The development of self-optimizing and pre-diagnosis about intelligent feeder based on digital technology

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Abstract: Cigarette factory barn feeder elevator belt starts and stops frequently cause feed flow unstable, and increased the equipment failure rate. Overhead materials lead to cut off flow and other problems will have a serious impact on the inherent quality of cigarette products. Transmission based digital technology; we developed an intelligent feeder for self-optimized pre-diagnosis. By improving the control mode of feeding bin bottom belt and lifting belt, it can realize the frequency conversion control of anti-overhead and lifting belt motor, with the help of Smart Sensor motor intelligent sensor and Ethernet IO module monitors the transmission of the feeder, realize that self-diagnostics and the whole monitoring of the running state. it achieves the purpose of intelligent early warning and prevention of equipment. The improved control system operates reliably and the material supply flow is stable, the frequency of cutoff is obviously reduced, disconnection associated with the feeder is completely eliminated, guarantee the technological quality of cigarette products.

1. Introduction
Tobacco silk production line barn feeder is mainly used for tobacco slice, tobacco silk, tobacco stem and other tobacco materials can be delivered continuously and uniformly, and it has buffering and adjusting function between each working procedure [1-2], provide stable flow rate for downstream main machine equipment for deep processing of materials. Tobacco in the manufacturing process, constant flow control is crucial, the system usually includes feeding machine system and electronic belt scale system [3-4], the feeding system serves as a caching device between the upper and lower production processes, supply material to electronic belt scale by lifting belts, use speed control method to ensure the stability of the electronic belt scale feed, satisfy that the flow requirement of the next process. Feeder system usually consist of photocell, feed bottom belt, elevator belt, the quantitative tube and so on [5-6], see figure 1.
Fig. 1. Structure diagram of constant flow control system
A  Feeding bin  B  tail band  C  Elevator belt  D  The quantitative tube  E  Electronic belt balance
1.Feeding high position photocell  2.Feeding low position photocell  3.Feeder full of photocell  4.Lift with material photocell  5.Plugging material photocell  6.High level photocell  7. Middle photocell  8.Low level photocell

2. The problem exists
The control about flow procedure of feeder is complex, at present, we use the fixed three-speed control method of high-medium-low speed. When the plugging material photocell is blocked, the lifting strip is out of action; When plugging material photocell light, and the high photocell is shielded, the lifting belt was in low speed operation; When the material photocell and the high photocell pass light, When the median photocell is shielded, Elevator belt running at a moderate speed; When the plugging material photocell, high photocell and middle photocell pass light and the low photocell is blocked, the lifting belt operates at high speed. Disadvantages of three speeds and one stop control method:

① The speed mode is fixed and cannot be adjusted, and the operation speed of the lifting belt is only three fixed values, namely high, medium and low speed. However, there are dozens of brands we produce, and the three fixed speed feeding control methods obviously cannot satisfy the requirements of stable feeding.

② Poor flow stability, in the process of feeding frequent appear that: feed insufficient -- high-speed feeding -- excess feeding -- stop feeding and so on, again and again, lifting belt frequent start and stop lead to its temperature is too high, resulting in lifting belt feed flow serious instability.

③ This kind of control mode leads to serious abrasion of equipment, high failure rate, which photoelectric switch reliability is low, and in the production process of any photoelectric switch failure will cause the feeder to stop running. Traditional feeding speed of feeder model is fixed cannot adjust random variation, flow stability is bad, at the same time is a high incidence of failure equipment, usually occurs that interruption of flow due to feeder fault, moreover, the silk feeder has a large number of motors, bearings, frequency converters and other equipment, in the past ensure it safety by the artificial daily inspection, it has deviation about measurement error and timeliness problems, while traditional equipment management relies on the tally, periodic maintenance to anticipation of failure, when the working condition of equipment changes, the traditional equipment management cannot found the problem in time, need to real-time monitor the health status of equipment, upgrade the later maintenance mode to advance warning maintenance.
3. The improved general idea and method to design

