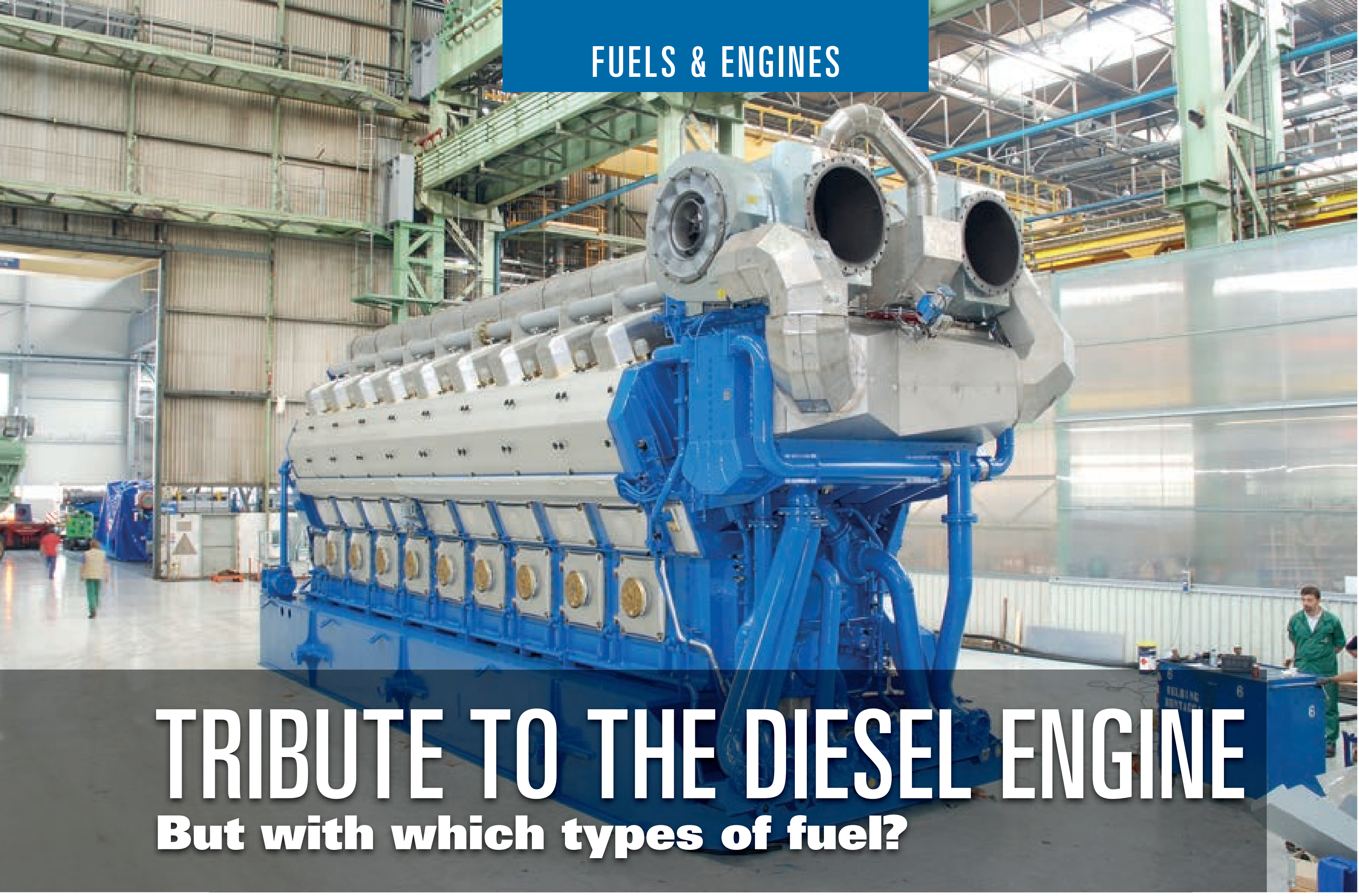

TRIBUTE TO THE DIESEL ENGINE

But with which types of fuel?

