Discussion on the Frequent Burning and Erosion of Marine Medium-Speed Diesel Engine Valves: A Case Study of MAR 8N330 Diesel Engine

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Abstract: In the practice of ship management, valve burning and erosion is a common and adversely affecting incident, which can lead to a series of serious consequences. This article analyzes the frequent burning and erosion of medium-speed diesel engine valves from seven aspects: the harsh working conditions of the valves, the impact of environmental temperature, the impact of cylinder sealing status, the corrosion of valves by low-quality fuel oil, the influence of the intake and exhaust system, the impact of high or too low load operation, and the influence of valve clearance and sealing surfaces. Corresponding prevention and control measures are proposed. This provides beneficial ideas and reference for decision-making for engine room personnel to smoothly handle valve burning and erosion faults and ensure the safe navigation of ships.

Keywords: Marine Diesel Engine; Valve Burning and Erosion; Causes; Measures

1. Introduction

Valve burning and erosion is a common malfunction in diesel engines, posing significant maintenance challenges for marine engineers. Colleagues in China have extensively researched this issue and summarized useful experiences. The main diesel engine model on my ship is MAR 8N330, with a rated speed of 400r/min. Every time the ship operates in the Middle East region, the phenomenon of valve burning and erosion occurs frequently. In severe cases, one or two valves may burn out within a day (see Figure 1 and Figure 2), greatly increasing the workload of the crew and the consumption of spare parts. Based on recent work practice, by frequent replacement, inspection, and analysis of valves, this paper summarizes several reasons for frequent valve burning and erosion and proposes corresponding solutions.

Figure 1. Mild Erosion

Figure 2. Severe Erosion

2. Harsh Working Conditions

2.1. Cause Analysis

In ship diesel engines, valves and valve seats are among the parts with the harshest working conditions. The valve disc and the seat base are part of the combustion chamber wall, subject to high temperature and pressure from combustion gases. Especially for exhaust valves, due to heating by exhaust gas flow, the temperature is very high; for turbo- charged marine diesel engines, the average temperature of the exhaust valve disc can reach 650-800°C, and the intake valve disc 450-500°C. Excessive temperatures can reduce the mechanical properties of metal materials and cause thermal deformation. When the valve seats, due to the elastic deformation of the valve and seat, vibration of the valve spring, and the torsional action of the valve spring coil, shearing and torsional slip occur between the valve face and seat. This slip causes dry friction between the valve face and seat, and the peeling metal particles, ash, and carbon particles further exacerbate wear.

2.2. Prevention and Control Measures

Since valves and seats work under high temperature, impact, wear, and corrosion conditions, valves are made of heat-resistant alloy steel (such as nickel-based heat-resistant alloy steel), while seats are made of alloy cast iron or heat-resistant alloy steel. Diesel engines with high supercharging and burning heavy oil also have cobalt-based hard alloy welded on the valve and seat surfaces. The valve seat uses drilled water cooling and has air grooves near the sealing surface, containing scavenging air. If the sealing surface leaks, it can prevent erosion by high-temperature exhaust gases.

Moreover, choosing the appropriate valve-to-seat fitting method is crucial in slowing down valve burning and erosion. There are three fitting methods for the valve face to the seat: full contact, outer contact, and inner contact. This engine uses outer contact, where the valve face cone angle is 0.5°~1° smaller than the seat cone angle. This method creates a small contact area, good sealing, and the inner side of the valve face and seat does not contact the combustion gases [1]. Arching deformation of the valve disc under the action of high-pressure gases makes the inner side of the valve face contact the seat, reducing contact stress and increasing heat dissipation. However, after grinding, it was found that the valve line surface was low. Adding a chamfer on the outer circumference of the valve will raise the valve face, ensuring proper contact and sealing with the seat.

