Date: March 02, 2017 **Caterpillar confidential: green**
Subject: Crankshaft, big end bearing
Engine type: M20C

Lubrication Oil Care at M20C engines

Since 1993 over 1200 M20 series engines have been delivered. Approx. 40% of these engines are equipped to operate on heavy fuel oil.

During the last years, excessive wear on crankpins was noted at several M20C installations, especially at HFO operated engines. In most cases, this kind of wear was noticed during scheduled overhauls and was caused by a high amount of dirt particles in the lube oil.

Due to these findings we recommend measuring the dimensions of crankpins regardless of the visual condition of crankpins and big end bearings during engine main overhauls (15,000 hrs / 30,000 hrs). This job should be carried out by your responsible MaK service representative. For big end bearing replacement we recommend using the current bearing design only.

Take special attention to the lube oil quality in the engine. Have lube oil analysis carried out on regular basis. Take special care to the engine lubrication oil filters and to the lubrication oil treatment components such as by-pass filters and purifiers.

Please note that undetected crankpin wear increases the risk of a big end bearing failures. Bearing failures most likely lead to extensive engine repair works where the crank shaft has to be removed for grinding.

Examples for crank pin wear (figure 1) and resulting damages in case of undetected wear (figure 2):

Worn crankpin and big end bearing with no visual damage.

Operating hours of both components: ~27.000 h

Figure 1 : worn crankpin with bearing

After installing a new big end bearing on an undetected worn crankpin, a visual damage will occur at the middle of both components.

Operating hours of the engine: ~27.000 h

Operating hours of the new installed bearing: ~3000 h

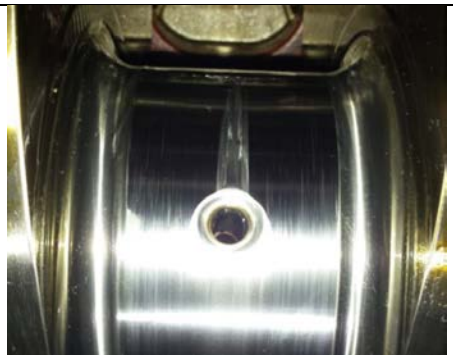

Figure 2 : damaged crankpin with bearing

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In order to prevent such damages, we strongly advise to follow the following recommendations regarding the crank pin measurement, layout and maintenance of the lubrication oil system.

Checking of the crankshaft journals

During 15.000 and 30.000 hrs M20C engine maintenance the dimension of the crankpins have to be checked (see figure 3). Please contact your local MaK service representative for an offer.

- Standard diameter: 152h6 mm.
- Diameter limit at any location: 151,90 mm
- Maximal ovality: 5/100 mm

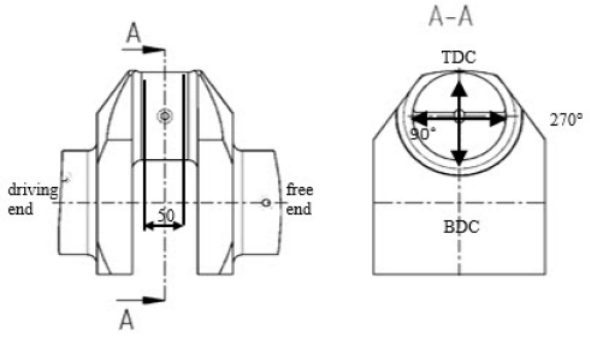

Figure 3 : measurement positions

Please note:

- In some cases ridge wear can occur. To ensure the function of a big end bearing, a cylindrical shape of the crankpin is the most important factor. A cylindrical shape is characterized by the roundness and the straightness of a crankpin. Only ridges smaller than 15 µm are allowed for the operation with new bearing shells, other ridges have to be removed.

- When exchanging bearings please use current bearing design only.

- When taking the measurement make sure that the measurement device, gauge blocks and crankpins have about the same temperature.

  Example: A temperature deviation of 11 K distorts the measurement by 2/100 mm at a crankpin diameter of 152 mm.

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Quality of lubrication oil

It is of utmost importance that the lubricating oil is always in a good condition and that its properties remain within specification. Therefore, frequent sampling (i.e. every 500 h.) is highly recommended. We recommend to take the oil sample as close to the engine intake as possible. At this position, you will get the most reliable information about concentration of dirt and wear particles to make the correct decisions for your lube oil treatment. If all values are within limits, no further actions have to be taken.

