Analysis and Improvement Research on Oil Leakage Mechanism of Large Bore Engine Oil Seal

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Abstract: This article conducts a systematic mechanism analysis on the continuous oil leakage of the rear oil seal of the 16M33 series diesel engine used for power generation after running for about 40 minutes under rated conditions during in plant testing. Based on the study of fault phenomena and key parameters, the root cause of oil leakage was deeply analyzed from multiple dimensions such as structural dynamics, tribology, and assembly technology. It was identified that the main causes were the excessive runout of the flywheel housing, uneven pressure of the oil seal spring, and mismatched surface roughness of the crankshaft. Based on this, a comprehensive improvement plan covering structural optimization, process innovation, and standard reconstruction was proposed. Through theoretical calculations and bench tests, the improvement measures proposed in this study have effectively achieved the goal of reducing the failure rate of such oil seals by 80%, and provide important references for the reliability design of rotary shaft seals in large bore engines.

Keywords: Diesel Engine; Oil Spill; Oil Seal; Reliability

1. Background

As the core power source for power generation, ships, and heavy machinery, the operational reliability of large bore diesel engines is crucial. As a key component of the engine lubrication system seal, the failure of the rotary shaft oil seal not only causes resource waste and environmental pollution, but also may trigger chain reactions such as insufficient lubrication and increased component wear, seriously threatening the long-term stable operation of the engine [1~2].

The 16M33 series diesel engine for power generation has a rated speed of up to 1800r/min and a main oil passage oil pressure of 400-650kPa, which places extremely high demands on the dynamic sealing performance of the rear oil seal. During the test run in the new factory, the rear oil seal experienced sustained oil leakage within a short period of time under rated operating conditions, exposing design or process defects in the sealing system under high-speed and high oil pressure conditions. The issue of bulk oil leakage in the rear oil seal has a significant impact on the quality and efficiency of the production process. In response to these problems, this article conducts an in-depth mechanism analysis of the rear oil seal oil leakage problem and seeks effective improvement solutions, which has important engineering practical value [3~4].

2. Analysis of Oil Leakage Fault Mechanism

2.1 Structural and Dynamic Factors

Flywheel shell runout and coaxiality deviation: "Large flywheel shell runout" is still the core factor causing oil leakage. The excessive radial runout of the flywheel housing directly causes a serious deviation between the center of the oil seal seat hole fixed on it and the crankshaft rotation center. The oil seal lip is forced to produce periodic eccentric wear with the crankshaft journal, which destroys the uniform and stable lubricating oil film between the lip and the journal, forms local dry friction, accelerates lip wear, and causes sealing failure in a short period of time.

Table 1. Measured Values of Flywheel Housing Runout for Faulty Machines

measurement position	measured value	marker point
6 o'clock direction	0	A
3 o'clock direction	0.45mm	B
12 o'clock direction	0.84mm	C
9 o'clock direction	0.45mm	D

As shown in Table 1, the total runout is greater than 0.84mm, exceeding the runout requirement by 0.4mm.

The influence of crankcase pressure and oil pressure: The main oil passage oil pressure of up to 650kPa creates a huge static pressure behind the oil seal. If the radial clamping force of the oil seal spring is not sufficient to balance this pressure, oil is easily leaked from the micro gap between the lip and the shaft neck.

2.2 Factors Related to Oil Seals and Fittings

Poor consistency of oil seal spring: In the presence of flywheel housing jumping, the spring needs to provide continuous, stable, and sufficient radial clamping force to compensate for eccentricity. If the spring pressure is insufficient or uneven, it will directly lead to local leakage, as shown in Table 2.

Table 2. Actual Measured Values of Oil Seal Spring Length

	Drawing requirements	measured value
1 # Spring	557±2.5mm	556.7mm
2 # Spring	557±2.5mm	557.6mm
3 # Spring	557±2.5mm	578.1mm

The surface roughness of the crankshaft is seriously low: we measured and found that the surface roughness of the crankshaft journal of 6 faulty machines is about Ra0.102 μ m, which is lower than the national standard requirement (Ra0.2~0.8 μ m). Low crankshaft roughness can lead to loss of lubricating oil film retention ability and a sharp increase in frictional heat. A very thin and stable lubricating oil film is required between the oil seal lip and the shaft neck for lubrication and heat dissipation. Appropriate micro protrusions (with a certain degree of roughness) can help maintain this oil film like "micro oil storage pits". When the surface is too smooth (Ra0.102 μ m), this oil film cannot be stably formed and maintained, and the lip and journal are prone to transition from fluid lubrication to boundary lubrication or even dry friction state. When the contact surface between the crankshaft and the oil seal lacks effective lubrication, the frictional force between the lip and the ultra smooth journal will significantly increase, generating a large amount of frictional heat. This leads to a rapid increase in temperature in the lip contact area, which may exceed the instantaneous tolerance limit of fluororubber, causing Joule heating effect (thermal hardening), softening, and even ablation of the material, thereby permanently damaging its sealing performance in a short period of time, as shown in Figure 1.

