Six Cylinder Diesel Engine Heat Exchanger Plate Failure Analysis through OES

Akshay R. Shitole[#1], Rishi Pratap Singh[*2], Sahil S. Anarse[#3], Vijay S. Diwate[#4]
[#1-3]*UG students, Department of Mechanical Engineering,NBNSSOE, Pune, Maharashtra, India*
[#4]*Engine Supdt, MSRTC Central Workshop, , Pune, Maharashtra, India*

Abstract

The performance of six cylinder internal combustion (IC) engine is depending on so many factors. One of the factors identified for the research work is the heat exchange assembly. The heat exchanger mainly its plate is the most vital part of the internal combustion engine. The engine oil is used for minimizing the frictional losses in the engine. The engine oil is used to remove the heat generated during the combustion process. The generated heat in the engine is absorbed by the oil is passes through the exchanger plate called as engine oil cooler. The basic function of engine cooler is to cool the oil flows and avoid the losses due to the heat generated in engine. The cooled oil is continuously passed through the hot object for maintain the temperature as low as possible. Hence the critical analysis of the heat exchanger cooler is carried out and presented in the paper. The failure analysis is carried out on the basic of the observation and the historical data and then the corrective measure was implemented to avoid the failure. It has been observed that the engine was failed due to the grace of engine oil, corrosion.

Keywords — *OES, Heat exchanger plate.*

I. INTRODUCTION

A heat exchanger plate is a device used to exchange heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent in grace of water into engine oil. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger plate is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant.

Plate-type heat exchangers are usually built of thin plates (all prime-surface). The plates are either smooth or have some form of corrugation, and they are either flat or wound in an exchanger. Generally, these exchangers cannot accommodate very high pressures, temperatures, or pressure and temperature differences. Plate heat exchangers (PHE's) can be classified as gasketed, welded (one or both fluid passages), or brazed, depending on the leak tightness required.

The plate heat exchanger (PHE) is a specialized design well suited to transferring heat between medium- and low-pressure fluids. Welded, semi-welded and brazed heat exchangers are used for heat exchange between high-pressure fluids or where a more compact product is required. In place of a pipe passing through a chamber, there are instead two alternating chambers, usually thin in depth, separated at their largest surface by a corrugated metal plate. Stainless steel is a commonly used metal for the plates because of its ability to withstand high temperatures, its strength, and its corrosion resistance. The actual heat exchanger plate is as shown in the following figure 1.

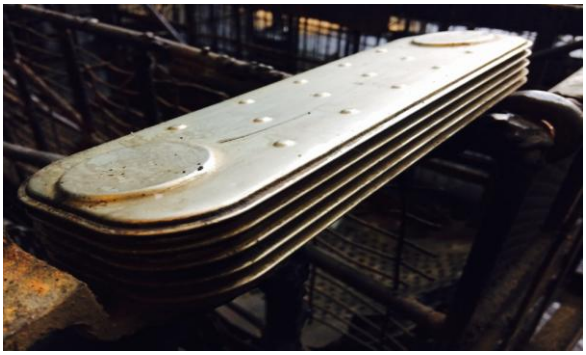

Fig.1 : Actual picture of the heat exchanger plate.

Based on the past data collected and subsequent observation made, the most important causes of engine failures can be due to the following reasons:

1. Overheating
2. Lubrication
3. Detonation
4. Disassembly]

1. Engine overheating

Overheating can be caused by various reasons. The main reason is due to the insufficient level of lubricant or the fault in the lubrication system. A we know that the high heat is generated during the combustion and it need to be control to avoid the damage comes due to the overheating of engine during the combustion process. The main

reason is the loss of coolant and a low level of coolant, which is turn, may be due to leakage in hoses, the radiator or the engine itself. The leakage is due to the weak sealing element s and the engine cap which allow the coolant to break away from from the system.

2. Engine Failure Caused By Lubrication Problems

We know that the all moving parts were friction occurs needs oil for the reducing the friction. Oil is required for minimizing the effect of friction as well as to carry out the heat. Oil is the principal way by which the rod and main bearings are cooled, as well as the pistons. So any decrease in oil flow may cause these parts.

3. Engine Failure Caused By Detonation

Piston blowing up damage (Spark Knock) is a form of irregular combustion that results from overheats and pressure in the combustion chamber. The fuel gets burned impulsively causing a sudden increase in cylinder pressure. The effect is a pointed hammer-like bluster on the piston that produces a metallic knocking or pinging noise. Light discharge is considered standard and should not damage any part, but heavy or prolonged discharge can crack rings, pound out piston ring grooves, punch holes through the tops of pistons, smash rod bearings and blow head gaskets.

From the above discussion, it is cleared that an improper engine cooling or lubricating system. likely the common causes of whole engine failure are improper lubrication, meaning there is not enough oil in the engine. The insufficient or shortage of oil will result in excessive heat on metal contact between the engine's moving parts, which can cause major damage to engine components which lead to reduce the efficiency or performance of the engine.