The following limits are applicable for lube oil in the M20C engine:

- max. Water content: 0,2 %*
- max. Vanadium content: 150 ppm
- Viscosity at 40°C between 120 mm²/s and 200 mm²/s
  OR
  Viscosity at 100°C between 12,5 mm²/s and 17,6 mm²/s
- TBN: 18 mg KOH/g. when running at HFO / On MDO it is 50% of new oil
- Insolubles < 1% by weight. The sum of soot and asphaltenes has to be below 1% by weight**
- Separation temperature to be kept > 95°C
- On HFO the LO Separator capacity to be set at least at 5 cleanings of the sump tank volume every day (On MDO the LO Separator capacity should be set on 3 cleanings every day)
- If one separator is responsible for cleaning the lube oil of several engines and sump tanks (not recommended!) it has to be switched between these engines several times per day

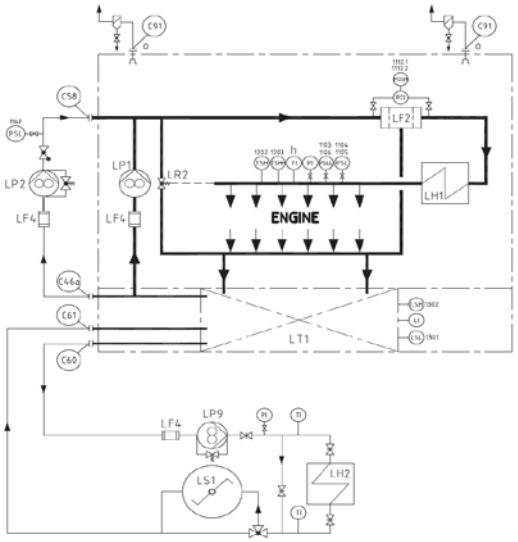

Figure 4 : Lube oil system diagram

* The water content is a good indicator for the correct setting of the lube oil separator. When correctly operating the separator, the water content can be kept clearly below 0,1%. A high water content in the lube oil also increases the tendency for cavitation.

** Soot and asphaltenes are insolubles. Often oil analysis show soot content and asphaltenes separately, if the amount of insolubles (i.e. soot and asphaltenes combined) exceeds 1% by weight, there might be a problem with your lube oil treatment. Check the settings of your separator. If the amount of insolubles will not drop to a level below 1% by weight, malfunction of the separation unit is likely.

If the amount of insolubles reaches 2% or higher, stop the engine. Exchange at least 50% of the lube oil volume. When operating the engine with this high amount of insolubles, the components of your tribological system could already suffer severe wear. Contact your local MaK Dealer to make sure the right actions are taken to get your lube oil system back to the optimum working conditions and no permanent damages have occurred at the components of your tribological system.

If you have any further questions regarding the lubrication system (see figure 4) or the separation unit, contact your MaK service representative for assistance.

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Automatic lubrication oil filter

The automatic LO filter attached to the M 20C engine is fitted with candles with a mesh size of 30 µm. When these filters clog up, the spring loaded bypass valves will open shortly after the second differential pressure alarm is triggered. When this happens, the lubrication oil is filtered through the 100 µm back up filter only.

During normal operation, the filter will not remove dirt from the oil, it will only protect the engine from particles with a diameter > 30 µm. Dirt is backflushed into the crankcase where it will flow into the oil pan or sump tank for cleaning by the separator. **!**

We would like to inform you about this filter as follows:

- The differential pressure alarm is an indicator that the separator is not working properly.
- There are two differential pressure alarm levels before the bypass valves open.
  - First alarm: Pressure >0.8 bar
  - Second alarm: Pressure >1.2 bar
  - Bypass valves will open at 2 bar
- When starting the engine with an oil temperature lower than 40°C, the bypass valves could open due to the increased viscosity creating differential pressure.
- Check your separator settings when a differential pressure alarm is triggered.
- The filter must be opened for manual cleaning when a differential pressure alarm is triggered.
- Caterpillar recommends taking lube oil samples for analysis when a differential pressure alarm is triggered.

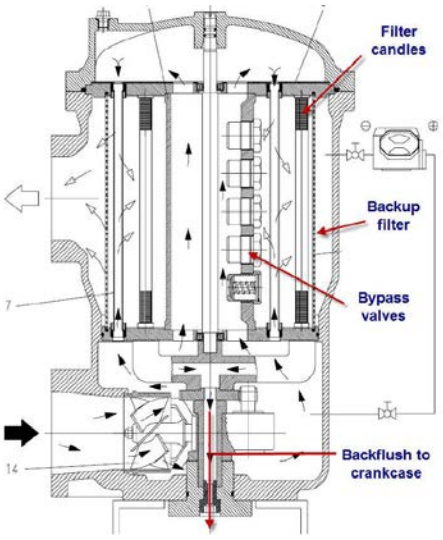

Figure 5 : Boll & Kirch 6.48 Lube oil automatic filter

- When the engine cannot be stopped for manual cleaning of the LO filter, it is possible to operate the engine in an emergency situation on the 100 µm backup filter (differential pressure > 2 bar) for a short period of time*. Any engine operation with open bypass valves will have negative impact on the lifetime of components of the tribological system, though.
- When opening the filter for cleaning, always check candles and back up filter for defects, mechanical damages and punctures. Also the bypass valves have to be checked for damages and verified to be in closed position (see figure 5).

The maintenance of the filter has to be performed according to manufactures documentation.

* When the emergency situation is over, the filter has to be opened for manual cleaning.

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Lube oil separator

Performing regular lube oil sampling and a continuous effective lube oil treatment are vital conditions for the reliable performance of an engine.

