Operational Guidelines to Operating MAN B&W 2-Stroke Engines on Distillate Fuels

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Traditionally, the lowest viscosity suitable for large marine diesels has been set at 2 cSt at engine inlet, however experience has shown us that the most reliable performance is achieved with viscosities above 3 cSt at engine inlet.

Fuels with a specified viscosity of minimum 2 cSt at 40 deg C can be used, however as many factors influence the performance operating on fuels in the low viscosity range, MAN Diesel believes that fuels with a viscosity of 3 cSt at 40 deg C hold the sufficient margin for safe and reliable engine performance.

1. Introduction

Due to the existing and coming environmental legislation on fuel sulphur contents MAN B&W 2-Stroke engines will increasingly operate on distillate fuels, marine gas oil (MGO) and marine diesel oil (MDO), in such areas where demanded.

MAN B&W 2-Stroke engines are optimized to operate on heavy fuel. The MGO / MDO fuels can be used, however, some individual considerations on the Engine and fuel system have to be done to ensure safe and reliable performance:

- Viscosity and lubricity of fuels
- Keeping high fuel pump pressure
- Use of cooler or chiller in external fuel supply system
- Other considerations, references for more information
reliable operation, MAN Diesel recommend that after the operator have tested the engines/external system sensitivity for low viscosity the necessity of installation of a cooler or chiller is considered or the operator aims at purchasing fuels with minimum level of viscosity necessary.

2. ISO 8217

In ISO 8217, Distillates grades DMX/DMA can be sold with a viscosity down to 1.4/1.5 cSt at 40°C. This will especially be the case if the DMX/DMA provided origins from automotive gas oil. The 1.4/1.5 cSt can as such only be utilized, if the distillates is Cooled/Chilled down correspondingly, to reach the 2 cSt minimum viscosity at engine inlet.

3. Influence of Lubricity and Viscosity

3.1 Lubricity

The refinery processes intended to remove e.g. sulphur from the oil result not only in low viscosity but also impacts the lubricity enhancing components of the fuel. Too little lubricity may result in fuel pump seizures. Although most refiners add lubricity enhancing additives to distillates, MAN Diesel recommends that, prior to using fuels with less than 0.05% sulphur, the lubricity is tested. Independent fuel laboratories can test lubricity according to ISO12156-1 (High-Frequency Reciprocating Rig, HFRR). The HFRR limit is max. 460 μm.

3.2 Viscosity

Low viscosity fuel oil challenges the function of the pump in two ways: 1. Break down of hydrodynamic oil film (resulting in seizures) and 2. Insufficient injection pressure (resulting in difficulties during start and low load operation).

Due to the design of the conventional pumps versus the pressure booster, the ME/ME-C engines are more tolerant towards low viscosity compared to the MC/MC-C engines. Many factors influence the viscosity tolerance during start and low load operation: Engine condition and maintenance, fuel pump wear, engine adjustment, actual fuel temperature in the fuel system, human factors etc. Although achievable, it is difficult to optimize all of these factors at the same time. This complicated operation on viscosities in the lowest end of the viscosity range. To build in some margin for safe and

Fig.1 Fuel system (cooler installed after the circulating pumps)
reliable operation, MAN Diesel recommends that the operator aims at purchasing fuels with viscosities above 3 cSt at 40 deg C and/or install a cooler or chiller.

4. Fuel Oil Pump Pressure

Worn fuel pumps increase the risk of starting difficulties as the fuel oil pump pressure needed for injection cannot be achieved. An indication of fuel pump wear can be achieved by reading the actual fuel pump index for comparison with the test bed measurements. As a rough guideline, we consider the pump worn out when the index increase is 10 or more. Such fuel pumps should be replaced for better engine performance.

It is always advisable to make start checks at regular intervals, however, as distillates of above 3 cSt at 40 deg C may not be available in all ports, it is an imperative necessity to perform start checks prior to entering high risk areas (e.g. ports). This way the individual low viscosity limit can be found for each engine. It is recommended to perform such check twice a year.

