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Research on Inverter Turbine System Based on Sliding Mode Variable Structure Control

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Abstract

This paper uses modern control theory, control the primary inverted tank, established on the basis of state space method, using state feedback to make feedback control. Then use the powerful numerical computing power and data visualization capability of MATLAB software, and the inverted swing system is used to control the simulation. The system simulation results show that the sliding mode variable structure is used to control the inverted shelter, the system is more stable, robustness Good, thereby proves the effectiveness of the sliding mode variable structure controller.

Keywords

Inverted Pendulum; State Feedback; Synovial Structure.

1. Introduction

The inverted pendulum system belongs to a variety of variables, fast, nonlinear, and absolute unstable systems. As early as in the 1960s, the research on the inversion system, 1966 Schaefer and Cannon application Bang-Bang control theory, stabilizing a crankshaft in an inverted position. In the late 1960s, as a typical instability, a serious nonlinear example proposes the concept of inverted pendulum, and its inspection control method has the ability to deactivate the unstable, nonlinear and rapid system, and is subject to many scientists in all countries. Pay attention to, thus controlling different types of inverted swings with different control methods, and is one of the challenging topics [1].

1, synovial constituent control

In recent years, uncertain systems have gradually increased, and people seek how effective control of uncertain systems, and try to improve the robustness and stability of uncertain systems, many scholars have also proposed a lot of improvement methods, already The robust control of the control system can be basically implemented under certain conditions.

However, even if people are constantly improving the control performance of uncertain systems, it is only the control performance of unilateral promoting uncertain systems, that is, improve the system's stability, and reduce the performance robustness of the system, or unilateral Increase the robustness of the system and reduce the stability of the system, so how to get a system, balance the contradiction between system robustness and stability, is especially critical [2].

For the robust control of the linear system, many achievements have been achieved, but the complexity of the actual engineering problem and the increase in non-linearity are not then that the control system is not so simple, so the masters tried to find another nonlinear system. Luzhou control method, thereby birth of the variable structure control theory - sliding model has the characteristics of the system parameters in the standard space, and its appearance, causing various scholars in the world to study and promote.

The definition of sliding mode variable structure control is as follows:

$$\dot{x} = f(x, u, t)$$

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Seek sliding mode variable structure control:

$$u_i(x) = \begin{cases} u_i^+(x), s_i(x) > 0 \\ u_i^-(x), s_i(x) < 0 \end{cases}$$

2. Inverted pendulum model analysis

Through the above assumption, the inverted pendulum is abstracted as the system shown in the figure, and the Newtonian mechanics analysis is utilized.

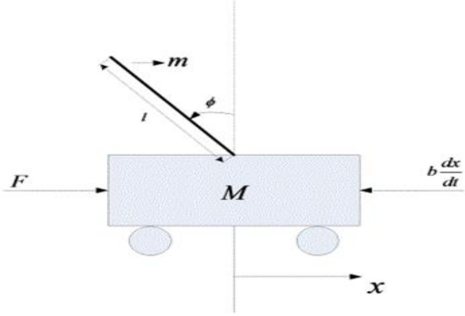

Figure 1. Straight line level inverted pendulum model

- M Quality of the car 1.098 Kg
- m Quality of the pendulum 0.108 Kg
- b Friction coefficient of the trolley 0.1N/m/sec
- n The swing rod rotation axis and the centroid distance 0.26m
- I Inertia 0.0034 kg·m2
- F Plus to the trolley
- x The actual location of the car
- The pendulum and the angle of vertical upward direction
- The angle between the pendulum and the vertical direction direction

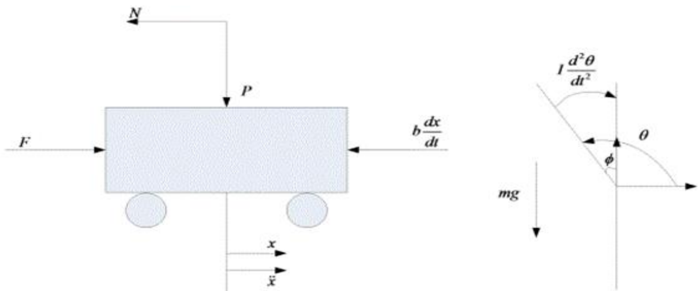

Figure 2. Vehicle and pendulum stress analysis

N is the horizontal direction component of the active force of the trailer homogenizer, and the p is the vertical direction.