Internal combustion engines play a very dominant role in shipping. They are by far the most popular way of powering ships. Is that going to change under pressure of environmental regulations and, in particular, the requirements to reduce the emission of greenhouse gases?

Presently, some 100,000 seagoing merchant ships sail our seas and oceans, with an installed power ranging from roughly 1 to 100 megawatts (MW) per ship. With very few exceptions, all these ships are propelled by diesel engines, most of these with a direct drive system, some with a diesel-electric propulsion or hybrid system. Until the end of last year, about 65,000 of these used heavy fuel oil (HFO) as fuel. Since the 1st of January, a few thousands of these still use the same high sulphur HFO in combination with scrubbers, which remove the sulphur from the exhaust gases. The majority, however, changed to a blend of low sulphur fuel oil or marine diesel oil (MDO). A large portion of the remaining ships use MDO or a similar diesel fuel. A few hundred ships use other fuels, such a LNG, LPG, methanol or biofuel. Similarly, many thousands of inland waterway ships, fishing vessels and yachts are being propelled by diesel engines, with usually MDO or marine gas oil (MGO) as fuel. Moreover, the many thousands of ships currently under construction or on order worldwide will almost all be powered by diesel engines. Upon completion, most of these ships will be fuelled by fossil oil fuels, at least initially. On average, the yearly fuel oil consumption of international shipping amounts to about 300 million tonnes.

No practical alternative

Apart from in shipping, the internal combustion engine is also extremely popular as a power source. In road and rail transport, agriculture, the building industry and military organisations, millions of diesel engines are being used. What explains this popularity? The main reasons are a high engine efficiency, flexibility in output power (from small to very large) and the availability of fuels with an attractive combination of high specific energy content, both in volume and weight, and good storage and combustion characteristics. In a way, it is remarkable how in spite of the many disadvantages of the diesel engine, such as size, weight, noise, vibration problems, harmful emissions, complex HFO treatment systems, lubricating oil systems and extensive maintenance requirements, the diesel engine has become such a great success. With for many applications no practical alternative.

During the twentieth century, steam power was gradually replaced by diesel power because the combination of a steam boiler and a turbine or any other form of steam power showed a maximum efficiency of about 25 per cent, whilst diesel engines, from small to large, deliver an efficiency of between thirty and fifty per cent, in recent years even up to 54 per cent for very large low speed two-

Photo: The Wärtsilä 50DF (dual-fuel) engine can be run on either natural gas, light fuel oil (LFO), or heavy fuel oil (HFO) (all pictures by Wärtsilä).

stroke engine installations. Gas turbines also have a poor efficiency and cannot compete successfully with diesel engines for most applications. Some naval ships use gas turbines or steam power, the latter mostly in combination with nuclear installations. There is also a sizeable number of mostly older LNG carriers operating on steam power, using boil-off methane gas from the cargo as fuel for their boilers.

Eighty per cent more fuel efficient

In accordance with the requirements of the International Maritime Organization (IMO), international shipping should reduce the emissions of greenhouse gases (GHGs) such as CO_2 and methane by 2050 to fifty per cent of the total amount of these emissions produced in 2008, whilst pursuing efforts towards phasing them out entirely. It has been estimated, based on expected trade and transport growth development and other factors affecting fuel consumption, that in order to reach the 2050 goal, by that time, on average, ships should be about eighty per cent more fuel efficient than they were in 2008. In spite of continuing efforts to make ships more fuel efficient, by improved hydrodynamics and propulsors, better hull surface coatings, use of wind propulsion assistance, hybrid power systems, slow steaming, and so on, it is unlikely that this 2050 goal can be reached by keeping to the kind of fossil fuels we abundantly use today. Consequently, the marine industry has to look at alternative power systems and/or fuels. In theory, ships could be powered by batteries, by fuel cell systems in conjunction with selected fuels, or by other systems, which are still on the drawing board.

