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Research on Overheating Defects and Faults of Engine Piston Top

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ABSTRACT : *The engine piston top is prone to overheating, but the specific causes are not clear. In this paper, various experimental methods are used to study a piston, including profile measurement, ellipticity measurement, oil passage detection, metallographic analysis, alloy element detection and hardness test. The experimental results show that the shape and ellipticity of the piston top meet the requirements of normal production. There are no casting defects in the cooling oil passage, no segregation of alloy elements in the melting top, and uniform distribution of black eutectic silicon and strip primary silicon. It can be inferred that the main cause of piston top overheating fault is the failure of cooling and lubrication system, which is of great significance for improving the reliability and service life of the engine.*

KEYWORDS -*overheating, experimental method, piston, engine*

I. INTRODUCTION

When an engine developed by a vehicle factory in cooperation with a matching factory runs, it appears that it is powerless and has white smoke exhaust, and then it cannot start. The preliminary test shows that the fuel injection performance is good by testing the fuel supply system, and two of the four cylinders are found to have low pressure by testing the air path of the engine. The state of the cylinder and piston was observed by endoscope. It was found that the top surface of the piston was severely ablated and melted locally. The inner wall of the cylinder was severely damaged, as shown in Fig.1.

Fig.1 Piston Top Melting and Deformation

The overheating fault of engine piston top has caused huge economic losses to enterprises, but its formation factors are not clear [1]. In order to analyze and study the causes of the faults of diesel engine piston melting roof, this paper synthetically uses the experimental methods of profile measurement, ellipticity measurement, oil passage detection, metallographic analysis, alloy element detection and hardness test. Through comprehensive analogy and analysis of the experimental results, the fault factors are obtained, which is of great significance for improving the reliability and service life of the engine.

II. CAUSES OF PISTON TOP OVERHEATING FAILURE

2.1 Engine cooling failure

The engine studied in this paper has two kinds of cooling systems, one is the engine external cooling system with coolant as the medium, which circulates the coolant through water pump to heat the heat from the cylinder, and the other is the engine lubricating oil flowing through the piston to reduce the piston temperature [2]. Because of the large power of the engine, the piston is subjected to high frequency impact of high temperature and high-pressure gas in the process of operation, which causes the temperature of the piston to rise continuously. The top surface of piston is the engine parts which directly bear the mixture of high temperature and high pressure. If the cooling system does not work well, the piston can not be cooled in time, which will result in the heat dissipation of the piston, and the mechanical strength of the piston will be reduced, and the phenomenon of melting and cylinder pulling will occur for a long time.

2.2. Excessive carbon deposition in combustion chamber

Generally, if the engine runs overloaded or the diesel oil is poor, there will be incomplete combustion of combustible mixture in the cylinder, burning engine oil and other issues, and produce a large number of colloidal carbon deposits [3]. These viscous substances will adhere to the combustion chamber wall and the top of the piston, and are not easy to fall off. Because the top surface of piston is the part with the lowest hardness and strength in the whole combustion chamber, the increase of the thickness of carbon deposit layer will lead to a sharp decline in the heat dissipation capacity of the combustion chamber, and the more heat is accumulated in the combustion chamber, which may eventually lead to a melting top phenomenon on the top surface of piston.

2.3 Fault Research Method

The casting process of piston is very complicated. Aluminum melt needs to be modified before pouring, so that the primary silicon in aluminium alloy decreases while the eutectic silicon quantity increases and refines. In the process of modification, pouring and heat treatment, any process problems will lead to casting defects of piston and easy to cause melting top.

According to the data provided by the main engine factory, the performance of the engine oil and the oil products meet the standard, so the carbon deposit of the engine is small, and there will be no bad heat dissipation. Aiming at the inducement of piston melting top, an experimental scheme is put forward in this paper. The main methods of detection and analysis are profile measurement, ellipticity measurement, oil passage detection, metallographic analysis, alloy element detection and hardness test. Among them, through the analysis of the metallographic structure, the hardness of the melting top and the alloy composition of the piston raw material, the performance change of the piston material after the melting top appears can be directly determined.

