Market Update Note

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24 April 2015

Light Running Margin (LRM)

To align with the rest of world’s ambitions to reduce greenhouse gas emissions, the shipping industry has developed the energy efficiency design index (EEDI) in cooperation with IMO. Combined with the steady increase in oil prices seen in the period from 2006 to 2014, the result has been improved ship designs with lower CO\textsubscript{2} emissions relative to their transportation capacity.

Lowering of the SMCR propulsion power installed is a key parameter for achieving a more fuel and CO\textsubscript{2}-efficient ship, evaluated according to the EEDI. Other parameters include lowering of the hull resistance, improving the hydrodynamic propulsion efficiency, and lowering of the specific fuel consumption of the main engine.

For a specific ship, less power installed will not only reduce the top speed of the vessel, but also reduce the vessel’s capability of accelerating or sailing with increased resistance from heavy sea and/or fouling of the hull.

To illustrate the situation, you could think of a car that has been fitted with an engine with less power than usual. The car would definitely have a lower top speed and acceleration, and the uphill running capability would be poorer. In those situations the lower power would have to be compensated for by using a lower gear ratio. However, a ship with an engine coupled directly to a fixed pitch propeller cannot shift gear. So, to cope with a smaller main engine, the engine and propeller must be designed with a lower gear ratio from the beginning, for example by using a propeller with a reduced pitch.

For a certain power, a reduction of the pitch will result in a higher engine speed. The ratio between the rpm value on the light propeller curve and the rpm value on the nominal propeller...
The light running margin (LRM) curve through SMCR is called the light running margin (LRM), see Fig. 1. For an unchanged engine SMCR point the LRM will be increased by reducing the pitch.

![Diagram of engine load showing light running margin (LRM)](image)

**Fig. 1: Engine load diagram showing also the definition of the light running margin (LRM)**

The LRM can be thought of as the ship’s gearing. The effect of changing the LRM, and thereby the ship’s gearing, is indicated in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Larger LRM</th>
<th>Smaller LRM</th>
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</thead>
<tbody>
<tr>
<td>Ship gearing</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Engine acceleration</td>
<td>Faster</td>
<td>Slower</td>
</tr>
<tr>
<td>Ship acceleration</td>
<td>Faster</td>
<td>Slower</td>
</tr>
<tr>
<td>Heavy weather speed</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Propeller speed</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>See text</td>
<td>See text</td>
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</table>

A larger LRM will reduce the daily fuel oil consumption in heavy weather because engine efficiency will be higher. Some ships may see a marginal increase in the daily fuel oil consumption in calm weather with an increased LRM. However, such a marginal increase in calm weather will be counteracted by a reduced consumption in heavy weather. In general, the average daily fuel consumption is largely unaffected by a larger LRM. Since 1999, our recommendation has been an LRM of 3-7%. But in view of the above development, and the service feedback received from newly delivered low-powered ships reporting poor acceleration and low heavy weather ship speed, it is increasingly important that ship designers and yards carefully consider how much LRM is required for a particular ship. The LRM should be sufficiently large to ensure a safe and satisfactory ship speed during heavy weather and satisfactory acceleration during manoeuvring.

The MAN B&W engine load diagram limits have stayed unchanged for years, and the basic designs of engine components with regards to stresses, temperatures, emissions etc., have been made up to these limits, leaving no room for a general increase of these limits.

In the coming years, the EEDI will put even stronger demands on a ship’s fuel efficiency and CO₂ emission, and we may see yards installing engines with even less power than today. So, to facilitate such ship designs from the yards, we will, for new projects as of 1st of May 2015, change our LRM recommendation to 4-10% that is applicable to all draughts at which the ship is intended to operate, whether ballast, design or scantling draught.

Our recommendations for engine and propeller layout are described in our project guides. We are in the process of updating our project guides with the new recommendation for LRM and we will include additional information on relevant issues to consider when selecting the LRM.

**Example 1 – Reducing SMCR power while maintaining available power for critical conditions**

In order to explain the influence of the LRM selected, this example demonstrates how two ships, A and B, with the same hull and propeller, but with 10% less SMCR power for ship B,
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require a different LRM to ensure that the same power is available to the propeller in heavy running conditions.

Fig. 2: Example 1a. Same hull, same propeller but two different engine choices. Ship B has an engine with 10% less power than ship A. Regardless of the position of the propeller curve ship B will have 10% less propulsion power available compared to ship A.

