Design and Application of Anti-interference Control System for the Concentration of Tobacco Paper Reinforcing Agent

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Abstract. Aimed at the improvement of the preparation accuracy of the tobacco paper reinforcing agent, the concentration control of the tobacco paper reinforcing agent was considered. The concentration of reinforcing agents is affected by many factors, such as influent flow, powder feeding speed, external interference, and so on. The compounding process has typical nonlinear, multivariable, strong coupling characteristics, and the traditional control method has a poor effect. In order to improve the quality of tobacco paper pulp, the linear auto disturbance rejection controller model of enhancer was designed to achieve the purpose of active disturbance resistance and improve the control effect of enhancer concentration. Through three groups of simulation experiments, simulation of ADRC to concentration tracking, concentration tracking under disturbance, and comparison with traditional PID control, the linear ADRC is capable of estimating and compensating well. The simulation results show that the linear ADRC has a good anti-interference performance. At the same time, the PLC control system and human-computer interaction software are designed to realize the monitoring of each process parameter in the preparation process of the reinforcing agent, which provides a practical approach for the concentration control in the preparation process of reinforcing agent.

Keywords: Tobacco paper; Disturbance Rejection Control; PLC; PID control; Concentration

1. Introduction
In the tobacco paper industry, the quality of tobacco paper is more and more strict. The quality of tobacco paper depends on the quality of the pulp [1-3]. The viscosity of the reinforcing agent directly affects the fluidity, dispersion, strength, and coefficient of variation of pulp. The viscosity of pulp is affected by temperature, release time, the concentration of the solution, and other factors. Among them, the concentration of the reinforcing agent has the greatest influence on its viscosity. Therefore, it is very important to control the concentration of the reinforcing agent reasonably and effectively from the perspective of the preparation process and effect of the reinforcing agent.

There are many ways to control the concentration of enhancer. At present, the traditional PID control is still dominant. However, the linear combination of the PID control process results in the contradiction between the rapid response characteristics and the serious overshoot of the system. When the system parameters change in a large range and the nonlinearity is more prominent, the reference input is not differentiable and the noise pollution appears in the output. The linear auto disturbance rejection control has strong robustness, which can effectively overcome the large time
delay, large inertia and effectively compensate for the disturbance caused by the change of working conditions inside and outside the system. Therefore, in this paper, auto disturbance rejection technology is used in the reinforcing agent preparation system.

In this paper, the rate of change of the influential flow rate that affects the concentration is regarded as the control quantity, and the fluctuation factor of the material adding rate is regarded as the disturbance factor.

2. Design of anti-interference model for enhancer concentration

The linear ADRC uses the linear extended state observer to estimate the total disturbance from the system itself and from the outside in real-time [4]. The nonlinear state error feedback law is used to compensate for the total disturbance dynamically and linearly so that the controlled object model can achieve better results [5]. The linear second-order ADRC structure is adopted for the concentration control of the papermaking reinforcing agent preparation system, as shown in Fig.1.

![Fig.1 Linear active disturbance rejection control for the concentration of the reinforcing agent](image)

In Fig.1: ZQJP is the preparation process of papermaking reinforcing agent. The dynamic equation can be expressed by the following equation (1), multivariable control model:

\[
\begin{align*}
\frac{dX(t)}{dt} &= \mu(t)X(t) - D(t)(1+r)X(t) + \mu(t)X(t) \\
\frac{dS(t)}{dt} &= -\frac{\mu(t)}{Y}X(t) - D(t)(1+r)S(t) + D(t)S(t) \\
\frac{dBP(t)}{dt} &= -\frac{K_{0} \mu(t)}{Y}X(t) - D(t)(1+r)BP(t) + K_{0}D(t)(BS - BP(t)) + D(t)BS \\
\frac{dX_{r}(t)}{dt} &= D(t)(1+r)X(t) - D(t)(\beta + r)X(t)
\end{align*}
\]

Where: \(X(t)\) is the viscosity at the outlet of the enhancer preparation device, \(s(t)\) is the viscosity value after the release of the viscosity of the enhancer preparation device, \(BP(t)\) is the concentration of the enhancer, \(D(t)\) is the flow rate change rate of clean water, \(\mu(t)\) is the addition rate of the flow inhibitor, \(K_{0}\) is the saturation constant, \(K_{La}\) is the molecular transfer coefficient of the polysaccharide, and the concentration of the enhancer at the bottom of the Sin preparation device.

