ISSN 2616-5767 Vol.8, Issue 3: 8-12, DOI: 10.25236/AJETS.2025.080302

The Application of Lubricating Oil Particle Size Analysis Technology in the Condition of CSP Line High-pressure Hydraulic System Pump Failure

Jing Wang, Jianfeng Wu, Yanjun Zhou*

Valin Lianyuan Iron and Steel Co, Ltd, Loudi, 417000, Hunan, China
**Corresponding author*

Abstract: *The CSP high-pressure hydraulic pump is the 'industrial heart' of continuous casting and rolling production lines. Its precise pressure control directly determines the millimeter-level thickness tolerance of steel plates and the rate of micro-defects, making it crucial for ensuring the quality of high-end sheet materials. Therefore, applying oil particle size analysis technology, which is essential for detecting wear conditions in steel equipment, to ensure the normal operation of the CSP high-pressure hydraulic pump has become an urgent topic of discussion.*

Keywords: *Lubricant Particle Size Analysis Technology, High-Pressure Hydraulic Systems, Oil Pumps*

1. Introduction

The heart of the CSP high-pressure hydraulic system - the oil pump, is responsible for the power source of the continuous casting and rolling production line. Its excellent performance is the key to ensuring the stability and product quality control of the entire process of thin slab from steel solidification to hot rolling into coils. In the core process of compact strip steel production (CSP), the pump unit utilizes high-precision pressure flow composite control technology to achieve rapid dynamic response in the high-pressure range, ensuring that the crystallizer hydraulic vibration system can accurately replicate non sinusoidal waveforms. This plays a crucial role in controlling the depth of vibration marks on the surface of the casting billet within the ideal range. By adopting innovative plunger pair plasma cladding strengthening technology (NiCr-Cr3C2 gradient coating), the micro motion wear of key friction pairs under high pressure impact is effectively reduced, greatly improving the service life of the sector roller gap adjustment hydraulic cylinder. This study integrates multiple physical field monitoring systems such as ultrasonic cavitation detection, online ferrography analysis, and vibration order tracking technology to construct a real-time three-dimensional feature matrix of pump body wear status. The diagnostic accuracy of typical faults such as uneven wear of sliding shoes and cavitation of the distribution plate is relatively high. Industrial data shows that the optimized CSP hydraulic system improves the dynamic control accuracy of the rolling mill roll gap. In the context of intelligent upgrading, the oil pump equipped with a digital twin operation and maintenance platform achieves a remaining life prediction error of ≤± 48 hours through online oil detection data aggregation, reducing preventive maintenance costs and fully reflecting its strategic value as the "industrial bloodline" in modern metallurgical processes [1].

On the map of modern industrial production, the continuous casting and rolling production line (CSP) is an indispensable core component, and its stable operation plays a decisive role in the efficiency and safety of steel production. The stable operation of the oil pump in the CSP high-pressure hydraulic system has immeasurable strategic significance for ensuring the smooth operation of production lines in the steel industry.

2. Particle size analysis technology for lubricating oil

The particle size analysis technology of lubricating oil is the core diagnostic method to ensure the stable operation of the oil pump in CSP high-pressure hydraulic system. In the micro level dynamic sealing of high-precision friction pairs (port plate/cylinder body, slide shoe/inclined plate) in axial piston pumps, solid particles carried by the oil can cause irreversible progressive damage. This technology utilizes a particle contamination grading system built according to the NAS 1638 standard,

ISSN 2616-5767 Vol.8, Issue 3: 8-12, DOI: 10.25236/AJETS.2025.080302

which enables precise mapping from microscopic wear characteristics to macroscopic failure modes.

Particle size analysis can effectively identify early abnormal wear of plunger pumps: when the proportion of 5-15 μ m metal particles in the oil suddenly increases, it indicates that the plunger pair has entered the boundary lubrication failure stage; The aggregation of 15-25 μ m spherical abrasive particles indicates the expansion of micro pitting corrosion in inclined disc thrust bearings; The detection of non-metallic particles above 50 μ m directly exposes the risk of seal aging or external pollutant invasion. By monitoring the particle size distribution characteristics online, typical faults such as plunger cylinder strain and sliding shoe sticking can be predicted in advance.

This technology distinguishes the differential mechanisms of mechanical wear, chemical corrosion, and cavitation damage by analyzing particle morphology and material properties. The ferromagnetic sheet-like particles indicate the normal running in wear of the plunger pair, while the appearance of copper alloy cutting like particles indicates the structural peeling of the Babbitt alloy layer [2]. By combining NAS 1638 multi-channel pollution level assessment, the remaining service life of the oil pump can be accurately determined, providing a scientific basis for developing predictive maintenance strategies[3].

Under high pressure cycling conditions above 35MPa in CSP systems, particle size analysis technology has become the core control node for hydraulic system health management. The real-time monitoring capability not only prevents sudden jamming faults, but also extends the service life of the key friction pair of the plunger pump by 2-3 maintenance cycles by controlling the cleanliness level of the oil, setting a new technical benchmark for the reliability engineering of high-pressure hydraulic systems.

