PARAMETERS IDENTIFICATION OF GANTRY CRANE BY THE METHOD OF LEAST SQUARES

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BẢN TÓM TẮT

Mục đích của bài báo này là nhận dạng những thông số quan trọng và khảo sát những mối tương quan của chúng, trong khi mô hình giàn cần cẩu được tạo dựng. Những phần tử quan trọng trong việc tính toán cấu trúc được kể đến như là độ cứng, độ giảm chấn, chuyển vị, tần số riêng. Chương trình MATLAB được dùng trong bài báo này. Tuy nhiên, phương pháp bình phương cực tiểu đã không là thuật toán phù hợp cho việc nhận dạng thông số của hệ thống giàn cần cẩu, bởi vì tính phi tuyến của hệ thống là rất cao .

ABSTRACT

The main purpose of this paper is to identify the important parameters and to examine their relations to one another while gantry crane structure was modeled. The important elements of the structural analysis are included, such as the stiffness, damping and its relations to the degrees of freedom, the displacement, and frequency responses. MATLAB program is applied in this paper. However, the least squares method can not be regarded as a suitable algorithm for parametric identification of the large-scale gantry crane system, because the nonlinear character of system is too high.

1. INTRODUCTION

Gantry crane has been applied for moving container over variable paths within restricted areas. The review of the literature has shown that most of the previous studies focused on optimal ways to control the crane trolley position so that the swing of the hanging container can be minimized. By using the models with the full-sized or reduced-sized gantry crane in the laboratory, a number of authors have found some solutions to this problem as in the studies of Kim, 2004, 2003, 2002; Wu, 2001; Choi, 2001; Albertos, 2000; Hong, 1999; Lee, 1998. However, there are still constrains which have not solved completely.

Firstly, until now large gantry crane has specially designed for loading and unloading containers from the ships with 10 to 18 rows. However, in the future, there are significant needs for bigger gantry crane with 22 or higher rows. Therefore, how to change the frame length of gantry crane, which influences other elements, is a more considerable problem.

Secondly, the full-sized gantry crane with wind effect has not considered thoroughly in the studies results. The whole structure of gantry crane is divided into two sections: the moving substructure and the static framework. Following the balance of forces, the relationship between the fixed framework and the moving sub-structure can be simplified into time-variant moving point loads.

During the operation of the gantry crane system, the moving substructure is subjected to wind flow; it may increase vibration or suddenly deflect its motion in wind flow around. Therefore, to understand the dynamical behaviors of the hanging container under wind excitation, the basic wind phenomena needs to be clearly understood.

In addition, designing a gantry crane includes designing structure, testing vibration, making

gantry crane, installing controller, and re-designing. In these steps, controllability has been ignored, even though this is an important parameter in operation of gantry crane in practical.

In this paper, we have proposed a modeling method by using virtual simulation to identify the important parameters of large-scaled gantry crane. Depending on the experiment results, system identification is used to identify parameters of gantry crane including damping and stiffness matrices. MATLAB program is also applied, with the least squares method. However, the least squares method can not be regarded as a suitable algorithm for parametric identification of the large-scale gantry crane system, because the nonlinear character of system is too high.

2. DYNAMIC SYSTEM

The procedure of dynamic modeling is shown in Fig.1. The inputs for system are measurements including wind pressure, motor torque, etc., while the inputs for system reaction are displacement, strain, stress. To model the system reaction as the output signal from the system inputs, a transmission through the object has been modeled.
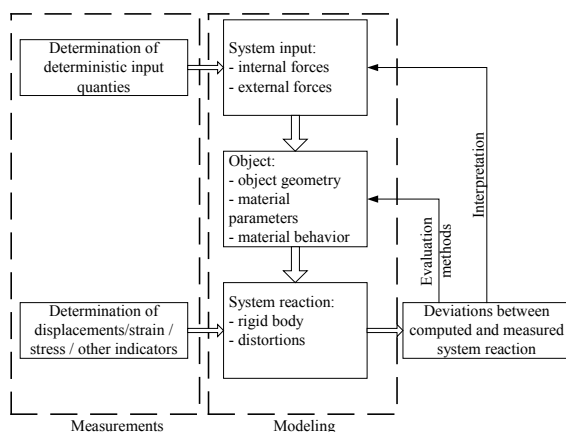

Fig.1 Dynamic Modeling

3. SYSTEM IDENTIFICATION

Generally, process identification, which catches some of the most important properties of the process behavior, is based on step response analysis.

