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Simulation analysis of crane anti-sway control system based on PID

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Abstract

As the speed of the crane increases, its lifting weight will inevitably swing and it is difficult to achieve accurate delivery of goods. Aiming at the movement characteristics of the crane trolley and the swing angle problem caused by the trolley movement, in the Simulink software environment, the conventional PID control parameter optimization and the control of the swing angle of the hoisting load are carried out on the trolley displacement, and the simulation analysis is carried out.

Keywords

Crane, Anti-sway, PID, Simulink.

1. Introduction

In the actual operation of the crane, it is easy to be disturbed from the outside and its own factors, which in turn causes a lot of confusion in the design of anti-sway control. This topic has made reasonable assumptions in advance in the research, and put forward a unified control variable about the reasonable neglect in the operation process. Use Lagrange to discuss the dynamics model of the system, and build a simplified system motion model. By adding a single-input single-output module and a differential module on the basis of no anti-sway system, the crane anti-sway is designed. control. Accurately reduce the swing amplitude during operation, improve operation efficiency and operation safety.

2. Modeling of crane hoisting system

For the crane anti-sway control system, because it is an unstable control system and there are many uncertain factors, there are certain experimental difficulties and risks in experimental modeling compared with theoretical modeling. Therefore, in order to make the experiment as simple as possible, the usual approach is to pass some conclusions and assumptions and ignore some minor factors, the crane anti-sway control system is a typical dynamic system [1]. There are usually two methods for studying dynamic system problems: vector dynamics analysis research and analytical dynamics research. The basis of vector dynamics research is based on the direct application of Newton's law of motion, focusing on the forces and motions associated with individual parts of the system and the interaction between the parts [2]. However, analytical dynamics research treats the system more as a whole and uses scalars such as kinetic energy and potential energy to describe functions [3]. Therefore, this paper adopts the Lagrange equation in the research of analytical mechanics to establish the mathematical model of the crane anti-sway system.

In actual operation, the crane anti-sway control system is more complicated and the various system parameters are difficult to determine. It is often subject to various disturbances and the nonlinear force generated by the components during the transmission process. Therefore, the crane anti-sway control system must be simplified, and the following assumptions must be made. Figure 1 is a simplified model:

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1). Relative to the weight of the hoisting weight, the quality of the wire rope can be ignored;

2). When lifting heavy objects, the elastic deformation of the wire rope caused by the lifting of heavy objects can be ignored;

3). Ignore the influence of air resistance and external wind resistance [4];

4). Ignore the friction between the trolley and the wire rope at the contact point;

5). When building a system model, hooks and lifting weights can be regarded as mass points with no volume [5];

6). During operation, the quality of the hook can be regarded as much less than the quality of the lifting weight, that is, the quality of the hook can ignore its influence when lifting heavy objects.

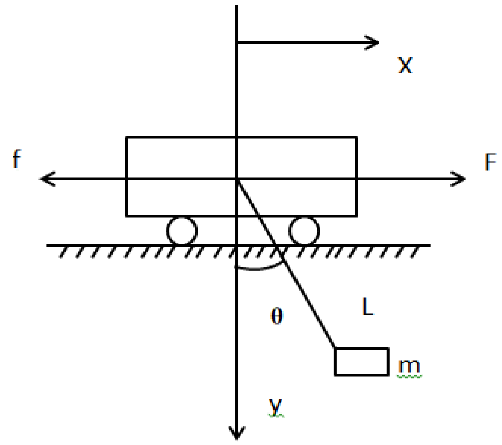

Figure 1: Simplified model of crane anti-sway control system mechanics

The simplified model of the crane anti-sway control system mechanics is shown in the figure. Many external factors need to be ignored in the idealized experimental modeling to simplify the modeling. Only the aspects that need to be considered in the modeling are: the quality of the trolley (M), the friction between the trolley and the track (f), the horizontal driving force (F) when the trolley is running, the weight of the hoisting weight (m), and the rope length (L) of the wire rope. Only by simplifying the system forces that the trolley receives during operation, can we better control the various parameters, so that we can better detect and obtain the sway angle generated by the trolley during operation, and then make corresponding adjustments to better improve the anti-sway Control System.

Table 1 will specify the meaning of the parameter symbols used in the modeling process.

