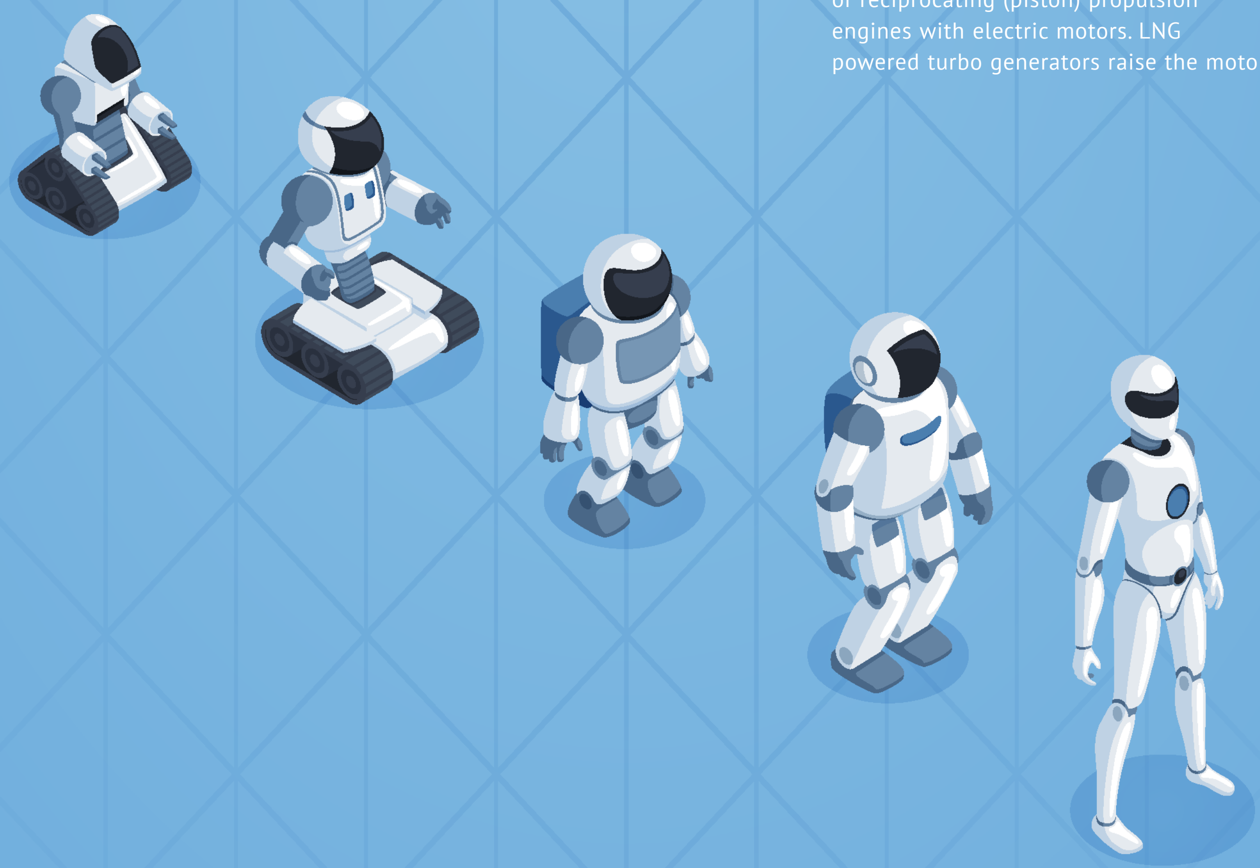
ENGINE EVOLUTION

Drew Robb, Robb Editorial, UK, examines the evolution of LNG in propulsion, and where the technology is heading.



LNG-powered vessels have been with us for some time. There are now more than 200 such vessels either operating or on order. However, current designs have shortcomings in terms of harmful emissions, lifecycle costs, and equipment footprint.

As a result, various parties have been looking at ways to make the technology more efficient and significantly lower their environmental impact. The most promising studies involve the replacement of reciprocating (piston) propulsion engines with electric motors. LNG powered turbo generators raise the motor electrical load and that of all other on board, or 'hotel', load.

COGES

GE Marine Engines' COmbined Gas turbine Electric and Steam (COGES) system popularised the use of LNG in larger ships. Originally appearing in the early 1990's, this approach is now used on eight different cruise ships (COGAS is a similar design – COmbined Gas And Steam turbine system– which uses turbines from Solar Turbines).

An alternate COGES design proposal is an LM2500-family GT for electrical generation, supplemented by a heat recovery system to drive an additional steam turbine (ST) generator. Another design shift being considered is removing one generator and coupling the ST to a single generator through an SSS Clutch; the advantage being reduced footprint and reduced CAPEX.

These COGES vessels can operate on various fuels including LNG or marine gas oil. Their compact footprint allows more space for additional cargo or passengers. The COGES arrangement is 80% lighter and 30% smaller than comparable two-stroke diesels. In addition, the system offers lower life cycle costs.

