

Research on reliability of scraper chain drive system

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Abstract. In the production practice, the key parts of scraper conveyor have a short life span and a high failure rate, which seriously restricts the production efficiency of coal mines in China. In order to ensure the high efficient and safe mining of coal resources, it is urgent to study the reliability of heavy scraper conveyor. With the development of deep and large coal mine in our country, the reliability of scraper conveyor is more and more high. In this paper, the structure of scraper chain transmission system is analyzed firstly, and then simulates the service age and reliability of the scraper chain system. Finally, it is concluded that when the scraper chain system transports different materials, the order of oscillation of the system reliability from long to short is lignite, coking coal, anthracite and gangue, and when entering the final plateau stage, the order of reliability from high to low is also lignite, coking coal, anthracite and gangue.

1. Structure Composition of the Scraper Chain Drive System

When analyzing the reliability life of the scraper chain drive system, it is first necessary to analyze the structure of the scraper chain drive system. The scraper chain drive system is composed of four subsystems in series, namely, the head, the middle part, the rear part and the accessory device. Each subsystem is also composed of related parts in series [1]. The block diagram of the scraper chain drive system is shown in Fig.1.

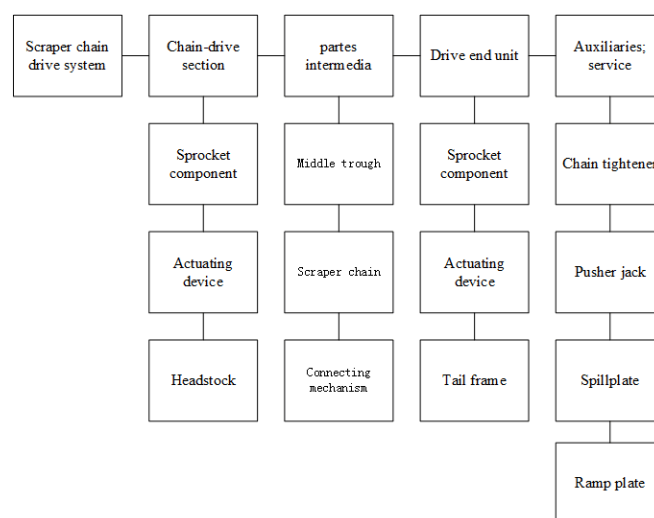


Figure 1. Structure block diagram of scraper chain drive system



2. Reliability Life Analysis of Scraper Chain System

2.1. Life Distribution Density Function of Scraper Chain System

It has been proved through practice that all system lifetimes that cause global failure due to partial component failures or failures obey Weibull distribution. In this paper, the two-parameter Weibull distribution is used as the distribution density function of the life of the scraper chain system. The expression is:

$$f(t) = mn^{-m}t^{m-1}\exp(-n^{-m}t^m) \quad t > 0 \quad (1)$$

In the formula, m is shape parameter and n is scale parameter.

The characteristic lifetime of the distribution by Weibull,

$$T_{e^{-1}} = n \left(\ln \frac{1}{e^{-1}} \right)^{1/m} = n \quad (2)$$

The feature life of the Weibull distribution is the scale parameter.

According to the references found, it can be concluded that when the scraper chain system is used to transport different types of coal, the minimum time required to change the ring chain is not the same. In the transportation of lignite, coking coal, anthracite and gangue, the working hours of the ring chain are approximately 24 months, 14 months, 9 months and 4 months [3]. Therefore, when transporting these four types of coal, the scale parameters can be 24, 14, 9, and 4. Another parameter in the Weibull distribution density function, the shape parameter is mainly determined by the type of the scraper conveyor and the working environment. According to related data, the shape parameter is taken as 3. After determining the relevant parameters in the Weibull distribution density function, the Weibull distribution density function curve of the life of the scraper chain system when transporting different coal materials can be obtained, as shown in Fig. 2.

