Cause Analysis and Preventive Measures of Cavitation Corrosion of Diesel Engine Exhaust Valve Seat

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Abstract. This paper analyses the formation of cavitation in the exhaust valve seat of marine diesel engine in combination with leakage of the exhaust valve seat. The paper mainly starts from the cooling water system of the diesel engine that affects cavitation. Finally, the paper puts forward some preventive measures of cavitation corrosion.

1. Introduction
A ship uses the W46 type diesel engine produced by Wärtsilä. The cylinder head is equipped with two inlet valves and two exhaust valves with mechanisms for rotary valves. The inlet valves are cooled by air. The exhaust valves cooling are achieved by cooling the exhaust valve seat with cooling water passing through the cylinder head. One day, the engineer on duty finds that the water level of the expansion tank of the engine drops abnormally. After various investigations, the fault is identified as the leakage of the exhaust valve seat of the No.8 cylinder of the engine. The leaked water directly entered the cylinder for combustion, which bring a lot of troubleshooting difficulty. After the disassembly and inspection, it was found that the exhaust valve seat was corroded and perforated, resulting in water leakage. Therefore, the cavitation of the valve seat directly affects the reliability and service life of the diesel engine.

2. Causes of valve seat cavitation
Exhaust valve seat cavitation mainly manifests as some needle-like holes formed on the surface of the back of the valve seat in contact with the coolant. Because the gas is dissolved in the coolant, when the high-frequency vibration of the cylinder liner reduces the local pressure of the coolant to a certain critical value, the gas dissolved in the coolant is separated in the form of bubbles, and these bubbles flow to the high-pressure area Collapse occurs when the pressure exceeds the bubble pressure. [1] The gas in the bubble state is redissolved in the cooling liquid, and its volume suddenly decreases. The cooling liquid moves toward the center of the bubble at high speed to produce a water hammer phenomenon, which generates a great impact force and high temperature, and propagates around the supersonic speed in the form of pressure waves. When it acts on the exhaust valve seat, it produces a large impact, squeeze and high temperature. Under the repeated action of this force, the surface of the valve seats is fatigued and gradually falls off, show pits and pinholes, and gradually expand as the cavitation progresses.
3. The influence of cooling water system on cavitation
The factors that affect the exhaust valve seats cavitation in the diesel engine cooling water system include: cooling water temperature, cooling method, structure and arrangement of the cooling water cavity, and cavitation corrosion of the cooling water, etc. but the degree of influence is not the same.

3.1. The influence of cooling water temperature
The temperature of diesel engine cooling water is closely related to the degree of cavitation. Each diesel engine has a corresponding temperature at which pitting is most likely to occur. Too high cooling water temperature will accelerate the corrosion process, but it is also inappropriate to keep the water temperature too low for a long time. Too low temperature will cause bad consequences such as poor combustion, carbon deposition, increased wear and increased fuel consumption. Experiments have proven that metal materials such as steel and aluminum have severe cavitation erosion at fresh water temperatures of 50-60℃. [2] As the water temperature increases, the cavitation damage is reduced. Considering the effectiveness of diesel engine and reducing corrosion and cavitation, the fresh water temperature in the cooling water cavity is best at 80-90℃.

3.2. The influence of cooling method
There are two types of cooling methods for diesel engines: open cooling system and closed cooling system. The open cooling system directly uses seawater as a cooling medium. In order to avoid salt deposits in the seawater from heating, the temperature of the cooling water must be maintained in the range of 55-55℃, and this temperature is conducive to the development of cavitation. Moreover, the cooling water containing a large amount of salt is a strong electrolyte, which leads to increased electrochemical corrosion of the exhaust valve seat. Seawater also contains a large amount of gases and impurities that directly cause chemical corrosion on the exhaust valve seat. [3] Therefore, using the open cooling water method, cavitation of the exhaust valve seat is most likely to occur and develops rapidly. In closed cooling water system, it is possible to increase and maintain high cooling water temperature and pressure. The general control temperature is 80-90℃, and the pressure is about (1-2) x 105Pa. With closed cooling water system, softened and purified cooling water can be used, without changing water for a long time, and additives to reduce pitting corrosion can be added. Therefore, the use of closed cooling method can effectively reduce the occurrence and development of exhaust valve seat cavitation.
3.3. The influence of cooling water cavity capacity and layout
The cooling water cavity channel is too narrow, which increases the water flow speed and easily generates cavitation. Coupled with the higher temperature there and the repeated transmission of shock waves generated by the bursting of the bubbles, these will accelerate the cavitation of the exhaust valves seat. The design of the diesel engine requires that the water flow velocity in the cooling water cavity should be less than 2 m/s, the width of the water cavity \( T = 14\%D \) or not less than 10mm, and the water flow should be uniform and uniform. [4] The flow of water will not form dead water areas and vortex areas, which will help reduce cavitation erosion.

