Harm and control of hydraulic oil pollution in coal mine machinery

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Abstract. Coal mining machinery such as shearer is one of the most important comprehensive mining equipment in coal mine. Once it breaks down, the consequences cannot be estimated. The data shows that about 2/3 of the faults in the hydraulic system of coal mine machinery are caused by the pollution of hydraulic oil. Therefore, this paper first analyzes the types and properties of various pollutants, then describes the harm of pollutants to the hydraulic system, and finally puts forward a comprehensive control scheme of hydraulic oil pollution, which provides a reference for engineering practice.

1. Introduction

According to the data, nearly 2/3 of the faults in the hydraulic system of coal mine machinery are caused by the pollution of hydraulic oil[1]. In recent years, experts at home and abroad have done a lot of research work on the pollution and control of hydraulic oil, including the analysis and detection of pollutants, the purification of hydraulic oil, and the formulation of pollution control standards[2]. This paper focuses on the types, properties, hazards and control measures of pollutants[3].

2. Types and properties of pollutants

2.1. solid pollutants----- solid particles

The common solid particles are diamond, big chip, silicon sand, volcanic ash, metal oxide and so on. Among them, diamond and metal oxides have higher hardness and are more harmful to components. Table 1 lists the common causes of solid particle pollution.

| Different particles | Mohs' scale of hardness | The reasons causing         |
|---------------------|-------------------------|-----------------------------|
| Diamond             | 9~10                    | Processing chip             |
| Large chips         | 4~7                     | Processing chip             |
| Silica sand         | 7                       | Environmental intrusion     |
| Volcanic ash        | 6.5                     | Environmental intrusion     |
| Metal oxide         | 9                       | System generated            |

The causes of solid particle pollution are divided into three aspects[4].
2.1.1. Residual pollution. Residual pollution, such as burr, chip and so on, generated during the manufacture and assembly of hydraulic parts.

2.1.2. Invasive pollution. Due to imperfect seals, harsh working conditions, and excessive dust, it has invaded the hydraulic system.

2.1.3. Generated pollution. Exfoliated particles, such as abraded hard metals, metal oxides, tungsten, cobalt and other metal particles, gels formed by aging of hydraulic oil and other pollutants generated by the system itself.

2.2. Water pollution
The data show that there are three states of water in oil: dissolved water, free water and emulsified water.

In recent years, more and more attention has been paid to the water pollution in the hydraulic system. The working conditions of the shearer are bad and the humidity is high. The water entering the oil will affect the formation of the lubricating oil film, resulting in a sharp decline in the lubricating performance and great harm.

2.3. Air pollution
When the absolute pressure drops to a certain value, if it is lower than the air separation pressure at this time, the air dissolved in the oil is forced to separate out, resulting in a large number of air bubbles, thereby forming a cavitation phenomenon; while when the pressure rises, this sometimes the air dissolves into the oil. the process of air sometimes separating and sometimes dissolving will cause great harm to the system. At the same time, if the air bubbles enter the high pressure area, the air bubbles will burst and cause the temperature to rise, which will cause the metal surfaces of the parts to be corroded and gas eclipse phenomenon.

3. Hazards of pollutants to hydraulic system

3.1. Hazards of solid particle pollution
Solid particle pollution is the main factor to shorten the service life and work failure of coal mining machines. It will cause gap blockage, failure of various valves, filter failure, etc. Small particles can even accelerate the wear of parts, scratch the seals, increase the leakage of hydraulic oil, and cause unpredictable economic losses. The solid particle pollution mainly includes the function failure caused by the surface wear of moving parts and the accelerated oxidation and deterioration of metal particles [5].

3.1.1. Function failure caused by surface wear of moving parts.
- Function failure of hydraulic pump and hydraulic motor. Under the condition of heavy load and small gap, solid pollutants will damage the lubricating oil film and scratch the surface, resulting in the decrease of lubricating performance; At the same time, a large number of metal particles will be produced, resulting in the decrease of outlet pressure, the increase of return oil volume, the increase of heat output, resulting in the decrease of efficiency, and even the failure of its function.
- Failure caused by wear of gear tooth surface. Gear engagement has the characteristics of heavy load and thin oil film. The solid pollutants entering the contact area of the tooth surface, especially those larger than the thickness of the oil film, will cause severe wear of the tooth surface, and the metal oxides with high hardness will scratch the surface. In addition, the instantaneous high temperature produced by meshing will make the tooth surface form a pit, and repeated actions will make the tooth surface fatigue damage, resulting in failure.
• Damage of sealing ring. The higher the pollution degree of solid pollutants, the greater the possibility of solid particles embedded in the friction surface, and the shorter the service life of the seal, the seal ring may scratch, peel off, and generate new pollutants.

3.1.2. *Metal particles accelerate oil oxidation.* The deterioration of the hydraulic oil will cause the moving parts to be stuck, the filter mesh to be blocked, the oil suction pressure to be increased, the viscosity of the hydraulic oil to be changed, and the acidity of the oil to be increased [6].

3.1.3. Test results of solid particle pollution.

Table 2. Purification effect of solid particles corresponding to the size of the gap.

| Element        | The effect                             |
|----------------|----------------------------------------|
| Pump           | 4 to 10 times longer life expectancy   |
| Valve          | The service life of different valves is increased by 5 ~ 300 times |
| Roller bearing | Fatigue life is extended 50 times      |
| Radial bearing | Fatigue life is extended 10 times      |

As shown in table 2, the service life of various components will be prolonged to varying degrees after the solid particles with the size of matching gap are purified. However, due to different working environment, different pollutant composition, different particle hardness and other reasons, the results of research on the influence of pollution degree on life vary greatly in different countries. Generally, according to NAS1638 standard, the pollution degree is reduced by one level and the life is doubled, as shown in table 3.