In Fig. 1: BS is the set value of enhancer concentration; BP is the measured value of enhancer concentration; D is the change rate of the flow rate of clean water; D is the external interference of the system. In the process of reinforcing agent preparation, the flow rate change rate is the control quantity,
so as to control the concentration of the reinforcing agent. The system has two input signals \( y_r \) and \( f \). According to the superposition principle, the output \( y(s) \) of the system can be obtained.

\[
y(s) = \frac{y_r}{s + w_c} + \frac{s^2 + (2w_0 + w_c)s}{(s + w_c)^2} f
\]

The input signal \( y_r \) and disturbance signal \( f \) are bounded, and the output of the closed-loop system is \( \text{sT} \) by using the best control parameter \( W_C \) and \( W_0 \). When the disturbance signal \( f \) is a step signal, the system output \( Y_f \) under the action of this:

\[
y_f(s) = \frac{s^2 + (2w_0 + w_c)s}{(s + w_c)^2} f = \frac{s + 2w_0 + w_c}{(s + w_c)^2} (s + w_c)
\]

As you can see,

\[
\lim_{t \to +\infty} y_f(t) = 0
\]

When the total disturbance is a step signal, the output steady-state effect is zero.

3. Simulation study

This paper mainly analyzes the concentration control effect of the second-order ADRC in the process of automatic preparation of cigarette paper reinforcing agents, designs the second-order ADRC controller to keep the reinforcing agent concentration within the ideal range required by the cigarette paper production line, changes the concentration setting value, increases the external interference factors, and studies the control effect of the ADRC system on the concentration of cigarette paper reinforcing agents. In addition, this paper analyzes and compares the difference between ADRC and the traditional PID control scheme on the control effect of the concentration of tobacco paper enhancer, so as to verify the rationality of the application of ADRC in the concentration control of tobacco paper enhancer. In an ideal state, MATLAB software is used for simulation tests.

Because the process of reinforcing agent concentration control has large inertia and a certain time delay, the second-order model can be used to describe it, and the transfer function is as follows:

\[
G(s) = \frac{e^{-\tau s}}{(T_1 s + 1)(T_2 s + 1)}
\]

Where: \( T_1 = 15 \), \( T_2 = 30 \), \( \tau = 0.04 \); Simulation program reference [6] for simulation analysis.

The setpoint tracking test of enhancer concentrations is shown in Fig 2.
Fig. 2 Tracking-response of enhancer concentration.

External interference is the set value tracking analysis test of intensifier concentration under sinusoidal interference, as shown in Fig. 3.

Fig. 3 Tracking-response of intensifier concentration under sinusoidal signal interference

The comparison test of auto disturbance rejection control and conventional PID control scheme is shown in Fig. 4.
The results show that the linear ADRC system can effectively compensate the system from the internal and external disturbance when the set value of enhancer concentration changes constantly and the ADRC system is interfered with by the external disturbance. The enhancer concentration control can obtain a better control effect, provide the enhancer concentration needed for the production of cigarette paper, ensure the viscosity and the stability of the production line.

It can be seen from Fig 4 that, compared with the conventional PID control, the linear auto disturbance rejection control has better tracking performance with smaller overshoot, and can ensure that the concentration of the enhancer fluctuates within a small range above and below the set value, which has a better ability to adapt to the change of the set value.

At the same time, it improves the dynamic and steady-state performance, solves the problem of time delay and large time lag in the process of reinforcing agent preparation, and realizes the optimal control of reinforcing agent concentration preparation.

4. Concrete implementing scheme
The traditional compounding method of the reinforcing agent is not only inefficient but also error-prone, which can no longer meet the needs of modern industrial production [7,8]. Now, the reinforcing agent is compounded by an automatic liquid preparation device. The automatic dispensing device is an intelligent, full-automatic, and continuously integrated dispensing and dispensing device. The system is applicable to the automatic feeding, dissolving, automatic dispensing, and automatic quantitative dosing of various solid pharmaceutical solutions. The whole process is unattended and runs automatically.

The concentration control of the enhancer adopts a PLC control system in the automatic liquid preparation device to realize the concentration control and then the viscosity control. The PLC system controls the change rate of the influent, so as to control the concentration of the enhancer. The automatic control system becomes the key to concentration control. Therefore, this paper realizes the above model design through PLC system design, applies the PLC system to the liquid distribution device, and enhances the key parameter control of the agent.