During engine operation, the lube oil is continuously contaminated by combustion residues, water, particles, acids and other foreign materials. In order to keep up the oil's lubricating characteristics and reach reasonable exchange intervals, it is necessary to remove these pollutants from the lube oil. This is the task of the lube oil separator unit.

Efficient continuous lube oil separation, 24h/day, assures reliable removal of the pollutants, thereby avoiding wear and tear on moving engine components.

In order to assure reliable and efficient operation of the separator, it is absolutely vital to maintain optimal settings and adjustments.

Best separation is achieved when the lube oil remains in the cleaning chamber of the separator as long as possible and at low viscosity. !

- A low viscosity is achieved when heating the lube oil to 95°C to 98°C.
- The remaining time in the cleaning chamber is increased by reducing the volume flow through the separator. At the same time it is important not to fall below the requirement of separating the total lube oil quantity five times per 24 hours.

The optimal volume flow (called "required operation flow" below) using the theoretical lube oil volume can be calculated with the following formula:

$$V_{eff} = \frac{P_{eng} \times 1{,}36 \times n}{\mathrm{t}}$$

$V_{eff} = \ required\ operation\ flow\ [l/h]$

$P_{eng} = Engine\ output\ [kW]$

$1{,}36 = theoretical\ oil\ volume\ corresponding\ to\ 1{,}36\ [l/kW]\ or\ 1\ [l/HP]$

$n = Number\ of\ turnovers\ per\ day$

$t = effective\ separation\ time\ per\ day\ (23.5\ h\ separating\ and\ 0.5h\ for\ sluge\ discharge)$

OR: Short form for HFO application (5 turnovers per day):

$$V_{eff} = \frac{P_{eng} \times 1{,}36 \times 5}{23.5} = 0.29 \times P_{eng}$$

Please note that the calculated volume flow determines the minimum separator capacity when the installation is in perfect condition. It is important to perform regular service and maintanance according to the separator manufacturer´s service instructions.

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When operating a M20C Genset the true oil volume can differ from the theretical oil volume. To calculate the optimal volume flow, please use the true volume which can be found in your technical data.
Note: When calculating the minimum required capacity during the layout of the lube oil system, the 1,36 l/ kW are essential.

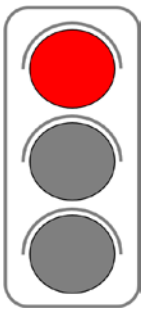
The effectiveness of the separators can be determined by taking samples at the separator intake and outlet. Comparing the results shows to what extent foreign materials and water are removed by the separator.

The following scenarios demonstrate what effects wrong operation can have on the cleaning effect of the separator. Basis for the calculation is an 8M20C engine operating on HFO with 1520 kW and a separator of a maximum effective capacity of 860 l/h.

Example 1:

In order to fulfil the requirement of separating the total lube oil quantity five times per 24h, the maximum capacity of the separator is utilized:

$$t = \frac{P_{eng} \times 1{,}36 \times n}{V_{eff}} = \frac{1520[kW] \times 1{,}36[l/kW] \times 5[1/d]}{860[l/h]} = 12.01[h/d]$$

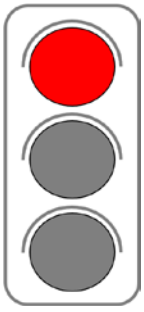


After 12 hours, the required quantity is separated and the separator is switched off.
However, for optimal separation, the lube oil must remain in the cleaning chamber as long as possible. In this example, the separator is adjusted to its maximum volume flow. Due to the resulting short remaining time in the cleaning chamber, only large and heavy particles can be removed from the lube oil. Smaller particles, that possibly have pass through the filters, remain in the lube oil and accelerate wear of engine components.

Example 2:

The last lube oil analysis shows an increased amount of insolubles. The decision is taken to "improve" the separation and to use the full capacity of the separator. Now, the separator is used 23,5 h / day:

$$n = \frac{V_{eff} \times t}{P_{eng} \times 1.36} = \frac{860[l/h] \times 23.5[h/d]}{1520[kW] \times 1{,}36[l/kW]} = 9.78[1/d]$$



Every day, the complete lube oil quantity is separated 9.8 times now. However, by utilizing the full volume flow, the time the lube oil remains in the cleaning chamber is the same as in Example 1. The short remaining time in the cleaning chamber leads to the same or very similar result as in Example 1.

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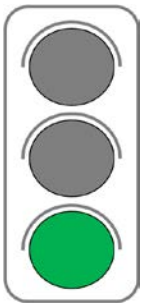
Example 3:

The optimal volume flow is calculated according to Caterpillar's specification and the separator's pump is adjusted accordingly:

$$V_{eff} = \frac{1520[kW] \times 1{,}36[l/kW] \times 5[1/d]}{23.5[h/d]} = 439.8\ [l/h]$$



To ensure a low viscosity the lube oil is heated to 95°C to 98°C. At a volume flow of approx. 440 l/h the total lube oil volume is circulated exactly 5 times per 24 h. This way, the time the lube oil remains in the cleaning chamber is maximized and even small particles with lower mass and density can be removed from the lube oil.

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