First complement the force analysis in the horizontal direction of the vehicle, the force analysis of the horizontal direction of the pendulum is completed, and the first motion equation is obtained.

Complete the force analysis of the horizontal direction of the car, obtain the following equation:

$$M\frac{d^2x}{dt^2} = F - b\frac{dx}{dt} - N \quad (1)$$

Complete the force analysis in the horizontal direction of the pendulor, and obtain the following equation:

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$$N = m\frac{d^2x}{dt^2} + m1\frac{d^2\theta}{dt^2}\cos\theta - m1(\frac{d\theta}{dt})^2\sin\theta \quad (2)$$

Get the first motion equation in the system after calculation:

$$(M+m)\frac{d^2\theta}{dt^2} + b\frac{dx}{dt} + ml\frac{d^2\theta}{dt^2}\cos\theta - ml(\frac{d\theta}{dt})^2\sin\theta = F \quad (3)$$

Second, according to the force of the pendulum vertical direction, another moving equation in the system is obtained.

The force analysis is performed in the vertical direction of the swing rod to obtain the following equation:

$$-Nl\cos\theta - pl\sin\theta = I\frac{d^2\theta}{dt^2} \quad (4)$$

Merge these two equations, eliminate P and N to get the following exercise equation:

$$(I+ml^2)\frac{d^2\theta}{dt^2} + mgl\sin\theta = -ml\frac{d^2x}{dt^2}\cos\theta \quad (5)$$

Set $\theta = \pi + \partial$, assuming that ∂ is far less than 1, It can be approximated that the output force F of the controlled object $\cos\theta = -1, \sin\theta = -\partial, (\frac{d\theta}{dt})^2 = 0$ is used u to indicate that the movement of the motion equation is as follows:

$$\begin{cases} (I+ml^2)\frac{d^2\partial}{dt^2} - mgl\partial = ml(\frac{d^2x}{dt^2}) \\ (M+m)\frac{d^2x}{dt^2} + b\frac{dx}{dt} - ml\frac{d^2\partial}{dt^2} = u \end{cases} \quad (6)$$

The initial conditions are set to 0, and the French group performs Laplas transform to get the following equation:

$$\begin{cases} (I+ml^2)\partial(s)s^2 - mgl\partial(s) = mlX(s)s^2 \\ (M+m)X(S)S^2 + bX(s)s - mls^2 = U(s) \end{cases} \quad (7)$$

Since the angle ∂ is the output, the first equation in the equation group can be obtained:

$$X(s) = \left[\frac{I+ml^2}{ml} - \frac{g}{s^2}\right]\partial(s) \quad (8)$$

$$\frac{\partial(s)}{x(s)} = \frac{mls^2}{(I+ml^2)s^2 - mgl} \quad (9)$$

Let $v = x$, must be:

$$\frac{\partial(s)}{v(s)} = \frac{ml}{(I+ml^2)s^2 - mgl} \quad (10)$$

This formulates this in the second movement equation in the above equations, obtained:

$$(M+m)[\frac{I+ml^2}{ml} - \frac{g}{s}]\partial s^2 + b[\frac{i+ml^2}{ml} + \frac{g}{s}]\partial s - ml\partial s^2 = u(s) \quad (11)$$

Get the transfer function after finishing:

$$\frac{\partial(s)}{u(s)} = \frac{\frac{mls^2}{q}}{s^4 + \frac{b(I+ml^2)}{q}s^3 - \frac{(M+m)mgl}{q}s^2 - \frac{bmgl}{q}s} \quad (12)$$

among them $q = [(M+m)(I+ml^2 - m^2l^2]$.

