Marine diesel engines

Two-stroke marine diesel engines today are designed to be able to operate within the ISO 8217 fuel standard and the CIMAC HFO 55 No. 21 recommendation. The condition is that the fuel is properly cleaned in the centrifuge. Both ISO 8217 and CIMAC fuel recommendation specify that the content of catalytic fines in the fuel oil delivered on board may not exceed a maximum of 80 ppm, an abbreviation for parts per million which is expressed as a weight-to-weight ratio.

To clean the fuel oil of catalytic fines and other impurities before injection into the engine, fuel cleaning systems are required on board. Engine builders generally anticipate that the maximum level of 80 ppm catalytic fines will be reduced by the fuel cleaning system on board to a maximum of 15 ppm before the fuel oil is injected into the engine. As the level of catalyst fines in the bunkered fuel is lowered, the engine builders expect a related reduction in the amount of catalyst fines in the fuel entering the engine.

The design of the fuel cleaning system to be used on board is the critical factor for optimal reduction of catalytic fines content in fuel oil from 80 ppm upon delivery to the ship to 15 ppm before injection into the engine. This is to ensure safe operation and optimal engine performance.

Catalytic fines and engine performance

Catalytic fines are small particles of spent catalyst, that remain in the fuel after employing catalytic cracking processes to refine crude oil into more valuable fractions, leaving residual fuel oil as a bottom phase, enriched in contaminants. These particles vary in size anywhere from submicron to tenths of microns, ranging from a speck of dust or pollen to the width of a strand of coarse human hair. Though virtually invisible to the human eye, catalytic fines are very hard and capable of severely scratching, if not cutting, metal.

All catalytic fines, that remain in the fuel oil after centrifugal separation have the potential to cause abrasive wear and damage to the engine, which in turn can lead to potentially unsafe operating conditions. That is why the level of catalytic fines must be reduced as much as feasibly possible by the fuel cleaning system. Catalytic fines smaller than five microns are considered to be less harmful than larger cat fines.

The higher the amount of catalytic fines is, the greater the risk for unsafe operating conditions due to engine wear and breakdown. Under such operating conditions, there is an increased risk for breakdown and it is likely that the engine will require more frequent maintenance than those recommended by the engine manufacturer.

If the amount of catalytic fines is removed at optimum efficiency by the fuel cleaning system, according to experience the engine has a controlled and acceptable wear, defined as mean time between overhaul, which is specified by engine suppliers.

The importance of fuel cleaning

Marine diesel engines are designed to be capable of accepting all commercially available fuel oils, provided they are adequately treated on board. For this purpose, a well-designed fuel cleaning system is a must. Centrifuges in combination with a settling tank are generally accepted within the marine industry as the fuel cleaning system of choice. Filters are only considered as a safety to pick up larger particles so that these particles do not reach the engine, and do not as such "clean" the fuel.

To ensure safe operation, a heavy fuel oil that meets ISO 8217 and the CIMAC fuel recommendations should be cleaned by an onboard fuel cleaning system that satisfies these conditions:

- Preheating the fuel oil to the correct temperature before the centrifuges;
- Correct capacity/layout of the centrifuge (i.e., correct throughput of fuel through the centrifuges);
- Proper operation and maintenance of the centrifuges;

Because of continuous advances in centrifuge technology, it is virtually impossible for any engine builder to specify the exact size requirements for the individual centrifuges that are part of an onboard fuel cleaning system. The correct sizing of the centrifuges depends on the daily fuel consumption and on the design viscosity of the system. Engine builders can only provide recommendations for optimal engine performance, which must then be confirmed by centrifuge manufacturers. See "Sizing of centrifuges".

Settling and service tanks

Heavy components of large sizes, such as large catalytic fines, in the fuel oil settle on the tank bottom due to gravitational force. However, at high sea and rough sea conditions, these components can be hurled up and fed into the centrifuges. The presence of such heavy components influences the purity of fuel after the fuel cleaning system. It is therefore important to drain the settling and service tanks regularly.