3. Application Examples

At around 10:40 on March 15, 2025, the AGC of the F1 rolling mill and F3 rolling mill in a certain secondary unit's CSP line experienced consecutive servo valve adhesion alarms. However, when the servo hydraulic valve was restarted, there was no response, and the adhesion alarm was triggered again. Switching to the backup servo valve control was still ineffective. After checking the PLC control cabinet, there were no abnormal alarms. After restarting the PLC system, the fault persisted. The faulty servo valve plug and line power supply were checked and found to be normal. The faulty servo valve was immediately replaced and put into testing. During the recovery process, other racks successively experienced AGC and active sleeve multiple servo valve adhesion alarms, and the CSP line could not continue production and was forced to shut down. As is show in Table 1 and Table 2.

Table1 F4 and F5 AGC servo valves have no feedback

AGC servo valves					
		Drive Side A	Drive Side B	Operator Side A	Operator Side B
F1	Output	0.00%	-11.94%	-19.17%	0.00%
	Feedback	2.02%	-5.47%	0.80%	-0.11%
F2	Output	0.00%	0.00%	0.00%	0.00%
	Feedback	-0.61%	5.30%	9.14%	-0.41%
F3	Output	0.00%	0.00%	0.00%	0.00%
	Feedback	0.14%	0.34%	5.48%	0.89%
F4	Output	0.00%	-3.02%	-100.00%	0.00%
	Feedback	-0.23%	-0.38%	2.42%	5.33%
F5	Output	-100.00%	-100.00%	1.21%	0.00%
	Feedback	4.42%	8.97%	1.41%	2.30%
F6	Output	0.00%	0.00%	0.00%	0.00%
	Feedback	6.44%	10.16%	3.83%	1.16%
F7	Output	0.00%	0.00%	0.00%	0.00%
	Feedback	3.45%	-1.55%	2.41%	2.36%

Table 2 F1 and F3 AGC servo valves without feedback

AGC servo valves					
		Drive Side A	Drive Side B	Operator Side A	Operator Side B
F1	Output	0.00%	0.00%	0.00%	0.00%
	Feedback	1.75%	-2.00%	-100.00%	-2.27%
F2	Output	0.00%	-4.50%	0.00%	-9.35%
	Feedback	1.25%	-2.61%	4.95%	-1.22%
F3	Output	0.00%	-13.75%	-100.00%	-100.00%
	Feedback	-0.38%	-8.53%	3.78%	-2.28%
F4	Output	1.01%	0.00%	1.41%	0.00%
	Feedback	0.28%	0.72%	2.41%	1.45%
F5	Output	0.00%	-10.70%	0.00%	-5.34%
	Feedback	3.78%	-0.63%	1.27%	-0.80%
F6	Output	0.00%	-3.45%	0.00%	-87.24%
	Feedback	0.70%	0.31%	0.56%	-0.38%
F7	Output	-3.57%	0.00%	-2.08%	0.00%
	Feedback	-0.14%	0.58%	0.89%	2.41%

The second level unit immediately organized an investigation of the hydraulic station system. Around 09:21, the HMI historical alarm screen showed that the CSP line's high-pressure hydraulic station 5 #, 3 #, and 1 # oil pump filters had successively experienced blockage alarms, and there were no power or control system alarms.

The unit quickly took samples and sent them to the testing laboratory for inspection of the high-pressure hydraulic station oil sample of the CSP line, in order to diagnose the wear condition of the equipment.

The ZHKT-2A desktop particle size counter was used in the testing laboratory to measure the particle size data of the hydraulic station oil sample as follows in Table 3.

Table 3 Test data

sampling location	Date of sampling	Test data					
		grade	5μm	15μm	25μm	50μm	100μm
Middle of the tank	3.15	7	17973	2353	660	146	26
Bottom of the tank	3.15	7	28960	3440	546	100	6
The valve platform	3.15	9	27233	4520	1496	400	6

According to the current hydraulic oil cleanliness management regulations in the factory area, the standard judgment for the cleanliness level of the conventional hydraulic system is level 8. The oil sample detection data of this hydraulic station meets the basic requirements in form, so the oil sample was initially judged to be qualified. However, combined with the large-scale stuck valve accident that occurred in the high-pressure hydraulic system of the CSP line, this conclusion has a standard applicability error. We need to re evaluate the special requirements of the high-pressure servo system based on the NAS 1638 standard. Technical analysis shows that the testing personnel did not fully consider the differences in equipment operating conditions and mistakenly applied the standard error set applicable to ordinary hydraulic systems to a 21MPa level servo high-pressure system.

According to clause 4.3 of the NAS 1638 standard, the pollution level of high-pressure servo hydraulic systems should be strictly controlled within the range of 4-6 levels, and the threshold for particle count ≥ 5 μ m is only 1/20 of that of conventional systems (320 particles/mL). After testing, the pollution levels of the three different spatial locations in the oil sample have all exceeded the upper limit of level 6. The concentration of particles ≥ 5 μ m exceeds the allowable value of the high-pressure system, and the system cleanliness has constituted a substantial unqualified state.