System identification, as shown in Fig. 2, can be achieved when the inputs as well as the output signals are available as measured quantities.
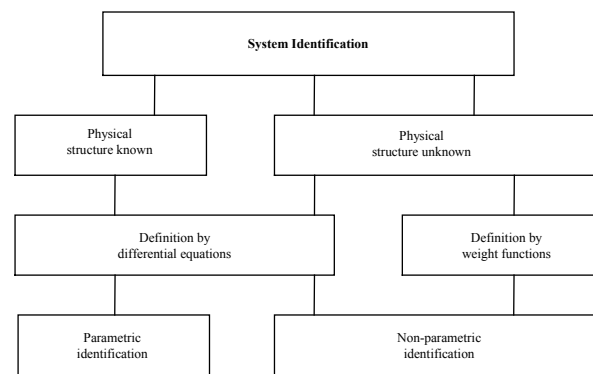

Fig.2 System identification

There are two kinds of models including parametric model and non parametric model. The parametric model (white box) is the model in which the transmission of the signal through the object is supposed to be known and can be described by differential equations. In non parametric model, on the contrary, modeling geometrical and the physical structure of a system can not be established except by the sense of regression and/or correlation analysis (behavior model). System identification means that determining the regression or correlation coefficients. Non-parametric models are called black box models because system identification is based not only on measurements but also on mechanical model. It is symptom but no model orientated.

4. PARAMETERS IDENTIFICATION OF GANTRY CRANE

4.1 Analytical Model

In Fig. 3, XY is the fixed coordinate system and $(\hat{X}, \hat{Y})$ is the trolley coordinate system which moves with the trolley.

The equations of motion of a two-dimensional gantry crane are obtained by Lagrange's equation as follows:

$$
\begin{cases}
(M_x + m)\ddot{x} + ml\cos\theta\,\ddot{\theta} + m\sin\theta\,\ddot{l} + C\,\dot{x} \\
\quad +2m\cos\theta\,\dot{l}\dot{\theta} - ml\sin\theta\,\dot{\theta}^2 = F_x^T \qquad (1) \\
\qquad\qquad ml^2\ddot{\theta} + ml\cos\theta\,\ddot{x} + 2ml\dot{l}\dot{\theta} \\
\qquad\qquad\qquad +mgl\sin\theta = 0 \qquad (2) \\
(M_l + m)\ddot{l} + m\sin\theta\,\ddot{x} + C_l\dot{l} - ml\dot{\theta}^2 \\
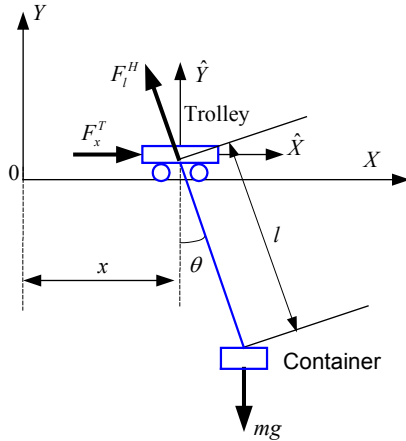\qquad\qquad\qquad -mg\cos\theta = F_l^H \qquad (3)
\end{cases}
$$

Fig. 3 Dynamic modeling of gantry crane

From Eqs. (1) and (3), the functions bellows are received

$$
\begin{cases}
C_x\dot{x} - k_{mx}F_{xe}^T = -(M_x + m)\ddot{x} - ml\cos\theta\,\ddot{\theta} - m\sin\theta\,\ddot{l} \\
\qquad\qquad -2m\cos\theta\,\dot{l}\dot{\theta} + ml\sin\theta\,\dot{\theta}^2 \quad (4) \\
C_l\dot{l} - k_{mi}F_{le}^H = -(M_l + m)\ddot{l} - m\sin\theta\,\ddot{x} + \\
\qquad\qquad +ml\dot{\theta}^2 + mg\cos\theta \qquad (5)
\end{cases}
$$

where C_x, C_l denote damping on x-axis and along cable; k_{mx}, k_{mi} denote stiffness along cable.