Fig. 3: Example 1b. Same hull. Ship A has a 10,000 kW engine and 5% LRM. Ship B has 10% less engine power and a lighter propeller with 6.9% LRM. In heavy running conditions, ship B will be able to deliver the same power to the propeller as ship A.

The conclusion from example 1 is that if the LRM is increased sufficiently, it is possible to reduce the engine SMCR power while still maintaining the available engine power output in critical conditions, such as very heavy weather and during manœuvring at low ship speeds.

Fig. 3 shows an example with a 10% reduction of the main engine power. The relation between the SMCR power reduction and the required increase in LRM for unchanged heavy propeller performance is nearly linear. For example, if the SMCR power was reduced by 20%, the corresponding LRM for unchanged power with heavy propeller would be about 9%.

Example 2 – Increasing the LRM to improve ship manœuvring performance

To explain how increasing the LRM can dramatically improve the available engine power for manoeuvering, this example demonstrates the difference in available engine power for two different choices of LRM.

To ensure sufficient steering forces on the rudder and sufficient ahead and astern accelerations of the vessel during ship manoeuvring in port or in otherwise restricted waters, it is important that the ship can quickly reach the necessary propeller speed even when the ship speed is zero (bollard pull). Pilots may complain about poor acceleration performance if it is not possible to reach half ahead revolutions quickly in such conditions. It is therefore relevant to consider the bollard pull propeller curve in relation to the engine load diagram.

Fig. 4 shows two different bollard pull propeller curves in the same engine load diagram. The two propellers have been designed with different LRMs. One propeller has 3% LRM and the other 10%
LRM, representing the combined range of our previous and new LRM recommendation. The light propeller curves are not shown in Fig. 4, instead bollard pull curves with 17.5% heavy running relative to the light propeller curves are shown (average of 15% to 20%).

Fig. 4 shows that choosing 10% LRM instead of 3% increases the available bollard pull power from 41% of SMCR power to 61% (assuming 17.5% heavy running relative to the light propeller curve due to the bollard pull condition). This is a large difference. The increase in bollard pull power is ~50%. The corresponding difference in engine rpm is from 63% to 77%. Considering that a typical “half ahead” speed setting is somewhere between 60% and 70% rpm the choice of LRM can decide whether it is possible to reach “half ahead” in bollard pull or not. It is therefore important to include manoeuvring in the considerations when selecting the LRM for a ship.

The conclusion from example 2 is that the choice of LRM has a strong impact on ship maneuverability. Increasing the LRM increases the manoeuvrability, reducing the LRM reduces manoeuvrability.

Quick passage of a barred speed range
Due to excessive torsional vibrations at certain shaft speeds, many shaft lines have a barred speed range. Fig. 4 includes an example of such a barred speed range. In order not to damage the shaft line, it must be possible to pass this barred speed range quickly in all relevant conditions. As a general rule, the barred speed range should be passed in seconds, not minutes. But the required maximum passage time depends on the magnitude of the stress levels in relation to the shaft material used and the operational profile of the ship (how often is it required to pass the barred speed range).

If the power margin between the actual propeller curve and the engine load diagram is too small within the barred speed range, passage of the barred speed range can take unacceptably long time. Increasing the LRM will increase the power margin in the barred speed range and thus reduce the time required for passage of the barred speed range, see Fig. 4.
Conclusion

The LRM is an important design parameter for the safe and efficient operation of a ship. Due to the changes in the shipping industry described in this Market Update Note, we have decided to increase our recommendation for LRM from 3-7% to 4-10%. The new recommendation is valid for new projects started after the 1st of May 2015.

Not all ships will perform well with 4.0% LRM. The actual ship trade, the chosen main engine power and the propeller, shaft and hull design of the vessel form the basis for the selection of the LRM and this work therefore belongs to the ship designer's responsibilities. A ship should have sufficient LRM such that:

- Safe and satisfactory ship speed can be maintained in heavy weather and/or with a fouled hull.
- Ship accelerations needed for safe and efficient manoeuvring operations can be achieved.
- A barred speed range can be passed quickly. This is often required also at zero ship speed (bollard pull).

For more details:

MAN Diesel & Turbo
Tegholmsgade 41
2450 Copenhagen SV, Denmark
Phone    +45 33 85 11 00
Fax       +45 33 85 10 30
info-cph@mandieselturbo.com
www.mandieselturbo.com