Fuzzy Control System for Load Stability of Intelligent Combine Harvester

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Abstract: When combine harvester is used in the field, the load is difficult to be stabilized due to the complex environment. Based on the analysis of the cylinder power model, this article identifies the factors that affect load stability. We calculated and studied the fuzzy control of the cylinder load. Cylinder two-dimensional fuzzy controller is established through the Matlab, and the cylinder fuzzy control model is set and simulated through the Simulink, which results prove that the fuzzy control of harvester load stability is accurate and effective.

1. Introduction

Because of the grain planting density, plant growth and different water content, walking speed of harvester in constant operation, will cause the cylinder load cannot be stable in the rated range, resulting in work load and under load and overload. Harvester operation process is complex, the main components of the operating parameters, and working environment, plant growth are always changing, so it is difficult to establish mathematical model of the working process, the traditional control theory is applied in this regard will be very difficult to. Fuzzy control without accurate mathematical model of the controlled object, as long as the operation experience and control traditional data to summarize, draw systematic control rules and reasoning rules, which can effectively control the object. Therefore, the fuzzy control can guarantee the load stability of the harvester. It is of great significance to ensure the reliability of the harvester and give full play to the operation efficiency of the harvester.

2 Cylinder fuzzy control

2.1 cylinder power model

The working condition of the cylinder is closely related to its power consumption. The longitudinal flow roller is taken as the object of study and the power model is as follows:

\[ J \omega \frac{d\omega}{dt} = P - (A\omega + B\omega^3) - \frac{Qr^2 \omega^5}{2(1-\alpha f)} \gamma + \lambda \]

(1)
\[ Q = H \rho_\omega \nu_x \]  

(2)

In formula:

\( J, \ \omega \) —rotary inertia and angular velocity of cylinder

\[ \frac{d \omega}{dt} \] —radius and angular acceleration of cylinder

\( P \) —input power

\( A, \ B \) —constant, which reflects the resistance when the roller is idling

\( \gamma \) —straw ratio of grain

\( \lambda \) —outlet velocity ratio of grain

\( Q \) —feed rate of cylinder

\( H \) —cutting table’s width of harvester

\( \rho_\omega \) —planting density of grain

\( \nu_x \) —operation speed of harvester

\( f \) —coefficient of rubbing between threshing elements and standard moisture content

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\( \alpha \) —grain moisture content coefficient, that is, the ratio of current moisture content to standard grain moisture content

Therefore, \( \alpha f \) indicates the coefficient of rubbing between a threshing element and an arbitrary moisture content grain.

The utility model (1) reflects the power consumption of the longitudinal flow cylinder, and the 3 items on the right indicate the input power of the cylinder, mechanical friction and air resistance at idle, and threshing resistance at work. The input power of the cylinder is equal to the total working resistance, the cylinder is in a uniform rotating state, and the harvester is stable when \( \frac{d \omega}{dt} = 0 \). The total working resistance of the cylinder is less than its input power, the cylinder is in the state of accelerated rotation, and the harvester does not exert the best operation performance when \( \frac{d \omega}{dt} > 0 \).

Mean grain planting density increases due to instantaneous feed rate suddenly increased, leading to the cylinder input power is less than the total resistance, roller speed has been decreased, if not promptly take measures to adjust the clogging fault when \( \frac{d \omega}{dt} < 0 \).

In the formula (1), only \( \nu_x, \ \omega, \ \rho_\omega \) and \( \alpha \) is the real time variation, grain planting density changes that directly affect the feeding amount, grain moisture coefficient of cylinder threshing components and grain between the rubbing coefficient, when the water content increases should
reduce the amount of feed, reducing hours may be appropriate to increase feed quantity. Therefore, according to the actual operation, adjusting the operation speed of the harvester and maintaining the stability of the angular speed of the cylinder can effectively adjust the performance of the cylinder. If the grain planting density or water content caused by abrupt change of roller speed changes rapidly adjust the harvester forward speed of the roller speed is always stable in a preset range, in order to prevent the best operation harvest machine performance under the premise of fault block.

2.2 fuzzification of input and output parameters
In the fuzzy control process, \( \omega_b \) represents the pre-set value of the cylinder angular velocity, that is, the rated value, \( \omega(t) \) represents the real-time speed of the cylinder measured by the Holzer speed sensor, then the deviation is \( e(t) \) and the deviation change rate is \( ec(t) \):

\[ e(t) = \omega_b - \omega(t), \quad ec(t) = e(t) - e(t-1) \]

The linguistic variable of deviation \( E \) is \( A_i \), the fuzzy subset is \( A_i (i=1,\ldots,7) \), and the domain is \( X \), divided into 13 grades, that is \( X = \{-6, -5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5, +6\} \), and the linguistic value of fuzzy subset \( A_i \) is \( \{NB, NM, NS, Z, PS, PM, PB\} \).