Table 3. The relationship between pollution degree and life span.

| Pollutant NAS 1638 standard (grade) | Life (years) |
|-------------------------------------|--------------|
| 11                                  | 0.63         |
| 9                                   | 2.5          |
| 7                                   | 10           |
| 5                                   | 40           |

3.2. *Hazards of water pollution*

The water in hydraulic oil, especially the free water, will destroy the formation of lubricating oil film, which will eventually lead to the wear on the moving surface of parts; the metal particles produced, especially copper or iron, will not only catalyze the oxidation and decomposition reaction of water and oil, but also generate acid corrosive substances, insoluble pollutants and other harmful substances (see table 4), which will corrode the surface of parts; after the water enters the hydraulic oil, it will cause the formation of lubricating oil film the compressibility becomes larger, the lubricity is reduced, and the action is unstable; At low temperature, small water droplets condense into ice particles, blocking the gap; at high temperature, water reacts with oil by oxidation, which will reduce the service life after modification; the additives in oil dissolve in water to increase the loss and reduce the oil performance.
### Table 4. Influence of metal particles on water pollution.

| Solid particles | Have water or no water | Time (h) | Acid value change |
|----------------|------------------------|----------|------------------|
| Iron           | No water               | 3500+    | +0.48            |
| Liron          | Have water             | 400      | +7.93            |
| Copper         | No water               | 3000     | +0.72            |
| Copper         | Have water             | 100      | +11.03           |

3.3. **Hazards of air pollution**

When air is mixed into the hydraulic oil, its bulk modulus of elasticity will be significantly reduced, which will seriously affect its performance; When encountering high pressure, cavitation will occur; It will cause the working failure of the electro-hydraulic servo valve; It will also cause the temperature of the hydraulic system to rise, resulting in the decrease of its viscosity and the increase of hydraulic oil leakage.

### 4. Comprehensively implement the pollution control of hydraulic oil

The hydraulic components in the hydraulic system constantly generate new pollutants, and the filter constantly filters out the pollutants. When the two reach a balance state, the pollution is controlled. In order to ensure the balance between the two, the following two aspects can be considered.

- Ensure that the larger particles are filtered out, and select the required filtering accuracy according to the sensitivity of hydraulic components to pollution.
- Small particles will increase wear and shorten the life of the pump. In order to keep the concentration of fine particles above a certain range of equilibrium state, partial filtration can be adopted.

In addition to ensuring the balance state, it is necessary to reduce and avoid the pollution to the oil. The common methods are as follows:

#### 4.1. Reduce latent pollutants

- Strictly inspect the pollution degree of components. In the process of transportation and storage, the human factor is very important. Always pay attention to the good sealing.
- Before assembly, the parts shall be cleaned to ensure that the molding sand hidden in the pump housing is cleaned.
- Strengthen oil management. Samples shall be taken in advance to check whether they are qualified, and then filtered again[7].

#### 4.2. Prevent the invasion of pollutants

It is mainly controlled from three aspects of assembly, use and maintenance:

#### 4.2.1. The following two points shall be considered during assembly.

- Prevent environmental pollution. The pressure in the assembly shop shall be higher than that outside to prevent dust pollution in the shop.
- Use "dry assembly" method. Use dry compressed air to blow dry the parts before assembly, avoid using fibrous objects such as cloth strips to wipe the parts, so as to avoid floc entering the system[8].
4.2.2. The following two points shall be considered during the use.
- Spanner, sling, refueling container, filter screen and other tools shall be kept clean to prevent pollutants from entering.
- The air filter set on the oil tank shall be replaced regularly, and the drain valve set on the bottom of the oil tank shall be drained regularly[9].

4.2.3. The following two points shall be considered during maintenance.
- When the system is in trouble and needs to be removed or overhauled, the parts that are not repaired immediately shall be sealed and the upper part of the oil tank shall be protected before maintenance[10].
- Pay attention to dust control, clean the coal dust through a series of means, and open the oil port for maintenance.

5. Conclusion
This paper first analyzes the types and properties of pollutants, then expounds the hazards of various pollutants to the hydraulic system, and finally puts forward targeted measures from the two aspects of reducing latent pollutants and preventing the invasion of pollutants, and comprehensively implements the pollution control scheme of hydraulic oil, which provides certain reference for the engineering practice.

References
[1] Yuan Ye 2009 China. J. Farm Machinery. 03 91-92
[2] Yu Hailong and Zhang Zhenzhen 2012 China. J. Technology Wind. 24 71
[3] Wu Zhimin 2017 China. J. Internal Combustion Engine & Parts. 20 88-89
[4] Li Qiang 2017 China. J. Agricultural Mechanization Using & Maintenance. 06 61
[5] Li Kezhong 2011 China. J. Construction Machinery & Maintenance. 09 190-1
[6] Huang Jian 2008 China. J. Equipment Manufacturing Technology. 02 87-89
[7] Wu Shiyou and Wang Shufang 2008 China. J. Equipment Manufacturing Technology. 03 80-82
[8] Zeng Ruwen 1995 China. J. Lubrication Engineering. 04 65-66
[9] Yang Zaizhong 2017 China. J. Agricultural Mechanization Using & Maintenance.
[10] Jiang Shengqun 2015 China. J. Science & Technology Vision. 35 191