Aiming at the drawbacks of the traditional feeding speed regulation mode of the feeder, this project uses programmable control technology and digital technology to develop a new frequency conversion speed regulation control system. The self-optimized pre-diagnosis intelligent feeder is designed, which is frequency conversion automatic speed regulation system which can diagnose and set parameters of the equipment remotely through programmable controller including PLC, frequency converter, I0-Link interface module, intelligent sensor, etc. Change three speed control into high and low two speed control, if the material is lower than the low switch, the lifting belt operates at high speed, if the materials between high and low level, the lifting belt operates at low speed, if the material is higher than the low switch, stop running the lifting belt, lifting belt low speed automatically according to the status of the photoelectric switch set frequency fine adjustment, can according to the density, moisture, and traffic of each batch of material, in the shortest time to match the most reasonable frequency, to realize automatic frequency conversion feeding speed, solve the problem of plugging material, and equipment start-stop frequency, etc. Through the digital technology and Ethernet IO module of feeding machine drive system real-time monitoring and fault diagnosis, the status of the Smart Sensor sends data - mobile phone via blue tooth or gateway to motor data transmission to safe cloud platform, analyze the data, through the phone and the web client display monitored motor overall state, the monitoring unit operation parameters (speed, surface temperature, running state), machine health monitoring components parameters (bearing, vibration, the medium) and motor fault alarm events are shown in figure 2 as the system organization chart. At the same time, ABB special server can store historical data and state of motor for fault analysis and maintenance planning. Modify translation results rely on Ethernet IO module built-in distributed intelligent control function, can directly handle some simple small tasks, no need through PLC control. Thus, the field response time can be accelerated, at the same time the control burden of PLC can be reduced, production efficiency can be improved, and the stability of process control can be enhanced. By that we can Master the running state of the equipment, realize the pre-judgment of the health index of the equipment, send out the alarm information in time, and facilitate the prior inspection and maintenance.

![Fig.2. Smart Sensor system architecture](image-url)
4. Improved implementation process

4.1. Improvement of feeder control program

Due to fixed three speed control mode is difficult to meet the demand of many brand of production, so we have developed Self-optimizing multimode of frequency control of motor speed, this method adopts Beano Ethernet IO-Link sensor to replace the traditional photoelectric switch, high and low IO sensors installed in the quantitative tube to control speed, high, medium and low three speed control becomes two speed frequency conversion control. First initial value for the setting value, keep high speed and low speed 40 Hz and 20 Hz, respectively, if the material is lower than the low switch, the lifting belt operates at high speed, if the materials is between high and low level, The lifting belt operates at low speed, if the material is higher than the low switch, The lifting belt stops running. The low-speed setting frequency of the lifting belt is adjusted automatically according to the status of the photoelectric sensor. Specifically, it can be divided into three situations: first, when the material is located near the low level photoelectric sensor, (1) when the light passing time $T < 300$MS, the system considers it as an interference signal. The low-speed setting frequency does not change, and it is still 27Hz and running at high speed at the moment;(2) When $300$MS < light time $T < 1.5$s, the system thinks that the material in the quantitative tube is a little less, and the set frequency of the lifting belt accumulates 0.3Hz successively, running at high speed at this moment;(3) when the light passing time is $t > 1.5$s, the system thinks that the quantitative tube is short of material, and the low-speed setting frequency accumulates 0.3Hz Hertz successively. At this moment, the lifting belt operates at high speed, and the high-speed filling prevents empty until the material is located between the high-low photoelectric sensors. Second, when the material is between the high and low level photoelectric sensors, the operating frequency of the lifting belt remains unchanged. Thirdly, when the material is located near the high photoelectric sensor, (1) when the light blocking time $t < 300$MS, the system considers it as an interference signal. The set frequency at low speed does not change, and it is still 27Hz and operates at low speed.(2) When $300$MS < light blocking time $T < 1.5$s, the system thinks that there are too many materials in the quantitative tube, and the set frequency of the lifting belt decreases 0.3Hz successively, running at low speed at the moment;(3) when the light blocking time is $t > 10S$, the system thinks that the quantitative tube is full, the low-speed setting frequency reduces 0.3Hz successively, and the lifting belt stops running at the same time. In the production site, the lifting belt motor adopts Danvers FC302 inverter with built-in logical control function, which can change the single acceleration and deceleration time control into two-stage acceleration and deceleration time control. The operation steps are as follows: when the frequency converter is at a lower frequency (below 23 Hz), use a smaller slope to accelerate and decelerate the time; When the frequency converter is at a higher frequency (above 23 Hz), a higher slope is used to accelerate and decelerate the time. After improvement, according to the different characteristics of each batch of materials, such as density, moisture and flow rate, intelligent judgment and decision can be made to match the most reasonable frequency in the shortest time to avoid frequent start and stop of the motor. The improvement program is shown in Figure 3.
In addition, in view of the condition of the feeder lifting belt photoelectric switch wire rack, developed bottom belt with shock program: in the PLC control program of bottom belt, will improve with time control signal into lifting with feed signal, namely due to ascend with photocell is blocked, the timing starts when the base band stops running, time promoting 6 s or material with a photocell light pass again as long as there is a meet two conditions, the bottom of the feeder with automatic forward 2 s. The new control method can effectively solve the problem of overhead cut off flow and ensure the smooth supply of material flow.