The linguistic variable with a deviation rate of \( EC \) is \( EC \), the fuzzy subset is \( B_j \), and the domain is \( Y \), divided into 13 grades, that is \( Y = \{-6, -5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5, +6\} \), and the linguistic value of fuzzy subset \( B_j \) is \( \{NB, NM, NS, Z, PS, PM, PB\} \).

The language variable of the output control quantity \( U \) is \( U \), the fuzzy subset is \( C_k \), and the domain is \( Z \), divided into 13 grades, that is \( Z = \{-6, -5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5, +6\} \), and the linguistic value of fuzzy subset \( C_k \) is \( \{NB, NM, NS, Z, PS, PM, PB\} \).

3 system simulation

3.1 design of cylinder fuzzy controller
A Mamdani type two-dimensional fuzzy controller is established with the angular speed deviation of the cylinder \( E \) and the deviation change rate \( EC \) as the input quantity and the change of the operation speed of the harvester \( U \) as the output quantity, as shown in figure 1.

Take the domain cylinder angular speed deviation \( E \) and deviation change rate of the operating speed of harvester \( EC \) and changes in the amount of \( U \) is \([-6, +6]\), fuzzy subset is \( \{NB, NM, NS, Z, PS, PM, PB\} \), and the selected triangle membership function and membership function \( E, EC \) and \( U \) are shown in Figure 2, 3, 4 shows.
In the If sentence, according to the fuzzy control rule table 4, 49 fuzzy inference rules are formulated, and the control rules in the fuzzy rule table are input according to the order from top to bottom, from left to right, as shown in Figure 5.

The spatial display surface of the fuzzy inference rule, as shown in Figure 6, can intuitively represent the correspondence between the input and output quantities.

3.2 establishment of fuzzy control model for cylinder

On the basis of formula 1, the model of cylinder power consumption subsystem is established by using Matlab software Simulink library, as shown in figure 7. Packaged and encapsulated by the creation subsystem functionality provided by Matlab, as shown in figure 8.
In this paper, we have established a cylinder fuzzy control model by using the two-dimensional fuzzy controller and the cylinder power consumption system model and its packaging model, as shown in Figure 9.

3.3 simulation results are presented and analyzed

We input the simulation parameters in the drum power subsystem model. By simulating the step signal, the corn plant density increases and the feed harvester’s operating state suddenly increases. The coefficient of friction moment increases simulation harvester status increases suddenly when the grain moisture content through the step signal, thus the fuzzy simulation control the model of the cylinder,[5] through two oscilloscope simulation results are shown in Figure 10 and 11 show.

(1) the amount of feed increases

The initial speed of 1.5m/s harvester in operation, the rotational speed of the roller is stable in 78.5rad/s, in 0.2S time by step signal increasing 30% feed processing capacity of simulated cylinder, the simulation results obtained velocity and angular velocity of the roller harvester, respectively, as shown in Figure 10 (a) and (b) shown in.

(a) operation speed of harvester    (b) angular speed of cylinder

The simulation results show that the initial angular velocity of rotation of the cylinder to 78.5rad/s, when the analog processing feed quantity increases immediately after the 30%, roller speed transient decline in fuzzy controller and 0.4s ~ 0.5s after adjustment, the operation speed of harvester dropped to close to 1m/s, cylinder returned to the initial angular velocity, the maximum deviation is 18rad/s and the steady-state error is 2rad/s, the relative deviation is 1.15%. It shows that the fuzzy controller has obvious effect on roller load control, and can effectively prevent the cylinder from clogging when the feed quantity suddenly increases.

(2) the moisture content of grain increases
The initial speed of 1.5m/s harvester work roller with 78.5rad/s initial angular velocity of rotation in 0.2S time by step simulation of signal processing of the grain moisture content were increased 20%, the simulation results get velocity and angular velocity of the roller harvester, respectively, as shown in Figure 11 (a) and (b).

![Operation speed of harvester and angular speed of cylinder](image)

(a) operation speed of harvester (b) angular speed of cylinder

Fig.11 simulation results of fuzzy control of cylinder (increasing moisture content of grain)

The simulation results show that the initial angular velocity of rotation of the cylinder to 78.5rad/s, when the water content of grain processing simulation instantly increased by 20% after the roller speed transient decline in fuzzy controller and 0.5s ~ 0.6s after adjustment, the operation speed of harvester dropped to close to 0.7m/s, cylinder returned to the initial angular velocity, maximum deviation 26rad/s, the steady-state error is 2.4rad/s, the relative deviation is 1.66%. It shows that the designed fuzzy controller has obvious effect on roller load control, and can effectively prevent the cylinder clogging when the moisture content of grain increases suddenly.

4. Conclusion
The paper studies the cylinder power model and determines the factors affecting the load stability. Based on the cylinder load and fuzzy control, the paper analyzes the input and output parameters of the fuzzy processing and determines the membership function allocation table, establish the fuzzy inference rules and fuzzy control query table. The two-dimensional fuzzy controller of cylinder is established by Matlab. The fuzzy control model of roller is modeled and simulated by Simulink. The result proves that fuzzy control is accurate and effective to control the load stability of harvester.

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