Low Container Ship
Speed Facilitated by Versatile ME/ME-C Engines
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Low Container Ship Speed
Facilitated by Versatile ME/ME-C Engines

Introduction

Recently, fuel oil prices have risen to unprecedented levels, bringing fuel oil consumption of diesel engines more into focus than for a long time. At the same time, exhaust gas emissions in general and CO₂ emission in particular are top priorities.

One way of reducing fuel consumption as well as CO₂ emission is to reduce the ship speed. Fig. 1 shows the relation between power and speed for a typical modern large post panamax container vessel.

It is obvious that reducing the ship speed reduces the power requirement substantially, see Fig. 1. Reducing the ship speed by e.g. 4 knots reduces the power requirement to some 50%. This means that in case the main engine has been chosen with sufficient power for high ship speeds, inclusive of margins on top of that, it must be able to operate at low loads for long periods. This is the situation that vessels in service are exposed to and must comply with. Typically, what happens is that a round trip normally lasting 8 weeks is changed to a duration of 9 weeks, leaving more time and a reduced ship speed demand.

Two very important issues must be considered in connection with reduced ship speed:

1. Main engines’ ability to operate at low loads for long periods of time.
2. Fuel oil consumption at such low load.

For new building projects, the operators must decide whether the vessel should be laid out for high ship speeds, as has been the case for a number of years, or whether they should choose an alternative design for lower ship speed (i.e. also choosing a smaller main engine), or as a third option, whether they should keep the full size engine in the specification, but have it delivered optimised for the lower load. So far, ship owners have chosen to maintain the flexibility in service by maintaining the prevailing high design ship speed.

The electronically controlled ME/ME-C engines have a major advantage with respect to operating at even very low load for indefinite periods of time, whilst offering a substantial reduction in fuel oil consumption compared to conventional engines at such low loads. In this respect, we refer to our recent service letter SL07-480.

In connection with fuel oil consumption, it should be realised that with the emission legislation (Tier 2) coming into force for vessels with keel laying after 1/1 2011, compliance with this legislation is possible with the ME/ME-C engines with a minimum of fuel oil consumption penalty. Tier 2 is expected to imply a reduction of the allowed NOₓ from the present 17g/kWh to 14.5 g/kWh, among other exhaust gas emission reductions. This NOₓ reduction can be met by engine tuning only and, for ME/ME-C engines, this is expected to have a fuel oil consumption penalty of up to 2 g/kWh. For the MC/MC-C en-
gines the fuel oil consumption penalty is expected to be 4 g/kWh.

The following will describe how low load and part load optimised operation can be implemented on ME/ME-C engines. We will also outline this for MC/MC-C engines, and describe how they differ from their more advanced electronically controlled counterparts.

**ME/ME-C Engines**

With the introduction of ME and ME-C engines as well as the slide fuel valves as standard, the engine conditions for service at low loads for long-term operation have improved considerably. One of the key benefits of the ME/ME-C engines is the ability to operate in different modes at the discretion of the operator. Presently, four different modes can be incorporated in the ME engine software.

Each individual mode can in principle be designed to fulfill specific needs of the shipowner in question, without any operating mode design limitations, as long as each mode meets the requirements of IMO set for the engine NOx emission. However, a fuel economy mode and an emission mode are occupied as MAN Diesel standard modes. Usually, licensees have chosen to deliver the engines in fuel economy mode, while the emission mode has been offered as an option. Emission mode is of particular interest to shipowners operating in waters where financial compensation is offered for low NOx/SOx emissions.

The general description of low load operation given in the section “Low Load Operation with MC/MC-C Engines” remains valid for ME/ME-C engines.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Engine power</th>
<th>SFOC</th>
<th>Fuel consumption</th>
<th>Operating time</th>
<th>Fuel consumption</th>
<th>Ship speed</th>
<th>Sailed distance</th>
<th>Fuel consumption per n mile</th>
<th>Fuel costs per n mile</th>
<th>Relative fuel cost per n mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>% SMCR</td>
<td>g/kWh</td>
<td>t/24h</td>
<td>h/week</td>
<td>t/week</td>
<td>knot</td>
<td>n mile/week</td>
<td>kg/n mile</td>
<td>USD/n mile</td>
<td>%</td>
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<td>Standard</td>
<td>90.0</td>
<td>167.5</td>
<td>263.3</td>
<td>168</td>
<td>1843.3</td>
<td>25.0</td>
<td>4200</td>
<td>439</td>
<td>219</td>
<td>100.0</td>
</tr>
<tr>
<td>12K98MC-C6</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>75.0</td>
<td>165.1</td>
<td>216.2</td>
<td>14</td>
<td>126.1</td>
<td>23.0</td>
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<td>Load runn.</td>
<td>30.0</td>
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<td>91.2</td>
<td>+154</td>
<td>+585.0</td>
<td>18.5</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>168</td>
<td>711.1</td>
<td>18.5(^2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12K98ME-C6</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>75.0</td>
<td>163.6</td>
<td>214.4</td>
<td>2</td>
<td>17.9</td>
<td>23.0</td>
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</tr>
<tr>
<td>Load runn.</td>
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<td>90.6</td>
<td>+166</td>
<td>+626.4</td>
<td>18.5</td>
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<td></td>
<td>168</td>
<td>644.3</td>
<td>18.5(^2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Including temporary load increase of up to 75% SMCR at low load operation. Ref. service letter SL07-480/SBE, June 2007
2. During 75% running load, the ship will often sail a longer curved/circular path instead of straight ahead. Therefore, no ship speed increase is assumed when calculating sailed distance (even if a longer sailed distance is assumed there will still be significant fuel cost savings)
   - SFOC refers to LCV = 42,700 kJ/kg
   - Fuel consumption refers to LCV = 40,200 kJ/kg
   - Fuel price used is 500 USD/t

