Urecol Journal. Part E: Engineering
Vol. 1 No. 2 (2021) pp. 44-51
eISSN: 2797-0418

Published by:
KONSORSIUM LPPM PTMA
KOORDINATOR WILAYAH JATENG & DIY

Analysis of Water Contaminated Engine Oil in Engine Generator Set

Wilarso[1], Firmansyah Azharul[1], Che Wan Mohd Noor[2], Dan Mugisidi[3]
[1] Sekolah Tinggi Teknologi Muhammadiyah Cileungsi, Bogor, Indonesia
[2] Universiti Malaysia Terengganu, Malaysia
[3] Universitas Muhammadiyah Prof. Dr. Hamka, Jakarta, Indonesia
wilarso@sttmcileungsi.ac.id

https://doi.org/10.53017/uje.66
Received: 25/07/2021 Revised: 29/08/2021 Accepted: 09/09/2021

Abstract
This case study was conducted in a manufacturing company that experienced a breakdown in a power generator set. A standard investigation was carried out by opening the crankcase cover and checking the dipstick. The results of the visual inspection showed that the engine oil was contaminated with water. Therefore, this study was conducted to further analyze the causes of oil contaminated with water in the unit being handled using fault tree analysis (FTA). As a result, cracks were found in the cylinder liner due to pitting on the outer liner with a pitting depth of more than 2 mm. In our analysis, pitting is formed due to the presence of air bubbles in the cooling system. Based on FTA, the formation of air bubbles is caused by the quality of the coolant. We also found that the coolant used was not added with any additives.

Keywords: Generator set, Oil mix water, Cylinder liner crack, Pitting

Analisis Oli Mesin yang Terkontaminasi Air di Mesin Genset

Abstrak
Studi kasus ini dilakukan pada sebuah perusahaan manufaktur yang mengalami gangguan pada power generator set. Penyelidikan standar dilakukan dengan membuka penutup bak mesin dan memeriksa dipstick. Hasil inspeksi visual menunjukkan bahwa oli mesin terkontaminasi air. Oleh karena itu, penelitian ini dilakukan untuk menganalisis lebih lanjut penyebab terjadinya pencemaran minyak dengan air pada unit yang ditangani menggunakan *fault tree analysis* (FTA). Hasilnya, ditemukan keretakan pada cylinder liner akibat adanya *pitting* pada *outer liner* dengan kedalaman *pitting* lebih dari 2 mm. Dalam analisis kami, pitting terbentuk karena adanya gelembung udara di sistem pendingin. Berdasarkan FTA, terbentuknya gelembung udara disebabkan oleh kualitas cairan pendingin. Kami juga menemukan bahwa pendingin yang digunakan tidak ditambahkan dengan aditif apa pun.

Kata-kata kunci: Genset, Air campuran oli, retakan liner silinder, *pitting*

1. Introduction

Damage of components in the diesel engine will reduce unit performance and reduce customer confidence in terms of power supply. Each breakdown incurs considerable costs [1], repair downtime takes a long time. A component failure must have an early indication

before experiencing a sudden malfunction or failure [2]. For equipment availability, the diesel engine needs to be checked regularly.

Generator sets operating at PT. XYZ cannot be operated because the engine oil is contaminated with water. The generator set unit operates for back-up power from the State Electricity Company, in the power outage not to interfere with production operations. With the occurrence of engine oil mixed with water, the back-up power of the State Electricity Company will be disrupted and will decrease production. It is very important to research the damage occurs. The operating unit type is 18V2000G63, has reliable performance for back-up power, maintenance is carried out according to the manufacturer's guidelines.

Periodic checks are carried out on August 20, 2020, the generator set will be operated by the operator on duty, but when it is started it cannot crank. Based on the initial analysis at that time the battery power was lacking, because the battery had been used for 3 years. Then the battery was charged and added power and on August 21, 2020 morning the unit was restarted, then it could be started for approximately 30 minutes. On the 22nd morning, an inspection was carried out and it was found that there was a lot of water under the generator unit, and further checks were made in the engine or oil pan, by checking the dipstick, it was found that the oil was coffee milk color and water was coming out of the muffler [3].

In Figure 1, it was found that oil mixed with radiator water, so that the radiator water turned the color into coffee milk. If these conditions are found, the steps that must be taken are to stop the unit and drain oil, then clean using diesel. So that the oil mixed with the coolant is clean and does not damage other components. If the oil is contaminated with water, the function of the oil is not optimal [4], where the oil will change color and affect the lubrication system of the diesel engine. If left for a long time, it will have a considerable impact on all engine components, such as cylinder liners, pistons, cylinder heads, rocker arms, connecting rods, and other spare parts in engine components.