After the system of the enhancer preparation is started, the electric valve is opened, the liquid distribution pump starts to rotate, the electromagnetic flowmeter starts to measure, and the flow signal is fed back to the quantitative controller. Clearwater enters the liquid distribution tank through the electromagnetic flowmeter pipeline. The system first distributes liquid to the No. 1 liquid distribution tank, which takes about 10 minutes. When the No. 1 liquid distribution tank is full, the solenoid valve of the No. 1 liquid distribution tank is closed, and the system starts to operate Start to dispense liquid to No. 2 liquid distribution tank, meanwhile, No. 1 liquid distribution tank starts to dispense liquid outwards and supply liquid continuously and stably.

When the solution of 1 preparation tank drops to the low level, the system will automatically start the No.2 solution tank to send out the liquid. At this time, the system will start to prepare liquid for the No.1 solution tank. When the liquid level in the tank reaches a high level, the preparation process will stop automatically. Each tank is equipped with a multi-blade agitator to fully ensure the dilute release and maturation of powder. The amount of dry powder is controlled by the amount of dry powder automatically following the change of water flow. The precise screw feeder is used for feeding powder, and the speed is closed-loop controlled to ensure the feeding uniformity and dispersion.

When the liquid level in the preparation tank reaches a certain height, the mixing device is automatically started, and the powder addition system automatically calculates the addition amount according to the concentration requirements of the solution, and automatically stops when the set amount is reached.

The reinforcing agent automatic control system is composed of a PLC controller, touch man-machine interface, and frequency conversion controller. PLC, as the control core of the automatic
liquid distribution system, adopts a modular design structure, and the system has good expandable performance [9,10].

PLC has the advantages of small size, strong function, simple programming, convenient maintenance, and high reliability, but the man-machine dialogue is not convenient [11]. Therefore, the human-computer interaction interface is set in the enhancer preparation system to realize human-computer dialogue. Siemens mp377 touch screen is used for the man-machine interface of the system to control the field equipment, and Siemens S7-300 PLC is selected, which is easy to expand and has strong functions. The electromagnetic flowmeter of Siemens 7ME6520-3TC13, FMU235A ultrasonic liquid level meter of E + H Company, electric ball valve of Shanghai JU Liang Co., Ltd. and electromagnetic valve of Wuhan Shang Run Company are selected as the liquid level meter.

As the configuration system belongs to the middle single equipment in the whole set of cigarette and paper production line, the system needs to be connected with the field equipment to realize the whole process control, and the system sets corresponding interfaces to realize the interconnection with other systems. In order to ensure response time, optical fiber is used to realize signal interconnection with external equipment. The touch screen inside the system is connected with the programmable controller by twisted pair. The structure block diagram is shown in Fig. 5.

![Fig.5 Structure diagram of control system](image)

**Fig.5 Structure diagram of control system**

System communication parameter setting:
1) Communication mode: half-duplex, start-stop synchronization;
2) Baud rate: 9.6 kbps;
3) Communication protocol: host link;

The software of the enhancer system uses a human-computer interface for human-computer interaction, which is realized by the touch screen. The touch screen interface is mainly composed of a startup interface, historical data query interface, system management interface, and feeding control interface. There are screen switching buttons [12] between each interface. Operate and display the operation status of each unit on the man-machine interface, display the material quantity of the storage tank in real-time, prompt the operator to add material when the material quantity in the storage tank is insufficient, and the system will stop automatically when there is no material in the storage tank. In the case of system failure, the alarm screen will appear, and relevant equipment will automatically stop as required in case of failure. Through the parameter setting of symmetrical quantity, liquid level, flow rate, and flow rate, the whole process can be automatically controlled. The man-machine interface can realize dynamic display, production implementation data history tracing and report printing, and can communicate and control with the upper computer. The system has the advantages of simple operation, reliable performance, and improved efficiency and quality of liquid preparation production.
5. Conclusion
The full-automatic compounding system of the reinforcing agent was successfully applied to the largest cigarette and paper plant in China in 2019, realizing the full process automatic operation of the paper production line. The concentration of the reinforcing agent solution is 0.01% - 0.1%. It has high precision and strong anti-interference ability. The control system realizes centralized management and decentralized control, a high degree of automation, maintenance free, and saves a lot of labor costs; the prepared pulp enhancer has good dispersion and meets the production index requirements. The phenomenon of powder in water is completely solved, a large amount of solid added powder is saved, and considerable economic benefits are created for the enterprise. The system can be applied to many fields of the liquid preparation, such as papermaking, food, metallurgy, and so on.

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