Mining Chain Failure Analysis and Quality Improvement

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Abstract. Mining chains are crucial transmission components for coal machine equipment, whose failures can directly affect the normal production of coal mines. The cause-factors of mining chain failure cases are summarized and analyzed. The fatigue life of chain is predicted by using the cumulative damage model based on miner's rule, and the results show that the fatigue life is seriously affected by operation. The corresponding quality improvement measures are put forward for the cause-factors, and are determined after full discussion and evaluation based on DRBFM.

1. Reasons for external loss of mining chain
Through background analysis, chain inspection, installation inspection, spectral analysis, mechanical testing, metallographic analysis, conducted special investigation and analysis of all cases of chain failure, determine the cause of chain failure as the basis for improving chain quality and technological innovation. The case studies show that the causes of chain failure mainly include the following factors.

1.1. Improper operation
The incorrect setting of the pre-tensioning force of the chain and the mismatch of the length of the paired chain of the conveyor can cause chain skipping, scraping, and premature wear of the chain caused by friction between the chain and the middle groove. No routine maintenance of the equipment was performed during the operation, such as inspection of chain pre-tensioning force, tightening scraper bolts, and whether the slime mixture blocked the sprockets. The link is not installed correctly. Use the wrong link chain. The brutal operation of the staff caused repeated impact on the chain. Due to the large stress, the chain is under tension in the downhole too long, the chain ring is easy to crack.

1.2. Corrosion effect
The corrosion pits that are generated when the chain is parked underground for a long time can easily cause the chain to fail. Deeper pits may act as a source of stress for fatigue striations. The downhole water is weakly acidic or the storage environment is corrosive, which can easily lead to corrosion pits in the chain. The chloride content of the water sample can be tested. For example, a chloride concentration of 1000 ppm produces a corrosion effect, and a PH value of 6.5 for downhole water detection accelerates corrosion.

1.3. Chain does not match
Mix old and new chains and sprockets. When the new chain caused by the design limitation does not match the old chain wheel, or when the chain passes through the chain wheel, the chain ring is repeatedly subjected to non-horizontal pulling force, and the E-type bolt of the assembling blade is also subjected to abnormal stress. Incorrect use of scrapers produced by other suppliers will also cause the links to withstand abnormal stresses.
1.4. High load/Overstress
Depending on the length of the working surface and the power of the equipment, a smaller chain is selected, and the chain ring is subjected to excessive stress, resulting in a decrease in the chain's fatigue life. It may be due to the unstable power supply to the mine, the conveyor stops, and the start-up is frequent, resulting in the chain undergoing excessive cyclic stress and reducing the service life of the chain. Collapse of the coal seam in the working face caused the chain to withstand abnormal tensile stress. Using higher pre-tensioning forces to make the chain fit can easily cause the link ring to withstand excessive stress.

1.5. Product defects caused by production process
The welding quality caused by different production processes is not ideal and the welding interface is weak. There is no "secondary stretch" or incorrect chain stretching. Without "secondary stretching", the link distance is too short, the chain is adjusted high when passing through the sprocket, and the degree of bending increases, causing the link to stretch. Forging vertical rings leave uneven edges after trimming to cause point contact, causing severe friction due to point contact, resulting in overheating of the link.

1.6. Raw material defects
Raw material defects can easily lead to premature failure of the chain. Frequent questions are inaccurate chemical compositions of materials, contaminated materials.

2. The fatigue life of mining chain
The above factors that induce chain failure all affect the fatigue life of the chain. This article assumes that other factors are under control. Apply the miner's law to consider the impact of load stress range on the chain's fatigue life.

2.1. The rules of miners
The miner law is one of the most widely used cumulative damage models. It points out that assuming that there are $k$ different stress levels, the average number of cycles leading to failure at the $i$th stress level $S_i$ is $N_i$, then the calculation of the damage rate $C$ is shown in Equation (1):

$$C = \sum_{i=1}^{k} \frac{n_i}{N_i}$$

In the formula $n_i$—Accumulation cycle number under stress level $S_i$
$C$—The life-cycle consumption rate caused by cycling at different stress levels usually occurs when the damage rate reaches 1.

Equation (1) can be used to calculate the ratio of life-time consumption at each stress level and their sum.

Usually a quantitative damage indicator $W_i$ can be defined as the product of the stress and the number of cycles under the stress, see equation (2):

$$W_i = S_i \times n_i$$

Assuming that the critical value of damage $W_f$ is the same at all stress levels, there is formula (3):

$$W_f = S_i \times N_i$$

Assuming a component damage threshold $W_f = 60$, according to equation (3) the assembly will cycle at 10 times at stress level 6 or 20 times at stress level 3 to reach fatigue life and will cause component failure. Thus, formula (1) can evolve to formula (4):
\[ C = \sum_{i=1}^{k} \frac{S_i \times n_i}{N_i} \Rightarrow C = \sum_{i=1}^{k} \frac{S_i \times n_i}{W_f} \] (4)

In the formula, \( C \) represents the proportion of accumulated damage reaching the critical value of damage.

