Market Update Note

25 February 2019

G70ME-C-GI design updates

The preferred engine choice for LNGC

The first dual fuel ME-GI engines entered service in October 2015, and today 58 engines are in service, increasing to about 100 in two years. The ME-GI dual fuel diesel concept with high-pressure injection of natural gas (LNG) is also the optimum technology to use for other gasses and low-flashpoint fuels like ethane, methanol and LPG, and MAN Energy Solutions has successfully developed the ME-GIE, LGIM and LGIP engine types for these purposes.

Based on the experience and knowledge gained from the successful introduction of the large number of ME-GI engines in service, we have enhanced the design of the G70ME-C-GI engines even further with the introduction of a number of features to improve both opex and capex:

1. New pilot oil injection system for 0.5% pilot oil
2. New control and safety software for gas operation below 5% load
3. ME-GI Mk. 2 design including CCO (cylinder cut out)
4. Tier III compliance: the recent development of EcoEGR with ME-GI gives a unique possibility to improve the fuel efficiency of the ME-GI engine in Tier II mode.

For 5/6/7G70ME-C-GI, the new designs will be ready for engines fulfilling the below three criteria:

- ordered after 1 March 2019
- shop test after Q4 2019
- sea trial after Q3 2020

In the following we give more details on the above four topics.

Reduction of pilot oil amount to 0.5%

The pilot oil consumption reduction is a specific requirement in the development of the ME-GI engine and it has been addressed with the development of a new PIV (pilot injection valve) fuel valve.

The PIV features a control function reducing the cut-off shaft lift in pilot operation mode.

The reduced cut-off shaft lift ensures that the nozzle area is significantly reduced in pilot mode, as illustrated Fig. 1.

In mid-January 2019, the first test of this combined pilot and main injection valve confirmed its capability to reduce the injection amounts significantly.

While maintaining a normal performance in fuel oil mode, the expected outcome is a specific pilot oil consumption (SPOC) of 0.5% or less in gas mode.

Minimum gas operation load below 5% of SMCR

A stable gas operation down to 10% engine load has been confirmed for the ME-GI engine.

Reducing the minimum gas operation to 5% and lower requires restructuring of the control architecture, especially on safety surveillance and gas index calibration.

This development of software architecture and injection hardware will ensure stable operation on gas below 5% engine load, especially in combination with the 0.5% pilot injection valve.

Market Update Note

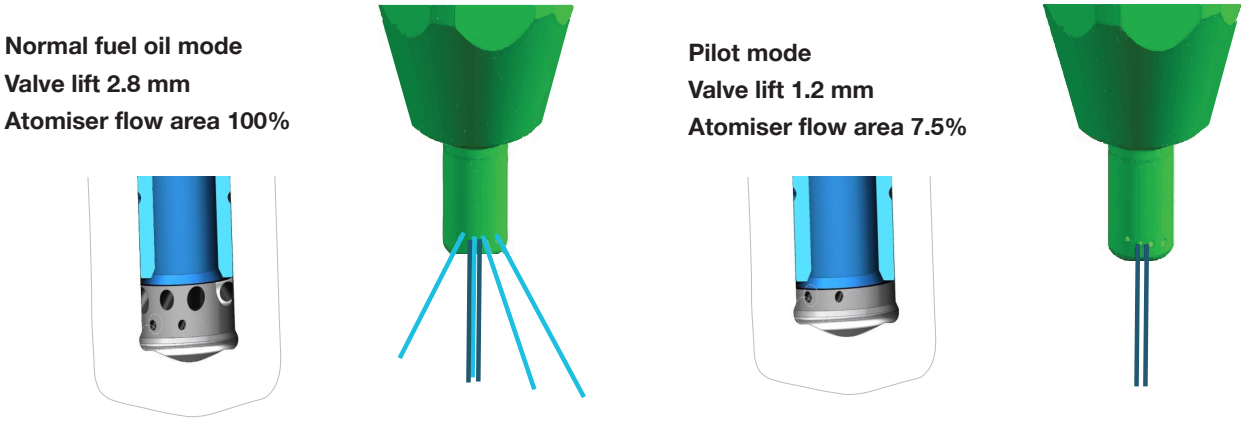

Fig. 1

ME-GI Mk. 2 design including CCO

In addition to the above, the ME-GI Mk. 2 design represents a significant reduction of complexity and first cost related to the engine itself as well as the installation of the engine. The ME-GI Mk. 2 design enhances the availability of gas operation by introducing the CCO (cylinder cut out) feature. Furthermore, a simplified design of the gas block has been obtained by removal of the return chain pipe.

Lower capex and opex with EGR Tier III technology

EcoEGR

Today, LNG vessels with 5G70ME-C9.5-GI use EGR as the Tier III solution. EcoEGR is available for all our engines including GI engines. EcoEGR is a tuning of the engine where the fuel consumption in Tier II mode is reduced, and the associated increase in NO_x emissions is counteracted by running the EGR at a reduced intensity. Fig. 2 compares the fuel consumption of two 5G70ME-C-GI engines (2x12,500 kW at 72 rpm), one in Tier II mode with normal EGRBP and the other with EcoEGR. In terms of fuel equivalents, there is a SFOC difference of 5-7 g/kWh in the NCR range.

EGR manufacturing cost

The EGR Tier III technology has been in the market for more than three years, and it has been selected for more than 130 engines. It consists of various standard components in different sizes, i.e. EGR blower, cooler, butterfly valves, and water treatment units (WTU), all being produced by a growing number of different manufactures. From a design point of view, MAN Energy Solutions has pursued any cost down opportunity in the design without compromising reliability. Most recently, we have changed the grade of the stainless steel material. A development that inevitably makes the EGR more attractive from a capex point of view.