COGES provides both power and propulsion. Its emissions levels meet International Maritime Organisation (IMO) Tier III and US EPA Tier 4 regulations, with no requirement for exhaust treatment or methane slip. Its GT and ST are united on the same shaft with an SSS clutch sitting between them.

Waste heat

The EMMA Maersk, introduced in 2006, was Maersk's first 'E-class' ship and the latest container vessel to use waste heat recovery technology in a maritime setting, realising improvements from its predecessor class of the 1990s. For many years, the EMMA Maersk containership was the biggest ship on the seven seas with the largest diesel engine in the world. Its 80 MW Wärtsilä 14RTFlex96C engine includes four ABB TPL85-B turbochargers, and a waste heat recovery system. This last element features an ABB TPL3200 power turbine which is coupled to the main power generation steam turbine through an SSS clutch. The power turbine delivers an additional 3.35 MW while the waste heat recovery provides 6.5 MW of power via the ST. In total, about 10 MW is recovered from the engine exhaust. This dropped fuel consumption by almost 8%. Despite this, criticism centred upon the high sulfur content of the fuel, which was said to be several orders of magnitude greater than that allowed by current automotive fuel standards.

Maersk upped the ante again in 2013 with the launch of its Triple-E (economy of scale, energy efficiency, and environmentally improved) container. Its Mitsubishi Energy Recovery Systems (MERS) allowed it to burn 35% less fuel and emit 50% less CO_2 per container compared to the typical ships plying the Asia/Europe route. The Triple-E has 16% more capacity than the earlier E-class ships such as the EMMA Maersk. Yet its ultra-long stroke, 43 000 hp engines from MAN Diesel & Turbo allowed operation at lower RPMs.

The MERS Super Turbo Generating (STG) system harnesses heat from the

Figure 1. A skid mounted Peter Brotherhood waste heat recovery system like this one operates inside all Emma Maersk E-Class Series supercontainers (photo credit: Peter Brotherhood Ltd.).

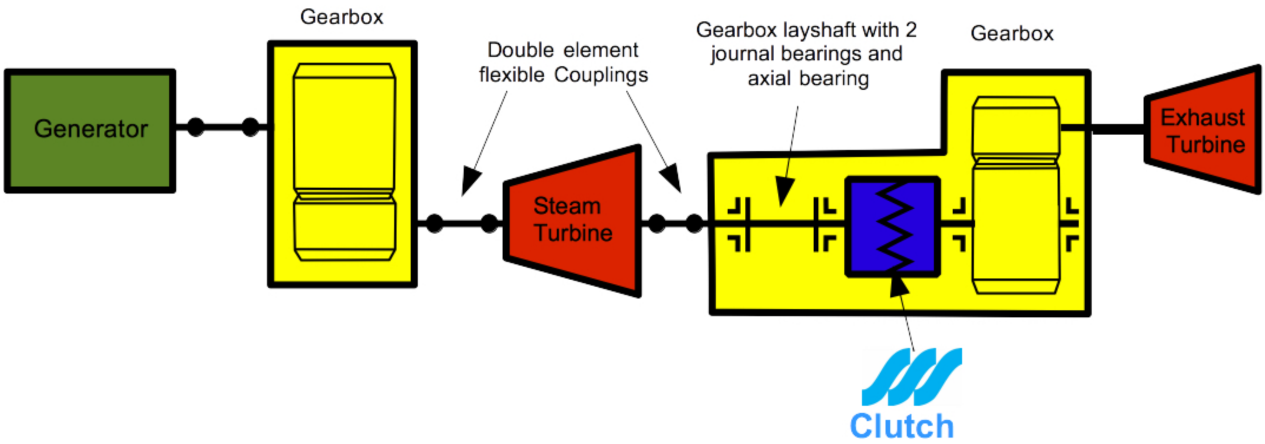


Figure 2. Machinery layout for the waste heat recovery system shown in Figure 1.

