Managing methane slip

For the shipping industry to become carbon-neutral, a change from liquid to gaseous, low-emission fuels is the starting point towards a “Maritime Energy Transition”. As a result, readily transportable liquefied natural gas, or LNG, is becoming more and more popular and has a number of well-known advantages. With its high heating value combined with low carbon content, LNG enables a significant reduction in emissions of greenhouse gases (GHG), while an absence of sulphur content eliminates emissions of sulphur oxides (SOx) and reduces particulate matter (PM) to a negligible level – and all with lower fuel costs.

“Building on this initial reduction in GHG emissions, the Maritime Energy Transition calls for large marine engines to further change from fossil liquid-fuels to alternative, carbon-neutral fuels,” said Dr Gunnar Stiesch, senior vice president and head of Engineering Engines at MAN Energy Solutions. “Hence, marine engines have to become capable of operation on a wide range of carbon-neutral fuels. In this transition, burning LNG in dual-fuel (DF) engines is the logical and important first step in preparing engines for the broader use of synthetic fuels on the way to carbon-neutrality.”

However, to leverage these economic and environmental benefits fully, the issue of methane slip needs to be resolved. “Typically, 85% to 95% of natural gas is methane, a greenhouse gas many times more potent than carbon dioxide, and there are several routes by which – without countermeasures – unburnt methane can be emitted from gas and dual-fuel engines,” said Stiesch.

Addressing methane slip

With the legislator’s eyes now firmly on GHG emissions, the methane slip issue has moved into focus, and if not properly addressed, could limit the expansion of LNG as a fuel for large engines. A recent study has calculated the global warming potential (GWP) of methane – i.e., its capability to trap heat in the atmosphere compared with the same mass of CO₂ (CO₂ equivalent or CO₂e) – at 84 to 86 over 20 years and 28 to 34 over 100 years.

“The economic and ecological rewards of LNG as a
shipping fuel are great and we are allocating considerable resources to minimising this form of methane wastage to the atmosphere,” stated Stiesch. “And of course, there is also a need to look at the issue from a ‘well-to-wake basis’ – from the moment natural gas emerges from the ground to the moment exhaust gases emerge from the gas-burning engine propelling a ship. The complete natural-gas supply chain must be made escape-proof.”

**Taking up the challenge**

As designers and builders of both two- and four-stroke gas-burning engines, the technical departments of MAN Energy Solutions have been engaged for some time in eliminating methane slip from DF engines using two different operating principles.

**Two-stroke dual-fuel engines**

In fact, as pointed out by Gunnar Stiesch, MAN’s two-stroke DF engines already incorporate very effective, intrinsic methane slip reduction technology. “Our low-speed ME-GI dual-fuel engines employ the diesel combustion process in which gaseous fuel is injected directly into the compressed charge-air around top dead centre and only slightly after the liquid-fuel pilot, when the pilot has already ignited. This ensures complete, very fuel-efficient combustion with maximised heat release.”

The high rate of combustion efficiency achieved by diesel DF combustion with direct gas injection has further benefits: it enables lower fuel consumption and thus lower CO₂ emissions than DF engines employing the Otto cycle and pre-mixed gas combustion. In addition, with direct gas injection, ME-GI engines also achieve very stable operation on all commercially available grades of LNG, irrespective of the fuel’s methane index.

“Since the levels of unburnt methane in the exhaust of MAN’s ME-GI two-stroke DF engine are very low, we can already claim an effective solution to methane slip,” Stiesch noted. “Indeed, our ME-GI engines are currently the only viable option on the two-stroke engine market capable of coping effectively with methane slip and we guarantee negligible methane-slip levels in a range from 0.2 - 0.3 g/kWh over the entire load range of the engine.”

The *Siem Confucius* and sister ship, *Siem Aristotle*, are the first trans-Atlantic pure car truck carriers to operate fully on LNG. The vessels will carry VW cars between Europe and China and are both powered by MAN B&W 560ME-GI dual-fuel, two-stroke main engines.

Source: Volkswagen AG

---

**Methane emissions in gas mode – comparison of different engine types**

Source: MAN Energy Solutions
At the same time, MAN is equally determined that methane slip should not undermine the economic and environmental benefits of LNG as a fuel in its four-stroke gas-burning engines. “Since the introduction of our 51/60 DF engine ten years ago, we have already halved methane slip,” said Stiesch. Even taking the remaining methane slip into account, a modern dual-fuel engine has a 5% to 10% greenhouse gas advantage compared with a conventional liquid-fuel engine. “Building on this, we are pursuing three separate routes to reduce levels of methane slip further: firstly, by improving the internal engine design of our gas engines; secondly, by adding advanced, aftertreatment solutions; and thirdly, by evaluating ways to apply the technology of direct gas injection to our four-stroke DF engines.”

**Internal engine design**

In the Otto combustion process used in MAN’s four-stroke DF engines, gaseous fuel is pre-mixed with air before ignition; the resulting mixture is compressed and then ignited by a liquid-fuel pilot injection. “There are more opportunities for the gaseous fuel to evade combustion in the four-stroke Otto process,” Stiesch explained. “An important line of attack centres on the reduction in the overlap of inlet and exhaust-valve openings required to ‘scavenge’ the cylinder of exhaust gases. Minimising this overlap while optimising gas-admission timing reduces the period in which in-flowing air/gas mixture can reach the exhaust port.”

MAN is further minimising crevice volumes – areas in the combustion chamber where pockets of unburnt gas can be trapped. “An example is the ‘top land’ of the piston in spark-ignited gas engines,” Stiesch noted. “This is the area above the top piston ring on the side of the piston crown. By raising the position of the piston ring,
Japanese research firm reveals latest electrification initiative

ROBOSHIP | Tokyo-based research firm, e5 Lab Inc, has revealed its latest project in furthering development of electrically-powered vessels for short-sea and coastal trades. The electrification and digitalisation specialist has embarked on the Roboship project to produce standard models of vessels powered by electricity with zero emissions. At the same time, the company has unveiled the Roboship Box, a digital initiative which combines communications, the Internet of Things, and software.

“Through this initiative, e5 Lab is working to address critical issues facing Japan’s ocean shipping and maritime industries,” the company said in a statement, “including a shortage of seafarers, environmental concerns, safety, and the sustainable growth of the shipbuilding and ship machinery sectors. With strategic partners in Japan and overseas, the development project team targets the commercialisation of electric-powered merchant vessels that adopt world-class propulsion systems at the most competitive price in the global market.”

In Roboship Ver. 1.0, the e5 team has developed two types of electric vessels with tonnages of 499gt and 749gt, capable of the same speeds and range as ships currently in service. In port, the vessels will be emissions-free by using large batteries in combination with a diesel-powered generator. With e5’s know-how and a range of efficient electric devices including DC grids, permanent magnet motors and artificial intelligence technology, the vessels will achieve higher energy efficiency than other ships in service, the company claimed.

The Roboship Ver. 1.0, with a 2022 delivery date, will significantly reduce the workload of seafarers, e5 said, whilst also lowering the risk of mechanical problems and cutting maintenance costs because the motors are powered only by electricity. The team is aiming to keep construction costs less than 5% above the cost of comparable existing vessels.