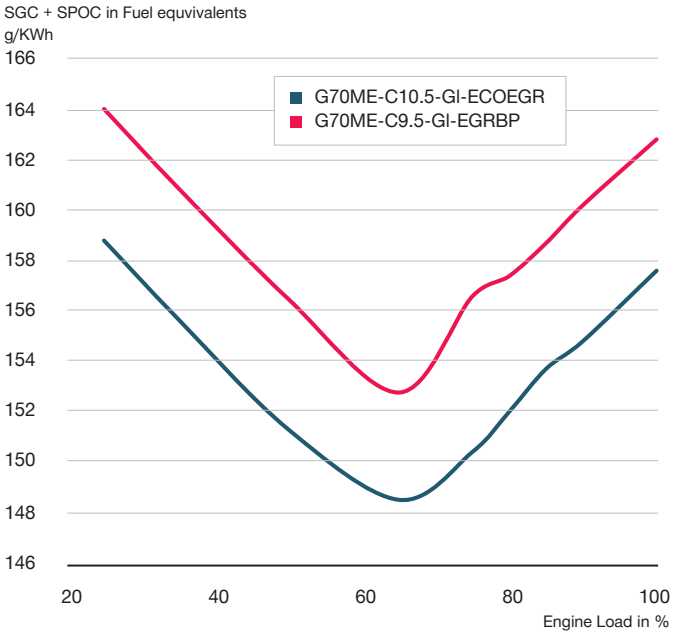

Fig. 2: 5G70ME-C10.5-GI-EcoEGR versus 5G70ME-C9.5-GI-EGRBP 12,500 kW at 72 rpm

Market Update Note

EGR downsizing for ME-GI engines
In addition to the above-mentioned general cost cuts for the EGR system, and after confirmation tests in June, we will be in a position where the ME-GI EGR system size can be reduced to approx. 60% of the size used on an EGR engine today. This size reduction (as illustrated below in Fig. 3) will be based on the fact that the GI engine in gas operation, simply due to fuel chemistry, has a 25%-30% lower NO_x emission level than the corresponding fuel oil operation. "De-tuning" the engine performance further for the Tier III gas mode operation will secure even further reduced NO_x levels (approx. 40%) compared to fuel oil operation.

Thanks to this 40% lower NO_x emission, the required EGR gas amount for obtaining Tier III NO_x levels will be reduced to approx. 60%.

The reduction in EGR gas amount will not only reduce the size of the EGR unit, but also reduce the required size of the cooler, WTS system and EGR blower (and the electricity consumption).

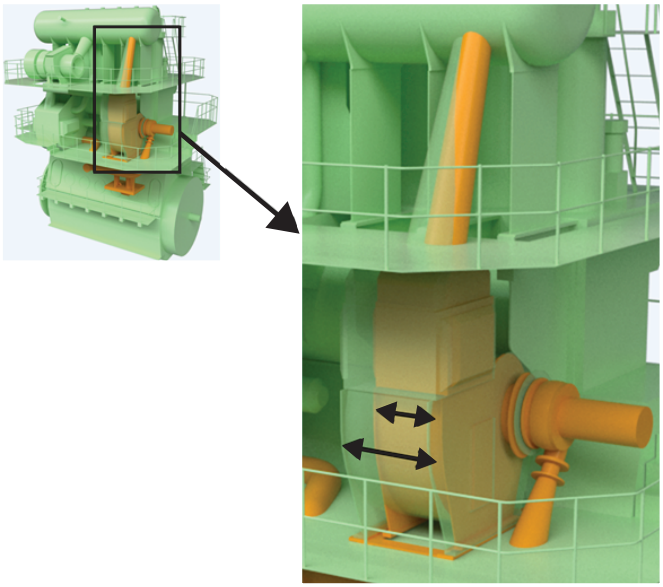

Fig. 3: Smaller EGR unit

Time schedule for introduction
The design improvements listed in items 1, 2 and 3 on page 1 are introduced for 5/6/7G70ME-C-GI engines and will be available for new engine orders after 1 March 2019.

The features mentioned in items 2 and 3 are closely related to the ME-GI Mk. 2 control architecture. The PIV for 0.5% pilot oil and the Mk. 2 features on the engine are ready for shop test and FAT after Q4 2019.

Operation below 5% engine load on gas will need to be demonstrated during sea trial, which will take place after Q3 2020.

In addition to the above upgrades related to engine performance, we are in close contact with Burckhardt, Kobelco, Wärtsilä, Babcock, and Air Liquide to evaluate the possibilities for not only optimising the power consumption of gas supply systems for ME-GI engines, but also the first cost of the gas supply systems.

A new trend in LNG vessel design is vessels with full BOG reliquefaction capacity. They are prepared for spot market trade where the vessel may have to wait or slow steam and thus need to reliquefy the excess BOG. If full reliquefaction capacity is available, the gas compressors for the ME-GI FGSS can be omitted and the compressed gas supply to the engine can be provided by an efficient LNG pump vaporiser unit.

We are very interested in working together with yards and subsuppliers and share our ideas and proposals for optimisation of the engine-related gas systems in the ship. Questions regarding this Market Update Note should be directed to our Promotion & Customers Support department, at renes.laursen@man-es.com.

For more details:
MAN Energy Solutions
Teglholmsgade 41
2450 Copenhagen SV, Denmark
Phone +45 33 85 11 00
www.marine.man-es.com