We assume that we observe the set of outputs and inputs

$$
\begin{bmatrix} \dot{x} & F_{xe}^T & 0 & 0 \\ 0 & 0 & \dot{l} & F_{le}^H \end{bmatrix}
\begin{bmatrix} C_x \\ -k_{mx} \\ C_l \\ -k_{mi} \end{bmatrix} =
$$

$$
= \begin{bmatrix} -(M_x + m)\ddot{x} - ml\cos\theta\ddot{\theta} - m\sin\theta\ddot{l} - 2m\cos\theta\dot{l}\dot{\theta} + ml\sin\theta\dot{\theta}^2 \\ -(M_l + m)\ddot{l} - m\sin\theta\ddot{x} + ml\dot{\theta}^2 + mg\cos\theta \end{bmatrix} \quad (6)
$$

and wish to compute values for the parameter

$$
\theta = \begin{bmatrix} C_x \\ -k_{mx} \\ C_l \\ -k_{mi} \end{bmatrix}
$$

$$
y = \begin{bmatrix} -(M_x + m)\ddot{x} - ml\cos\theta\ddot{\theta} - m\sin\theta\ddot{l} - 2m\cos\theta\dot{l}\dot{\theta} + ml\sin\theta\dot{\theta}^2 \\ -(M_l + m)\ddot{l} - m\sin\theta\ddot{x} + ml\dot{\theta}^2 + mg\cos\theta \end{bmatrix}
$$

$$
\phi = \begin{bmatrix} \dot{x} & F_{xe}^T & 0 & 0 \\ 0 & 0 & \dot{l} & F_{le}^H \end{bmatrix}^T
$$

We obtain equation

$$
\phi^T\theta = y
$$

4.2. Experimental Model

The model used for this case is shown in Fig. 4. Firstly, the container moves along the y-axis, from A point to B point, then travels along the x-axis, from B point to C point, and finally moves along the y-axis, from C point to D point.

In Fig. 5, driving forces F_x^T and F_l^H are installed by joysticks. Displacement of trolley and length of rope are obtained by two encoders. Results of swing angle and driving forces are obtained by potential. (5.37)

By using microcontroller (ATMEGA128), the experimental model is defined in Fig. 5. The parameters are as follows: length of rope is $l = 1.11[m]$, acceleration of gravity is
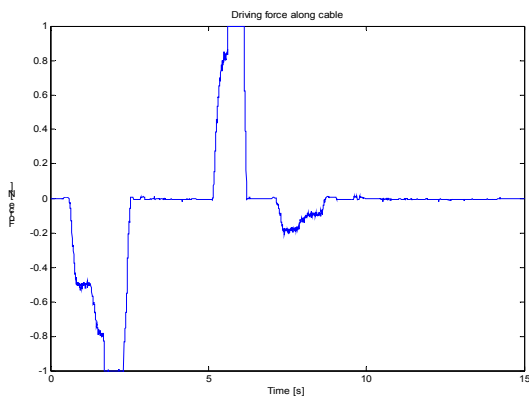
$g = 9.81 [m/s^2]$, mass of trolley is $M = 100 [kg]$, mass of container is $m = 60 [kg]$, respectively.

Fig.4 Transportation sequence of the container

Fig. 5 Experimental model

4.3. Results

Depending on the experiment results, system identification is used to identify parameters of gantry crane including damping and stiffness matrices. MATLAB program is also applied, with the least squares method.

4.3.1. Case 1

The driving force (by using joystick in experimental result) are put in Figs. 6-7.

Fig. 6 Driving force F_x^T

Fig. 7 Driving force F_l^H

We obtain the results :

$$\begin{bmatrix} C_x \\ -k_{mx} \\ C_l \\ -k_{mi} \end{bmatrix} = 1.e^3 \begin{bmatrix} -2.4167 \\ 0.4223 \\ -0.7486 \\ 0.3499 \end{bmatrix}$$

4.3.2. Case 2

The driving force (by using joystick in experimental result) are put in Figs. 8-9.

