Research on Networked Hydraulic Synchronous Control System

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Abstract. Networked synchronous control systems (NSCS) are developed rapidly. Networked synchronous control system refers to the distributed subsystems whose outputs need to be synchronized are connected through the network to form a distributed control type, and multi-node coordinated synchronization. Subsystems of hydraulic synchronous systems are normally distributed in a wide range of industrial area. The requirement of low-cost synchronous inter-subsystem data collection, communication and system distribution control are achieved by applying internet connection. In order to transmit sensing and control information, each subsystem inevitably generate network delay issues for networking synchronous control system. Therefore, setting up a hydraulic synchronization control system error model with network delay function to solve the network delay problem. Meanwhile, the robust asymptotic synchronization controller is designed by robust control theory, which could adopt a series of relevant simulations and experiments to verify the effectiveness. It has great engineering application value.

Keywords. Hydraulic system; network communication robust control; synchronous controller.

1. Introduction

With the improvement of mechanical system cooperation capability, the increase of load and the rapid development of computer network technology, various types of networks are widely used as communication media in engineering to connect control units with specific functions in the control system into networked control systems (Networked control). Systems: NCS) [1]. Networked synchronous control systems (NSCS) were developed in this context. The so-called networked synchronous control system refers to the distributed subsystems whose outputs need to be synchronized are connected through the network to form a distributed control type, and multi-node coordinated synchronization.

The offshore wind turbine lifting installation process includes hoisting, rough guiding, buffering, synchronous lifting, accurate-positioning automatic centering, flange connection and removal of the lifting system and so on. The synchronous lifting process is used to adjust the posture of the upper hanger and the fan after the buffering process, so as to facilitate the operation of accurate-positioning automatic centering process. Since the upper hanger and the fan have a total weight of several hundred tons, the synchronous lifting process is completed by using a hydraulic synchronous control system [2]. The entire hydraulic synchronous control system consists of four subsystems which are connected via a network. From the view of close-loop control, the sensors, controllers, and actuators in the hydraulic synchronous control system form a close-loop through the control network. These nodes share the network and send them in a time-sharing manner, which unavoidably generates network delays. Since
the forward channel and the feedback channel have pure hysteresis links related to the network delay, it is difficult to analyze and design the synchronous control system [3, 4].

In this paper, the network induced delay of the hydraulic synchronous control system used in offshore wind turbine installation is established. The system error model with time delay is established. The robust asymptotic synchronous controller is designed and verified by simulation and experiment. It has great engineering application value.

2. Offshore Wind Turbine Installation Hydraulic Synchronous Control System

The four subsystems of the Hydraulic Synchronous Control System are mounted on the four seating arms of the lower seating structure (located on the base platform), each subsystem controlling two hydraulic cylinders by one pumping station. During synchronous lifting, the eight hydraulic cylinders simultaneously support the synchronous platform on the upper hanger (the upper hanger is consolidated by the inner flange on the lower ring beam and the outer flange of the fan), and the synchronous platform is raised or lowered simultaneously to adjust the attitude of the upper hanger and the fan. Each pump station of the Hydraulic Synchronous Control System has a local controller (with CAN network interface). In order to realize the data acquisition, communication and system distributed control between subsystems, this project uses CAN bus to connect four subsystems. The network connection is shown in figure 1. Since the inconvenience of using wired connection, ZigBee wireless network communication is used to connect the upper computer (on the operating ship) and the main controller (on the base platform). The upper computer is only used to send the operation command and the operation of the monitoring system. The structure of the hydraulic synchronization control system is shown in figure 2. The main controller is used to receive the sensing information of each subsystem and calculate the control amount according to the set algorithm. The local controller is responsible for sampling the sensor signals of the subsystem, receiving the control volume sent by the main controller and controlling the pump station.

![Figure 1. Figure connection diagram.](image1)

![Figure 2. Structure of hydraulic synchronous control system.](image2)
3. Hydraulic Synchronous Control System Modeling

A hydraulic cylinder is used as the master cylinder, and the other hydraulic cylinders (slave cylinders) track the output of the master cylinder for synchronization purposes. As long as each slave cylinder can accurately track the master cylinder, the synchronization performance of the whole system can be guaranteed. Therefore, the synchronous control problem of multiple subsystems can come down to a single synchronization between the slave cylinder and the master cylinder. Its equivalent control structure is shown in figure 3.

