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in detail

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Cover photo: Wärtsilä

RENEWABLE ENERGY IS FUTURE-PROOF

We are on the brink of pivotal change in the world's energy system, with immense challenges and opportunities ahead. Wärtsilä is at the forefront of sustainable strategy and innovative solutions, in preparation for a more energy-efficient, cleaner future. We are focusing on strengthening our presence in key markets and market shares, such as Africa and global biogas, and on offering environmentally sound, safe solutions to our customers, as well as optimising system performance, across the board.

According to the DNV GL Energy Transition Outlook 2018, we can expect that while the world will require less energy from the 2030s onwards, owing to rapid gains in efficiency, global demand for electricity consumption will more than double by 2050 to meet 45% of the world energy demands. The market share of solar and wind energy will subsequently increase, and the world's energy system will likely decarbonise, with an equal split of fossil and non-fossil fuel usage by 2050.

In this issue, you can read how Africa's energy sector is transforming and undergoing rapid growth, close to 10% yearly, likely increasing exponentially in the coming years (page 4). Africa's abundance of sunlight makes it a prime location for solar energy, and it is well placed to become a key player in renewables.

The world is shifting away from traditional baseload generation to renewable energy. Wärtsilä's hybrid solar PV and storage solution (page 16) is being installed at a record rate to meet the needs of a growing world population and the demand for cleaner energy.

Our acquisition of Guidance Marine and Puregas Solutions during the past year, (page 30) is part of our tactical strategy to strengthen our market share in key expanding markets, such as gas processing, and to focus on smart, sustainable, safety-centric technology and solutions.

Puregas Solutions' expertise is in manufacturing biogas upgrading technology. As biomethane is becoming a popular choice of renewable, with growth at about 15 % per year, and gaining more interest from major energy players, this acquisition opens up a vast, new and fast-growing market for Wärtsilä.

Guidance Marine specialises in dynamic positioning sensors and other vessel control systems, such as collision avoidance and remote-controlled operations, critical in oil drilling and transport, and offshore industries. Wärtsilä now offers state-of-the-art positioning services for many vessel types, enhancing safety and precision in operations.

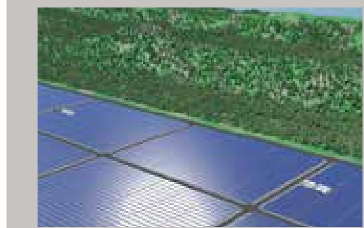
We need to continue to invest in energy, marine and gas solutions that are future-proof, environmentally sustainable and flexible enough to fulfill our world's ever-changing needs.

Mikael Wideskog
General Manager,
Technology Strategy & Innovation Process
Wärtsilä
Editor-in-Chief of *In Detail*

A NEW WAVE

Wärtsilä's LPG power plants are perfectly suited to fulfill the energy market's unique requirements.

REFERENCES



The case for hybrid solar plants

As cost-efficient storage solutions improve, renewable energy solutions like hybrid solar take centre-stage.

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Anticipating the future

Artificial intelligence can help identify anomalies and potential failures before they occur.

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Taking accuracy to the next level

Wärtsilä's CFD simulations reveal the shortcomings of the ITTC'78 extrapolation method.

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Transforming Africa's energy sector

AUTHOR: Payal Bhattar

With abundant sunlight and ideal wind conditions, Africa is naturally well-positioned for renewables.

Africa is amongst the world's most underserviced energy markets, accounting for 13% of the world's population but just 4% of its energy demand. It is estimated that close to 620 million Africans live without access to reliable electricity. But that may change soon.

Africa will need to grow its electricity market by 8.4% annually to reach universal access by 2030. That will be possible, assuming there is constant growth in electricity and population, no major changes in political willingness and increasing access to financial investments, according to the World Bank. Universal access to electricity in Africa is a big target to meet because it requires huge investments in new power infrastructure that will have to be built in a relatively short period of time.

Between 2000 and 2016, Sub-Saharan Africa saw capacity additions of close to 13.8 GW driven by privately financed independent power producers (IPPs) and Chinese investments. While the majority of the new power projects were thermal-based (gas or diesel), renewable energy began breaking through significantly via the auction route during this period.