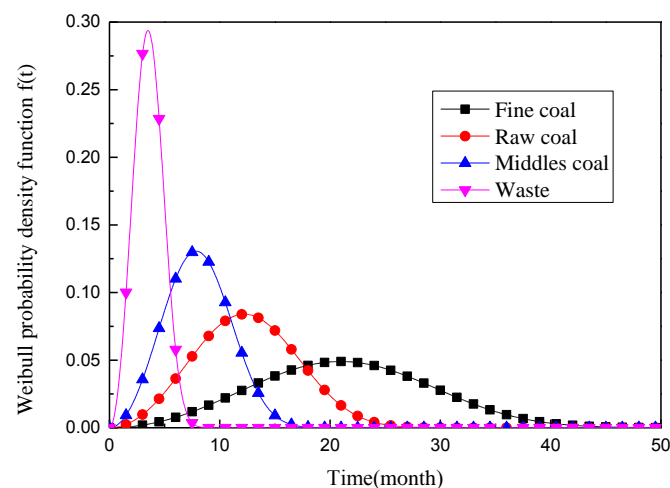


Figure 2. Distribution curve of density function of Weibull distribution

2.2. Scraper Chain System Service Age Mathematical Model

The scraper chain system often causes the failure of the scraper chain system in the transmission process. The staff will timely repair and replaces the faulty circular chain, and after the replacement, the scraper chain system and the round chain age composition will also change [4]. Assume that the maintenance period of the scraper chain system is Δt , according to the on-site maintenance data analysis, you can use month as the unit of time. After the scraper chain system was operated at $t_n = n\Delta t$, the service age distribution of the ring chain was statistically analyzed. Let the distribution density function of the ring chain failure time be $f(x)$, then the possibility of failure of the ring chain after the time of use t_n can be expressed as an integral of the function over the interval $[0, t_n]$. The

$p_n(t_i)$ represents the proportion of the circle chain with the serving age at the moment of the scraper chain system, which can be used to represent the age distribution of serving age at various times.

At the beginning stage, all ring chains in the scraper chain system are new and their service age is 0. The distribution of the first age group is:

$$p_0(t_0) = 1 \quad (3)$$

When $n = 1, t_1 = \Delta t$, the distribution of the first and second age groups is:

$$\begin{cases} p_1(t_1) = p_0(t_0) \left[1 - \int_0^{\Delta t} f(x) dx \right] \\ p_1(t_0) = p_0(t_0) \int_0^{\Delta t} f(x) dx \end{cases} \quad (4)$$

When $n = 2, t_2 = 2\Delta t$, the distribution of the first, second, and third age groups is:

$$\begin{cases} p_2(t_2) = p_1(t_1) \left[1 - \int_0^{2\Delta t} f(x) dx \right] \\ p_2(t_1) = p_1(t_0) \left[1 - \int_0^{\Delta t} f(x) dx \right] \\ p_2(t_0) = p_1(t_1) \int_0^{2\Delta t} f(x) dx + p_1(t_0) \int_0^{\Delta t} f(x) dx \end{cases} \quad (5)$$

By analogy, when the scraper chain system runs $n\Delta t$ times, the distribution mathematical model of the age group is:

$$\begin{cases} p_n(t_n) = p_{n-1}(t_{n-1}) \left[1 - \int_0^{n\Delta t} f(x) dx \right] \\ p_n(t_{n-1}) = p_{n-1}(t_{n-2}) \left[1 - \int_0^{(n-1)\Delta t} f(x) dx \right] \\ \vdots \\ p_n(t_2) = p_{n-1}(t_1) \left[1 - \int_0^{2\Delta t} f(x) dx \right] \\ p_n(t_1) = p_{n-1}(t_0) \left[1 - \int_0^{\Delta t} f(x) dx \right] \\ p_n(t_0) = \sum_{i=0}^{n-1} p_i(t_{n-1}) \int_0^{(i+1)\Delta t} f(x) dx \end{cases} \quad (6)$$

The reliability of the scraper chain system is:

$$R = \sqrt[n]{\prod_{i=0}^n \left[1 - \int_0^{i\Delta t} f(x) dx \right]^{p_i(t_n)N}} = \prod_{i=0}^n \left[1 - \int_0^{i\Delta t} f(x) dx \right]^{p_i(t_n)} \quad (7)$$

In the formula, R is the reliability of the scraper chain system.

The mathematical model is used to calculate the reliability of the scraper chain system when the maintenance period of the scraper chain system is Δt , and the running time is t_n .

3. Simulated Analysis of Service Age and Reliability of Scraper Chain System

3.1. Serving Age Simulation Analysis of Scraper Chain System

The scraper chain system consists of a series of ring chains, and the service age distribution of the ring chains directly determines the service age of the scraper chain system [5] [6]. From the analysis in the previous section, the age distribution of circular chain plays a decisive role in the reliability of scraper chain system. When the scraper chain system transported four different kinds of coal materials, namely lignite, coking coal, anthracite and gangue, the service age of the ring chain in the scraper chain system is analyzed by simulation. The results are shown in Figure 3 to Fig. 6.