Setting the system status space equation is: $\begin{cases} \dot{X} = AX + Bu \\ y = CX + Du \end{cases}$

The equation group is solved to $\ddot{x}, \ddot{\phi}$ quotient equation to obtain a solution:

$$\begin{cases} \dot{x} = \dot{x} \\ \ddot{x} = \frac{-(I+ml^2)b\dot{x}}{I(M+m)+Mml^2} + \frac{m^2gl^2\varphi}{I(M+m)+Mml^2} + \frac{(I+ml^2)u}{I(M+m)+Mml^2} \\ \dot{\varphi} = \dot{\varphi} \\ \ddot{\varphi} = \frac{-mlb\dot{x}}{I(M+m)+Mml^2} + \frac{mgl(M+m)\varphi}{I(M+m)+Mml^2} + \frac{mlu}{I(M+m)+Mml^2} \end{cases} \quad (13)$$

After the finishing system status equation is:

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$$\begin{bmatrix} \dot{x} \\ \ddot{x} \\ \dot{\varphi} \\ \ddot{\varphi} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & \frac{-(I+ml^2)b}{I(M+m)+Mml^2} & \frac{m^2gl^2}{I(M+m)+Mml^2} & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{-mlb}{I(M+m)+Mml^2} & \frac{mgl(M+m)}{I(M+m)+Mml^2} & 0 \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \varphi \\ \dot{\varphi} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{I+ml^2}{I(M+m)+Mml^2} \\ 0 \\ \frac{ml}{I(M+m)+Mml^2} \end{bmatrix} u \quad (14)$$

3. Simulation analysis

3.1. Simulation of inverted pendulum control system based on PID

The design of the PID controller is originally indeed necessary to accurately analyze the control system [3]. In order to emphasize this advantage of PID control, we use the PID controller to set parameters [4], the Simullink simulation test in Matlab, using the experiment method to detect the correct parameters of the PID controller. The system structure is shown below:

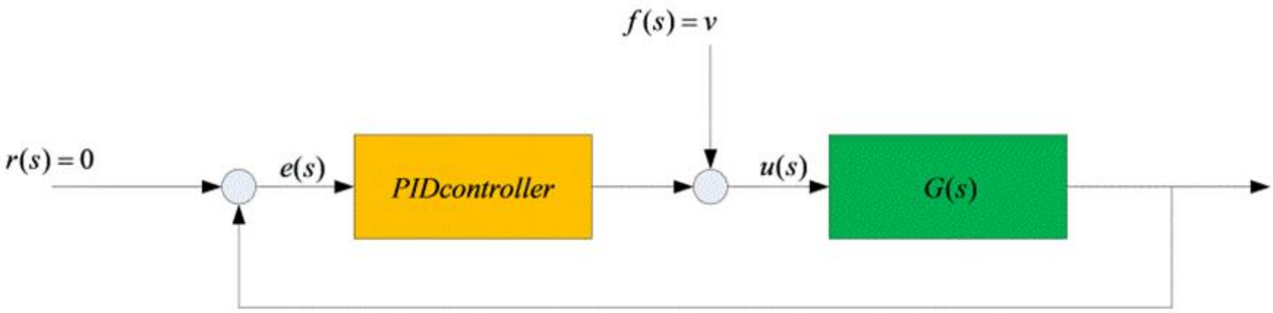

Figure 3. Configuration of PID Control

State-based spatial model for inverted PID controller design

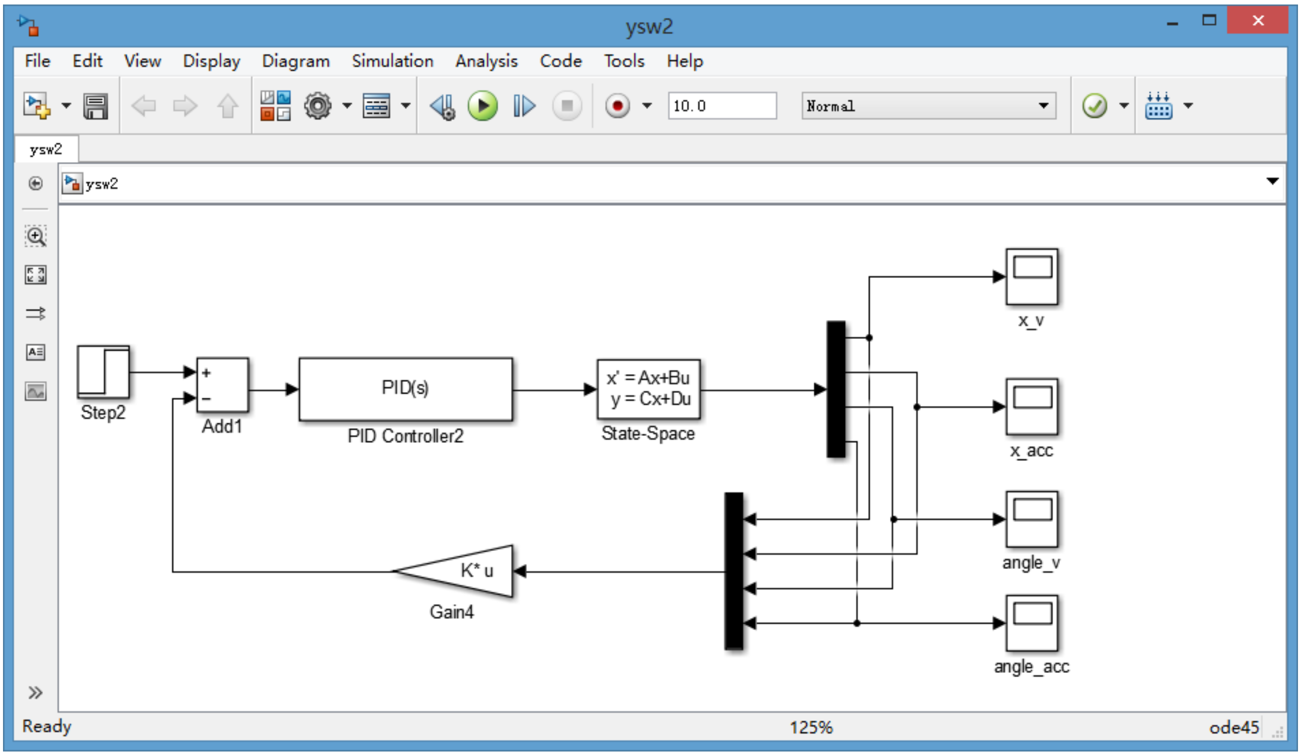

Figure 4. PID inverted pendulum control simulation diagram

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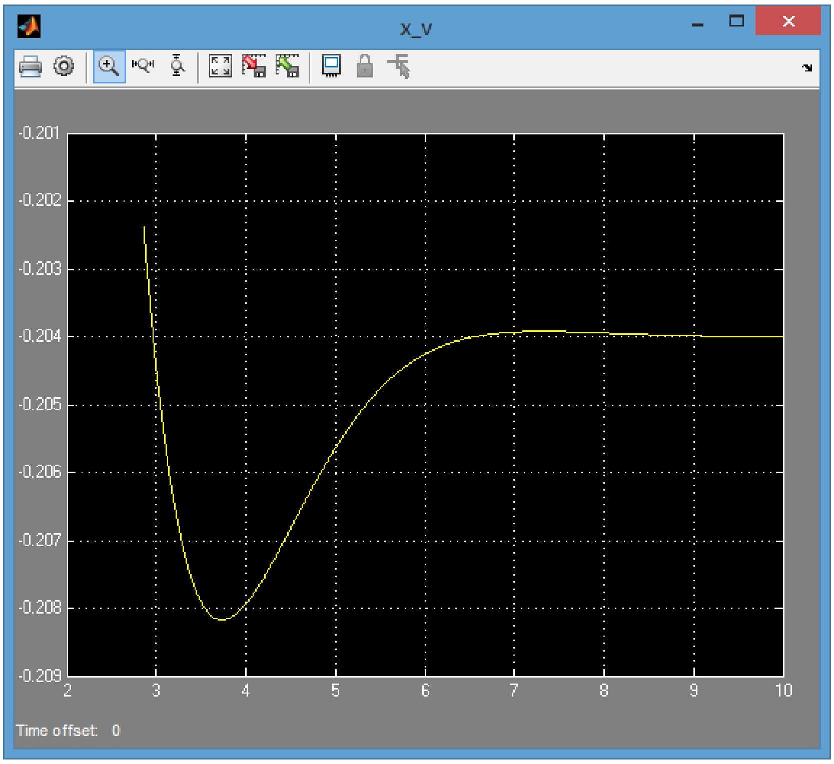