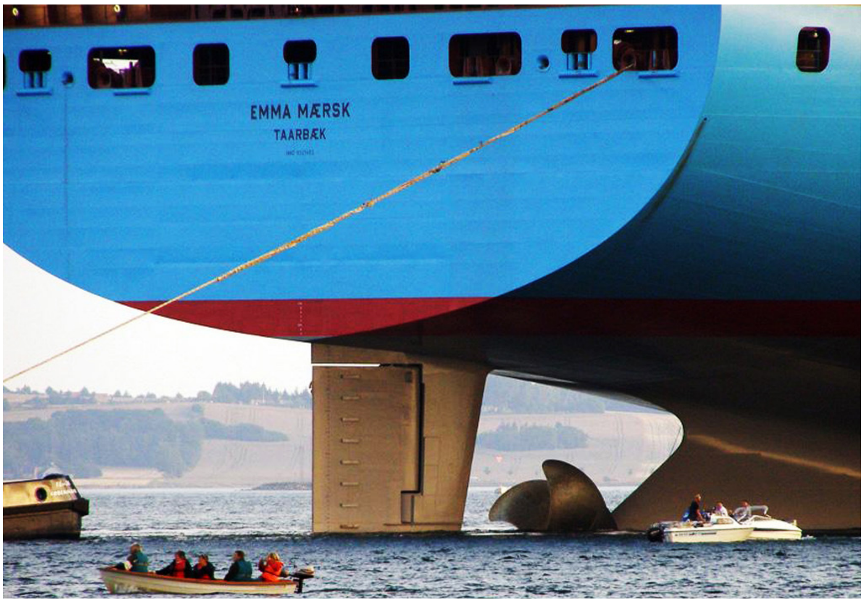


Figure 3. The SSS Clutch helps return 6% propulsion energy to Emma Maersk E-Class Series supercontainers (photo credit: Jesper T. Andersen / jtashipphoto).

exhaust gas to create steam to drive a steam turbine generator. The exhaust gas pressure drives a geared turbo expander, coupled to the same generator. An SSS clutch sits between the turbo expander gear and generator. This overrunning clutch automatically connects when the driver exceeds the speed of the load and disconnects when the driver slows below load speed. According to Hans Christensen, a consultant engineer for Turbo Marine Consult apS, the MERS STG produces 2.4 – 2.8 times more power than a conventional MERS system. Overall, this innovative design reduced fuel consumption and CO_2 emissions by approximately 9%.

Not enough

Gains clearly have been made over the years. Yet with almost 3% of global greenhouse gas emissions traced to international maritime shipping according to the IMO, improvements in efficiency and emissions levels are being demanded. As a result, the dominance is being challenged of two-stroke engines with turbochargers in large vessels. Waste heat recovery has made a difference, but further improvement is called for in an ever-more environmentally conscious world. A sulfur cap for shipping is looming with a 2020 deadline. And that is where LNG-powered GTs come into the picture. GE already has experience in the world's first LNG gas turbine-powered vessel *Buquebus' Francisco*, which is said to be the fastest commercial ship on the planet. Each GT drives her main reduction gearboxes through SSS Clutches.

In a refinement of the COGES concept, LNG is used to drive a gas turbine generator, which powers the onboard electrics, hotel load, and the (electric) main propulsion motors. This is based on the popular combined cycle configuration which has become the standard for efficiency and low emission levels in power plants around the world. The majority of power plants, these days, favour a combined cycle design fuelled by natural gas. The steam turbine and gas turbine are coupled onto the same shaft with a clutch in between. The benefits of aggregating them onto one shaft include: Capital savings, a smaller emissions footprint, and higher efficiency.

In this arrangement, waste heat is recovered from the GT to operate the ST. As a result, efficiency levels of more than 60% are routinely achieved in power plants. The steam turbine drives a generator, which powers onboard electrical loads. Alternatively, steam can be used for onboard heating and cooling if desired.

LNG-powered ships

Far from being pie in the sky, large LNG-powered vessels are on the horizon. Gas turbine OEMs such as GE and Solar Turbines have signed agreements to forward this technology. The PERFECt project, for example, involves ABB, OMT, GTT, Solar Turbines, CMA CGM, its subsidiary CMA Ships, and DNV GL. Early results show promise for an electric-driven 20 000 TEU ultra-large container vessel with a LNG-fuelled combined cycle gas and steam turbine (COGES) electric power plant. It utilises LNG as a primary fuel, in concordance with the basic COGES system. As the power plant and LNG tanks are situated below the deck house, space is freed up for more container slots. Total efficiency is increased by around 5%.

There are downsides, of course, to this idea. It requires a more complex fuel tank design, and the need for refueling terminals, as well as the increased cost of fuel. LNG carriers, therefore, might be the first ones to embark upon this approach, harnessing the fuel they already carry and the LNG infrastructure already established aboard and at their ports of call. By doing so, they gain greater efficiency and will face fewer fines for using dirty fuel.

An LNG-fuelled future?

There is still a long way to go before LNG-fuelled vessels rule the ocean. In the meantime, steps are being taken in that direction. As well as the PERFECt project, GE is pursuing a COGES project in partnership with Youngsung Global, Dintec, Far East Ship Design & Engineering Co (FESDEC), and Cryos. Instead of LNG, however, this will be a Liquid Propane Gas (LPG)-fuelled COGES ferry.

Goals for the project include better safety and efficiency, a drop in operating costs of 35%, and a reduction in nitrogen oxide and carbon dioxide emissions to meet IMO standards.

The success of that project could have a major bearing on future designs. If the LPG-fuelled ferry realises its promise, it is likely to encourage GE and other OEMs to take the next step up and invest in a large LNG-powered container vessel. It may take a few years for more designs to appear. But within a decade, it is likely that we will see a great many more LNG-powered vessels in service around the globe. **LNG**