From Figure 3, we can see that when the scraper chain system transports lignite, after 19 months of

system service, the age distribution of the ring chain tends to be stable and closes to zero. The age distribution of the ring chain is mainly concentrated in the range of 0-19 months. It can be seen from Fig. 4 that when the scraper chain system transports coking coal, the age distribution of the ring chain tends to be stable and close to zero after the system has been in service for 15 months. The age distribution of the ring chain is mainly concentrated in the range of 0-15 months; it can be seen from Fig. 5 that when the scraper chain system transports anthracite coal, the age distribution of the ring chain tends to be stable and close to zero when the system is in service for 10 months. The distribution is mainly concentrated in the range of 0-10 months; from Figure 6, it can be seen that when the scraper chain system transports vermiculite, after the system is in service for 5 months, the age distribution of the ring chain tends to be stable and close to zero. The age distribution of the chain is mainly concentrated in the range of 0-5 months; the above phenomenon occurs because when the age of the scraper chain system reaches a certain period of time, all the ring chains in the system will fail, when the ring fails. After the chain is replaced, the age distribution of the ring chain will produce change, after repeated failure-replacement process, the age distribution of the ring chain tends to be stable; after comparative analysis of Figure 3 to Figure 6, it is found that when the scraper chain system transports lignite, the age distribution range of the ring chain is the largest. When transporting ganuge, the concentration range of the ring chain is the smallest. This is due to the fact that during the transmission of the scraper chain, the scraper advances the material and the relative displacement of the material and the circular chain occurs, and the hardness of the corresponding material is different. Differently, different degrees of hardness have different degrees of wear on the ring chain. The greater the hardness of the transport material, the faster the rate of failure of the circular chain, the shorter the time required replacing the new chain, the more concentrated the age distribution, and the opposite, the age distribution will be dispersed.