Figure 5. Current chart of inverted trap

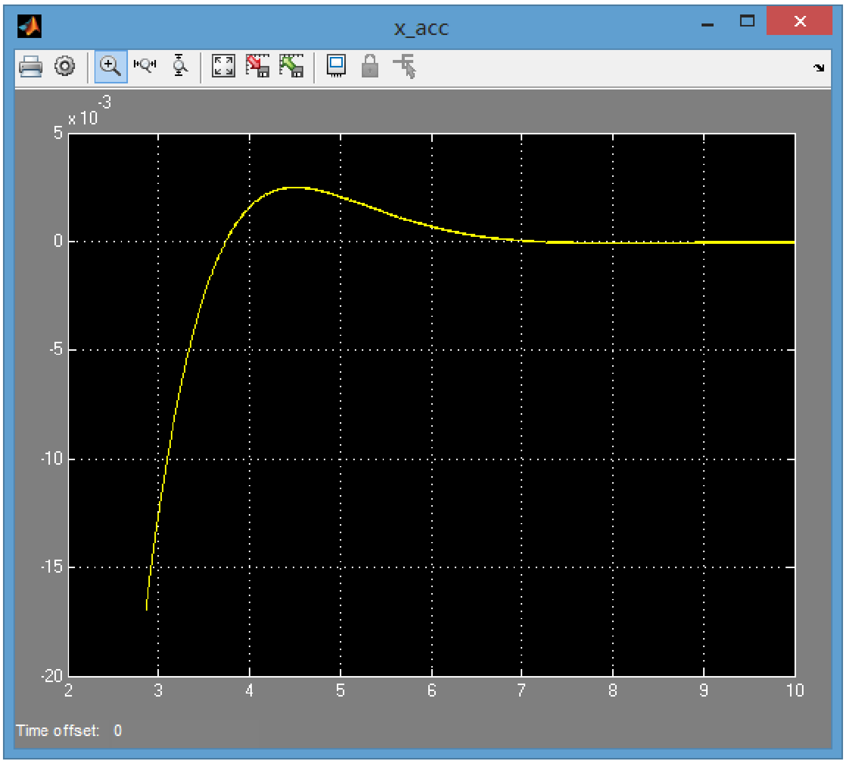

Figure 6. Change graph inverting train speed

3.2. Immulation of inverted pendulum control system based on sliding mode

The carrier mass M is 0.5, the pendulum mass M is 0.5, the length of the swing rod rotation is 0.3, and the gravity acceleration coefficient is 9.8. Take the initial state of the controlled object is $[\pi/3,0,0.5,0]$.

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The parameter $\alpha_a = 1$ is used, then the α_a, λ_a, α_u and λ_u passes through $\begin{cases} \lambda_u = \lambda_a + 6(\alpha_u - 1) \\ \alpha_u = 1 + \frac{g}{11l} \\ \lambda_a = \frac{6l}{g}(\alpha_u - 1) \end{cases}$, the control rate G, the control method, the saturation function method, take the boundary layer thickness H, establish the sliding mode control simulation map of the system.