Figure 1.
Engine oil contaminated with water

Contamination occurs to engine performance and integrity, and lastly provides insight for maintenance decision making and highlights important used oil analysis parameters that correlate with degradation through fuel contamination [5].

Engine oil mixed with diesel fuel results in reduced lubricant viscosity (fuel dilution) caused by damage to the injector seal hardening, by friction hardening of the injector seal, which occurs with damaged cylinder liner seals and irregularly shaped grooves [6].

The continuous formation and destruction of bubbles in the cylinder liner cooler releases energy that will strike the cylinder liner and cause a pitting action. For this reason, line analysis using harmonic analysis is carried out in the frequency range 0-100 Hz. The applied thermal load from the combustion chamber and the structural interaction fluid are also considered for analysis. The presence of cavitation is shown as the negative pressure in the analysis [7].

The purpose of this study is to analyze engine oil contaminated by water to determine the root cause, as well as to provide recommendations in terms of improvement so that the same incident does not happen again.

2. Method

In this study, the method used to determine the root cause of the damage was the fault tree analysis. As for the flow of research carried out, starting from the identification of the damage that occurred to the engine oil contaminated by water [8]. Then check for damage to the impact because contamination will affect the performance of engine components. After checking, an analysis of the findings was carried out to determine the root of the problem that occurred.

In the flow of research in Figure 2, it is explained in researching 1) Identification of damage to the diesel engine from the discovery of oil-contaminated by oil, then leading to components that experienced the impact of the incident, until the components have something to do with water or oil. 2) Checking this component to find out how severe the consequences are. 3) Damage analysis compiles the findings obtained to determine which component is the cause or effect, if the analysis carried out still requires specimens or the required data is lacking, it is necessary to re-identify the diesel engine components. 4) The results and discussion determine the sequence of events to the root cause of component damage due to engine oil being contaminated with water. 5) Conclusions provide decisions in terms of the analysis carried out and provide recommendations for improvement.

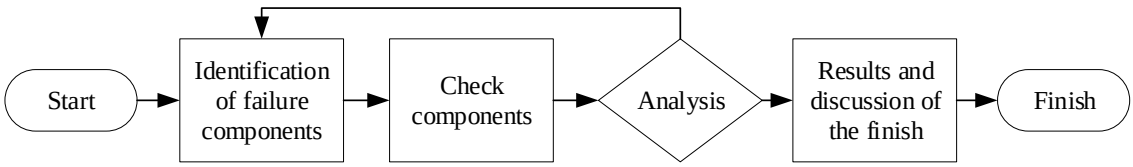

Figure 2. Research flow

3. Result and Discussion

3.1. Damage facts

In Figure 3 the rocker arm is rusty caused by condensation when the engine oil is contaminated with water. The steam from inside the crankcase goes to the rocker arm, then the steam flows to the breather. Rust on this engine component if not cleaned immediately, will damage other components.

As described in Figure 3 rust on the surface of the rocker arm intake and exhaust caused by water vapor from the oil pan, this rocker arm as a result, not a cause. It is recommended that if rocker arm rust is found due to moisture, it should be cleaned immediately with clean oil (new oil), so as not to harm other components.

The condition of the radiator on the unit, contaminated with dust, etc., will have an impact on the engine cooling system. This can have an impact on the cooling water circulation system that is not optimal [9], causing the radiator water temperature to increase and can cause overheating [10]. Recommendations for blocked radiator conditions, so that routine maintenance is carried out every 3 months. And when cleaning the radiator, In Figure 4 the condition of the radiator is covered by dust contamination which causes the radiator to be blocked.

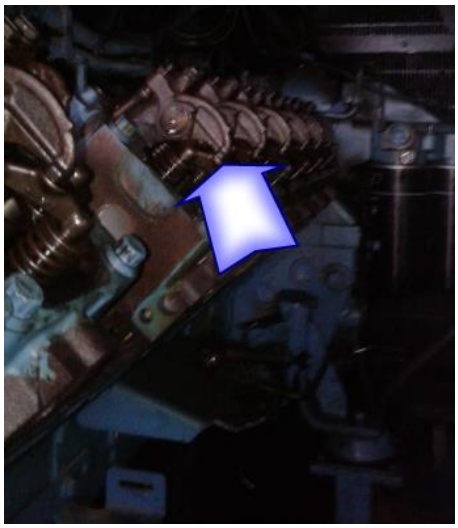

Figure 3. Rocker arm rust

Figure 4. Radiator blocked

While the surface of the inner liner wall has an indication of rust, which is due to the radiator water being in the combustion chamber, which is described in Figure 5. After identification of the engine oil being contaminated with water, a crack was found in one of the cylinder liner cracks at the bottom of the cylinder liner [11].

