The added water control system based on neural network model and double parameter corrected for loosening and conditioning cylinder

Zijuan Li¹, Jiaojiao Chen¹*, Yang Gao¹, Xiaohui Jia², Liyuan Zhao¹, Zixian Feng¹

¹Tobacco Silk Workshop, Zhangjiakou Cigarette Factory Co., Ltd., Zhangjiakou, China
²Technical Center Product Research and Development Department, China Tobacco Hebei Industrial Co. LTD. Shijiazhuang, China

*Corresponding author: 987243725@qq.com

Abstract. In order to improve the stability of outlet moisture in the of loosening and conditioning cylinder, we concentrate on loosening and conditioning cylinder, and design the prediction model of the added water volume based on neural network technology and the double parameter corrected control system of material balance and moisture deviation for loosening and conditioning cylinder by using historical production data. Taking the set value of inlet and outlet moisture of the loosening and conditioning cylinder as the input factor and the added water volume as the output factor, the prediction model of the added water volume was to predict the total volume of the added water. When there was a big deviation between the actual value and the set value of outlet moisture, the double parameter corrected control system of material balance and moisture deviation was used to correct the deviation, so as to improve the outlet moisture stability and the control accuracy of the added water volume. Using Cigarette brand “diamond (hard-case Yingbin)” produced by Zhangjiakou cigarette factory to built model and analysis, the results showed that after the improvement, the standard deviation of output moisture of loosening and conditioning cylinder reduced by 0.27%, and the control stability and the control level of production process were improved.

Keywords: loosening and conditioning; added water control; neural network model; material balance; outlet moisture

1. Introduction
The loosening and conditioning process is one of the critical processes in the silk production process. Its main technological task is to loosen the tobacco, increase the moisture and temperature of the tobacco, and improve the processing resistance of the tobacco leaves [1]. Currently, the loosening and conditioning cylinder used in the cigarette industry is characterized by good loosening effect and good processing resistance. However, there are many problems, such as poor export moisture stability, feedback lag of water pumping control system, etc. Accordingly, tobacco workers have done a great many research. Duan realized the automatic control of loosening and conditioning outlet moisture by
adopting the control method of professional (fuzzy processing) + conventional PID, and improved the stability of loosening and conditioning outlet moisture [2]. Guo designed a cascade PID feeding moisture content control system, adding the outlet moisture detection into the feedback loop to improve the accuracy of outlet moisture control [3]. Wu improved the CPK value of loosening and conditioning outlet moisture by designing and optimizing the parameter combination [4]. Ouyang constructed a dynamic prediction and automatic adjustment model of water addition with adaptive production environment by using the generalized predictive control method, and realized the dynamic optimization of process parameters [5-8]. Huang optimized the purified water pipeline to improve the control accuracy of the belt scale, and replaced the pneumatic diaphragm valve to improve the water adding proportion stability of the loosening and conditioning cylinder [9]. Wu established the water adding coefficient library by designing the loosening and conditioning control system with trend + deviation control, upgraded the water adding method of loosening and conditioning from "pre-water adding mainly" to "post-water adding mainly and post-water adding adjustment", reduced the standard deviation of outlet moisture content, and improved the control stability of the water adding system [10]. Chen constructed a loose regain outlet moisture prediction model based on Elman neural network [11]. The model obtained the optimal water addition ratio corresponding to outlet moisture by approximating the temperature and humidity of the current production environment. The above studies are based on the outlet moisture accurate control of the loosening and conditioning cylinder and the water adding system of the loosening and conditioning cylinder. Although the stability of loosening and conditioning outlet moisture has been improved to a certain extent, the adaptive control of pumping water and the control ability have not been improved. Therefore, taking the loosening and conditioning equipment as the object, the existing calculation formula of beating water amount and "front and rear water addition adjustment" are improved into a control system for predicting the water addition amount with the help of neural network prediction technology. When there is a large deviation of outlet moisture, the double correction control system combining material balance and moisture deviation control is used to improve the stability and precision control of outlet moisture in loosening and conditioning process.