Fig. 8 Driving force F_x^T

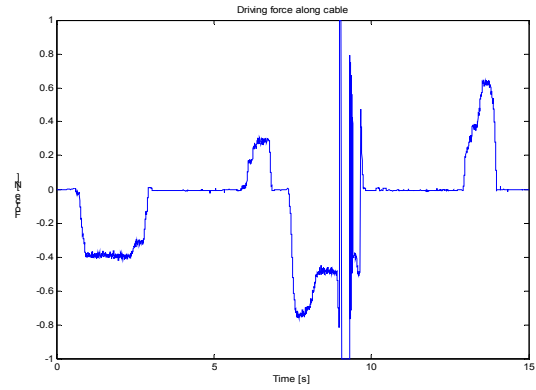Fig. 9 Driving force F_l^H

Fig. 11 Driving force F_l^H

We obtain the results :

$$\begin{bmatrix} C_x \\ -k_{mx} \\ C_l \\ -k_{mi} \end{bmatrix} = \begin{bmatrix} -943.3135 \\ 155.6088 \\ 86.9206 \\ -32.9107 \end{bmatrix}$$

We obtain the results:

$$\begin{bmatrix} C_x \\ -k_{mx} \\ C_l \\ -k_{mi} \end{bmatrix} = 1.e^3 \begin{bmatrix} -9.6000 \\ 4.4745 \\ -3.8999 \\ 0.4365 \end{bmatrix}$$

4.3.3. Case 3

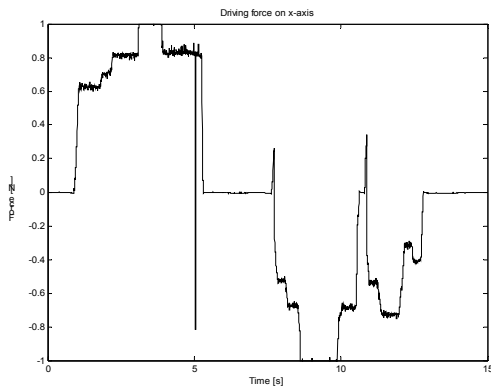The driving force (by using joystick in experimental result) are put in Figs. 10-11.

4.3.3. Case 4

The driving force (by using joystick in experimental result) are put in Figs. 12-13.

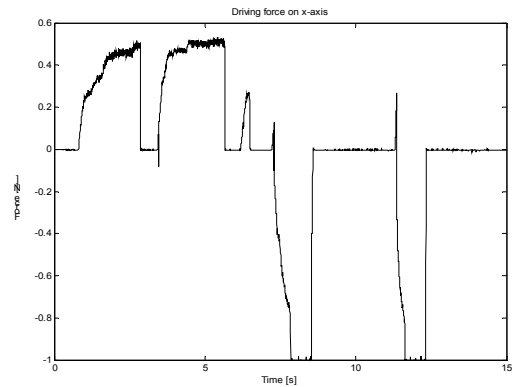Fig. 10 Driving force F_x^T

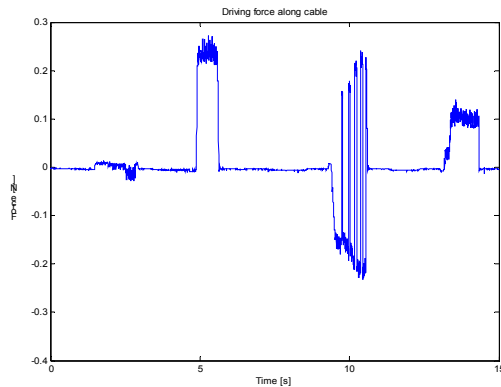Fig. 12 Driving force F_x^T

Fig. 13 Driving force F_l^H

We obtain the results :

$$
\begin{bmatrix}
C_x \\
-k_{mx} \\
C_l \\
-k_{mi}
\end{bmatrix}
= 1.e^5
\begin{bmatrix}
1.2641 \\
-0.2109 \\
-0.0378 \\
-2.5368
\end{bmatrix}
$$

5. CONCLUSIONS

In this paper, we have proposed a modeling method by using virtual simulation to identify the important parameters of large-scaled gantry crane. Depending on the experiment results, system identification is used to identify parameters of gantry crane including damping and stiffness matrices. MATLAB program is also applied, with the least squares method. However, the least squares method can not be regarded as a suitable algorithm for parametric identification of the large-scale gantry crane system, because the nonlinear character of system is too high.

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