At the time of dismantling the liner, the outer liner wall was found, pitting was found in the bad filler area and the other outer walls, the pitting depth was more than 2 mm (see Figure 6). With the finding of pitting occurring on the outer liner wall [12], the beginning of the cracking of the liner wall. The pitting is formed due to the presence of air bubbles in the cooling system. Air bubbles are formed due to radiator water that does not use additives [13].

Figure 5. Cylinder crack

Figure 6. Pitting

3.2. Fault Tree Analysis

From the analysis carried out using fault tree analysis, several parts cause pitting on the liner resulting in cylinder liner cracking, according to the explanation in Figure 7.

3.2.1. High jacket water temperature.

- High radiator water temperature caused by radiator damage, especially radiator core covered with dust, oil, and diesel contamination, so the water flowing through the radiator is hot. Then it has flowed back to the engine in hot conditions, the hot radiator water cannot absorb heat properly, and will cause damage to the components that are fed by the radiator water. As for the contamination of the radiator core against oil leakage caused by damage to the actuator seal, and contamination of dust and diesel, there is damage to the fuel cooler, and the engine operates in an area with high dust.
- Blocked radiator tubes: Silica deposits in the cooling system will affect the heat distribution to the cooling system. If the additive concentration exceeds 60% it will affect the ability of the water as a coolant and will produce silica deposits. This silica deposit will reduce the diameter of the oil cooler tube. Excessive mineral content in water can cause damage to engine components, due to the inhibition of heat transfer[14]. Coolant radiators that do not use additives will affect the boiling point of the coolant and make it easier for air bubbles to form in the cooling system.
- The relationship with high radiator water temperature, as stated in point A (2), is related to damage to the radiator core.
- Broken Radiator Cap [7][15]: Leaking water on the radiator cap can cause reduced pressure and coolant, the air in the system will cause bubbles or aeration and will affect the ability of the water pump.

3.2.2. Bubble at cooling system.

- Radiator water quality that is not per the specifications used, where the excessive mineral content in the water can cause damage to the engine due to inhibited heat transfer [16]. In this case, it will affect the boiling point of the radiator water which can cause air bubbles [17].
- Air bubbles bursting at hot spots in the cylinder liner area will result in corrosion wear [18]. Air bubbles in the cooling system can form because the radiator water does not use additives [19][20].

3.2.3. Hidrolik lock.

The hydraulic lock that occurs is due to the presence of liquid fluid (diesel and water) in the combustion chamber. This event occurs when the unit is on standby (not operating), and when it is about to be operated the engine cannot crank or start, and if forced it will result in broken connecting rods and damage to other engine components.

- Damage to the aftercooler (air cooler) due to corrosion of aftercooler components. Corrosion that occurs is due to the quality of radiator water that does not use additives.
- Pitting on the cylinder liner can result in liquid fluid being in the combustion chamber because the pitting depth is more than 2 mm.