2. Control System Design

The calculation formula of pumping water before improvement is calculated by the actual value of inlet moisture, the set value of outlet moisture, the actual flow of inlet scale and steam water coefficient, as shown in formula (1). The water coefficient is set by the equipment personnel according to each brand of cigarette export moisture set value. It gives an empirical value, then looks at the actual export moisture to adjust, and finally determine the steam water coefficient for curing. The system adopts the control mode of adding water before and after the inlet end and outlet end at the same time. The operation time of materials from the moisture regain nozzle to the moisture meter at the loosening and conditioning outlet is about 180s, and the lag time of the system feedback is long. In the process of production and operation, it is necessary to manually adjust the water addition at the inlet and outlet to realize the adjustment of outlet moisture. When the deviation between the actual value of outlet water and the set value of outlet moisture is small, the water addition at the outlet end should be adjusted. When the deviation is large, the water addition at the inlet end should be adjusted. In most cases, it is mainly to adjust the amount of water added at the outlet. In the loose regain pumping control system, the actual value of outlet moisture does not participate in the calculation of pumping water, which is often used as the reference basis for manual adjustment. Therefore, the system is a classic open-loop control, as shown in Fig. 1. After improvement, the method of neural network is used to change the current formula of water adding in loosening and conditioning, and the prediction model of loosening and conditioning water addition is established. The parameters under the current production conditions are collected by the system, and the optimal water addition corresponding to the set value of outlet moisture is given through the model. Then, the water added before the inlet end and after the outlet end are distributed according to the water distribution coefficient at the inlet end and outlet end (the experimental brand in this work is 7:3). After improvement, the actual value of outlet moisture is added to the feedback control, and a double correction system combining material balance and moisture deviation control is added in
the system. Based on the deviation between the actual value of outlet moisture and the set value, it is used as the basis for adjusting the total water addition, the adjusted water addition and the adjustment range, thus realizing the accurate and intelligent control of outlet moisture, as shown in Fig. 2.

\[
\text{Water} = F \times \frac{100 - M_{RS}}{100 - (M_{CS} - S)} - F \tag{1}
\]

Among them, Water -- water addition, kg; F -- the actual flow of the scale, kg/h; \(M_{RS}\) -- the actual value of inlet moisture, %; \(M_{CS}\) -- the set value of outlet moisture, %; S -- the steam water coefficient; The steam water coefficient of the brand tested in this work is 0.5.

Fig 1. Control flow of water supply before modification

Fig 2. Control flow of water supply after modification
2.1. **Neural network algorithm**

Neural network algorithm simulates the operation mode of human brain, adopts topological structure, and is characterized by self-learning and self-adaptive ability [12]. The training algorithm of multi-layer error inverse propagation is adopted. The neural network takes neurons as the path from one neuron to the next, as shown in Fig. 3 [13-15]. When the output result is not the expected result of the system, the system adjusts the network weight and threshold in the form of back propagation to reduce the error function towards the negative gradient, thus making the output value close to the actual value [16-18].

![Fig 3. Structure chart of neural network model](image)

2.2. **Prediction model of loosening and conditioning water addition based on neural network**

Based on the historical production data, the training target of the model was set as 0.05 with the set values of inlet moisture and outlet moisture in the loosening and conditioning process as the input and the water addition as the output. Also, the training speed was set as 0.01, and the maximum step number was set as 100. Neural network training was carried out, and the prediction model of loosening and conditioning water addition based on neural network algorithm was established. The neural network structure includes three layers: input layer, hidden layer and output layer.

![Fig 4. Prediction model of loosening and conditioning water addition](image)
2.3. Correction control mode based on material balance and deviation

Material balance controls the TotalWater(T) within the sampling period T. The calculation formula is as follows:

\[
TotalWater(T) = F \times T \times M_C + C - (Q + F \times T \times M_R)
\]

\[
= F \times T \times (M_C - M_R) - (Q - C)
\]

(2)

Among them, \(Q\) -- the steam injection volume, kg; \(F\) -- the flow of electronic scale, kg/h; \(T\) -- a sampling period, s; \(M_C\) -- the average value of outlet moisture, \%; \(TotalWater(T)\) -- the total water addition, kg; \(M_R\) -- the average value of inlet moisture, \%; \(C\) -- water consumption, kg.

Outlet moisture deviation is defined as the deviation of the actual outlet moisture value from the set value, and the deviation value is defined as \(\Delta S\). The calculation formula is as follows:

\[
\Delta S = M_C - M_S
\]

(3)

Among them, \(M_C\) -- the actual value of outlet moisture, \%; \(M_S\) -- the set value of outlet moisture, %.

2.3.1. Sampling period. The set value of sampling period \(T\) is the frequency for the system to adjust the water flow, and it is set according to the time taken for the material from the rear water pump to the outlet moisture meter. The smaller the sampling period \(T\), the more frequent the regulation of loosening and conditioning water addition. After field measurement, the sampling period of the water control system is 12s.