2.2. Prediction of chain fatigue life

To calculate the fatigue life of a chain, the first thing to do is to simplify a series of complex loads. Including only the falling of the top coal seam, starting the conveyor, normal operation, the impact of the scraper on the big coal stuck on the headstock. Then use the rules of the miners to calculate the above data.

The miner's law requires a final fatigue test value for each stress level as a reference, so a fatigue test is performed at different stress ranges. The technical engineer obtains the number of chain cycles under each stress range from the S-N graph (recording of the number of cycles at a given load). It can be seen from the calculation that the fatigue life is severely affected by the operation, especially when large coals are stuck on the headstock, which has a very important influence on the chain.

Based on the above assumptions, we come to figure 1. This figure shows the effect on the estimated fatigue life and provides a deeper analysis. That is, with a conveyor length of 260 meters and a running speed of 1.8 meters per second, the scraper impacts the large pieces of coal stuck on the headstock and impacts the large pieces into small pieces, which have an effect on the fatigue life of the chain. If the large pieces of coal stuck in the nose need to be scraped 75 times by the squeegee to pass the squeegee, the large pieces of card are once every 20 minutes. In this case, the life of the chain is 7 months. If an oversized piece of coal gets stuck on the headstock, it takes 150 to 300 shots to make it into small pieces, and the carding frequency is every 15 to 20 minutes. The chain is reduced to 3 to 5 months.

![Figure 1. Effect of large coal blocking on headstock's fatigue life](image)

1. Scratch impact number is 75
2. Scratch impact number is 150
3. Scratch impact number is 300

If the prediction is more accurate, more information is needed. For example, the frequency of seizure of large coal, the size of large coal, how many times the scraper impacts can damage large blocks, and the additional fatigue test values of different stress ranges are used as reference.

3. Quality improvement of mining chain based on DRBFM

Based on the above analysis, it is possible to improve the quality of the mining chain through measures such as production process control, provision of comprehensive services, improved chain selection, and improved chain performance. It should be noted that before deciding on improvement measures for specific reasons, full discussion and communication should be carried out in the order in which DRBFM
(Design Review Based on Failure Mode) thinks (See Figure 2), to assess the impact of changes resulting from improvements or innovations on the upstream and downstream customers of the change chain and the final quality of the chain, so as to prevent and control the risk of change.

Figure 2. The DRBFM thinking process of improving the quality of the chain

3.1. Production process control
The quality of workers' self-control is the key to effectively control the production process. Through good quality of worker self-control, some mistakes in the production process can be avoided, for example, the welding quality is not good, the internal size is unqualified, the fluctuation of the hardness is changed, the second proofreading is not performed, the tensile test is unqualified, and the chain pairing is not suitable. The bending test is the most important test for testing the welding process and it needs to be carried out firmly. In the heat treatment process, more links need to be inspected to ensure that the link's hardness is as stable as possible. The investigation report on chain failure should be feedback to the workshop to help production to improve quality control.

3.2. Full service
The technician should help mine personnel to complete proper operation and maintenance, and provide them with the correct operation, correct maintenance and the importance of training. For example, the correct setting of the pre-tensioning force, the routine inspection of the chain pre-tensioning force, and the routine inspection of the damage, wear and looseness of the sprocket, the chain, the scraper and the attachment link. When the old and new sprocket or the old and new chain are working at the same time, observe that when using the squeegee from different manufacturers, it is necessary to pay attention to the compatibility of different products, and when the working surface has an inclination, properly install and correct the scraper.

3.3. Improving chain selection
The change in the load coefficient of the chain indicates that the different working surfaces should be chosen to use the most suitable chain. The selection process includes reference to consistent parameters and conditions of the work surface. The parameters to be considered include the length of the working surface, the height and thickness of the coal seam, the power of the conveyor motor, corrosion of groundwater, the hardness of the coal, and the ratio of the vermiculite. The relevant information from the mining party needs to be taken into consideration when selecting the chain.

3.4. Improving chain performance
Improve materials, select cleaner steel (less impurities, high purity), adopt steel with higher and harder alloy content, improve existing steel quality; optimized heat treatment, sub-zero quenching, new
induction heating process (local hardening); optimize welding, find welding defects through more
detailed analysis of production conditions of welding equipment, develop reliable nondestructive
inspection methods; surface treatment, resist corrosion, help lubrication (hot-dip zinc, zinc-chromium
coating, Flowserve anti-rust oil, paint, etc.).

4. Conclusion
The main causes of mining chain failure are improper operation, corrosion, chain does not match, high
load/tolerate excessive pressure, product defects caused by the production process, and raw material
defects. Usually the failure are caused by the combination of the above factors. By using the cumulative
damage model based on the rules of the miners, a scientific prediction of chain fatigue life can be made.
The actual data shows that the fatigue life is severely affected by the operation, especially when large
pieces of coal are stuck on the headstock and have a crucial influence on the chain. Regarding the causes
of chain external damage, corresponding improvement measures have been made from the aspects of
production process control, provision of comprehensive services, improvement of chain selection, and
improvement of the performance of the chain, and before the improvement is proposed, full discussion
and evaluation based on DRBFM should be adopted.

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