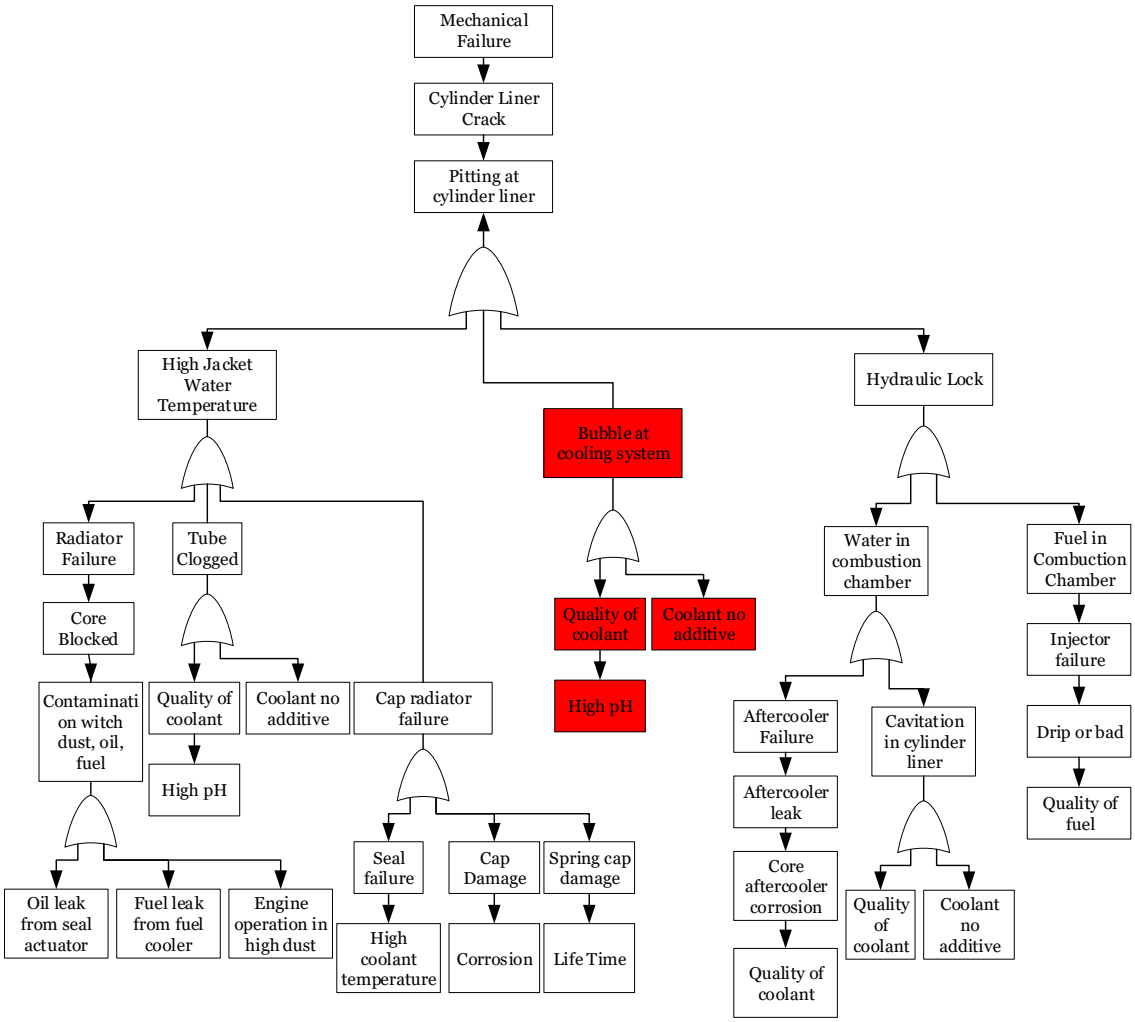

Figure 7. Fault tree analysis

4. Conclusion

Engine oil contaminated with radiator water causes the oil to turn milky white, this incident is due to the cylinder liner having a hole (pitting), with a depth of more than 2 mm. So that when the combustion process occurs, an explosion occurs in the combustion chamber reducing the performance of the cylinder liner which causes the cylinder liner to crack. The formation of pitting on the liner wall is caused by air bubbles that break on the liner wall, the coolant condition used does not use additives. This results in the quality of the radiator water not being able to protect the liner walls. Corrective measures to prevent pitting on the liner, which must be done 1) Add additives to the radiator water according to the needs and capacity of the radiator water. 2) Routine maintenance of the radiator, so that the cooling system is maximized, 3) periodically check the radiator cap, so that there is no low tension that can cause air to enter the cooling system, and water to come out of the radiator cap.

Reference

[1] M. Carla Estorilio, "Cost reduction of a diesel engine using the DFMA method," *Prod. Manag. Dev.*, vol. 4, no. 2, pp. 95–103, 2006.

[2] K. M. Tsitsilonis and G. Theotokatos, "Engine malfunctioning conditions identification through instantaneous crankshaft torque measurement analysis," *Appl. Sci.*, vol. 11,

no. 8, 2021, doi: 10.3390/app11083522.

[3] A. D. Davydov, "Analysis of pitting corrosion rate," *Russ. J. Electrochem.*, vol. 44, no. 7, pp. 835–839, 2008, doi: 10.1134/S1023193508070100.