2.3.2. Material balance control. Within a sampling period \(T\), the water addition \(\Delta FlowRate\) (1) controlled by the material balance of material input and output in the loosening and conditioning process is:

\[
\Delta FlowRate (1) = \frac{F \times T \times (M_C - M_S) - (Q - C)}{T} = \frac{TotalWater(T)}{T}
\]

(4)

It can be seen from equation (4) that the water consumption standard is the average water consumption of historical production batches. When the water consumption standard and steam injection amount are fixed, the outlet moisture will also increase when the water flow increases. When the water flow decreases, the outlet moisture will also decrease.

2.3.3. Deviation corrections. In the sampling period \(T\), when the outlet moisture deviation occurs, the water addition \(\Delta FlowRate\) (2) corrected by the outlet moisture deviation is:

\[
\Delta FlowRate(2) = \frac{\Delta S(T) \times F(T)}{T}
\]

(5)

In the equation, \(F(T)\) -- the flow of electronic scale, kg/h. When the deviation value \(\Delta S(T)\) is positive, the actual value of outlet moisture is greater than the set value, and the amount of water addition shall be reduced; When the deviation value \(\Delta S(T)\) is negative, the actual value of outlet moisture is less than the set value, and the amount of water addition shall be increased. The greater the absolute value of \(\Delta S(T)\), the greater the adjusted value \(\Delta FlowRate\) (2) of water addition.

2.3.4. Double correction parameter selection. According to the outlet moisture deviation, it is determined whether to select the value of material balance for correction or deviation correction. In this system, when the deviation of outlet moisture is more than 0.5%, the value of material balance is used
for correction, which is fed back to the total water addition for correction. When the deviation of outlet moisture is less than 0.5%, the deviation value is revised, and the feedback is given to the outlet moisture addition for correction. The field test and calculation results show that the regulation accuracy of deviation correction value is higher when the adjustment range is small, and the material balance value is better in adjusting the feedback speed.

3. Application Effect

3.1. Test design
Material: "diamond (hard-case Yingbin)" brand cigarette (provided by Zhangjiakou cigarette factory). Experimental method: The data collected by the information management system of silk making were compared and analyzed with 20 batches of data before and after improvement.

3.2. Data analysis
It can be seen from Table 1 that the standard deviation of loosening and conditioning cylinder outlet moisture was reduced by 0.27% from 0.61% to 0.34% after the improvement, and the stability of outlet moisture was significantly improved.

![Control feedback flow of water supply system](image)

**Fig 5.** Control feedback flow of water supply system
Table 1. Standard deviations of moisture content in output tobacco before and after modification (%)

| Number | Standard deviation before improvement | Improved standard deviation |
|--------|--------------------------------------|----------------------------|
| 1      | 0.65                                 | 0.37                       |
| 2      | 0.71                                 | 0.31                       |
| 3      | 0.68                                 | 0.4                        |
| 4      | 0.59                                 | 0.32                       |
| 5      | 0.67                                 | 0.29                       |
| 6      | 0.63                                 | 0.38                       |
| 7      | 0.62                                 | 0.32                       |
| 8      | 0.72                                 | 0.31                       |
| 9      | 0.59                                 | 0.28                       |
| 10     | 0.6                                  | 0.34                       |
| 11     | 0.54                                 | 0.41                       |
| 12     | 0.61                                 | 0.35                       |
| 13     | 0.58                                 | 0.37                       |
| 14     | 0.56                                 | 0.31                       |
| 15     | 0.53                                 | 0.28                       |
| 16     | 0.61                                 | 0.26                       |
| 17     | 0.63                                 | 0.34                       |
| 18     | 0.62                                 | 0.36                       |
| 19     | 0.57                                 | 0.39                       |
| 20     | 0.49                                 | 0.34                       |

Means 0.61 0.34

4. Conclusion
A method for predicting and controlling the loosening and conditioning water addition was proposed to regulate the outlet moisture of loosening and conditioning process. Simultaneously, the moisture deviation benchmark was obtained, and the corresponding correction system was used to calculate according to the deviation between the actual value of outlet moisture and the set value. Firstly, the control model of loosening and conditioning water addition based on neural network was established to improve the intelligent level of loosening and conditioning process. Second, the deviation was corrected in groups according to the deviation between the actual value of outlet moisture and the set value. Compared with before and after improvement, the standard deviation of loosening and conditioning outlet moisture was reduced by 0.27% from 0.61% to 0.34%, and the stability of outlet moisture was significantly improved.

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