4.2. Improvement of intelligent early warning diagnosis of the feeder
In order to monitor the transmission chain equipment of the feeding machine effectively, a complete set of digital monitoring means should be established to facilitate the unified collection, storage, access and management of key data of the equipment, improve the ability of early warning and predictive diagnosis of faults, and enhance the ability of analyzing the root causes of faults. Two sets of motor intelligent sensors are installed in the bottom belt and lifting belt of the feeder. 6 sets of mounted bearings and bearings intelligent sensors and 2 sets of inverters (ACS880) and intelligent sensors are installed in it.

The condition of motor, bearing and frequency converter is accurately and real-time monitored. The diagnosis and monitoring data are automatically uploaded and displayed on the monitoring computer of the main customer, and the key performance indicators are displayed in the system. All intelligent sensor data can finally be transmitted to the workshop equipment monitoring system for integration, and the intelligent manufacturing scenario of "Internet of Things" is shown in Figure 4.
Fig.4. Intelligent sensor application scenario

By intelligent sensors send data - by corresponding network transmission way to transmit data transmission chain to ABB Ability™ cloud platform, analyze the data, through the phone and the web client presented alone monitored motor, bearing, inverter monitoring unit operation parameters (speed, running state, etc.), the health monitoring components parameters (temperature, vibration, etc.) and fault alarm events, the integration acceleration, temperature, magnetic field, voice, and other physical measurement using wireless data transmission, the signal covers a wide range, no manual data analysis is required, according to the state of motor, automatic push operational Suggestions, Establish an electronic medical record card for the equipment and store the history and status of the drive chain for failure analysis and maintenance planning.

5. Improved effect displays

Through the development of a new control program, an innovative self-optimizing multi-mode frequency conversion speed regulation method is proposed, which can make intelligent judgment and decision according to the different characteristics of each batch of materials, such as density, moisture, flow, etc. After the improvement of the control system of the feeding machine, it is found through follow-up statistics in the later period:

1) Figure 5 (a) is the operating frequency diagram of the lifting belt motor before the improvement, and Figure 5 (b) is the operating frequency diagram of the lifting belt motor after the improvement. After the improvement, increase with frequency adjust itself, according to different type of material in the shortest possible time to match the most reasonable frequency, the materials always can control between high and low level, and effectively solved from feeding the tail into the material caused by changes in the rate of ascension with frequent start-stop, big span, large equipment mechanical loss, etc.

2) Figure 5 (c) is the material flow chart of electronic belt scale before the improvement, and Figure 5 (d) is the material flow chart of the electronic belt scale after the improvement. It can be found that the flow is more uniform and stable than before, which greatly improves the processing technology level of the next process.
Fig. 5. Comparison diagram of motor frequency and material flow before and after improvement

Through the exclusive web client, you can see the overall state of your own motor, bearing, frequency converter and so on, for instance, vibration, speed, output power, health parameters, such as surface temperature, overall vibration, bearing health index, alignment state, etc. At the same time, you can choose the electrical parameters to be displayed and the corresponding state of any time period. The health status of multiple motors, bearings and frequency transducers can be seen at a glance, and the subtle hidden dangers in the operation of the equipment can be forecast and warned. The maintenance plan can be arranged reasonably according to the specific status, as shown in Figure 6.
6. Conclusion

Based on the research of self-optimizing pre-diagnosis intelligent feeder, the self-matching multi-modal frequency conversion speed regulation method is proposed, in the shortest possible time to match the frequency of the most reasonable, make intelligent judgment decisions, and use digital technology to construct the transducer and the drive motor intelligent early warning, prevention and control of elevator belt down times, high frequency operation time and high frequency times, which is greatly reduced. It is pioneering in the industry, and have very good promotion of innovation, generalization equipment operation reliability is greatly increased, the fault forecasting rate is significantly increased, the cutoff associated with the feeder is also significantly reduced, ensure the continuous and uniform transportation of tobacco materials, The technological quality of cigarette products is improved.

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