[4] R. T. Mousavian, E. Hajjari, D. Ghasemi, M. K. Manesh, and K. Ranjbar, "Failure analysis of a shell and tube oil cooler," *Eng. Fail. Anal.*, vol. 18, no. 1, pp. 202–211, 2011, doi: 10.1016/j.engfailanal.2010.08.022.

[5] J. Wakiru, L. Pintelon, P. Chemweno, and P. Muchiri, "Analysis of lubrication oil contamination by fuel dilution with application of cluster analysis," *XVII Int. Sci. Conf. Ind. Syst.*, pp. 252–257, 2017.

[6] Wilarso, A. Domodite, H. Sholih, and Mujiarto, "Analysis of SOS Results for Engine Lubricants Contaminated by the Fuel in the 3516 TA Diesel Engine Generator Set," *J. Phys. Conf. Ser.*, vol. 1764, no. 1, 2021, doi: 10.1088/1742-6596/1764/1/012172.

[7] M. Raviraju and K. R. V, "Pitting action due to bubble formation in the Cooling fluid of a piston liner," *Int. J. Mech. Eng.*, vol. 1, no. 6, pp. 5–10, 2014, doi: 10.14445/23488360/ijme-v1i6p103.

[8] S. A. E. International and S. A. E. Transactions, "Author (s): Lillian M Gilbreth Source : SAE Transactions , Vol . 20 , PART II (1925), pp . 735-760 Published by : SAE International Stable URL : https://www.jstor.org/stable/44729815," vol. 20, no. 1925, pp. 735–760, 2018.

[9] A. K. Hossain, D. I. Smith, and P. A. Davies, "Effects of engine cooling water temperature on performance and emission characteristics of a compression ignition engine operated with biofuel blend," *J. Sustain. Dev. Energy, Water Environ. Syst.*, vol. 5, no. 1, pp. 46–57, 2017, doi: 10.13044/j.sdewes.d5.0132.

[10] S. Muthukumarasamy, R. Dinesh, and K. D. Kumar, "Analysing the Causes of Overheating of Heavy Duty Truck Engines and Heat Flux of Radiator Using Pareto Principle Ansys Software," vol. 118, no. 20, pp. 4955–4963, 2018.

[11] B. N. Goel, "Case Study : Failure Analysis of Diesel Engine Cylinder Liners."

[12] S. Bako, T. Usman, I. Bori, and A. Nasir, "Simulation of a Wet Cylinder Liner," *Int. J. Mech. Eng.*, vol. 6, no. 4, pp. 12–17, 2019, doi: 10.14445/23488360/ijme-v6i4p103.

[13] Cummins, "Cavitation Corrosion / Erosion Coolant Testing Kit CC2602M or CC2602AM," p. 2.

[14] S. W. Beni Kurniawan Saputra, M Ginting, "Analisa Pengaruh Penggantian Material Tube Terhadap Kecepatan , Suhu Dan Tekanan Pada Lube Oil Cooler Untuk Pendingin Compressor 103 Di Pt Pusri," *J. Austenit*, vol. 8, pp. 33–35, 2016.

[15] D. Belloli, S. M. Savaresi, A. Cologni, F. Previdi, and D. Cazzola, "Modeling and control of an Internal Bubble Cooling system," *2012 8th Int. Symp. Mechatronics its Appl. ISMA 2012*, no. May 2016, 2012, doi: 10.1109/ISMA.2012.6215168.

[16] T. Dow and C. Company, "AMBITROL Inhibited Glycol-based Coolants."

[17] V. Enontiemonria and O. Nathaniel, "Comparison of the cooling effects of a locally formulated car radiator coolant with water and a commercial coolant," *Int. J. Eng. Sci.*, vol. 2, no. 1, pp. 254–262, 2013.

[18] M. A. Hosien and S. M. Selim, "Cavitation Erosion Damage in Diesel Engines Wet Cylinder Liners," *ERJ. Eng. Res. J.*, vol. 40, no. 1, pp. 31–36, 2017, doi: 10.21608/erjm.2017.66330.

[19] S. Jafari *et al.*, "A review of evaporative cooling system concepts for engine thermal

management in motor vehicles," *Proc. Inst. Mech. Eng. Part D J. Automob. Eng.*, vol. 231, no. 8, pp. 1126–1143, 2017, doi: 10.1177/0954407016674606.

[20] A. M. Fsadni and Y. Ge, "Micro bubble formation and bubble dissolution in domestic wet central heating systems," *EPJ Web Conf.*, vol. 25, 2012, doi: 10.1051/epjconf/20122501016.