3. The Impact of Ambient Temperature

3.1. Cause Analysis

Under the rated speed of the main engine, the air temperature discharged from the turbocharger's compression end is 130-180°C. This requires cooling of the air compressed by the turbocharger to increase its density, ensuring optimal combustion conditions [2]. The diesel engine manual for this ship specifies that the air temperature before entering the engine after cooling should be around 32°C. However, in the Middle East region, the ambient temperature often remains above 30°C, meaning that seawater temperature is also often above 30°C, making it impossible to ensure the required scavenging air temperature. Typically, for every 1°C increase in diesel engine intake air temperature, the exhaust temperature rises by 3°C. An increase in ambient temperature inevitably leads to a higher exhaust temperature, which can easily cause valve burning and erosion.

3.2. Prevention and Control Measures

Crew members should regularly clean the air cooler and maintain the automatic temperature control valve to ensure it is in good working condition. This helps to meet the required scavenging air temperature and improve ventilation quality.

4. The Impact of Cylinder Sealing Status

4.1. Cause Analysis

Each diesel engine model has a fixed compression ratio, i.e., the volume ratio of the cylinder before and after gas compression. Generally, in medium-speed diesel engines, the gas entering the cylinder reaches a pressure of 3-6MPa (also known as the diesel engine compression pressure) and a temperature of 600-700°C at the end of compression, instantly igniting the fuel injected into the cylinder. If the cylinder sealing is poor, the compression pressure will decrease, leading to a lower temperature at the end of compression. This causes delayed combustion and afterburning, resulting in abnormally high exhaust temperatures [3].

4.2. Prevention and Control Measures

Regularly measure the compression pressure of each cylinder and maintain the diesel engine's valves, pistons, and cylinder liners to ensure good cylinder sealing [4].

5. Corrosion of Exhaust Valves by Low-Quality Fuel Oil

5.1. Corrosion Cause Analysis

The use of low-quality fuel oil is an important technological achievement in the development of marine diesel engines. It significantly reduces the operational costs of ships while making reasonable use of petroleum resources. However, poor handling of fuel oil or inadequate daily management can cause many problems.

Corrosion by vanadium in low-quality fuel oil. The ship uses 380Cst fuel oil, and due to the high viscosity and long ignition delay of the oil in the Middle East, it contains higher levels of vanadium, sodium, and sulfur. From the perspective of fuel oil combustion theory, vanadium reacts with oxygen during combustion to form V_2O_5, an active catalyst. It catalyzes the conversion of sulfur in the fuel from SO_2 to SO_3. Some of the SO_3 reacts with potassium, sodium, magnesium, and other elements in the ash to form low-melting-point sulfate compounds and V_2O_5 compounds, further reducing the melting point of vanadium oxides and accelerating corrosion. When the exhaust temperature exceeds 550°C, vanadium and sodium compounds can melt and adhere to metal surfaces, causing high-temperature corrosion.

Corrosion by sulfur in low-quality fuel oil. The sulfur in the fuel burns to form sulfur dioxide, which is further oxidized to sulfur trioxide under the action of catalysts and reacts with water vapor in the flue gas to form sulfuric acid vapor. The presence of sulfuric acid vapor significantly raises the dew point of the flue gas. If the main engine operates at low load for a long time and the load distribution is uneven, the exhaust temperature of individual cylinders may fall below the dew point temperature of the combustion products. When the temperature of the exhaust valve surface is lower than the dew point of the combustion products, sulfuric acid vapor will condense on the heat-receiving surfaces of the valve, causing low-temperature corrosion.

5.2. Prevention and Control Measures

(1) Proper and effective pre-treatment of low-quality fuel oil according to procedures. Technical measures such as preheating, purifying, and adding relevant additives should be taken before the low-quality oil enters the fuel injection pump.

(2) Avoid mixing different grades of fuel or the same grade of fuel from different ports in the same tank to prevent incompatibility between the two types of oil, which can lead to sludge precipitation and consequently cause fuel injection equipment failure and black smoke from exhaust.