![Figure 3. Structure of the master-slave hydraulic synchronization system.](image)

The hydraulic system principle of the subsystem is shown in figure 4. The two parallel hydraulic cylinders use variable frequency speed regulation. When the displacement between the two parallel hydraulic cylinders is not synchronized, the stop valve 21 is used for adjustment. A non-contact displacement sensor 19 is mounted in the hydraulic cylinder, and a hydraulic pressure sensor 18 is mounted on the large cavity of the cylinder. To visually verify the effectiveness of the prediction algorithm, each synchronization subsystem is modeled as a pump station and a hydraulic cylinder.

![Figure 4. Schematic diagram of the hydraulic synchronization system.](image)

1 oil ball valve, 2 fuel tank, 3 oil/filter, 4 liquid level liquid temperature meter, 5 oil filter, 6 frequency converter, 7 motor, 8 pump, 9 high pressure oil filter, 10 check valve, 11 overflow valve, 12 three-position four-way solenoid valve, 13 pressure measuring hose, 14 pressure measuring joint, 15 pressure gauge, 16 hose, 17 balance valve, 18 oil pressure sensor, 19 displacement sensor, 20 hydraulic cylinder, 21 stop valve.
The following minor problems are neglected when establishing the mathematical model: pressure loss of check valves, oil filters, pipes, etc.; leakage of various hydraulic components except hydraulic cylinders; nonlinear friction and temperature characteristics of hydraulic systems; flow pulsation of pumps. Modeling the ascending process of the hydraulic cylinder, the established motor torque balance equation, flow equation, hydraulic cylinder force balance equation and displacement equation are as follows:

\[
\begin{align*}
2\pi f_0 \frac{dn_p}{dt} &= \frac{m_p p}{2\pi r_2} K_f f - \frac{m_p p^2}{120\pi r_2} K_f^2 n_p - \frac{D_p}{2\pi \eta_m} - \frac{2\pi}{60} \eta_p n_p \\
\frac{dp_p}{dt} &= \frac{E}{V_0} \frac{D_p n_p}{60} - C_p p_p - A_p v - C_m p_p \\
m \frac{dv}{dt} &= A_p p_p - B_p v - F_i \\
\frac{ds}{dt} &= v
\end{align*}
\]

(1)

In the formula, \(n_p\) is the motor speed, \(r / \text{min} \); \(J_f\) is the moment of inertia converted to the motor shaft, \(J_f = 0.045 \text{ Kg m}^2\); \(p\) is the number of poles of the motor, \(p = 2\); \(m\) is the number of stator phases of the motor, \(m_1 = 3\); \(r_2\) is the rotor resistance after conversion, \(r_2 = 2.59 \Omega\); \(K_f\) is the frequency conversion coefficient. The rated voltage of the selected motor is 380V and the fundamental frequency is 50Hz. Therefore, \(K_f = 7.6V/(Hz)^{-1}\); \(f\) is the output frequency of the inverter, \(Hz\); \(B_p\) is the damping coefficient of the motor shaft, \(B_p = 0.01 \text{ Nm} / \text{rad}\); \(n_p\) is the actual speed of the asynchronous motor, \(r / \text{min}\); \(P_m\) is the pump outlet pressure, \(Pa\); \(D_p\) is the pump displacement, \(D_p = 10 \text{ml} / r\); \(\eta_m\) is the mechanical transmission efficiency, \(m B\); \(C_n\) is the pump leakage coefficient, can be determined by the pump’s volumetric efficiency, \(C_v = 7 \times 10^{-12} \text{m}^3 / \text{s} \cdot \text{Pa}\); \(V_0\) is the high pressure chamber initial volume, here \(V_0 = 8 \times 10^{-3} \text{m}^3\); \(A_1\) is the large cavity area of the piston, here \(A_1 = 0.038 \text{m}^2\); \(v\) is the hydraulic cylinder movement speed, \(m / s\); \(E\) is the oil and pipe bulk elastic modulus, \(E = 0.9 \times 10^9 \text{Pa}\) is taken here; \(C_m\) is the hydraulic cylinder leakage coefficient, \(C_m = 9 \times 10^{-12} \text{m}^3 / \text{s} \cdot \text{Pa}\) is taken here; \(P_i\) is the cylinder return cavity pressure, \(P_i = 0 \text{MPa}\); \(A_2\) is the small cavity area of the piston, here \(A_2 = 0.024 \text{m}^2\); \(B_u\) is the viscous damping coefficient on the hydraulic cylinder, \(B_u = 1000 \text{N} \cdot \text{S} / \text{m}\) is taken here; \(F_i\) is the load resistance, here the experiment is empty Load; \(m\) is the total mass of the load and the piston rod, \(m = 450 \text{kg}\); \(s\) is the displacement of the hydraulic cylinder, \(m\).