Table 1: The meaning of physical quantities in the simplified model

Serial Number	Symbol	Physical Quantity	Unit	Remarks
1	m	Lifting weight	kg	Controllable amount
2	f	Friction between trolley and track	N	Variable
3	F	Horizontal driving force	N	Controllable amount
4	L	Wire rope length	m	Value
5	M	Trolley quality	kg	Value
6	u	Track friction coefficient	Null	Value
7	y	Horizontal displacement of trolley	m/s	Control amount
8	θ	Swing angle	deg	Variable

The simplified system dynamics equation is:

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$$\begin{cases}(M+m)\ddot{y}+ml\ddot{\theta}\cos\theta-ml\theta^2\sin\theta+\mu y=f\\ \ddot{y}\cos\theta+l\ddot{\theta}+g\sin\theta=0\end{cases}$$

3. Optimization of PID control parameters

PID control is widely used in the actual industry because of its advantages of simplicity, reliability, stability, and easy implementation. Nowadays, even though the control technology has been developed rapidly, there are still quite a few users who use PID control to simplify the control system.

PID control optimization formula expression:

$$u(t)=k_p(e(t))+k_i\int_0^t e(t)dt+k_d\frac{de(t)}{dt}$$

u: control amount;

kp: proportional gain coefficient (purpose: reduce static error);

ki: integral gain coefficient (purpose: eliminate static error);

kd: differential gain coefficient (purpose: to enhance system stability and reduce overshoot);

Because the changes of PID control parameters are affected by interaction, the change of one of the parameters will also cause the corresponding change, so parameter optimization should be carried out when using anti-sway control. However, because PID control parameters do not have the function of automatic tuning, it is difficult to use PID control to meet the demand when the parameter error and rate of change are large. Therefore, it is necessary to ignore some external factors that are difficult to control during model simulation. Variables need to be unified to control variable parameters, so PID control parameters have a streamlined effect on experimental simulation, and it is easy to realize simulation.

Table 2: The influence of PID internal settings on the overall performance of the model

Parameters (increase)	Rise time	Overshoot	Transition time	Static error
k_p	Decrease	Increase	Small impact	Decrease
k_i	Decrease	Increase	Increase	Decrease
k_d	Small impact	Decrease	Decrease	Small impact

4. Simulation analysis of PID anti-sway control algorithm

After booting into the Simulink environment, you can build a model that meets the requirements in it and perform numerical simulations. After the model is built, you need to enter the pre-set parameters and click the simulation command to see the simulation results.

First, in order to verify the anti-sway effect of the crane anti-sway control system, two simulation models need to be built:

1): The crane is not equipped with an anti-sway control system model;

2): Crane plus anti-sway control system model;

Secondly, in order to verify the anti-sway function, for the controllable variables, the parameter values of the control variables need to be unified. For example, suppose m=100kg, L=1.7m, etc.

4.1. Model and simulation of crane without anti-sway control system

In order to make the simulation results more representative, and for better control variables, in the control system without anti-sway, the gain factor adopts the amplification factor k=1 to make the comparison between the upper and lower results more representative in order to increase In the anti-sway simulation, the integral module (gain2) in order to make the waveform more obvious, the amplification factor k=20 at this time. The experimental simulation is shown in Figure 2 and Figure 3:

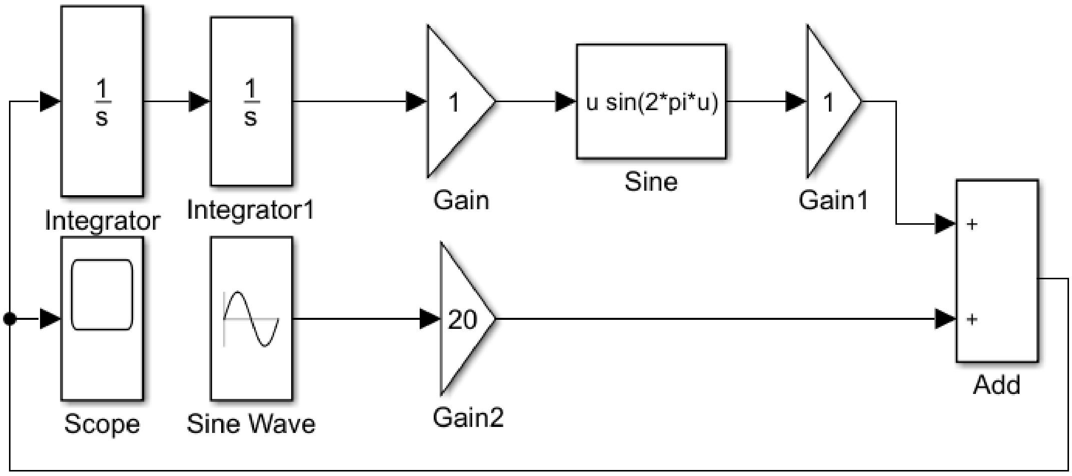

Figure 2: Crane anti-sway simulation model (without anti-sway system)

