Diesel engine troubleshooting and diagnostic

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Every ship’s engine room is equipped with some kind of diesel engine and most big ships nowadays are powered by two-stroke diesel engines, although the usage of four-stroke engines for propulsion is increasing due to the flexibility in where they may be installed and the enhanced redundancy that a larger number of smaller engines can give. Four stroke diesel engines are commonly utilized to generate electricity.  
Diesel engine troubleshooting or diagnosis is a tool that should help ensure the diesel engine’s dependability as well as its maximum efficiency, to prevent severe problems at sea and to have condition-based maintenance and be possible to assess the technical state of the engine sections without disassembling the engine.  
Engine monitoring can be thought of as a simpler diagnosis that follows this simple rule: as long as the vital engine parameters are within a particular range, we can conclude that a critical defect is not imminent. However, such basic monitoring does not help striving for optimal engine efficiency or maintenance optimization and as a result, a more complete troubleshooting can be extremely beneficial.

The values of the engine parameters are affected by both the engine’s condition and the operating conditions (e.g. ambient elements such as draught, sea water status, air pressure, and temperatures, as well as selectable criteria such as demanded ship speed or specified electrical load). As a result, we must compare the values of diagnostic parameters not merely with their prior values, but also with the reference values obtained from the sea trial data, also known as model diagrams.

Because we can use different settings to analyze different engine components, different conditions should be used as independent variables for distinct troubleshooting and diagnostic metrics and model diagrams are typically based on the findings of sea trials or test beds.

The best troubleshooting and diagnosis parameters to use are measured engine values that meet the following criteria:

* + their value is dependent not only on operating conditions but also, to a large extent, on the technical state of the engine;
  + they assist us in avoiding the most serious faults;
  + they assist us in optimizing the maintenance process;
  + they can be measured using the engine equipment that is available.

*Load index, engine torque, engine rpm and power and fuel specific consumption, calculated over a long enough period of time, are the troubleshooting and diagnostic measures most typically used for evaluating engine performance.*

Engine overload is commonly produced by attempting to sail the ship through severe seas while setting the requested engine rpm to a high value. Usually, engine overload is frequently detected by the engine monitoring system, however regular monitoring of the operating point position is required to avoid such a problem.

Because fuel consumption varies with engine load, we must first compare the actual value with the model diagram value for the same engine power to develop a trend in Specific Fuel Consumption (SFOC). We can then display the deviation over time, most likely weeks, because some external influences, such as tide or weather conditions, may affect individual observations in the long run. If the SFOC is higher, it indicates that the total engine efficiency is worse, which should prompt more troubleshooting to determine the problem.

Engine vibrations are common, especially when starting the engine or sailing in rough waves. The majority of engine issues fall into two categories: combustion faults and mechanical faults.

The combustion defects, vibration-based condition monitoring may be further classified into two types: one is based on translational acceleration signals detected on the engine block or cylinder tightening bolts, and the other is based on torsional vibration signals produced from the torque meter. It is normally important to have data analysis software in order to use these signals. Even still, problems cannot always be detected automatically based on the studied vibration signals. As a result, any divergence should prompt a new search to pinpoint the specific cause of the issue.

A diagram of a sound wave

Description automatically generated

Example of engine vibration diagram

At its most basic, the frequency vibrations are usually the most telling indicator of where the flaws are located, as the vibrations will have the same frequency or components with frequencies multiples of the frequency of the faulty portion. For example, very high frequency vibrations are most often caused by high speed components such as those found in turbochargers. The shafting system is commonly linked with very low vibrations.

*Indicator diagrams, mean indicated pressure, exhaust gas temperature after each cylinder, compression pressure in each cylinder and maximum pressure in each cylinder are the troubleshooting and diagnostic metrics used to evaluate combustion.*

The most common engine combustion symptoms include:

* + **Dark smoke from the funnel**
* Dark smoke from the funnel usually indicates a lack of combustion air and it can appear when the engine starts, during a sudden load increase (e.g. during maneuvering and in rough seas due to abnormal engine loads). A failure in the turbocharging system might create dark smoke under constant engine loads.