(3) Appropriately increase the fuel injection advance angle to ensure ignition near the top dead center and maintain normal maximum explosion pressure.

6. The Impact of the Intake and Exhaust System

6.1. Cause Analysis

The intake and exhaust system is the respiratory system of a diesel engine. When it experiences carbon deposition or clogging, it directly affects the engine's operating condition. Common blockages in the intake system occur at the turbocharger inlet filter, blades, air side of the intercooler, and cylinder head intake ports (see Figure 3 and Figure 4); while blockages in the exhaust system often occur at the turbine front grille, nozzle ring, nozzles, and the smoke tubes of waste heat boilers without bypass. Blockage in any part of the intake and exhaust system can cause a decrease in turbocharger power, reduced air intake, lowered air density, poor combustion, increased carbon deposit, elevated exhaust temperatures, and consequently valve burning. Additionally, the reduced airflow through the compressor can cause turbine surging.

Figure 3. Slight Blockage

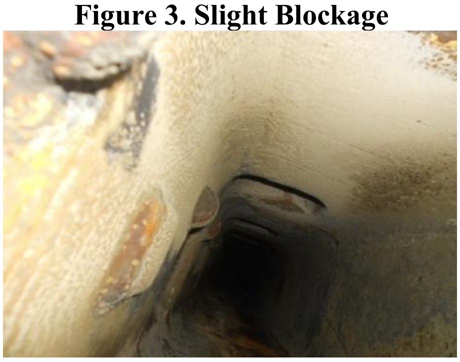

Figure 4. Severe Blockage

Moreover, clogging on the seawater side of the intercooler can also indirectly cause valve burning. The seawater side of the intercooler is easily clogged by mud and marine life, preventing the turbocharged air from cooling. This leads to higher scavenging temperatures, reduced air density, less air entering the cylinders, resulting in poor combustion, severe afterburning, and valve burning. On this engine, when the exhaust temperature rises to nearly 400°C, washing the seawater side of the intercooler typically brings the exhaust temperature down to around 380°C immediately.

6.2. Prevention and Control Measures

(1) Ensure regular flushing of the turbine during navigation and maintain the quality of flushing. However, if the turbine has not been flushed for a long time, it is better not to flush it to avoid incomplete cleaning and disturbing the dynamic balance.
(2) Regularly check and clean the intake air filter, intercooler, scavenging pipe, and intake ports.
(3) Perform timely ash blowing and cleaning of the exhaust gas boiler and flues.
(4) As an eight-cylinder engine, with equal throttle settings, cylinders 1 and 2, which are farthest from the turbocharger, have noticeably higher exhaust temperatures. The throttle should be appropriately reduced to control the exhaust temperature.

7. The Impact of High or Too Low Load Operation

7.1. Cause Analysis

Operating the main engine under excessively high loads for extended periods can cause exhaust temperatures in each cylinder to exceed the specified range, leading to valve burning. For instance, when a ship stays in areas prone to oyster proliferation, marine organisms easily grow on the hull and propeller, significantly increasing the load on the main engine.

If a diesel engine operates at low load for a long time, deviating too much from its optimal condition, it will inevitably lead to poor combustion.

7.2. Prevention and Control Measures

To improve the performance of the diesel engine when operating at low load, the following optimization adjustments can be made while running at reduced speed:
(1) Appropriately increase the fuel injection advance angle to ensure a sufficiently high maximum explosion pressure.
(2) Slightly raise the valve opening pressure to improve atomization quality.
(3) Ensure normal cooling of cylinder liners, injectors, etc., and adjust the temperature of the air after the intercooler to prevent low-temperature corrosion.