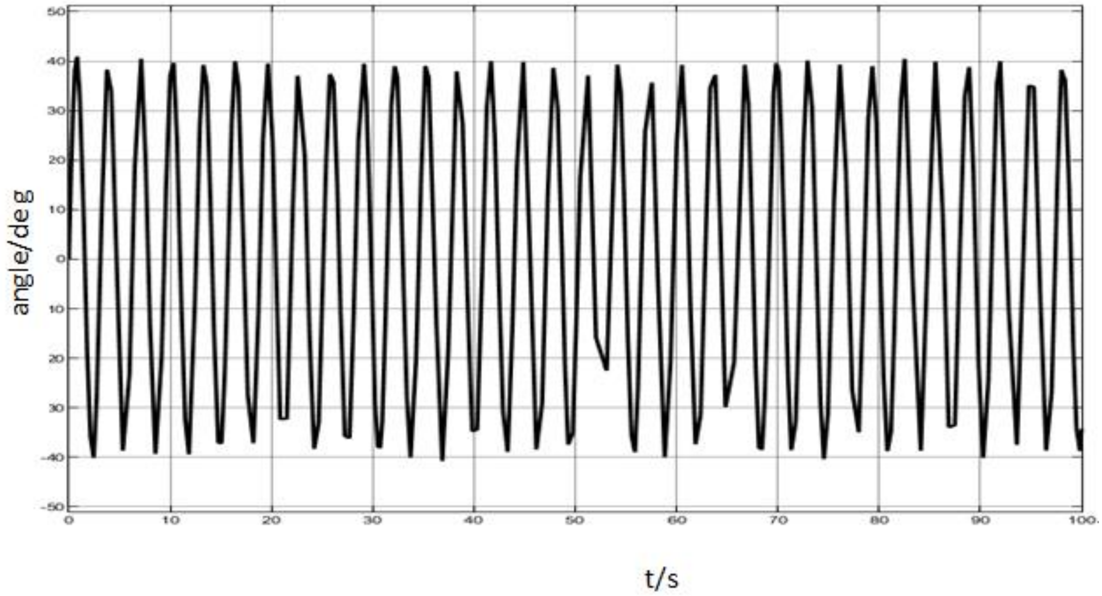

Figure 3: Lifting weight swing angle (without anti-sway system)

4.2. Model and simulation of crane plus anti-sway control system

The design of the crane with anti-sway control system is based on the addition of Function (single input single output module) and Derivative (differential module). At this time, it represents the reciprocal output part, and the Integrator (integrator) is on the original basis. Two more purposes are to be able to better detect the signal. The crane anti-sway control system is a further improvement on the unadded basis. The function, Derivative and Integrator modules are added to better receive information to better respond, and to better cope with crane movement. The swaying phenomenon produced by the time. The simulation diagrams 4, 5, and 6 show:

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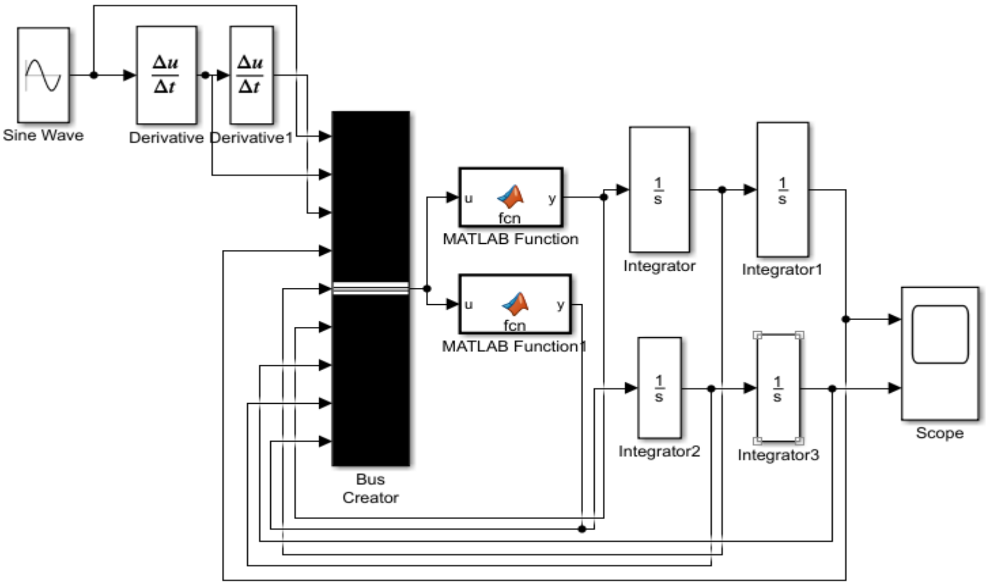