A ship on the water

Description automatically generated

* + **An increase in the positive deviation of the mean exhaust gas temperature**
* The first stage in analyzing exhaust gas temperatures is to compare the actual value of the average exhaust temperature with the average value from the model diagram for the same engine power. The following issues can cause an increasing positive deviation of the average exhaust gas temperature:
  + - * high inlet temperature of the cylinder cooling water;
      * low inlet pressure of the cylinder cooling water;
      * high inlet temperature of the oil cooling the pistons;
      * low inlet pressure of the oil cooling the pistons;
      * insufficient combustion air.
  + **An increase in the deviation of the exhaust gas temperature after a single cylinder**
* The first stage in analyzing exhaust gas temperatures after each cylinder is to compare the actual value to the average exhaust temperature after all cylinders at the same time.  Some variances in exhaust temperatures between units may be normal, but increases in detected deviations indicate that something has occurred and can be used to troubleshoot engine conditions. The following issues can cause an increasing positive variance in exhaust gas temperature after a single cylinder:
  + - * late combustion, caused by the wrong injection timing or by worn fuel injector valve, which can be identified using an indicator diagram;
      * a leaking exhaust valve, which can be identified by an increasing negative deviation of the compression pressure.
  + **An increase in the negative deviation of the compression pressure in a single cylinder**
* When evaluating the compression pressure in a cylinder, compare the actual value of the compression pressure with the value from the model diagram for the same scavenge air pressure.  
  The following issues, which are normally visible during a scavenging port examination, might cause a growing negative deviation of the compression pressure in a cylinder:
  + - * blocked cylinder inlet ports;
      * wear of the piston rings or the cylinder;
      * clogged or burned out piston rings.
  + **An increase in the negative deviation of the maximum combustion pressure in a single cylinder**
* Compare the actual maximum combustion pressure in each cylinder to the average maximum combustion pressure in all cylinders at the same time when evaluating the maximum combustion pressure in each cylinder. Some variation in maximum combustion pressure between units is usual.  
  An increasing negative deviation of the cylinder maximum combustion pressure can be caused by the following issues:
  + - * a low compression pressure, which should be eliminated first as previously described;
    - A graph with lines drawn on it

      Description automatically generated

Example of low combustion pressure due low compression pressure

* + - * delayed combustion, which can be caused by incorrect injection timing or worn injection nozzles (this problem can be observed on the indicator diagram);
    - A graph with a line and a circle

      Description automatically generated

Example of low combustion due wrong timing

* + - * a decreased quantity of fuel injected, which can be caused by a worn plunger in the fuel pump (this can be confirmed by checking the Mean Indicated Pressure ) and if this is the cause the pump should be overhauled.
  + **An increase in the negative deviation of the Mean Indicated Pressure, M.I.P. in a single cylinder or group of cylinders**

*The following diagnostic parameters are used to evaluate a turbocharger:  turbocharger rpm, exhaust temperature before and after the turbocharger, scavenge air pressure, air pressure drop at the air filter, air pressure drop at the air cooler, exhaust pressure after the turbocharger (also known as the counter-pressure) and the cooling water temperature difference at the air cooler.*

The typical symptoms of turbocharging problems are:

* + **Increased negative deviation of the scavenge air pressure**

The following issues can cause an increasing negative divergence in scavenging air pressure:

* + - * a clogged air filter (which should be replaced first);
      * a malfunctioning or dirty turbocharger;
      * a clogged exhaust duct after the engine, which can be found by measuring the exhaust pressure after the turbocharger.
  + **Increasing deviation of the turbocharger speed (positive or negative)**

A corroded turbocharger nozzle ring or turbine blades, an excessive clearance between the turbine blades and the shroud or cover can all cause an increase in negative turbocharger speed deviation. As a result, on the model diagram, turbocharger speed should be referred to the scavenging air pressure.  
The following issues can cause an increasing positive divergence in turbocharger speed:

* + - * a dirty air filter;
      * a dirty air cooler;
      * a dirty turbocharger, either air or gas side, which should be removed by washing both sides according to the manufacturer’s instructions.
  + **Increasing positive deviation of the air pressure drop at the air filter**

When assessing the air pressure decrease at the air filter, start by comparing the actual value to the value from the model diagram for the same scavenging air pressure. A dirty air filter, which should be cleaned according to the manufacturer’s instructions, might produce a rising positive deviation of the air pressure drop at the air filter.

A large machine with a metal cylinder

Description automatically generated with medium confidence

View of turbocharger air filter

* + **Increasing positive deviation of the air pressure drop at the air cooler**

When assessing the air pressure drop at the air cooler, start by comparing the actual value to the value from the model diagram for the same scavenging air pressure. A dirty air side of the air cooler, which should be cleaned according to the engine manual, can cause an increasing positive deviation of the air pressure drop at the air cooler.

* + **Increasing negative deviation of the cooling water temperature at the air cooler**
* A dirty water side of the air cooler, which should be cleaned according to the engine handbook, can create a growing negative deviation of the cooling water temperature differential.
  + **Increasing cylinder block temperature near the scavenge box**

The temperature of the cylinder block surface near the scavenge box should be assessed using an infrared camera or measured by placing the palm of the hand close to, but without touching, the cylinder block and comparing it to other cylinders. A rising cylinder block temperature near the scavenge box, particularly when accompanied with rising exhaust gas and cooling water temperatures, can be a sign of a scavenge box fire. This type of fire is frequently caused by worn piston rings or an overabundance of cylinder oil. When a scavenge box fire is detected, the engine load should be quickly reduced and a fire extinguishing method (CO2, steam, etc.) should be used in accordance with the engine manual.

