Dynamic model research and Intelligent system development of belt conveyor

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Abstract. The dynamic problem of belt conveyor is analyzed systematically and the whole dynamic model of belt conveyor is established. This paper studies the solution of the dynamic equation of belt conveyor, develops the intelligent system software of dynamic analysis and simulation of conveyor, and conducts the dynamic simulation of a coal mine belt conveyor system.

Keywords: Belt conveyor, belt, dynamic model, dynamic analysis, intelligent system.

1. Introduction
The belt conveyor is simple in structure, stable and reliable in operation, low in noise, capable of continuous long distance and large in inclined conveyance, low in equipment operation cost, and can be fed or unloaded at any position of the belt. It is characterized by high production efficiency, large in throughput, and low in energy consumption. Therefore, it is widely used in many industrial fields. The dynamic analysis of belt conveyor is directly related to the technical level of conveyor design and manufacture. So countries (or companies) study this issue to make their products technologically advanced. Conveyor dynamics was first studied in the former Soviet union, and then some scholars in mining industry and port transportation developed countries such as Germany, Britain and Australia also studied the conveyor dynamics theory. The dynamic research and dynamic analysis software of belt conveyor is also in the development and gradual practice. This paper makes a systematic analysis of the dynamic problem of the belt conveyor, studies the solution of the dynamic equation of the belt conveyor, develops the software of the dynamic analysis simulation intelligent system of the conveyor, and conducts a dynamic computer simulation of a coal mine belt conveyor intelligent system.

2. Establishment of dynamic model of belt conveyor
The dynamic analysis of belt conveyor involves the whole system problems such as conveyor belt, driving device, take-up device and brake device. The analysis of a part alone can not reflect the characteristics of conveyor system. Therefore, dynamic analysis method of belt conveyor is the conveyor belt according to the mechanical properties of the viscoelastic body, the braking characteristics of integrated into the drive, the movement of body distribution, the quality of the line of each section of the slope change, all kinds of running resistance and the initial tension of conveyor belt, deflection change and take-up device of belt conveyor, position, in the form of the effect of factors such as tension, conveyor dynamic mathematical model is set up, to ensure our conveyor in the braking process, the
conveyor belt of differences over time by changing the speed, acceleration and tension. It can forecast the possible dynamic danger and insecurity of the conveyor designed according to the traditional static design method, put forward improvement and adjustment measures, and optimize the design scheme.

2.1. Belt mathematical model of belt
Because belt plays an important role in the whole belt conveyor system. Therefore, it is very important to establish the dynamic equation of the belt reasonably for the whole system. After dividing the conveyor belt into several units, the effect of unit $i$ stiffness $k_i$, $k_{i+1}$, damping $c_i$, $c_{i+1}$, mass $m_i$ and operating resistance $w_i$, if its displacement is $u_i$ [1] (shown in FIG. 1), The dynamic equation of the element $i$ is obtained by using the equilibrium equation of force [2-4]:

$$m_i \ddot{u}_i - k_i u_{i-1} + (k_i + k_{i+1})u_i - k_{i+1}u_{i+1} - c_i \dot{u}_{i-1} + (c_i + c_{i+1})\dot{u}_i - c_{i+1}\dot{u}_{i+1} = -w_i$$

(1)

2.2. Establishment of dynamic equation of driving device
It is assumed that there is only elastic sliding between the belt and the driving pulley without relative sliding, and the mass of the driving pulley can be converted into the belt segment in contact with it as the inertial mass (similar to the idler). In fact, as a result of the tension extension of the belt, the driving pulley and the belt segment will slide relative to each other and affect the size of the Angle. However, this is a normal operating condition and has little influence on the operating characteristics of the conveyor as a whole without integral sliding. Therefore, the overall relative sliding is not considered in this paper. Therefore, the dynamic model of the driving unit is similar to that of the conveyor belt unit

$$m_i \ddot{u}_i - k_i u_{i-1} + (k_i + k_{i+1})u_j - k_{i+1}u_{i+1} - c_i \dot{u}_{i-1} + (c_i + c_{i+1})\dot{u}_i - c_{i+1}\dot{u}_{i+1} = -w_i + F_d$$

(2)

2.3. Establishment of dynamic equation of take-up device
In the process of starting, running and braking, the conveyor belt will creep due to the action of tension and inertia, which can cause the conveyor belt to become longer and loose and cannot work. The belt take-up device is an important component to ensure the belt has a certain tensile force and works normally without skid. So the take-up device has to take into account the whole system equation. The dynamic equation of the take-up is as follows:

$$m_{it} \ddot{u}_{i+1} + zk_{i+1}u_i - k_{i+1}u_i + (k_{i+1} + k_{i+2})u_{i+1} - k_{i+2}u_{i+2} + ze_{i+1}\dot{u}_i - k_{i+1}\dot{u}_i + (c_{i+1} + c_{i+2})\dot{u}_{i+1} - c_{i+2}\dot{u}_{i+2} + w_{i+1} = 0$$

(3)
2.4. Establishment of dynamic equation of brake device

The braking of belt conveyor is like starting, and the belt is subject to dynamic tension due to the deceleration of moving parts. The purpose of calculating the dynamic tension of the belt during braking is to determine the maximum braking force allowed when the brake device performs emergency braking to prevent the belt from sliding relatively on the driving roller. Calculate the tension required to ensure the lateral stability of the bearing branch of the belt, so the minimum tension of the belt shall not be less than the following values [5]: \((5 - 8)q_u\). Since the braking process generally adopts the free stop and the braking moment stop, and these two stops are mainly changes in the input force on the model, the dynamic equation of the brake device is as follows:

\[
\begin{align*}
    m_i \ddot{u}_i - k_i u_{i-1} + (k_i + k_{i+1}) u_i - k_{i+1} u_{i+1} & = -w_i \quad \text{(4)}
    \end{align*}
\]