Let \(x = [n_p, p_p, v, s]^T\), \(u = f\), respectively represent the state and input of the system, take \(s\) as the output of the system, and obtain the model described by the following equation of state from equation (1).

\[
\begin{align*}
\dot{x} &= Ax + Bu + HF_L \\
y &= Cx
\end{align*}
\]

(2)

In order to facilitate digital simulation and single-chip computing, the units of \(n_p, p_p, v, s\) and \(f\) are set to \(100 \text{r} / \text{min}\), \(10^4 \text{Pa}\), \(\text{mm} / \text{s}\), \(\text{mm}\) and \(\text{Hz}\) respectively, then the parameters of equation (2) can be expressed as follows:

\[
A = \begin{bmatrix}
-151 & -0.36 & 0 & 0 \\
18.75 & -1.8 & -42.75 & 0 \\
0 & 8444.4 & -2.22 & 0 \\
0 & 0 & 1 & 0
\end{bmatrix}, \quad B = \begin{bmatrix}
45.24 \\
0 \\
0 \\
0
\end{bmatrix}, \quad H = \begin{bmatrix}
0 & -2.22 & 0 \\
0 & 0 & 0 \\
0 & 0 & 1
\end{bmatrix}, \quad C = \begin{bmatrix}
0^T \\
0 \\
0 \\
1
\end{bmatrix}
\]

(3)
Make $x_1(t) \in \mathbb{R}^n$, $u_1(t) \in \mathbb{R}^n$, and $y_1(t) \in \mathbb{R}^n$ as the state vector, control vector, and output vector respectively for the main system. $x_2(t) \in \mathbb{R}^n$, $u_2(t) \in \mathbb{R}^n$, and $y_2(t) \in \mathbb{R}^n$ of the slave system’s. Among them, $u_1(t) = r(t)$ and $r(t) \in \mathbb{R}^n$ are the reference input of the main system, $u_2(t) = r(t) - u(t)$ and $u(t) \in \mathbb{R}^n$ are the output vector of the controller. Further define synchronization error $e(t)$ and error status $x(t)$.

$$
\begin{align*}
  e(t) &= y_1(t) - y_2(t) \\
  x(t) &= x_1(t) - x_2(t)
\end{align*}
$$

(4)

The following can be obtained as follows: the master-slave system error model without considering the influence of network communication.

$$
\begin{align*}
  \dot{x}(t) &= Ax(t) - Bu(t) \\
  e(t) &= Cx(t)
\end{align*}
$$

(5)

4. Robust Asymptotic Synchronous Controller Design

The master-slave NSCS controller is designed to track the output of the primary system asymptotically from the output of the system in the presence of network latency. Regardless of the packet loss that occurs during network transmission, the master-slave NSCS can be simplified to the structure diagram shown in figure 5. The control object in the figure is the synchronous control system error model, $e/x$ is the sensor output, $\tau_{ca}$ is the controller-to-actuator delay, $\tau_{sc}$ is the sensor-to-controller delay.

![Figure 5. Master-slave NSCS control structure diagram.](image)

The master-slave NSCS error model added to the influence of network communication can be expressed by the following formula:

$$
\begin{align*}
  \dot{x}(t) &= Ax(t) - Bu(t - \tau_{ca}(t)) \\
  e(t) &= Cx(t)
\end{align*}
$$

(6)

In the equation, $x(t) \in \mathbb{R}^n$ is the error state vector of the master-slave system, and $u \in \mathbb{R}^n$ and $e \in \mathbb{R}^n$ are the control vector and the error vector respectively; A, B, and C are the suitable dimension coefficients matrix, $\tau_{ca}(t)$ is the controller-to-actuator delay, which is a continuous function of time. Assuming that the master-slave system state can be measured, its error state vectors can be obtained. Due to the sensor-to-controller delay, the state feedback synchronous controller can be expressed as

$$
  u(t) = Kx(t - \tau_{sc}(t))
$$

(7)

Substituting equation (7) into equation (6) can obtain the NSCS error model using state feedback.

$$
\begin{align*}
  \dot{x}(t) &= Ax(t) + A_x x(t) - \tau_{ca}(t) - \tau_{ca}(t) \\
  e(t) &= Cx(t)
\end{align*}
$$

(8)

In the formula, $A_x = -BK$.