Figure 1. Actual Measurement of Roughness on the Installation Surface of the Crankshaft Rear Oil Seal

The "pumping effect" is obstructed: One microscopic mechanism of action of the oil seal lip is to use its blade shape and microscopic texture of the shaft to produce an effect of pumping leaked oil back into the tank. The excessively smooth surface makes it impossible to effectively establish this effect.

Poor lip tracking performance: In the presence of jumping, the oil seal lip needs good elasticity to track the instantaneous deflection of the shaft. The changes in friction and high temperature caused by excessively smooth surfaces can weaken this dynamic following ability. Oil seal material and adaptability to working conditions: The temperature resistance of fluororubber (FKM) is severely tested when the lip experiences abnormal high temperatures due to the above reasons. Local overheating is the direct cause of its rapid failure.

2.3 Assembly Process Factors

Irregular assembly operations, such as deformation of the skeleton, lip scratches, or spring detachment, are common causes of early failure, as shown in Table 3.

Table 3. Summary of Failure Modes and Mechanism Analysis of Oil Seal Leakage

failure mode	**Potential mechanism**	**Supporting phenomena/parameters**
Continuous oil flow	1. The flywheel housing is roughly unevenly worn due to jumping; 2. Low crankshaft roughness leads to poor lubrication and high temperature; 3. The spring is too loose or partially ineffective, and the clamping force is insufficient; 4. Improper assembly leading to lip damage;	Short term occurrence under rated operating conditions, new machine test run

Occurred in a short period of time	1. Low roughness and jumping overlap, quickly causing high-temperature ablation of the lip; 2. Initial damage caused by assembly process;	Appears after running for about 40 minutes
Abnormal lip wear/erosion	1. The roughness of the shaft neck Ra0.102 is severely low; 2. The coaxiality of the system exceeds the tolerance;	The crankshaft roughness is Ra0.102m, and the flywheel housing has large runout

3. Improvement Plan Design and Implementation

3.1 Optimization of Crankshaft and Flywheel Housing System

(1) Strictly control the runout of the flywheel housing: the total runout is strictly controlled within 0.4mm.
(2) Correction of surface characteristics of crankshaft journal: Adjust the surface roughness of the journal at the fit between the crankshaft and the oil seal lip from Ra0.102 μ m to the ideal range of Ra0.2~0.8 μ m. This can be achieved through precision grinding combined with honing technology to create a suitable microstructure that can store lubricating oil.

3.2 Improvement in Oil Seal and Spring Design

(1) Upgrading Oil Seal Structure: Adopting a combination oil seal to improve the sealing performance of the structure.
(2) Improving Spring Performance Consistency: Implement 100% pressure sorting for oil seal springs to ensure consistency.

3.3 Standardization of Assembly Processes and Innovation of Tools

(1) Research and development of specialized installation fixtures: Design and manufacture automated installation tools for crankshaft rear oil seals to achieve synchronous installation and testing.
(2) Standardize assembly process: Strictly implement cleanliness control and lubrication management.

4. Conclusion and Prospect

This article deeply analyzes the oil leakage fault of the rear oil seal of the 16M33 diesel engine and reveals a key but easily overlooked mechanism: in the presence of system jumping, the loss of lubricating film and abnormal frictional heat caused by the low surface roughness of the crankshaft journal (Ra0.102 μ m) are one of the fundamental reasons for the short-term ablation failure of the oil seal under rated operating conditions. Based on this, this study proposes a collaborative improvement plan that focuses on correcting crankshaft roughness to a reasonable range, and synergistically controlling runout, improving component consistency, and standardizing assembly processes.
This solution overturns the misconception that "the smoother the surface, the better the seal", and achieves the goal of reducing the failure rate by more than 80% within two months after implementing the improvement, solving the problem of batch oil leakage of the oil seal during factory testing.

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