In the formula: \(FB\) - braking force

2.5. Establishment of dynamic equation of belt conveyor system

The above analyses the dynamic equation of each part of the belt conveyor. Since there is no practical significance for the study of single part, the above unit equation is integrated to form the dynamic equation of the whole system. Through the solution of the entire system, the required results of the conveyor can be obtained. The general formula of the dynamic equation is obtained by combining and finishing

\[
\begin{align*}
    [M]\ddot{u} + [C]\dot{u} + [K]u & = \{F\} \quad \text{(5)}
    \end{align*}
\]

The formula: \([M]\): mass matrix of the unit; \([C]\): damping matrix of the unit; \([K]\): stiffness matrix of the element; \(\{F\}\): the external force matrix acting on the system, including the driving force of the system, the tensile force of the hammer, and the operating resistance; \(\{\ddot{u}\}, \{\dot{u}\}, \{u\}\) — the acceleration of the unit and the column vectors of velocity and displacement.

3. Mathematical solution of dynamic equation of belt conveyor

In the process of starting and braking of the conveyor, the dynamic equation of the system is a nonlinear equation with variable stiffness, variable damping and variable input force, as the equivalent elastic modulus changes with the tension of the conveyor belt, the directivity of the running resistance is variable, and the linear fitting of mechanical characteristics of the driving device is variable. The iterative method is used to solve the problem. This method not only has a small deviation from the actual results, but also has a short solution time and simple parameter setting.

4. Development of belt conveyor simulation intelligent system

Based on the establishment of accurate system dynamics model and solution method, VC is used as the development tool in the Chinese Windows hyperdrive system to develop the general effective simulation intelligent system software. The system strives for practicability in the development process, and makes a thorough investigation on the operating conditions of the conveyor. During the development process, the working conditions of the conveyor are almost taken into account, leaving an interface for those temporarily not considered. For other development.

4.1. Parameter setting

The computer simulation takes a coal mine belt conveyor as an example. Its main parameters are shown in figure 2: (1) performance parameters: material name: coal; Transport capacity (t/h): 1400; Bandwidth
(m) : 1.2; Design band speed (m/s) : 3; Total length of transport (m) : 2444; Lifting height (m) : 22; (2) load distribution and drive system setting: load distribution: overloaded operation; Starting condition: direct starting; Motor type: ykk4001-4; Rated power (KW) : 710; Rated speed: 1480r/min; Moment of inertia: 7.2kg. M2; Speed reducer model: SH145; Total deceleration ratio: 23; Driving mode: single head drive; Form of tension: single weight of the head; (3) other parameters: conveyor belt model: ST2500; Elastic modulus (N/m) : 1,200000000; Weight of head hammer (kg) : 18000; Form of idler for bearing section: trough forward idler; Return roller form: parallel roller; Roller groove Angle (degree) of bearing section: 35; Roller groove Angle (degree) in the return section: 0; Distance between idlers in load bearing section (m) : 1.2; Distance between idlers in the return section (m) : 3.

4.2. Dynamic simulation results and analysis of starting process

The simulation results of the starting process are shown in figure.

Fig. 2 The layout of conveyor

Fig. 3 The velocity of comparing curve at the head and trail

Fig. 4 The dynamic tension of comparing curve at the head and trail
Since the motor starts directly, the instantaneous acceleration is very large at the beginning of starting, so the speed increases relatively fast, and then the speed decreases. This is caused by the sliding of the driving roller in the process of starting, which should be avoided. 2.3 s, the speed curve of the tail starts to have a movement trend, indicating that the effect of the head driving force just reaches the tail and the tail reversing roller starts to move. Then the velocity continues to rise, but with some fluctuations along the way. This is mainly caused by the addition of waves. It's going to stabilize. The displacement of the take-up device also fluctuates at startup and finally tends to stabilize. Comply with startup process changes.

The three-dimensional diagram of dynamic tension of conveyor is very important. The precondition of designing belt conveyor is to make the tension of each position meet the design requirements. Figure 6 shows that the dynamic tension bearing section of the whole belt gradually decreases from the head to the tail, and the tension of the return section changes less, because the parameters used are not inclined at a large Angle, and the frictional resistance of each element of the return section is similar to that of the lifting resistance, so the dynamic tension changes very little.
As can be seen from the change of speed with time in FIG. 7, the starting speed of the whole belt conveyor is a delayed process. There is an obvious dark section in the figure, which indicates that the starting of the conveyor is a step by step process.

The dynamic intelligent analysis software can provide the basis for the design of belt conveyor. The main function is as follows: (1) give the stress state of all major parts of the conveyor, and use these results to further design the strength of all parts, so as to make the conveyor system more economically rational; (2) provide reasonable driving device, driving force during braking and control requirements of braking force; (3) provide reasonable arrangement of driving device, tension device and brake device; (4) provide design parameters for the take-up device of the conveyor, including the speed and travel of the tension device, so as to design the driving power of the tension device; (5) verify the rationality of the preliminary design results, and improve the preliminary design by analyzing the results.

5. Conclusion
This paper established the dynamic model of belt conveyor, puts forward the dynamic model of algorithm design, solve the problem of the large dynamic design of belt conveyor. The dynamic analysis intelligent software application development successfully has carried on the dynamic simulation of belt conveyor system, puts forward the improved design scheme, and applied in the actual system, avoid the design flaws.

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