- In an area for safe operation, the fuel is changed to an available distillate.
- At different operating conditions, e.g. start, idle, astern and steady low rpm, change the temperature at the pumps at fuel main supply line gradually corresponding to respectively 2, 2.5 and 3 cSt. See typical viscosity and temperature relationship in appendix A.
- Test start ahead/astern from the control room. If the engine does not start at the first attempt, try to cancel the “start limiter” (increase of fuel limits) and repeat start attempt. If the start ahead/astern is ok with cancelled limiter, this solution can be used temporarily until either new fuel pumps are installed or if a higher viscosity fuel is available.

An outcome of the test might be that the specific engine requires a viscosity that cannot be kept due to the influence from the many factors. If the fuel pumps are worn, they must be replaced and the start check repeated. Should the given engine still require a higher viscosity, fuels with sufficient viscosity must be obtained. An alternative solution is to install a cooler or a chiller in the fuel system to increase viscosity.

5. Installation of Cooler or Chiller

One way to maintain the required viscosity at engine inlet is to install a cooler in the system. Fig. 1 shows the recommended location to install a cooler.

5.1 Cooler

One way to ensure a minimum viscosity of 2 cSt is to install a cooler in the system. Figure 1 shows the recommended location to install a cooler.

The advantage of installing the cooler just before the engine is that it is possible to optimize the viscosity regulation at the engine inlet. However, the viscosity may drop below 2 cSt at the circulating (and other) pumps in the system.

The cooler can also be installed before the circulating pumps. The advantage in this case is that the viscosity regulation may be optimized for both the engine and the circulating pumps.

It is not advisable to install the cooler just after the engine or after the diesel oil service tank as this will complicate viscosity control at the engine inlet. In case the cooler is installed after the service tank, the supply pumps will have to handle the pressure drop across the cooler. This cannot be recommended.

Seawater should not be used for the cooler due to the risk of fuel leaking into the sea water and polluting the environment.

The following items should be considered before specifying the cooler:

- The flow on the oil side should be the same as the capacity of the fuel oil circulating pump.
- The fuel temperature to the cooler depends on the temperature of the fuel in the service tank and the temperature of return oil from the engine.
- The temperature of the cooling medium inlet to the cooler depends on the desired fuel temperature to keep a min. viscosity of 2-3 cSt.
- The flow of the cooling medium inlet to the cooler depends on the flow on the oil side and how much the fuel has to be cooled.
Based on the fuel oils available in the market as of July 2009, a fuel inlet temperature of min. 40 deg C is expected to be sufficient to achieve 2 cSt at engine inlet. In such case, the central cooling water (max. 36 deg C) can be used as coolant.

5.2 Chiller
For the lowest viscosity distillates, a cooler may not be enough to sufficiently cool the fuel as the cooling water available onboard is typically LT cooling water (36 deg C). In such cases, it is recommended to install a so-called ‘Chiller’ which removes heat through vapour-compression or an absorption refrigeration cycle.

A ‘Chiller’ is a machine that removes heat from a liquid via a vapour-compression or an absorption refrigeration cycle. The ‘Chiller’ principle is shown in Fig. 2.

5.3 Pour point
A highly paraffinic fuel has a higher risk of wax formation. An oil with a high pour point also contains many paraffins and are more likely to create wax crystals which will block the filters and at worst influence the pumppability of the fuel.

To avoid wax formation, the fuel should not be cooled below the pour point of the fuel. The pour point is limited by the ISO8217 specification and can be measured by independent labs.

6. Change-over between HFO and MGO/MDO

Prior to the intended change-over from HFO to MGO and vice versa, we recommend that the compatibility of the two fuels is checked – preferably at the bunkering stage. The compatibility can be checked either in an independent laboratory or by using test kits onboard.

Incompatible fuels may lead to filter blocking and extra focus should be on filter operation in case of incompatibility.

Change-over to/from MGO can be somewhat dangerous for the fuel equipment as hot heavy fuel (80 deg C) is mixed into relatively cold gas/diesel oil. The mixture is not expected to be homogeneous immediately and some temperature/viscosity fluctuations are to be expected. The process therefore needs careful monitoring of temperature and viscosity.