II. METHODOLOGY

For getting the information regarding causes of failure, the data of nearly 100 diesel was observed. From the historical data, it has been observed that the most failure cause is due to the mixing of oil with water. Frequency of failure due this reason is the most one amongst other causes. Hence the aid cause is targeted for the analysis. The major advantages of oil cooling system are discussed below.

i. The boiling point of oil is higher than the water, hence it is used for the cooling hot elements.
ii. As the oil is already used as coolant no extra accessories or storage device is required.
iii. Oil along some anti corrosive additives can be used to avoid the damage due to corrosion.

According to below table the repetitive problem of respective problems in engines are: The engine defects data is as shown in the following table 1.

TABLE 1 : Engine and defects observed for oil with water.

Sr.no	Type of Engine	Number of defects observed
1	697 TCIC	7
2	TC-BSII	4
3	TC-BSIII	6
4	EURO-I,II,III	4

The heat exchanger frame model is as shown in figure 2.

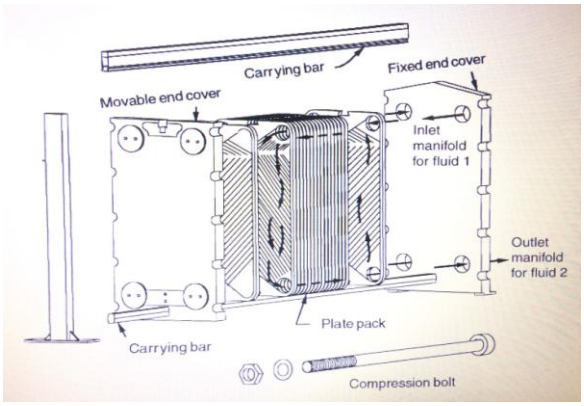

Fig. 2 : Schematic of Heat Exchanger Plate

After the observation fro table 1, it was, it was decided to carry out the material related analysis of the heat exchanger plate. The basic objective of the material analysis is to find out the material chemical composition and the properties of the material use for the heat exchanger plate. For that purpose (Material analysis) Optical Emission Spectrometry (OES) was used.

A. What is Optical Emission Spectrometer (OES):

This is the well known instrument used for measuring the properties with the help of electromagnetic spectrum light projected on a specified area of the sample specimen. The variable measured is most often the light's intensity but could also, for instance be the polarization state. The independent variable is usually the wavelength of the light or a unit directly proportional to the photon energy, such as reciprocal centimeters or electron volts, which has a reciprocal relationship to wavelength.

It use a charge coupled device (CCD) or charge injection device (CID) solid-state detector array in order to provide simultaneous determination of analyte lines. The optical bench is thermally controllable. It is capable to measure upto nono-mertic range. This nono range allows the measurement of phosphorus and sulfur in the vacuum UV range and potassium at long wavelength;

The OES system has a torch facility in a radial, axial, or dual direction. It consists of an axial view torch which provides some method to moderate the effects of viewing through cold plasma. Optical emission

spectrometry utilized the application of electrical energy in the structure of spark generated between an electrode and a metal sample, whereby the vaporized atoms are brought to a high energy state within discharge plasma.The working of OEs is as shown in Figure 3

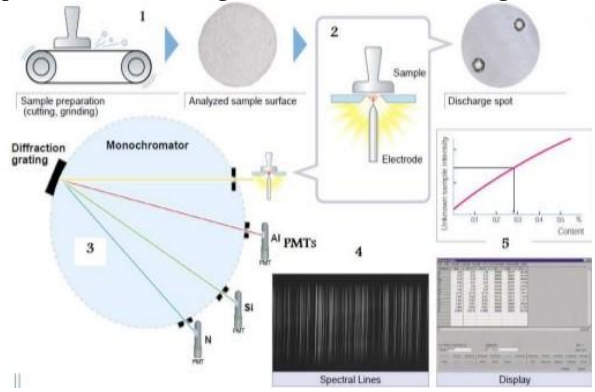

Fig. 3: Working principle Optical Emission Spectrometer [8]

Principle of Optical Emission Spectrometry (OES) and the order is as follows:

i. Optical emission spectrometry involves applying electrical energy in the form of spark generated between an electrode and a metal sample, whereby the vaporized atoms are brought to a high energy state within a so-called **"discharge plasma"**.
ii. These excited atoms and ions in the discharge plasma create a unique emission spectrum specific to each element, as shown above.
iii. Sample material is vaporized with the testing probe by an arc spark discharge.
iv. Therefore, the light generated by the discharge can be said to be a collection of the spectral lines generated by the elements in the sample. This light is split by a diffraction grating to extract the emission spectrum for the target elements. The intensity of each emission spectrum depends on the concentration of the element in the sample. Detectors measure the presence or absence of the spectrum extracted for each element and the intensity of the spectrum to perform qualitative and quantitative analysis of the elements.