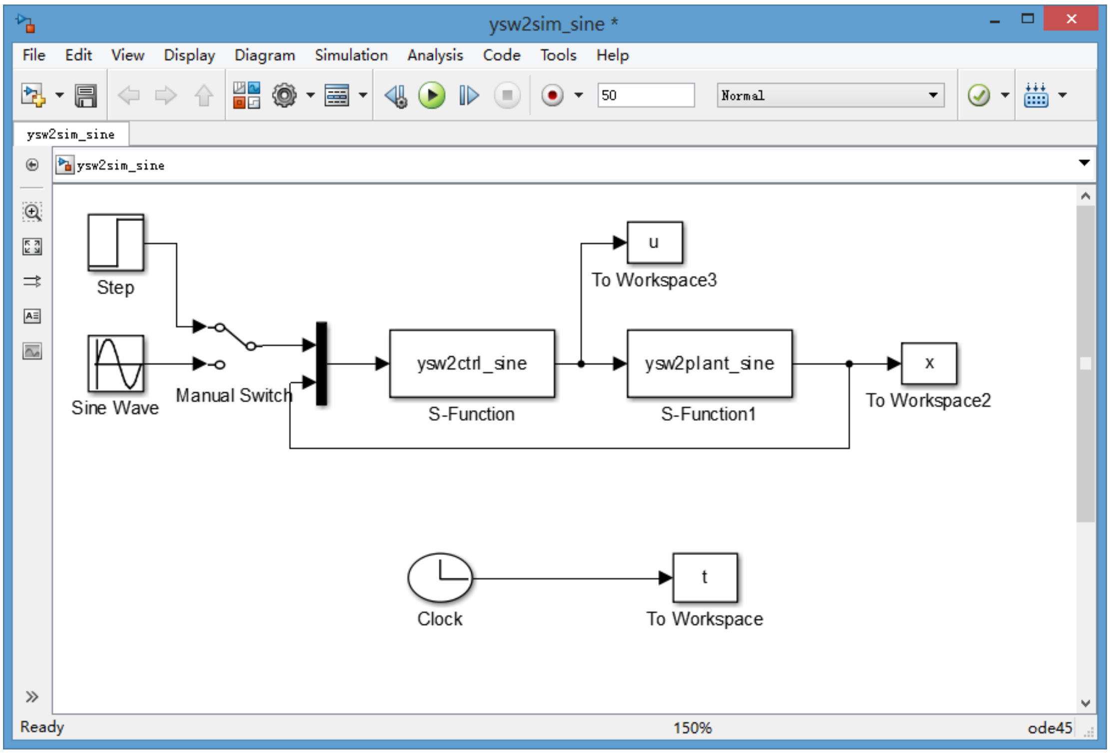

Figure 7. Sliding mode inverted pendulum control simulation diagram

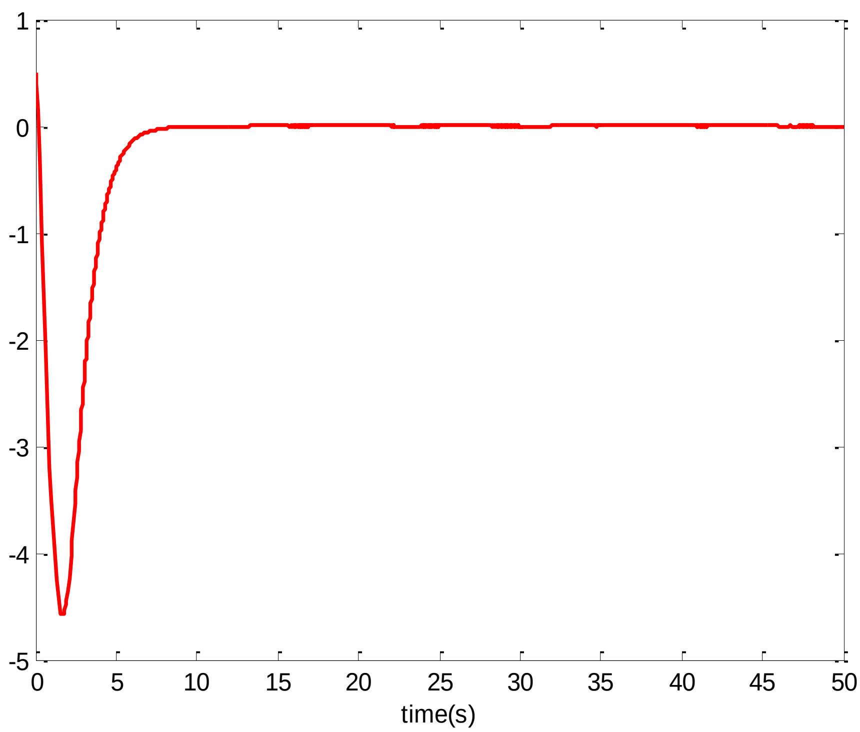

Figure 8. Inverted trap cell displacement chart

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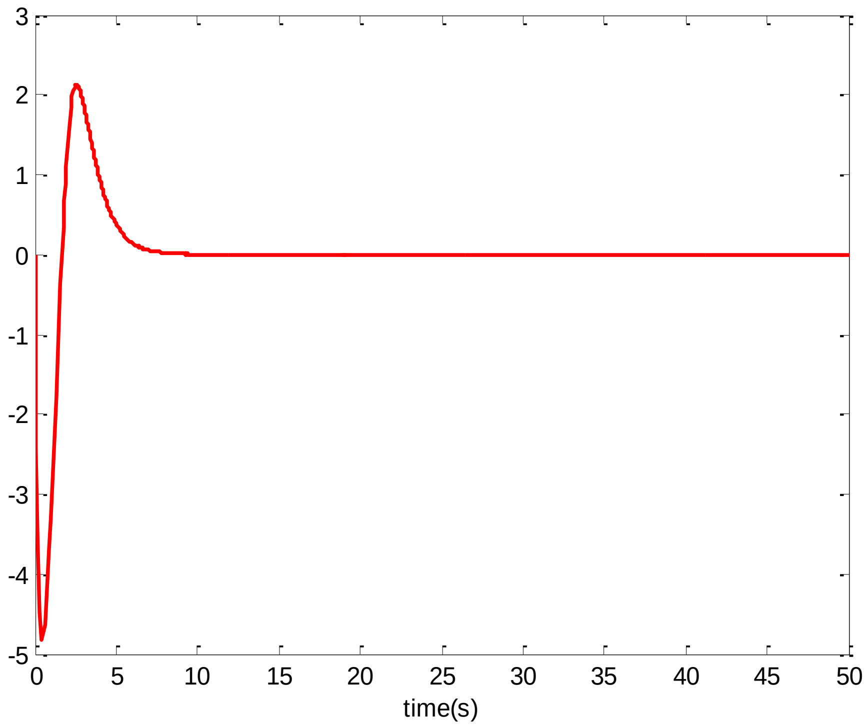

Figure 9. Change graph inverting train speed

As can be seen from the figure, it is possible to control the inverted flame by using a sliding mode. When using a sinusoidal excitation, the system can still be well stabilized, and the system can be controlled, so the inverted pendulum system control of the sliding mode is controlled, and the performance is better.

4. Conclusion

The inverted pendulum system belongs to a variety of variables, fast, nonlinear, and absolute unstable systems. The inverted pendulum system acts as an object, and its control effect can be directly measured by swing angle, displacement, and stable time. VARIABLE-STRUCTURE CONTROL System with Sliding Mode, is referred to as VSS is a special nonlinear system whose nonlinear manifests is discontinuities of control. This chapter has studied the design and simulation study of primary inverted swing structure control system, analyzing the status quo of sliding mode variable structure control, studied the control definition of sliding modes, basic principles, and sliding modes of syndrome, and On this basis, the mathematical model of the inverted pendulum is discussed, providing