Considering that under the action of the controller, if the system error state $x(t)$ shown in equation (8) is asymptotically zero, the output error of the primary system and the secondary system can also be
asymptotically zero, so the synchronous control problem can be simplified into close-loop control. The asymptotic stability of the system (8) solves the problem.

Definition 4.1: For uncertain delays \( \tau_c(t) + \tau_a(t) \), if there is a gain matrix \( K \) such that the state feedback system (8) is asymptotically stable, then NSCS (6) is asymptotically synchronized. In order to obtain a robust asymptotic synchronization controller, the following time-vary and time-delay liner systems are considered.

\[
\begin{align*}
\dot{x}(t) &= Ax(t) + A_\tau x(t - \tau(t)), \quad t > 0 \\
x(t) &= \phi(t), \quad t \in [-\tau(t), 0]
\end{align*}
\]

where, \( x(t) \in R^n \) is the state vector, \( A \) and \( B \) are suitable dimension constant coefficient matrix, the time-delay \( \tau(t) \) is a continuous function with respect to time \( t \); the vector value initial function \( \phi(t) \in C([-\tau(t), 0], R^n) \), which represents the space formed by the continuous function that maps the interval \([-\tau(t), 0]\) to \( R^n \).

Assume that the time-delay has the following conditions.

\[
0 \leq \tau(t) \leq h
\]

Lemma 1 [5]: If there is a suitable dimension matrix

\[
P = P^T > 0, \quad Q = Q^T \geq 0, \quad Z = Z^T > 0 \quad \text{and} \quad \begin{bmatrix} X_{11} & X_{12} \\ * & X_{22} \end{bmatrix} \geq 0, \text{any suitable dimension of the matrix N1 and N2,}
\]

the following LMI is established.

\[
\begin{bmatrix}
\Phi_{11} & \Phi_{12} & hA^T Z \\
* & \Phi_{22} & hA_\tau^T Z \\
* & * & -hZ
\end{bmatrix} < 0
\]

(12)

In the formula,

\[
\Phi_{11} = PA + A^TP + N_1 + N_2^T + Q + hX_{11}, \quad \Phi_{22} = -N_1 - N_2^T - (1 - \mu)Q + hX_{22}, \quad \Phi_{12} = PA_\tau - N_1 + N_2^T + hX_{12}.
\]

Then the system (9) is asymptotically stable for the time-delay \( \tau(t) \) satisfying the restrictions (10) and (11).

The following Theorem 1 uses Lemma 1 to give a synchronous controller design method in which NSCS (6) depends on the time-delay variation and the time-delay derivative variation. Theorem 1 also implies a synchronous controller design method that only depends on the time-delay variation. Assuming delay \( \tau_a(t) \) and \( \tau_c(t) \) have the following conditions:

\[
0 \leq \tau_a(t) + \tau_c(t) \leq h
\]

(14)

\[
\dot{\tau}_a(t) + \dot{\tau}_c(t) \leq \mu
\]

(15)

Theorem 1: Consider NSCS (5), if there is a suitable dimension matrix

\[
P = P^T > 0, \quad Z = Z^T > 0, \quad Q = Q^T > 0 \quad \text{and} \quad \begin{bmatrix} Y_{11} & Y_{12} \\ * & Y_{22} \end{bmatrix} \geq 0, \text{any suitable dimension matrix G, M1 and M2, let}
\]

equations (16) and (17) be established.

\[
\begin{bmatrix}
\Phi_{11} & \Phi_{12} & hP^T \alpha \alpha^T \\
* & \Phi_{22} & -hG^T B^T \\
* & * & -hZ
\end{bmatrix} < 0
\]