Fig. 2a: Example of reduced fuel consumption at low load operation for large container vessels with 12K98MC-C6 and 12K98ME-C6, SMCR = 68,520 kW at 104 r/min
Traditionally, MC/MC-C engines require a load increase (when operating with loads under 20%) of 1hr every 12hrs at 75% load, which equates to 14hrs a week. With ME/ME-C engines the load increase requirement is reduced to just 2hrs every week at 75% load. This simplification in a trade with prolonged or even indefinite low load operation may in its own right give fuel consumption savings of up to 10% of the total fuel cost in the extreme case! This is shown as an example in tabular form, Fig. 2a, valid for a 12K98MC-C6 and a 12K98ME-C6 operating at 30% SMCR, and also illustrated in Fig. 2b.

ME/ME-C engines are, as previously mentioned, equipped with slide fuel valves as standard. The injection pressure is independent of the engine load and creates an optimised injection on all load levels and, accordingly, makes another often used low load feature on mechanically controlled engines, cylinder cut-out, less relevant for securing stable running conditions at very low loads.

ME/ME-C engines are delivered in economy mode as standard, ensuring optimal SFOC for a traditional load pattern. Of course, the economy mode meets the requirements with regard to the IMO NOx emission limits.

In the economy mode, the engine is fully capable of operating continuously for long periods at part load and low load without making any special adjustments of the engine.

In emission mode, the NOx emission cycle value is lowered by 10% to 25% through special adjustment of engine parameters, mainly at high load (75% and 100%). In this mode, the ME/ME-C engine is also capable of operating continuously for long periods at part load and low load, without adjusting parameters.

As mentioned, the ME/ME-C engine offers two additional operating modes, and lately there have been increasing requirements for investigating the possibilities of applying a low load and a part load optimised operating mode, the latter included in the standard economy mode.

The method in which the low load or part load optimised operating mode is applied will very much depend on the specific requirements to the operation profile of the engine and vessel.

**Part Load Optimisation, ME/ME-C Engines**

Any engine may be optimised at any load between 85% and 100% of the specified MCR. The optimising methods are special matching of turbochargers, optimisation of compression volume, and special fuel valve nozzles. Part load optimisation should be used if most of the operating time for the entire lifetime of the ship is expected to be in the low and part load areas. The change to special fuel nozzles serves the purpose of optimising the fuel consumption, although for reasons of combustion cleanliness this is not required with slide type fuel valves. This is done in the standard economy mode in which the engine is delivered.

By operating with part load optimisation the SFOC reduction will be up to 4 g/kWh.
when compared to the obtainable reference full load economy mode SFOC. The SFOC increase in the high and full load area will also be up to 4 g/kWh when compared to the obtainable reference full load economy mode SFOC (see Fig. 3a). It should be mentioned that the obtainable reference full load economy mode can only be obtained if the engine is rebuilt to standard with regard to matching of turbochargers, resetting of compression volume and special fuel valve nozzles. The engine settings will, however, secure that full load (MCR) operation can be obtained even with the engine delivered in a part load optimisation/economy mode.

**Low Load Mode**

The simplest possible low and part load optimisation of the ME/ME-C engine is limited to such actions as special parameter settings of the exhaust valve actuation and fuel injection timing and profile in the low and part load areas. This option can be applied if the vessel has schedules planned where low and part load operation is foreseen. An example could be a container vessel requiring low load on certain “legs” of its route.

The SFOC reduction in the low and part load areas will in such case be an additional 1-2 g/kWh (see Fig. 3b) compared to the obtainable reference economy mode, and the SFOC increase in the high and full load area will also be 1-2 g/kWh when compared to the obtainable reference economy mode.