For ships for deep sea operation, these alternatives are for the time being most probably not very practicable if at all possible. This leads us to the question whether by further development or by the use of fuels producing less GHG emissions, the diesel engine will be allowed to survive. As a number of ships operating today or now being built will still be around in 2050, this is not just a theoretical question. Moreover, the 2050 goal is not the end of the story. The final target will be to phase out fossil fuels completely. In earlier issues of this magazine, our regular contributor Kees Kuiken has published a number of articles explaining developments in the design and use of diesel engines. Based on present knowledge, this article will men-

> In 2050, ships should be about eighty per cent more fuel efficient than in 2008

The Wärtsilä X35 engine is a two-stroke, slow speed diesel engine.

The Wärtsilä 34 DF engine is popular with short sea vessels, such as the three new ships for Spliethoff's affiliate Bore Ltd.

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Articles on diesel engines in SWZ|Maritime written by Kees Kuiken:

- October 2017: *Dieselmotoren in ontwikkeling* (Diesel engines under development)
- March and April 2018 (in two parts): *Staat LNG als brandstof voor een doorbraak?* (Is LNG as a fuel facing a breakthrough?)
- January and February 2019 (in two parts): *Tweeslag-kruishoofdmotoren en alternatieve brandstoffen* (Two-stroke crosshead engines and alternative fuels)

tion a number of fuels which may or may not play a role to keep the good old diesel engine running on our ships. In this overview, the emphasis will be on GHG emissions with less or no attention being paid to other harmful emissions like NO_X, CO, particulate matter (PM) and black carbon.
From various publications it is understood that the industry considers the following alternative fuel types for diesel engines, both for new installations and, equally important, for the conversion of existing diesel engine installations.

LNG or CNG, liquefied or pressurised methane

Presently, there are some 325 seagoing ships operating on LNG or CNG as fuel whilst there are about 220 on order. More than half of these ships sailing or under construction are LNG carriers, using boil-off gas from the cargo as fuel. The uptake of LNG as a fuel has been much slower than was expected a few years ago. As far as harmful emissions such as NO_X, SO_2, and PM are concerned, ships running on LNG comply with all environmental requirements. It is an attractive fuel to be used instead of HFO to deal with the 2020 sulphur rules.
However, experts have different opinions on the advantages of LNG as a fuel with regard to GHG emissions. Without taking into account methane slip, that is, the leaking of methane, a very strong GHG, into the atmosphere through incomplete combustion or otherwise, CO_2 emissions of LNG fuel are twenty to 25 per cent lower than those from an oil installation. The Norwegian research institute Sintef carried out an eight-year project comparing the LNG technology in diesel engines and used the emissions for MGO as a baseline, or one hundred per cent emission level. The results of this project showed that, depending on the engine type, due to the methane slip problem along the whole supply chain and in the engine, the GHG emissions could be higher rather than lower when using LNG. Other experts and some classification societies are more optimistic about this problem and support the use of methane, at least as an intermediate solution, to reduce GHG emissions and particularly other harmful emissions.
Engine builders are actively engaged in trying to minimise the methane slip problem. This fuel as is will not meet the 2050 GHG emission target. In case the methane would be produced from biogas derived from biomass (biomethane) rather than taken from a natural gas field, that would be different. Biomethane would make it possible to achieve the 2050 target with the methane slip problem as a remaining challenge.

LPG, liquefied petroleum gas

Although there are at present only a few ships using LPG as fuel for its engines, support for this fuel seems to grow. It is produced from gas fields or from crude oil. The gas is heavier than air and requires adequate engine room ventilation. It is abundantly available on global markets and more easily shipped and stored than LNG. It produces much less harmful emissions than oil fuels, but achieves only a limited CO_2 emission reduction of no more than ten per cent. This fuel will not solve the 2050 problem.

Biofuels
These fuels could offer a largely carbon-neutral solution, but are unfortunately in short supply. A limited number of shipping companies have so far been able to contract sizeable quantities. Volumes seem to be growing, but it is most unlikely that these fuels could ever play a decisive role to solve the 2050 issue. That is regrettable because diesel engines would allow the use of this fuel without serious complications. Bunkering and storage would also be easy.