III. PISTON DETECTION AND ANALYSIS

3.1. Piston profile measurement

Piston profile is the outer profile of the piston, which is usually measured by a profilometer. For the piston with sticky cylinder, it is only necessary to confirm whether there is a profile, because the profile processing is based on the established procedures of CNC lathe, and the profile meets the standard. The detection diagram of the fault piston profile is shown in Fig. 2. As can be seen in Fig.2, significant wear occurs at positions 1 and 3, and severe scratches occur at the remaining two locations. From the whole contour diagram, the contour of the fault piston exists, and the contour of position 1 and 3 basically conforms to the standard trajectory. Some of the contours of position 1 and 3 exceed the standard trajectory because of the convex deformation caused by the extrusion deformation of the piston behind the viscous cylinder.The contours of position 2 and 4 are seriously depressed and deformed, all of which are caused by the serious wear and tear of the piston after the viscous cylinder. Caused by depressions of varying degrees. In summary, the processing profile of the fault piston is within the trajectory of the standard profile, so the profile of the fault piston meets the requirements.

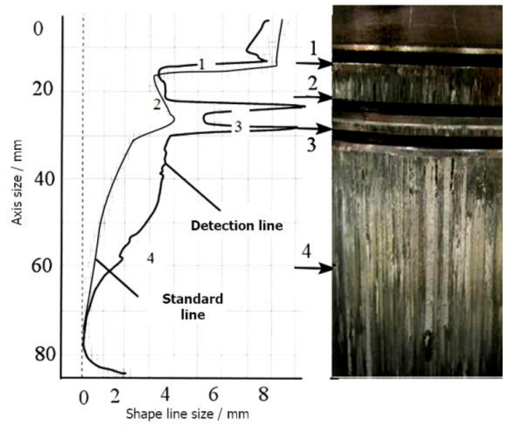
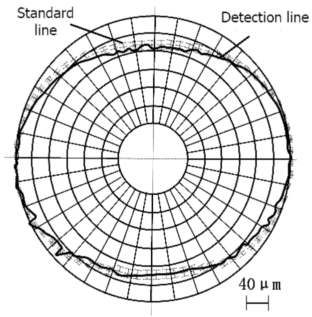


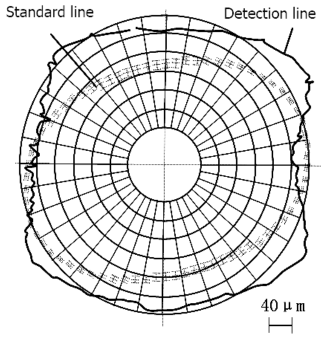
Fig.2 Detection results of shape line

3.2. Measurement of piston ellipticity

Because the piston obtains the most heat at the top of the piston and produces the largest expansion during its operation, in order to prevent its top deformation from excessive causing cylinder sticking, the piston is generally processed into an approximate cone with a small top and a large bottom, and its cross-section is elliptical or quasi-elliptical, and its ellipticity changes along the piston axis. The deformation of piston caused by thermal expansion expands along the piston pin axis, which makes the skirt cross-section nearly circular, so that the piston can work with a wider and more uniform bearing surface. The ellipticity of the piston is measured by a roundness meter. The measuring position is the same as that in Fig.2. The ellipticity curves of positions 1 and 4 are obtained as shown in Fig.3. In Fig.3, it can be seen that there is no viscous cylinder in position 1, and the piston damage is small. The ellipticity line of piston in this position basically coincides with the standard ellipticity line and meets the standard value. The ellipticity distortion of position 4 is serious and the deformation is obvious, which proves that the position bears much heat and load and is prone to wear and tear, which is consistent with the measurement results of profile. The ellipticity test results show that the melting phenomenon of the piston top surface has nothing to do with the quality of the piston machined and the load-bearing state of the piston during working.



(a) position 1



(b) position 4

Fig.3 Test results of ellipticity

3.3. Piston oil pipeline detection

The piston is equipped with a cooling oil passage. The lubricant circulates reciprocating in the cooling oil passage of the piston, which takes away part of the heat of the piston and reduces the temperature of the piston. Because the piston cooling oil duct is completed by casting, it is easy to appear the phenomenon of smaller inner diameter of the oil duct in the casting process, which leads to less lubricant flowing through the cooling oil duct, and makes the cooling effect of the piston worse. Because the piston cooling oil pipeline is inside the piston, it can not be detected directly. Therefore, water injection method and cutting method are used to detect indirectly.