Centrifuges
If properly operated, a centrifuge has the capability to remove nearly 100 percent of all catalytic fines that are larger than 10 microns. However, the majority of catalytic fines smaller than five microns will not be removed due to small size and their relative light weight.

In order to check the efficiency of the centrifuges, it is recommended that samples be taken before and after the centrifuges at least every four months and sent to an established institution for analysis. Samples should be taken more frequently whenever operating on fuel oil with more than 25 ppm of catalytic fines when the fuel is bunkered.

Homogenisers
Some fuel cleaning systems use homogenisers, which split any water present in the fuel into small uniform droplets. Positioning homogenisers upstream from the centrifuges, however, is not currently recommended. This is because catalytic fines are hydrophilic, which means that they are attracted to any water present in the fuel oil. It is therefore expected that it will be difficult for the centrifuge to remove the small homogenised water droplets, which include any salt water and attached catalytic fines.

Filters
Filters in relation to fuel cleaning are to be considered as additional protection, guarding the engine from large particles.

Engine wear and damage from catalytic fines

Abrasive wear is mainly caused by the failure of the centrifuges to remove catalytic fines from the fuel oil. Rust, sand and dust are other components, which are also removed by the centrifuges; however, they are normally less harmful and are found in the fuel in much smaller quantities.

Fuel injection system
The fuel pump is the first component on the engine that is subject to the harmful effects of catalytic fines. The fuel pump pressurises the injectors, which enables the injectors to deliver the correct amount of fuel to the engine under the different operating conditions.

The fuel pump consists of a plunger that slides back and forth within the fuel pump barrel. There are relatively small tolerances between the components. Any catalytic fines that approximate the size of these clearances will be forced between the plunger and barrel and may become embedded in the material of the plunger and/or the barrel (Figure 1).

Excessive wear of the plunger or the barrel affects the injection pressure and thereby performance. If abrasive wear to the fuel pump has occurred, it is impossible to maintain the correct compression pressure for the individual cylinder units.

Catalytic fines that manage to pass through the fuel pump will reach the fuel injectors, where excessive wear can change the size and shape of the injector holes. Any change in the size and shape of the holes alters the injector pattern of the fuel oil, which in turn can decrease combustion efficiency.
Changes in the fuel injection pattern also result in fouling of combustion chamber components and increase the amount of unburned hydrocarbons (HC) emissions in the exhaust gas.

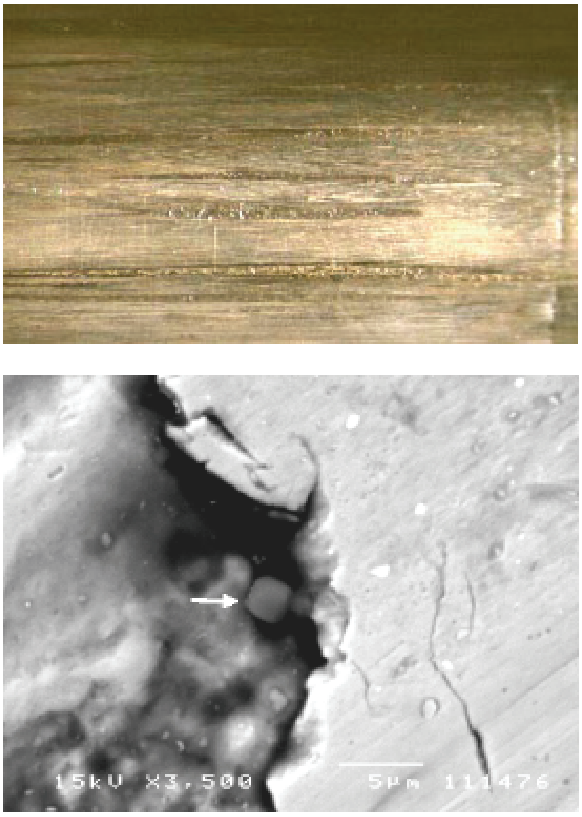

Figure 1. Fuel pump spindle guide with scuffing and excessive wear.