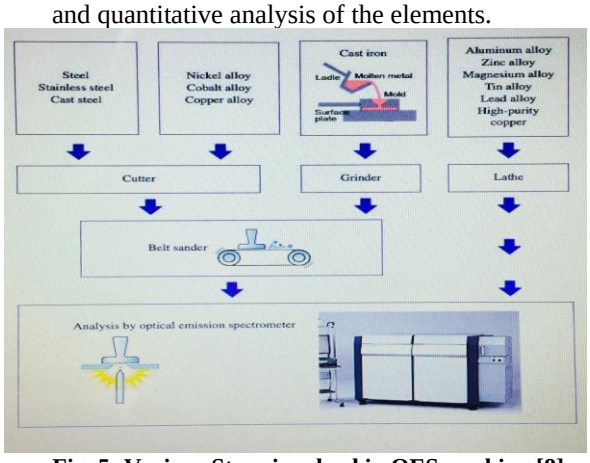

Fig. 5: Various Steps involved in OES working [8]

B. Advantages of OES

The advantages of OES are as follows:

i. This is Fast, robust, precise, stable and reliable technology.
ii. It is very easy for sample preparation.
iii. It has a Low capital investment and operating costs.
iv. Range is from trace (sub-ppm) to alloy concentration levels.
v. Unmatched technique for fast analysis of C, N, O, P and S in steels.

A successful use of Optical Emission Spectrometer (OES) test for carrying out the chemical composition of the metal was done on the Heat Exchanger Plate. The results that were obtained after the chemical composition OES test are as shown in Table 2

TABLE 2: Chemical composition of heat exchanger plate

S.N	Elements	Specified Composition (%)	Spectromax Observation (%)
1	C	0.08(Max)	**0.09**
2	Mn	2.0(Max)	1.31
3	Cr	18.0-20.0	18.45
4	Mo	-	-
5	Ni	8.0-10.5	8.27
6	V	-	-
7	W	-	-
8	Al	-	-
9	Si	0.75(Max)	0.48
10	S	0.03(Max)	0.01
11	P	0.045(Max)	0.031
12	Fe	Remainder	Remainder

Type of Material: Steel Alloy
Part Name: Heat Exchanger Plate
Material Grade: AISI 304
Note: % of indicated elements is approximate.

From the OES report tabulated in the table 3, It has been observed that the carbon percentage in the tested heat exchanger plate is 0.09 % which is greater the standard specified max 0.08 % for the AUSI 304 grade steel. The other elements are in the specified range specified. AISI 304 is an austenitic grade steel which can be easy for the deep drawing process. Due to the higher value of the C % in the composition, the properties like sinks and saucepans are affected which leads to the failure of the plate. The import properties of the AISI 304 steel are

1. It has an excellent corrosive resistance property in a wide range of environmental variation. Pitting and crevice corrosion can occur in environments containing chlorides. Stress corrosion cracking can occur at temperatures over 60°C.
2. It has anti oxidation property and good resistance to oxidation in intermittent service up to 870°C and in continuous service to 925°C. 3. It has good machinability property hence it is recommended for the said part.

From the OES analysis , it has ben observed that the percentage of expected carbon is more than that of 0.01%. Type 304 is a variation of base 18-8 grade, with a higher chromium and lower carbon percentage. The lower carbon content reduced the chromium carbide precipitation due to welding and its susceptibility to inter-granular corrosion. As the carbon percentage content rises, steel has the capability to become harder and stronger through heat treating; however, it becomes fewer ductile. Regardless of the heat treatment, higher carbon content reduces weld ability. In carbon steels, the higher carbon content lowers the melting point. It also reduces the ductility and forge ability of steels. Hence the required lesser percentage of carbon will definitely eradicate the frequent failure of mixture of water and oil.

III. CONCLUSIONS

The heat exchanger plate is the most important component observed to be responsible for the failure of the IC engine. Majorly two type of failure observed in the heat exchanger plate, the first one is the pitting marks which are crated due to the corrosion which finally lead to the cracks and the coolant leakage which increased the heat and cause permanent failure of the engine. While the second one is that some of the pit marks lead to cracks at oil gallery areas which tend to in-grace of water into engine oil. This is mostly due to non-use of coolant into the water radiator. However the lesser quality of heat exchanger plate or oil cooler also leads to higher corrosion of oil cooler cover. Hence to avoid this, it was decide or suggested to decrease the carbon percentage. The previous carbon percentage observed was 0.09%. Hence there is a need to keep the quantity of carbon utmost 0.08 % or as minimum as possible. With said suggested remedies the major cause of engine failure i.e the problem of oil mixing with water and corrosion will be eradicated soon will be eliminated and the engine damage can be avoided the future . This will enhance the life of engine as well increase the utilization of engine in a very efficient and effective way.

ACKNOWLEDGMENT

The author thanks to the institute NBN Sinhgad School of Engineering, Pune of Mechanical Engineering Department, Maharashtra State Road Transport Corporation (MSRTC) for providing us proper guidance and support in completing this project.

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