During change-over, the temperature increase/decrease rate should be less than 2 deg C pr min. to protect the fuel equipment from thermal shock (expansion problems) resulting in sticking. A fully automatic change-over function including the fuel cooler control will be beneficial to avoid incidents related to human mistakes.

An MAN Diesel special automatic change-over system (the “Diesel Switch”) is offered from PrimeServ.

7. Change-over from HFO to MGO

- Ensure that the temperature of the MGO in the service tank is on an acceptable level regarding the expected viscosity at the engine inlet.
- Reduce the engine load
  - The load during this process should be 25-40% to ensure a slow reduction of the temperature.
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8. Change-over from MGO to HFO

The mixing of the hot heavy fuel (80 to 90 deg C) into relatively cold gas oil can be somewhat difficult as the mixture is not expected to be homogeneous immediately and some temperature/viscosity fluctuations are to be expected.

- Ensure that the temperature of the heavy oil in the service tank is about 80 deg C.
- Reduce the engine load
  - The load during this process should be 25-40 % to ensure a slow heat-up of the system from max. 35 deg C for the MGO to normal heavy fuel service temperature (up to 150 deg C).
  - This load can, based on experience, be changed to a higher level - up to 75 % as described in the instruction book, Operation.
- Start changing over the fuel.
- Start steam tracing when the viscosity reaches 5 cSt.

In general, only the viscosirator should control the steam valve for the fuel oil heater. However, observations of the temperature/viscosity must be the factor for manually taking over the control of the steam valve to protect the fuel components.

Two things to be kept under observation during this change-over are:
- The viscosity must not drop below 2-3 cSt and not exceed 20 cSt.
- The rate of temperature change of the fuel inlet to the fuel pumps must not exceed 2 deg C per minute.

9. Correlation between fuel sulphur level and cylinder condition

During combustion, sulphuric acid is formed from the fuel sulphur. Part of the sulphuric acid condenses on the cylinder liner causing corrosive attack. The cylinder lube oil contains base with the aim of neutralising the acid.

Some corrosion is beneficial to the cylinder condition as this keeps an open graphite lamella structure of the cylinder liner surface from where the cylinder lubricant can spread. The purpose is therefore not to avoid corrosion but to control corrosion. This is done by adjusting the amount of base, i.e. by either using BN40 cylinder lube oil (instead of BN70 as normal for operation on HFO), by optimising the cylinder oil feed rate to the actual fuel sulphur level or a combination of both.

Over-additivation, i.e. too much base compared to the actual fuel sulphur level, may result in bore polishing (mirror-like surface indicating a closed liner structure) and deposit formation on the piston – both increasing the risk of scuffing significantly.

For high topland engines (high topland pistons are pistons where the topland is significantly higher than the ringland), MAN Diesel recommends to change to a BN40 cylinder oil at minimum feed rate operating for extended periods (typically more than two weeks) on low sulphur fuel in e.g. SECAs (SECA = Sulphur Emission Control Area). This also goes for distillate fuels.

We have reports of older low topland engines operating continuously on low sulphur fuels and with BN70 cylinder oil without problems. In such cases, it is subject to owner decision whether to change to BN40 cylinder oil.

For continuous operation on distillate fuels, a change of...
piston rings might be called for to ensure good cylinder condition.

Appendix A
Temperature of MGO to ensure viscosity below recommended 2 cSt

The horizontal axis shows the bunkered fuel viscosity in cSt at 40 deg C, which should be informed in the bunker analysis report. If the temperature of the MGO is below the red curve at engine inlet, the viscosity is above 2 cSt.

Example: MGO with viscosity of 3 cSt at 40 deg C must have a temperature below 63 deg C at engine inlet to ensure a viscosity above 2 cSt.

Example: MGO with a viscosity of 5 cSt at 40 deg C is entering the engine at 50 deg C. The green curves show that the fuel enters the engine at approximately 4.0 cSt.

Example: MGO with a viscosity of 1.5 cSt at 40 deg C needs cooling to 22 deg C to reach 2 cSt.