Figure 4: Crane anti-sway simulation model (with anti-sway system)

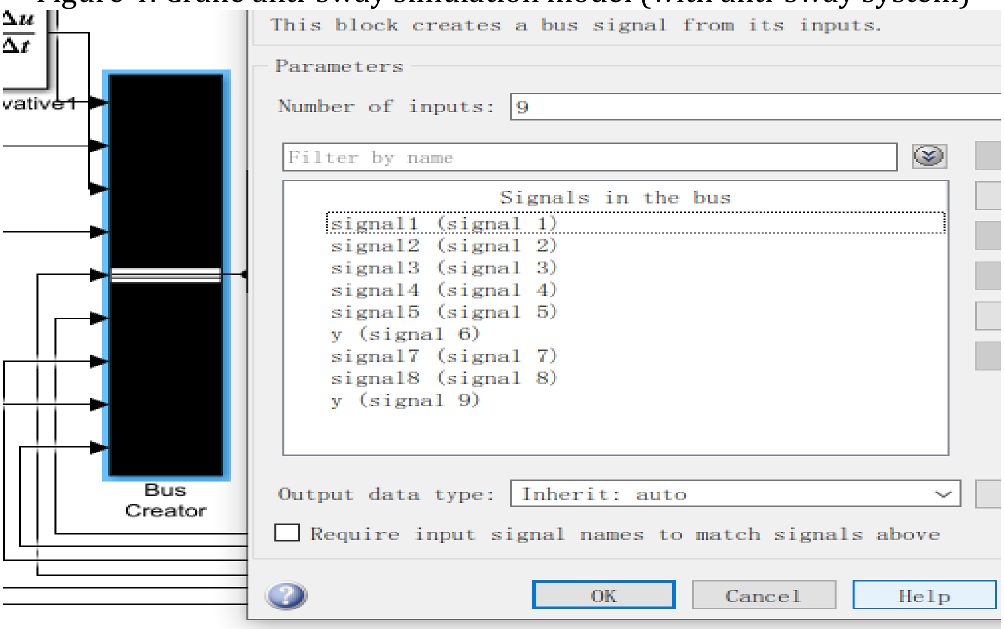

Figure 5: The meaning of each line end of Bus creator (with anti-sway system)

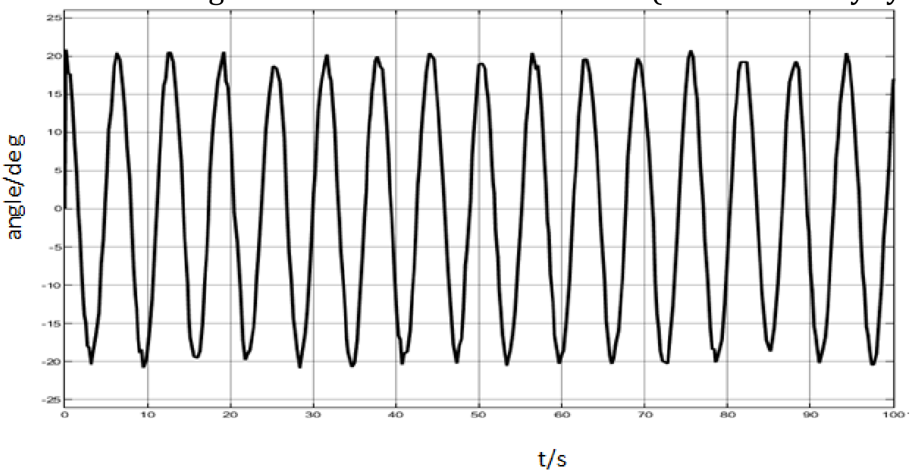

Figure 6: Swing angle of lifting weight (with anti-sway system)

It can be seen from Figure 3 and Figure 6 of the model simulation results that when the variable input parameters that can be controlled are constant, after the crane is installed with anti-sway control, with the operation of the crane's operating mechanism, the crane's installation of the anti-sway control system is significantly better than without The swing angle of the lifting weight of the anti-sway control system model should be small, and the swing amplitude is significantly reduced. Therefore, under special circumstances, when the controllable variables can be within the control range, the crane anti-sway control system can significantly improve the crane's swing control and improve the system's operational capacity, stability and safety.

5. Conclusion

This article mainly studies the anti-sway control scheme of the spreader, and derives the PID control algorithm. The analysis uses Simulink to carry out the simulation test of the anti-sway of the spreader on the PID control method, and compares and analyzes the results. It is found that the PID control can effectively solve the swing problem after adjusting the appropriate control parameters in the control process.

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