The analysis of particle distribution characteristics shows that the proportion of pollutants in the 5-15 μ m range is significantly abnormal. The hard particles within this particle size range not only accelerate the abrasive wear of the plunger pump friction pair, but also form a dense accumulation layer on the surface of the filter element due to their coupling effect with the system working pressure. This dynamic blockage mechanism can lead to typical fault characteristics such as pressure pulsation and flow attenuation in the system, which are highly correlated with the observed oil pump filter blockage and servo valve non feedback faults on site.

The 5-15 μ m particle group, as a sensitive pollutant in the servo system, not only violates the

ISSN 2616-5767 Vol.8, Issue 3: 8-12, DOI: 10.25236/AJETS.2025.080302

technical red line of NAS 1638 standard, but also constitutes a dual damage path of abnormal wear of the hydraulic station oil pump and functional failure of the filter element.

After data analysis and on-site investigation, as expected, fine copper powder was detected in the oil inlet pipe of the high-pressure hydraulic system's oil pump, and a small amount of copper powder was also found in the overflow pipe. There were also fine copper powder distributions inside the pump casing. There is wear and pitting on the oil distribution plate and plunger slide shoe. The filtering effect of the filter element at the outlet of the high-pressure oil pump is not ideal, resulting in copper powder particles smaller than 10 μ m infiltrating the hydraulic system pipeline, thereby blocking the 3 μ m filter element of the servo valve pilot stage, causing instability in the control oil circuit, and ultimately causing the servo valve to adhere and trigger an alarm, becoming the direct cause of the accident. As is show in Figure 1, Figure 2 and Figure 3.

Figure 1 Pump Overflow Pipe

Figure 2 Bottom of Pump Inlet Pipe

Figure 3 Inside the pump casing

On site technicians immediately organized the replacement of servo valves, and at the same time, replaced all oil pump outlet filter elements and faulty valve control oil filter elements in the hydraulic

ISSN 2616-5767 Vol.8, Issue 3: 8-12, DOI: 10.25236/AJETS.2025.080302

station (a total of 13 hydraulic valves and 15 filter elements were replaced). 17: 43 points, production resumed after zero adjustment simulation of the rolling mill.

Lubricant particle size analysis technology is an advanced diagnostic tool that evaluates the wear condition and potential faults of mechanical equipment by analyzing the particle size, quantity, and type in the oil. In the high-pressure hydraulic system of CSP production lines, the wear and failure of oil pumps are often difficult to detect in a timely manner through routine inspection methods. However, the application of lubricant particle size analysis technology enables engineers to quickly identify abnormal wear particles inside the oil pump through microscopic analysis of oil samples, thereby accurately determining the nature and degree of faults.

The scientific nature of this technology lies in its reliance on the principle of photoresist, which provides reliable data support for fault diagnosis through precise particle counting and classification. Its accuracy is ensured through advanced analytical instruments and standardized testing procedures, ensuring the repeatability and accuracy of the analysis results. These characteristics make the particle size analysis technology of lubricating oil highly practical in equipment maintenance and fault prevention.

The simplicity of the operation process of this technology is another significant advantage. Through standardized sampling, testing, and analysis processes, technicians can complete the processing and analysis of oil samples in a short amount of time without the need for complex equipment or lengthy training. The improvement of execution efficiency means that the production line can obtain fault diagnosis results in the shortest possible time, so as to quickly take maintenance measures, reduce downtime, and improve production efficiency.

In practical applications, the particle size analysis technology of lubricating oil is like the "eagle eye" of equipment operation monitoring, helping engineers to understand the wear and tear status inside the equipment, predict potential faults, and achieve preventive maintenance. For example, in a certain oil pump fault diagnosis, through the analysis of lubricating oil particle size, technicians found abnormal iron filings in the oil, indicating the presence of metal component wear inside the oil pump. Further analysis of particle size and shape can determine the specific components and degree of wear, providing clear direction for maintenance work. Through timely maintenance, more serious equipment damage and production accidents have been effectively avoided, ensuring the stable operation of the production line.

4. Conclusion

In summary, the application of lubricant particle size analysis technology in the diagnosis of oil pump faults in high-pressure hydraulic systems of CSP production lines not only improves the accuracy and efficiency of fault diagnosis, but also significantly reduces equipment failure rates and production costs through preventive maintenance, which is of great significance for improving the economic benefits and safety of the entire production line.

References

[1] Liu K, Wang S Y, Li W. Fault Analysis and Improvement of High Pressure Hydraulic System in Rolling Mill [J]. Science and Technology Wind, 2017, (03): 127.

[2] Chen Y L, Wei H F, Cheng Z H. Analysis and Research on Channel Pollution in Oil Particle Counter Detection [J]. Mechanical Science and Technology, 2017, 36 (S1): 75-78.

[3] Zhao J Y, Cao C, Wang H, etal. Current situation and intelligent development trend of high power liquid supply system of hydraulic support [J]. Journal of China Coal Society, 2025, (1): 676-693