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![Fig. 3a: Reduced SFOC for part load optimisation of ME/ME-C engines when operating in Economy mode](image)

**Operation modes for ME/ME-C engines**

<table>
<thead>
<tr>
<th>Engine Load</th>
<th>Exh. boiler by-pass</th>
<th>Slide valves</th>
<th>Cylinder cut-out</th>
<th>Low load mode possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 40%</td>
<td>Not required</td>
<td>Standard</td>
<td>Not needed</td>
<td>Yes</td>
</tr>
<tr>
<td>20 – 40%</td>
<td>Yes, recommended</td>
<td>Standard</td>
<td>Not needed</td>
<td>Yes</td>
</tr>
<tr>
<td>&lt; 20%</td>
<td>Yes, required</td>
<td>Standard</td>
<td>Not needed</td>
<td>Yes</td>
</tr>
</tbody>
</table>
The engine is able to switch from the selected economy mode to low load mode and back by pushing a button on the ME/ME-C engine control panel.

In the case of an engine that has been part load optimised for economy mode, and is running in low load mode, the total SFOC reduction will be the sum of the SFOC reduction due to part load optimisation and the SFOC reduction due to low load mode. The SFOC reduction would therefore be 4-6g/kWh (see Fig. 3c), when compared to a 100% SMCR optimised reference engine.

**Low Load Operation with MC/MC-C Engines**

Recapping the case for the ME/ME-C engines before going to the MC/MC-C engines, it is clear that with the introduction of slide fuel valves, engine conditions for service at low loads for long-term operation have been significantly improved.

With slide valves, satisfactory continuous running conditions can be obtained down to 50-60% of SMCR rpm (10-20% engine load) without making any changes on the engine itself. However, for the load range below 40% some special procedures have to be observed, see below.
WITHOUT slide valves, the MC/MC-C engines can be operated below 20% load without special measures for improvement of slow steaming conditions for short periods (12-24 hours).

However, in both cases, when operating with loads under 20%, it is recommended to increase the engine load above 75% load for approx. one hour every 12 hours in order to increase the velocity of the gas and thereby cleaning the gas ways.

In relation to the expected increased depositing of soot in the internal parts of the engine and turbocharger, special attention should be paid to turbocharger cleaning, which should be carried out more frequently than stated in the instruction for normal operation.

The engine load can be reduced to 40% without taking any particular precautions in the systems and procedures. At any load above 40%, the auxiliary blower has generally switched off, and the exhaust gas has a velocity which is sufficient for transporting soot away during normal operation and soot blasting. However, with a few engine layouts, the auxiliary blowers switch off at a load slightly above 40%. If so, the actual cut-out level of the auxiliary blower determines the engine load level for the introduction of special countermeasures.

At a permanent load below 40% for long-term operation, preparations should be evaluated in accordance with the conditions described below.

It is our experience that long-term low load operation increases the risk of exhaust gas boiler fouling caused by a build-up of carbon and hydrocarbons in the exhaust gas boiler at low temperatures. Furthermore, the exhaust gas velocity is so low at low load that deposits from soot blasting cannot be removed.

The increased fouling can generally be related to the more difficult operation conditions for the fuel system at low load, with relatively small injection amounts at lower injection pressure (due to the low rpm).

Depending on the boiler configuration, it may be recommendable to install a by-pass of the exhaust gas boiler, so that all the exhaust gas, at proper velocities, can be sent through this by-pass connection at low loads.

Uncontrolled building up of soot in the exhaust gas boiler can lead to fires and, in the worst case, melting of the boiler tubes, see Fig. 4!

Even with a by-pass of the exhaust gas boiler at low loads, the depositing of soot which settles in the gas ways should always be reduced to ensure a safe operation of the engine and turbocharger.

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Fig. 4: Example of a high temperature fire in a water tube type exhaust gas boiler
Measures to improve the performance at low load:

1. Introduction of slide valves. Slide valves are standard today and can be installed as retrofit on MC/ME-C engines in service. In the slide valve, the sac volume is omitted and the combustion is improved during all load steps.

2. Cylinder cut-out system. The cylinder cut-out system (see Fig. 5) to be used at rpm below 40% of MCR rpm, allows the engine to operate with only half of the cylinders, resulting in increased load on the operating cylinders with improved operating conditions for the fuel system as a result, thereby ensuring stable running conditions down to 20-25% of nominal rpm. The speed limits for the actual plant should be evaluated by MAN Diesel on a case-to-case basis as the individual shaft vibration characteristics have to be considered.

Furthermore, in some special cases, it may be relevant to introduce auxiliary blowers with increased capacity in order to reach a higher load before they switch off. In such case, the auxiliary blowers are running permanently at relatively high part loads in accordance with the increased setting point for “cut out”. To avoid continuous start/stop of the auxiliary blowers, the permanent low load operation should be set to a level outside cut in/cut out of the auxiliary blowers.