(16)
In the formula, 
\[ \Phi_{i1} = AP + \tilde{P}A^T + M_i + M_i^T + \tilde{Q} + hY_{i1}, \quad \Phi_{i2} = -M_2 - M_2^T - (1 - \mu)\tilde{Q} + hY_{i2}, \quad \Phi_{i3} = -BG - M_1 + M_1^T + hY_{i3}. \]

Then there is a state feedback synchronous controller (7) whose delay \( \tau_{\omega}(t) + \tau_{\alpha}(t) \) satisfying the restrictions (14) and (15), the NSCS (6) is asymptotically synchronized, and the state feedback gain matrix can be expressed as follows:

\[ K = G\tilde{P}^{-1} \quad (18) \]

Proof: Substituting \( A_j = -BK \) into equation (12), then multiplying both sides \( \text{diag}(P^1, P^2, Z^1) \) to obtain:

\[ \begin{bmatrix} \Phi_{i1} & hP^1A^T \\ -hP^1B^T & -hZ^1 \end{bmatrix} < 0 \quad (19) \]

In the formula,
\[ \Phi_{i1} = AP^2 + P^1A^T + P^1N_iP^1 + P^1N_i^TP^1 + P^1QP^1 + hP^1X_{i1}P^1 \]
\[ \Phi_{i2} = -BK^TP^2 - P^1N_iP^1 + P^1N_i^TP^1 + hP^1X_{i2}P^1 \]
\[ \Phi_{i3} = -P^1N_iP^1 - P^1N_i^TP^1 - (1 - \mu)P^1QP^1 + hP^1X_{i3}P^1 \]

Multiplying the formula (13) both sides \( \text{diag}(P^1, P^1, P^1) \) to obtain:

\[ \begin{bmatrix} P^1X_{i1}P^1 & P^1X_{i2}P^1 & P^1N_iP^1 \\ * & P^1X_{i2}P^1 & P^1N_iP^1 \\ * & * & P^1ZP^2 \end{bmatrix} \geq 0 \quad (20) \]

Making \( M_i = \tilde{P}N_i\tilde{P}, \quad M_1 = \tilde{P}N_i\tilde{P}, \quad \tilde{Q} = \tilde{Q}\tilde{P}, \quad Y_{i1} = P^1X_{i1}P^1, \quad Y_{i2} = P^1X_{i2}P^1, \quad Y_{i3} = P^1X_{i3}P^1, \quad Z = Z^1, \quad \tilde{P} = P^1, \quad G = k\tilde{P} \) and substituting into equations (19) and (20), equations (16) and (17) are obtained.

In Theorem 1, if \( \tilde{Q} = 0 \), an asymptotic synchronization condition can obtained that depends only on the time-delay variation and not on the time-delay derivative variation. that is, The delay that NSCS (6) uses the state feedback matrix (18) to satisfy the restriction condition (14) \( \tau_{\omega}(t) + \tau_{\alpha}(t) \) is asymptotically synchronized. It should be pointed out that equation (17) in Theorem 1 is not LMI. For this non-convex feasibility problem, it is difficult to find the global maximum delay \( h \) that can make the NSCS (6) asymptotically synchronized. Obviously \( Z = \tilde{P}^2 \) can be chosen, equation (17) will become LMI and it is convenient to solve a suboptimal maximum delay \( h \) with the minimization problem solver MINCX in the MATLAB LMI toolbox. However, this is not the best way. We can use the method of paper [6] about introducing new variables, \( J = \tilde{P}Z^1\tilde{P}, \quad J = J^1, \quad \tilde{P} = \tilde{P}^1 \) and \( Z = Z^1 \), then replace the non-convex feasibility problem of Theorem 1 with the following LMI-based nonlinear minimization problem by using the cone complement method.

\[ \text{Min} \quad \text{Tr}(JJ + \tilde{P}\tilde{P} + ZZ) \]
\[ \text{S.t} \quad (16) \] and

\[ \begin{bmatrix} \tilde{P} & \tilde{P} & \tilde{P} \\ \tilde{P} & J & I \\ \tilde{P} & I & \tilde{Z} \end{bmatrix} \geq 0, \quad \begin{bmatrix} Y_{i1} & Y_{i2} & M_i \\ * & Y_{i2} & M_i \\ * & * & J \end{bmatrix} \geq 0 \quad (21) \]
If the solution to minimize the problem is 3n, then NSCS (6) is robustly asymptotically synchronized by the controller \( u(t) = G\tilde{P}x(t) \). Although this LMI-based nonlinear minimization problem is difficult to solve the global maximum delay \( h \), it is easier to solve than the non-convex feasibility problem of Theorem 1. Moreover, the following iterative method can be used to easily solve a suboptimal maximum delay \( h \).