the theoretical basis for simulation analysis. However, there are many shortcomings in inverted pendulum control, and the sliding mode variable structure control is relatively simple, and there is a strong robustness when uninterrupted and parameter uncertainty. However, the synovial control has a dazzling phenomenon, which not only affects the control accuracy of the system, which increases energy consumption to reduce the service life of the machine, but also possibly stimulating the force of the system without modeling part, which will cause the system to install the system.

References

[1] V.S. Sorokin.Analysis of motion of inverted pendulum with vibrating suspension axis at low-frequency excitation as an illustration of a new approach for solving equations without explicit small parameter[J]. International journal of non-linear mechanics, 2014, 63(1): 1-9.

ISSN: 2710-0588 DOI: 10.29556/FSE.202105_1(2).0007

[2] Hyungjik Lee, Seul Jung. Balancing and navigation control of a mobile inverted pendulum robot using sensor fusion of low cost sensors[J]. Mechatronics: The Science of Intelligent Machines, 2012, 22(1): 95-105.

[3] M. Bettayeb,C. Boussalem,R. Mansouri et al.Stabilization of an inverted pendulum-cart system by fractional PI-state feedback[J]. ISA Transactions, 2014, 53(2): 508-516.

[4] Wang Jun. Research on PID control algorithm based on inverted pendulum [J]. Modern Electronic Technology, 2012, 35 (23): 3-9.