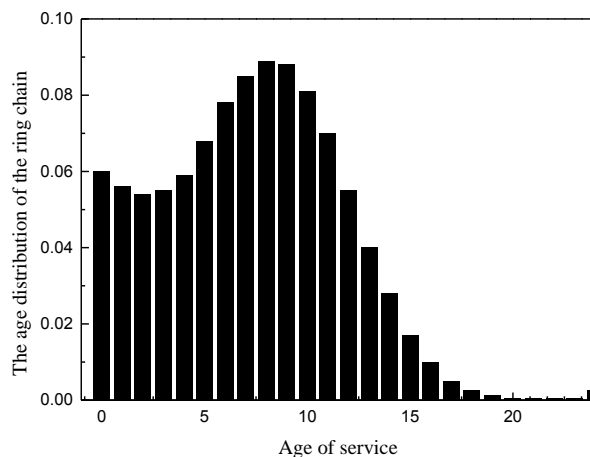


Figure 3. Age distribution of the ring chain during transport of fine coal

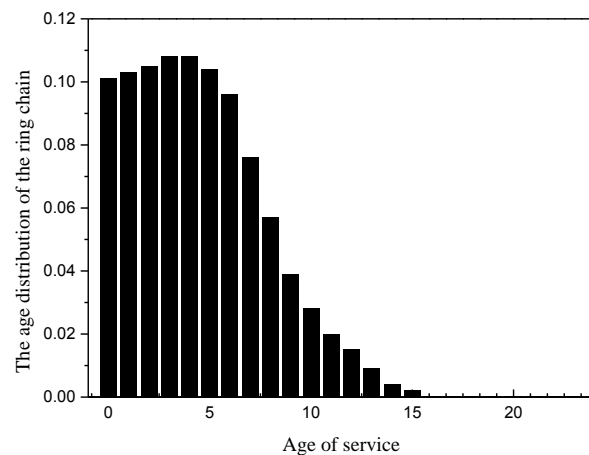


Figure 4. Age distribution of the ring chain during transport of raw coal

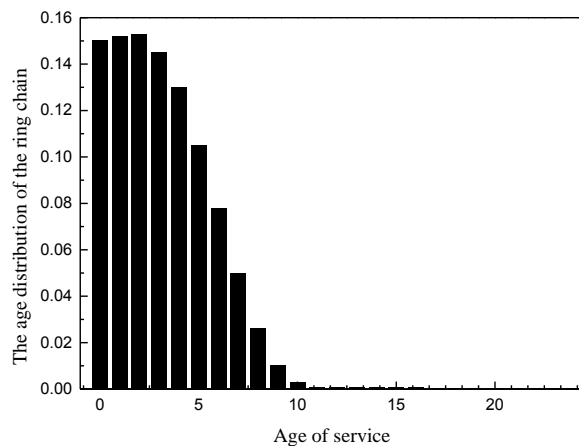


Figure 5. Age distribution of the ring chain during transport of middle coal

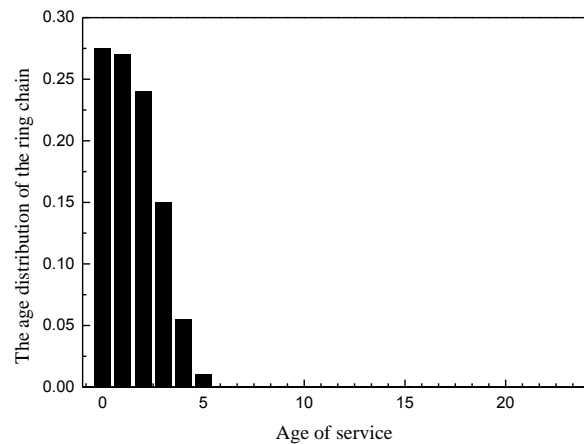


Figure 6. Age distribution of the ring chain during transport of waste rock

3.2. Analysis on the Reliability of Scraper Chain System

According to the reliability mathematical model of the scraper chain system. That is, equation 8 can be used to analyze the variation of reliability of scraper chain system when transporting different coal materials by using the analysis software MATLAB. This article analyzes the rule of reliability of the system when the scraper chain system is in service for 36 months, as shown in Fig. 7.

It can be seen from Fig. 7 that when the scraper chain system transports different materials, the reliability of the system is also not the same. According to the curve of the reliability of the scraper chain system, it can be divided into two phases: fluctuation and stability. In the fluctuation phase, the amplitude of oscillation will become smaller with the age of service, and finally it is in a stable phase. This is due to the fact that, at the beginning stage the ring chains are all new, and the failure rate of the ring chain is low. As the service age increases, the failure rate of the ring chain increases and the reliability of the scraper chain system decreases. Part of the ring chain fails, but because of the replacement of the failed ring chain, the reliability of the scraper chain system will increase. Over time, the ring chain failure and replacement process are repeated, so a fluctuation phase occurs. With the constant failure and replacement of the ring chain, the service age of the ring chain becomes diversified, and the system reliability will eventually enter a stable stage. After comparing the reliability change curves of different materials, it can be seen that when the scraper chain system transports different materials, the order of oscillation of the system reliability from long to short is lignite, coking coal, anthracite and gangue, and when entering the final plateau stage, the order of reliability from high to low is also lignite, coking coal, anthracite and gangue. This is due to the fact that different types of materials have different densities and different degrees of wear on the circular chain. That makes the frequency of changing the ring chain different. Therefore, when transporting different materials, the oscillation cycle is different and the system reliability is also different.

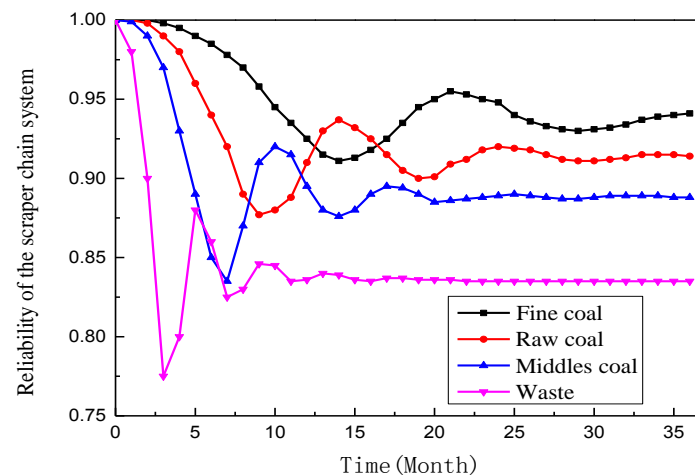


Figure 7. Change curve of system reliability when transporting different materials

4. Conclusion

This paper first analyzes the structure of the scraper chain drive system, and concludes that the scraper chain drive system is mainly composed of four subsystems connected in series, and the major subsystems are formed by connecting related components in series. Meanwhile, after analysis, it is concluded that the scraper chain system is the key factor affecting the scraper chain transmission system; then the reliability life of the scraper chain system is analyzed, and the age and reliability of the scraper chain system are simulated and analyzed.

Finally, the optimal maintenance period of the system for transporting different materials is obtained. After the above analysis, the following main conclusions are drawn:

(1) Through the reliability life analysis of scraper chain system, the distribution curve of Weibull density function of scraper chain system life is obtained when different materials are transported by scraper chain drive. The mathematical model of circular chain service age group and the reliability mathematical model of scraper chain system are obtained.

(2) Through the simulation analysis of service age of scraper chain system, it is concluded that when the scraper chain system carries lignite, coking coal, anthracite and gangue, the service age of circular chain is mainly between 0-19 months, 0-15 months, 0-10 months and 0-5 months respectively. Through the simulation and analysis of the reliability of scraper chain system, the variation law of system reliability is obtained when different materials are transported.

5. References

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