Iterative algorithm:
(1) Set \( h \) to a sufficiently small initial value \( h_0 \) so that equations (16) and (21) hold;
(2) Find a set of solutions \( \{\tilde{P},\tilde{Q},Y_1^{0},Y_2^{0},Y_2^{0},M_1^{0},M_2^{0},G_1^{0},P_1^{0},Z_1^{0},J_1^{0}\} \) so that equations (16) and (21) are true and set \( k = 0 \);
(3) Solve the problem of minimizing matrix
\[
J^*J_1 + J_2^*J_2 + \tilde{P}^*\tilde{P} + \tilde{P}_1^*\tilde{P}_1 + \tilde{Z}_1^*\tilde{Z}_1 + \tilde{Z}_2^*\tilde{Z}_2 \quad \text{Min}, \quad \text{s.t (16) and (21)};
\]
(4) Substitute the result of the previous step into equation (17). If inequality (17) is established, increase \( h_k \) appropriately and return to the second step. If inequality (17) is not true and the number of iterations \( k \) exceeds the specified number of times, the program is terminated, otherwise, \( k = k + 1 \), back to the third step. Since it is difficult to obtain an optimal solution that \( \text{Tr}(J_1 + \tilde{P}_1^*\tilde{P}_1 + \tilde{Z}_1^*\tilde{Z}_1) \) is exactly equal to \( 3n \), the iterative algorithm uses equation (17) as the condition for iterative suspension, and only obtains a suboptimal maximum delay \( h \). When the maximum delay \( h \) of the NSCS is known, the above iterative method is slightly modified, and can also be used to obtain a state feedback controller that can make the NSCS asymptotically synchronized.

5. Hydraulic Synchronous Control System Modeling

The Hydraulic Pressure Synchronization Control System uses CAN bus to connect each function node in the system, and the baud rate of CAN bus data transmission is set to 200 kbps. The sensor information required for the synchronous control between the single slave cylinder and the master cylinder is two data packets. The control information has only one data packet, and each data packet is 8 bytes. These data are transmitted through the CAN bus. Tested by the CAN bus experimental platform [7], the average total network delay of the forward channel and the feedback channel of the NSCS is 1.8 ms, and packet loss does not occur during the process of the entire data transmission. When the state feedback controller is used, the control variable calculation time can be ignored, so the total network delay of the entire control closed loop is less than 0.05 s.

For equation (4), regardless of the influence of parameter uncertainty, external disturbance and delay derivative, using Theorem 1 and iterative algorithm, a robust controller capable of asymptotic synchronization which can enable the hydraulic synchronous control system to asymptotically synchronize with a random network delay of less than 0.05 s can be obtained, and with a gain of \( K = [0.0058 \quad 0.047 \quad -0.00015 \quad 2] \). The sensor node and the actuator node in the networked hydraulic synchronous control system are set to time drive [8], the controller node is set to event-driven, the sampling period is set to 0.05s, and the controller adopts the above robust control law, the initial error state is set to [0 0 0 0 20], the displacement synchronization error simulation curve is shown in Figure 6. The result shows that the displacement of the master cylinder and the slave cylinder can be asymptotically synchronized. Experiment with the master cylinder and a slave cylinder, the reference frequency of the main system is set to 35 Hz, the initial displacement of the master cylinder is set to 8mm, the initial displacement of the cylinder is set to 28 mm, and the measured displacement synchronization error curve and the displacement curve are shown in Figures 7 and 8, respectively. The results show that in the case where the above-described robust control law is employed, the displacement synchronization error between the master cylinder and the slave cylinder is in the interval \([-\text{Inm}, \text{Inm}]\).
6. Conclusion
Offshore wind turbine installation The various subsystems of the soft landing hydraulic synchronous control system are connected via a CAN network and are a typical NSCS. Firstly, the mathematical model of the system is constructed. The modeling method used has certain universal significance for the hydraulic synchronous control system. Then based on the established data model and the time delay measured by the CAN experimental platform, the robust control law is solved. The effectiveness of the control law is proved by simulation and experiment.

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