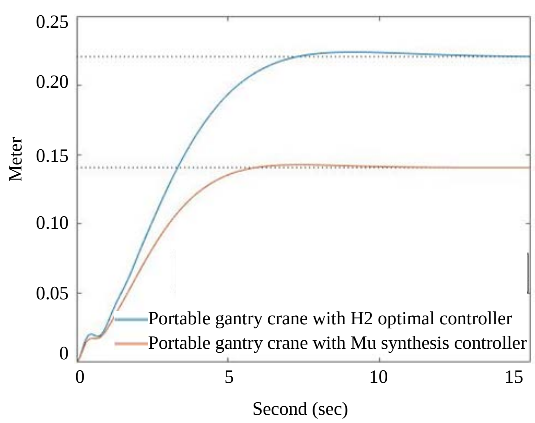

Fig. 9: Comparison simulation result of the step response of the trolley position; Trolley position step response comparison

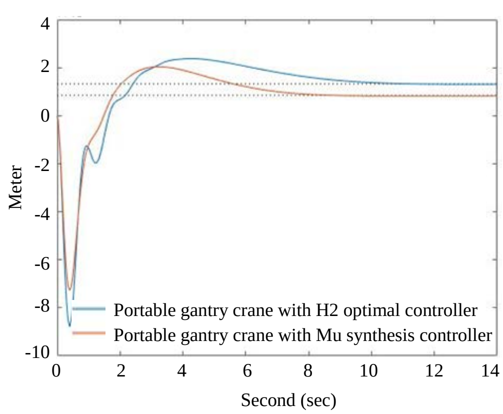

Fig. 10: Comparison simulation result of the step response of the payload angle; Payload angle step response comparison

The step response comparison simulation result shows that the portable gantry crane with μ-synthesis controller improves the trolley vibration and minimized the payload angle.

CONCLUSION

In this study, modeling, designing and controlling of a portable gantry crane have been done considering trolley vibration effect on payload angle limitation. The open loop system shows that the system is not stable therefore a robust control technique have been used. H2 and μ-synthesis controllers are designed for the system and simulation test has been done for a step and impulse force input signal. Both of the simulation results proves the effectiveness of the proposed μ-synthesis controller for improving the payload angle limitation with the presence of trolley position disturbance.

REFERENCES

01. Guo, P., X. He, Y. Luan and Y. Wang, 2020. Logic-based benders decomposition for gantry crane scheduling with transferring position constraints in a rail-road container terminal. Eng. Optim., 1: 1-21.
02. Nguyen, T.L., T.H. Do and H.Q. Nguyen, 2019. Vibration suppression control of a flexible gantry crane system with varying rope length. J. Control Sci. Eng., Vol. 2019.
03. Nguyen, T.L. and M.D. Duong, 2018. Nonlinear Control of Flexible Two Dimentional Overhead Cranes. In: Adaptive Robust Control Systems, Le, A.T. (Ed.). IntechOpen, New York, USA., pp: 315-333.
04. Luo, T., D. Chang and Y. Gao, 2018. Optimization of gantry crane scheduling in container sea-rail intermodal transport yard. Math. Prob. Eng., Vol. 2018, 10.1155/2018/9585294
05. Guo, P., W. Cheng, Y. Wang and N. Boysen, 2018. Gantry crane scheduling in intermodal rail-road container terminals. Int. J. Prod. Res., 56: 5419-5436.
06. Nguyen, H.H., N.D. Toan, N.B. Kha, M.T. Thang and T.T.H. Tham, 2018. Nonlinear control of a gantry crane system with limited payload angle. Int. J. Electr. Electron. Eng., Vol. 5, No. 8.