*The following diagnostic metrics are used to evaluate engine cooling: cooling water temperature after each cylinder, cooling water temperature at the engine’s inlet and piston cooling oil temperature at the engine’s inlet.*

An rising positive deviation of the cooling water temperature difference at the cylinder is a common indicator of an engine problem.

When assessing the cooling water temperature differential at the cylinder, start by comparing the actual value to the value from the model diagram for the same engine power. Several problems can cause an increasing positive deviation of the cooling water temperature difference at a cylinder:

* + - a crack in the cylinder liner (which can be accompanied by bubbles in the cooling water expansion tank);
    - a crack in the cylinder head (which can be accompanied by bubbles in the cooling water expansion tank);
    - an obstacle in the cylinder liner or the cylinder head cooling space (in this case there are no bubbles in the cooling water expansion tank).



Piece of rag found inside cooling pipe

*The diagnostic parameters utilized for engine lubrication evaluation are: main bearing temperatures (if available), lubricating oil temperature before the engine, lubricating oil water content, lubricating oil pH and lubricating oil viscosity.*

The typical signs of an engine lubrication problem are:

* **Increased positive deviation of the main bearing temperatures**

The temperature of each main bearing should be compared to the limiting value, and an alert should be generated when it reaches the limit, which depends on both the main bearing material and the placement of the temperature sensor.

All possible causes of an increased positive deviation of the main bearing temperature are:

* + - * A seizure process in the bearing, which can be caused by material failure, a sudden load increase, or obstructed oil flow;
      * An obstructed flow in the crankshaft drilling caused by lubrication oil impurities;
      * A cylinder mechanical overload caused by an excessively high maximum combustion pressure;
      * Bearing corrosion

A main bearing seizure can result in the bearing’s disintegration and a main engine emergency stop.

A close-up of a metal bowl

Description automatically generated

Example of main bearing failure

* **High water content in the lubricating oil**

The water content can be measured on-board with special equipment, but it can also be monitored continuously by a sensor fitted in the lubricating oil inlet line.

A close-up of a blue circular device

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Example of water in oil tester

A rising water content in the lubricating oil can be caused by a number of issues, including:

* + - * insufficient or faulty operation of the lubricating oil separator;
      * a cooling water leak into the cylinder due to a crack in the cylinder liner or cylinder head;
    - A close-up of a large cement container

      Description automatically generated

Exampled of cracked cylinder liner

A circular metal object with blue arrows pointing at the center

Description automatically generated

Crank in cylinder head

* + - * excessive water condensation in the charge air after the cooler (this usually occurs when humidity is high and the scavenge air temperature is low, allowing the dew point to be reached). This can be verified by opening the scavenge box’s drain valve); a worn or broken stuffing box can allow water to seep from the scavenge box into the engine crankcase.

Lubricating oil with a high water concentration can cause bearing corrosion, inadequate lubrication, and bearing seizures.

* **Low pH of the lubricating oil**

The pH of the lubricant oil can be measured aboard using pH test strips.

A hand holding a test strip

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Example of pH test strips

A low pH of the lubricating oil can be caused by a number of issues, including an increased amount of acidic combustion products due to a high sulphur content in the fuel or a low TBN of the cylinder oil and a worn or broken stuffing box, which allows combustion products to enter the engine crankcase.

Low lubricating oil pH is a severe issue since it can cause bearing corrosion.

* **Low viscosity of the lubricating oil**

Onboard, the viscosity of lubrication oil is determined by comparing the oil flow speed with a flow stick.

A yellow device with a few cups of liquid

Description automatically generated with medium confidence

Example of a viscosity testing flow stick

A low viscosity of the lubricating oil can be caused by several issues, including:

* + - * unburned fuel oil leaking past the piston rings to the stuffing box and further into the crankcase through an untighten stuffing box;
      * contamination with fuel oil from fuel pump lubrication;
      * a high water content in the lubricating oil;
      * oil deterioration due to age or contamination.

Lubricating oil with a low viscosity can cause significant engine damage.

* **High contamination, or low dispersancy, of the lubricating oil**

A spot test can be used to check for contamination and dispersancy in lubricating oil.

A collage of different types of oil stains

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Example of a spot test used onboard

A drop of oil is placed on blotter paper and dried for a few hours in this test. The dry spot is then compared to the available example spots, allowing the insoluble components in the oil to be determined.  
Lubricating oil contamination is typically caused by poor oil filtering or insufficient cleaning in the lubrication oil separator and oil contaminants can clog oil flow in small clearances and disrupt hydrodynamic lubrication.  
The ageing of the oil usually causes low dispersancy of the lubricating oil. Lubricating oil dispersancy is required to separate larger size deposits into microscopic particles that may then be transported uniformly throughout the majority of the oil and afterwards removed by filtering.