(1) Water injection method. One end of the hose is connected with the outlet pipe of the press, and the other end is inserted into the piston cooling oil inlet. The outlet of the cooling oil pipeline is also connected with a hose to observe the water flow rate. Water is injected into piston cooling oil duct by manual hydraulic press to observe whether the flow velocity of inlet and outlet water is the same. The inconsistency of flow velocity indicates that there is a partition wall in the piston oil passage, which hinders the flow of water. If the same, it proves that there is no partition in the piston oil pipeline.

(2) Cutting method. In this paper, the fault piston is cut along the position between the first piston ring and the second piston ring. Whether there is a "partition" in the inner wall of the cooling oil channel of the fault piston is observed, that is, whether there is a casting thin wall blocking the oil channel is detected. It is found that there is no "partition" structure in the smooth inner wall. Thus, there is no casting defect in the cooling oil channel of the faulty piston.

3.4 Metallographic Structure and Element Analysis

Piston material for aluminum silicon alloy. In this paper, a small cutting machine was used to cut and prepare the metallographic sample from the detected melting top piston and place it on the xjg-05 horizontal metallographic microscope for observation, as shown in Fig.4.

As can be seen from Fig.4, this material belongs to eutectic structure. Eutectic silicon is distributed in the matrix of α-Al in granule or rod shape. It also has a large number of metallic compound phases, such as Mg, Fe, Gu, etc. The black eutectic silicon and the strip primary silicon have no segregation and are evenly distributed among the aluminum metals. Compared with the standard metallography, the particle sizes of the eutectic silicon and the strip primary silicon are in line with the standards and no microstructure abnormality is found.

Fig.4Metallographic examination results

The testing surface of metallographic sample was ground and polished again. The content of alloy elements was detected by spectroscopic analyzer. The results are shown in Table 1. As can be seen from Table 1, the alloy elements in the fused top piston are still within the standard range, and there is no serious segregation, which is consistent with the results in Fig.4.

Tab.1 Detection of alloy elements

element	standard value/ ppm	detection value/ ppm
Al	balance	78.129
Cu	4.5-5.9	4.893
Mg	0.5-1.5	0.662
Si	12-14.5	13.211
Fe	0.7Max	0.365
Mn	0.5Max	0.142
Ni	1.6-3.0	2.563
Pb	0.08Max	0
Zn	0.1Max	0.02

3.5 Hardness testing

The hardness of the piston is directly related to the temperature at which the crown piston operates in the engine. The hardness test values at different temperatures are used to analyze and predict the amount of heat sustained in the operation process, which is an important means to study the high-temperature crack on the top surface of the piston [4]. In this paper, a milling machine is used to mill out the melted part of the top surface of the piston, and 8 reference points are uniformly selected on the plane for testing. The hardness values of the 8 points tested are all lower than the standard hardness value of 110-140 HB, failing the piston hardness requirements [5]. Thus, it can be seen that the maximum temperature type endured by the diesel piston is one of the key factors that lead to the roof melting failure and limit the diesel engine to increase the power. After the experimental data of repeated verification, the diesel engine on the surface of the aluminum alloy piston top limit should be less than 350 ℃ temperature, more than the temperature, the piston at the top will produce a tiny crack. Piston at above 330 ℃ for a long time, impacted by the high temperature gas alternating load, there will be a hardness falling rapidly even partial melting, melt roof failure.

IV. CONCLUSION

In this paper, three main factors causing engine piston top surface melting are analyzed. Based on the experimental results, the following conclusions can be drawn:

(1) The machining profile of the faulty piston is within the range of the trajectory of the standard profile. The non-viscous cylinder phenomenon occurs at the top of the piston, and its ovality line basically coincides with the standard ovality line.

(2) The performance of oil channel was tested by water injection and cutting method. The results show that the size of eutectic silicon and primary silicon are up to the standard. Therefore, the melting phenomenon of piston top surface has nothing to do with manufacturing technology and material properties.

(3)According to the different temperature, melting the top of the piston and part of the reference point hardness testing result, when the piston is above 330 ℃ for a long time, the piston top surface hardness is lower than the standard value, proved the piston melt overheat and there is no heat in time, before eventually lead to the top surface melting.

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