Combustion chamber
When the fuel is ignited, the catalytic fines become trapped in between the various working components of the combustion chamber between the piston ring and ring groove or between the piston ring and liner. This creates a potentially high-risk situation in the combustion chamber.

Any catalytic fines that are not taken out by the exhaust gas or drained to the bottom of the cylinder unit can become embedded in the softer material of the piston rings. This quickly creates wear on both the liner and the chrome-plated piston ring or piston ring grooves (Figure 2).

Figure 2. Catalytic fines embedded in the surface of a piston ring.

Case study: Land-based power plant

The quality of fuel delivered to a land-based power plant varied widely in the levels of catalytic fines. At various times and with various fuels, the amount of catalytic fines contained in the fuels was measured at up to 125 ppm.

Moreover, the fuel quality after cleaning was not acceptable due to complications relating to the operation of the fuel cleaning equipment. Good maintenance practices are critical to the proper operation of auxiliary machinery; it is virtually impossible for engine designers to predict the mean time between overhauls (MTBO) if the engines and fuel cleaning system are not properly maintained and the fuel oil specifications are not followed.

The high level of catalytic fines resulted in heavy wear and scuffing on the cylinder liners and pistons. Catalytic fines became embedded in the piston ring surface, causing excessive wear on the cylinder (see Figures 2 and 3).

Before determining that catalytic fines were the root cause of engine malfunction, several possible reasons for excessive wear were investigated.

The situation for this plant could have been avoided if the fuel had been in accordance with ISO 8217 and CIMAC recommendations and the fuel cleaning system had been functioning properly.

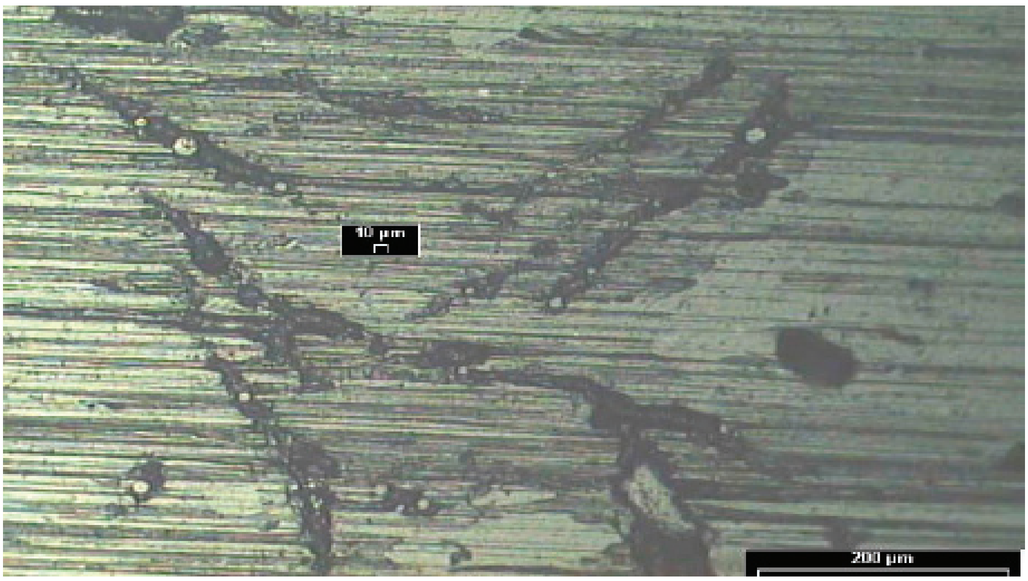

Figure 3. Wear on a cylinder liner.

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