8. The Impact of Valve Clearance and Sealing Surface

8.1. Cause Analysis

Improper adjustment of valve clearance, especially when the clearance is too small, can lead to incomplete valve closure during engine operation. High-temperature flames passing through valve gaps can damage the valves. The width of the exhaust valve's sealing surface significantly affects the valve's service life. If the sealing surface is too narrow or fails to form a complete annular seal, its ability to withstand high temperature and pressure decreases, and the valve can quickly burn through after the engine operates [5]. A too wide sealing surface can trap carbon deposits, affecting the seal and eventually leading to valve burning. An overly wide exhaust valve sealing surface can also cause uneven heating of the contact surface, leading to thermal stress. When this thermal stress exceeds the material's elastic limit, the valve head warps, causing leakage and quickly damaging the exhaust valve [6]. The use of thinned old valves exacerbates these effects due to the overly wide sealing surface.

8.2. Prevention and Control Measures:

(1) Strictly adjust the valve clearance according to the instructions in the manual.
(2) Carefully inspect the wear condition of the valves. Before maintenance, measure whether the distance between the valve bottom and the cylinder head bottom exceeds the specified value [7].
(3) Grinding. For valves with slight corrosion or pitting on the valve face, mechanical machining for repair and manual grinding to restore the sealing line can be used. In severe cases, the valves should be scrapped and

replaced. During grinding, the grinding angles of the valve disc and seat must be strictly adjusted and measured according to the manual's requirements [8-10].

9. Conclusion

In summary, valve burnout is a result of multiple factors, and the reasons for simultaneous valve failure in the same diesel engine can vary. Valves are a critical component of a diesel engine, and their performance directly affects the normal operation of the main engine. Therefore, marine engineers must pay great attention to the functioning of valves. During navigation, it's crucial to conduct thorough inspections and monitor changes in exhaust temperatures. Assuming constant external sea conditions and main engine load, if a gradual increase in exhaust temperature, abnormal sounds, or other issues are observed in any cylinder, it's imperative to accurately diagnose the fault and take decisive measures to effectively control and prevent accidents.

References

[1] Hao Lantian. Preliminary Discussion on the Causes of Exhaust Valve Erosion in 10PC2-6V Diesel Engines and Countermeasures. Heilongjiang Science and Technology Information, 2009, No. 30.

[2] Li Liang, Sun Jishu, Liu Meiqing, Li Fuhai. Analysis and Verification of the Causes of Valve Erosion in a High-Power Medium-Speed Diesel Engine. China Ship Inspection, 2021, No. 10.

[3] Liu You. Analysis and Solutions for High Exhaust Temperature in Marine Diesel Engines. [Accessed 2017-11-10]. http://www.qikan.com.cn.

[4] Huang Busong, Lü Fengming. Marine Diesel Engines. Beijing: People's Transportation Publishing House, 2009, September.

[5] Zhang Shoujun. Causes and Solutions for Frequent Fracture of Diesel Engine Exhaust Valve Stems. Ship Science and Technology, 2010, No. 9.

[6] Li Chen, Wang Hongming, Tang Ming, Zhao Chunsheng, Zhao Feng. Design and Performance Analysis of an Automatic Mutual Grinding Device for Ship Diesel Engine Exhaust Valves. Ship Engineering, 2020, No. 4.

[7] Yu Dezhao. Discussion on the Causes of Exhaust Valve Erosion in a 14VV40/54 Diesel Engine. Maritime Science and Technology, 1991, No. 9.

[8] Sun Xiuzhong. Design and Performance Analysis of an Automatic Mutual Grinding Device for Ship Diesel Engine Exhaust Valves. Navigation Technology, 1998, No. 3.

[9] GAO Yong, WANG Jinjin, ZHA Bailin, et al. Effect of ablation time on ablation mechanism of C/C-SiC composites in hypersonic and oxygen-enriched environment. Acta Materiae Compositae Sinica, 2023, 40(1).

[10] Wei Shengli, et al. Miller Cycle with Early Intake Valve Closing in Marine Medium-Speed Diesel Engines. Journal of Marine Science and Application 21.1(2022):151-160.