Part Load Optimisation, MC/ME-C Engines

Optimisation of the part load service conditions by turbocharger re-matching and change of fuel nozzles will change the IMO NOx certification and require a new IMO certification of the engine.

If the desired ship speed is at very low loads (i.e. below 20% load), turbocharger matching has only marginal influence on the engine performance, and only marginal improvements can be obtained by re-matching.

In previous service letters on low load operation, it has been recommended to change fuel valve nozzles to new nozzles with smaller nozzle holes. This is no longer required with slide fuel valves. If non-slide fuel valve types are used, MAN Diesel recommends...
changing to slide fuel valves. A change of nozzle hole size and a change to slide fuel valves have the same impact on the IMO NOx certification of the engine, which is merely that the new configuration has to be amended to the technical file of the engine.

MAN Diesel is able to assist with IMO certification when new modes on board the vessels are defined.

**Cylinder Lubrication at Low Load**

The electronically controlled Alpha lubricators are an integrated part of the ME/ME-C concept, and they are frequently used also on MC/MC-C engines.

One of the many benefits of the Alpha lubricators is that they lubricate the cylinder units as a function of the main engine load, and not as a function of engine speed or engine MEP. This means that the Alpha lubricators offer substantial savings at low load, as can be seen in Fig. 6.

In fact, at e.g. 80% engine speed (50% engine load) Alpha lubricators lubricate with 35% less cylinder lube oil compared to the lube oil feed rate provided by a purely speed dependent mechanical lubrication system.

**Derating**

Derating is a traditional method of reducing fuel oil consumption, i.e. choosing a specified MCR point lower than the nominal MCR point along the vertical constant engine speed line in the layout diagram, see Fig. 7.

Previously, this layout philosophy was widely used, and most engines were derated. The advantage is that SFOC is significantly reduced, the disadvantage is that the engine generates less propulsion power.

<table>
<thead>
<tr>
<th>Engine Load</th>
<th>Exh. boiler by-pass</th>
<th>Slide valves</th>
<th>Cylinder cut-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 40%</td>
<td>Not required</td>
<td>Recommended</td>
<td>Not required</td>
</tr>
<tr>
<td>20 – 40%</td>
<td>Yes, recommended</td>
<td>Yes, recommended</td>
<td>Not required</td>
</tr>
<tr>
<td>&lt; 20%</td>
<td>Yes, required</td>
<td>Yes, required</td>
<td>Yes, recommended*</td>
</tr>
</tbody>
</table>

* Only at extreme low load (less than 40% MCR-rpm). This is mainly relevant for tankers during so-called lightering service, or low load leaving/entering harbour of container ships.
Derating is possible for ME/ME-C as well as for MC/MC-C engines.

For example, if the power of a 10K98ME engine is required, but a derated version of a 11K98ME engine is chosen instead, SFOC is reduced as shown in Fig. 7. The extra cylinder obviously represents an extra expense, but with the current fuel oil prices, the expense is paid back in 3-4 years. Similarly, if a 12K98ME engine is chosen, the SFOC reduction is twice as big, as is the initial extra expense, however, the pay-back period remains 3-4 years.

Making such a choice also means that if fuel oil prices should go down in the future, calling for increased ship speeds again, the engine can be uprated to the original full L1 power. Changing the rating of an engine in service may not be so simple, but if the possibility of changing the rating in the future is considered in the project phase, it may be relatively simple. The choice of turbochargers and air coolers should be considered.

![Fig. 7: SFOC reduction by derating a K98ME7 engine](image-url)
**Conclusion**

In conclusion, it is clear that the electronically controlled ME/ME-C engines offer better possibilities for long-term operation at low loads while, at the same time, giving an improved fuel oil consumption at such low loads.

To summarise on the benefits of the ME/ME-C engines in a situation where low load operation is expected to prevail for a long period of time, these are:

- Part load optimisation, giving a reduction in SFOC of up to 4g/kWh for part load operation
- Low load mode, cutting an additional 1-2 g/kWh SFOC
- Less operating hours at higher load to keep engine, gas ways and boiler clean
- Alpha lubricators, reducing the lube oil consumption at part load

The ME/ME-C engines also offer IMO Tier 2 compliance with a lower SFOC, i.e. lower CO₂ emission than its mechanical counterparts.

The MC/MC-C engines also offer a degree of flexibility when a lower ship speed is required for normal operation:

- The use of slide fuel valves (which can be retrofitted) will facilitate low load operation down to 40% engine load
- Further measures can be taken for lower engine load running such as a cylinder cut-out system

We suggest operators to contact MAN Diesel regarding low load operation to obtain recommendations tailor-made to their specific mode of operation, both for vessels already in service and in connection with new building projects.