Zero carbon is not the problem, paying for the fuel is

Methanol
Since a couple of years, Methanex, the world's largest supplier of methanol, operates diesel driven methanol-fuelled tankers. Since 2015, Stena also operates its large ferry Stena Germanica with methanol as its main fuel. Stena claims that with methanol the emissions of sulphur have been reduced by 99 per cent, NO_X by sixty per cent, PM by 95 per cent and CO_2 by 25 per cent. Methanol can be used in standard diesel engines with relatively minor modifications. It is liquid at room temperature, toxic and its heating value is about half the typical value of diesel fuel. When made from biomass or from green electrical power, it is a carbon neutral fuel. It is seen as one of the most promising fuels to help us to reach the 2050 target.

Ammonia
Ammonia has so far not been used as a fuel for ships, but interest in it is growing. It can be stored and transported either at low temperatures (-34°C) or pressurised (10 bar at 20°C). The heating value is half of that of diesel oil in terms of mass and a third in volume. It is claimed that it can be used in diesel engines, be it with some additional treatment and with a significantly higher compression ratio because of the limited combustibility compared with diesel oil. It is toxic and highly corrosive. Ammonia in a diesel engine emits no SO_X or PM, but it does require NO_X mitigation because of the high combustion temperature. Green ammonia, produced from renewable energy, would also enable shipping to meet the 2050 target. MAN Energy Solutions is involved in a few ammonia based design projects and aims to have an ammonia-combusting engine commercially available in two to four years.

Hydrogen
Worldwide there is a growing interest in the development of hydrogen as a potentially important alternative fuel, mostly for use with fuel cells. Is it also attractive for use as a fuel for marine diesel engines? The Hydroville, a small passenger ferry sailing in Antwerp and built for the local shipping company CMB, operates its small diesel engines on a mixture of diesel oil and hydrogen. CMB is involved in further hydrogen-fuelled diesel engine projects, presumably with a view to using such systems ultimately on its large cargo ships.
Hydrogen is not an easy fuel: it requires various precautions to deal with the storage system, avoidance of leakages, embrittlement behaviour and its flammability, cryogenic temperatures are needed to store it with a meaningful energy density and so on. As shown by the Hydroville, it can be used in diesel engines. Like with ammonia, the combustion temperature is high leading to a potential NO_X problem requiring attention. One distinguishes three types of hydrogen: grey, blue and green. Grey hydrogen is the normal industrial hydrogen and is not carbon free. Blue hydrogen is the same, but made "carbon free" by injecting the CO_2 produced by the chemical process and stored for example in empty gas fields (CCS: carbon capture system). Green hydrogen is made using green electrical energy to produce hydrogen and is carbon free. A potentially attractive way to store hydrogen is through sodium borohydride, which binds the hydrogen and from which it can be released if and where needed.

OPEX issue
A study recently carried out by A.P. Moller-Maersk together with Lloyd's Register, identified three fuels to focus on towards decarbonisation by 2050, namely alcohols (such as methanol), biomethane and ammonia. The above list of fuels is not complete, there are more options being studied and this overview also does not discuss factors like price, availability and bunker facilities, space required on board and many other important issues. However it is quite clear: none of the alternatives offer the same ease of operation, flexibility and affordability as the various types of diesel oil shipping used to burn.
The A.P. Moller-Maersk/L.R. study referred to above, concludes that achieving net zero carbon emissions is not a capital expenditure (CAPEX) challenge, but an operating expenditure issue (OPEX). In other words: making our ships ready for zero carbon operation is not the problem, the problem will lie in paying for the fuel. The new fuels are projected to be significantly more expensive than existing fossil fuel solutions. If this analysis will be found to be correct, it will not stimulate ship owners to change over to new fuels earlier than absolutely necessary. But it looks like the humble diesel engine will survive the upcoming changes, and will be adapted to the new fuels. This will not always be easy and may well cause engine builders, ship owners and ship's officers a few sleepless nights. It will all be part of the price we will have to pay to fight climate change.

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