3.4. The influence of cavitation corrosion in cooling water cavity
Cavitation corrosion is characterized by clean valve seat surfaces and red pits, which often appear on internal combustion engines in fresh water-cooled closed-cycle systems. Cavitation corrosion is caused by cyclic changes in pressure and high-frequency vibration in the cylinder. [5] When the cooling water is compressed, the "bubbles" is also compressed. The water vapor in the bubbles is rapidly liquefied and the bubbles burst. The water around the bubbles quickly rushes into space, generating a strong shock wave acts on the surface of the valve seats. Although this impact force has a small time and space, it is continuously and repeatedly generated and acts on a very small area of the valve seat, causing plastic deformation and fatigue damage of the metal, and the metal on the surface of the valve seat gradually drops to form hole. This slowly formed cavitation corrosion.

4. Preventive measures against cavitation
The damage of the exhaust valve seat cavitation is related to many factors. To slow down the exhaust valve seat cavitation, it is important to consider how to reduce the vibration intensity of the exhaust valve seats and correctly design the water jacket. Also pay attention to the selection of exhaust valve seat materials and improve surface processing quality (using surface metal plating and non-metallic coating treatment) and cooling water treatment to add additives.

4.1. Improve the anti-cavitation strength of the exhaust valve seat
1) High-quality materials should be selected according to the performance parameters and characteristics of the internal combustion engine;
   2) The surface of the valve seats can be plated with a hard layer or nitrided to improve its surface hardness and finish. [6] The surface of the valve seat can be coated with different coatings to separate the metal surface from the cooling water or strengthen the surface of the cylinder liner, which can effectively prevent electrochemical corrosion and cavitation.

4.2. Strict requirements for cooling water system
1) The cooling water is properly selected and filled. The filled cooling water is as clean and pollution-free as possible to prevent corrosion and scaling. In addition, the cooling water should be added in time to prevent the air from dissolving. Do not change the cooling water frequently;
   2) Control the cooling water temperature below the critical temperature for the release of bubbles;
   3) Install zinc blocks in the cooling water cavity for protection to prevent electrochemical corrosion;
   4) Strengthen the inspection and maintenance of the water tank cover, and at the same time ensure the good performance of the valve.

4.3. Reduce cylinder liner vibration
1) Increase the rigidity of the cylinder liner, such as increasing the thickness of the cylinder liner or adopting unequal thickness cylinder walls, shortening the span between the upper and lower supports, increasing the auxiliary support and increasing the thickness of the supporting in conjunction with cooling holes, etc.;
   2) Select the appropriate positioning ring of cylinder liner to match the engine body, or install rubber seals to absorb vibration energy;
3) Alleviate the impact of the piston on the cylinder liner;
4) Reduce the gap between the piston and the cylinder liner;
5) In some areas with severe cavitation, materials such as artificial resin and paint can be coated on the surface. These materials have good corrosion resistance and their good plasticity can effectively absorb shock waves.

5. Conclusion
Due to the harsh working conditions of the exhaust valve seats, cavitation erosion of the exhaust valve seat is inevitable. There are many reasons for the cavitation of the exhaust valve seats. Based on the analysis and discussion of the cavitation of the exhaust valve seats in the cooling water system of the diesel engine, this paper suggests the treatment and preventive measures to reduce the cavitation of the exhaust valve seats and warranty to maintain the good performance of the diesel engine. It is great significance to improve the life of marine diesel engines and the benefits of using mechanical equipment.

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