The International Renewable Energy Agency (IRENA) estimates that 13 countries in Sub-Saharan Africa account for more than 80% of the region's installed power generation capacity (90 GW). While 27 countries have installed capacity of less than 500 MW each, 14 countries have power systems of less than 100 MW. This is in stark comparison to say, a country like India, which is not amongst the most developed energy markets in the world but has a total installed generation capacity of 344 GW.

Mix & match

While South Africa uses coal to generate most of its power, the remaining Sub-Saharan region uses hydropower (51%) and fossil fuels (24% natural gas, 18% diesel or heavy fuel oil).

The heavy concentration of hydropower is a matter of concern for countries that are reliant on it for their energy supply. For instance in Zambia, which is dependent on hydropower for over 90% of its electricity supply, in 2016 witnessed a power-deficit rise to 1 GW due to drought-like conditions driven by climate change. The same happened with Malawi, which is dependent on hydropower for 98% of its power supply. Since then, many countries have been working more seriously on diversifying their power mix.

Renewables are a good option for Africa as it is naturally well positioned with abundant sunlight and ideal wind circumstances. Add to that the fact that micro-grids, off-grid solutions, storage and prices for renewable technologies across the globe are falling and what you have is a potentially bright and powerful future for the region with the lowest per capita energy consumption in the world. But making the switch is easier said than done.

"The main issue for the introduction of renewables is the inflexibility of current production sources. Some technologies like turbines and coal are not intended for ramping up and down the power generation capacity, and they need more time to ramp up. Therefore, they don't support the intermittent nature of renewables," explains Mamadou Goumble, Vice President Africa, Wärtsilä.

Experts believe that although renewables (apart from hydropower) currently account for a very small portion of the power mix in Africa, it's a market that will grow exponentially over the next few years. IRENA estimates that electricity demand in Africa will triple by 2040 and close to half of the new capacity will come from renewables.

Making the switch

The good news is that more than 40 countries in Africa already have their renewable energy targets in place and have ambitious projects under way.

For instance, South Africa is reported to have recently signed contracts with 27 independent renewable energy power producers, worth USD 4.6 billion, to produce 2,300 MW of electricity over the next five years. Ghana plans to generate 10% of its energy from renewable resources by 2020 and has set up the world's fourth largest solar photovoltaic (PV) power plant – the 155 MW Nzema Solar Power Station. Senegal is in the midst of setting up a 158 MW wind project in Taiba N'Diaye. Its national electricity utility Senelec (Société nationale d'électricité du Sénégal) is looking to add 100 MW of additional solar capacity under the Scaling Solar Initiative, which is a World Bank programme covering Zambia, Ethiopia, Madagascar and Senegal for mobilising privately funded grid-connected solar projects at competitive tariffs.

"The last tender on scaling solar IPP prices was one of the lowest in Africa, and therefore it will allow Senelec to have cheaper solar-based power. Also, with the development of gas reserves discoveries in Senegal, the country will be able to use the local resources from 2023–2025. Senelec will master the costs of fuels and will generate cheaper energy," says Goumble.

In focus: Senegal

Experts say that diversification and good economics call for Africa to have an ideal mix of renewables, thermal power generation and energy storage. And this is where Senegal stands tall as one of the main pillars for energy growth in Sub-Saharan Africa. The country is reducing the cost of electricity by building fuel-flexible power plants that can use its high-quality gas reserves and tap into its huge potential for solar and wind power.

Take for example the case of the 130 MW Malicounda power plant in the Dakar region that is expected to become operational by 2020. Matelec, the contractor for the project, chose Wärtsilä to supply, manufacture, deliver and commission this flexible power plant.

The Malicounda Flexicycle™ power plant will initially operate on Wärtsilä 50 engines running on heavy fuel oil (HFO) and can be converted to gas-fuelled operations once gas is available in the region.

Flexicycle power plants are based on gas, multi-fuel or liquid fuel combined with a steam turbine; have superior synchronisation and ramp-up time; and offer flexibility to have multiple independent units. This makes them an ideal solution for grids requiring flexibility due to daily load fluctuations, or significant installed base of wind or other non-dispatchable power like solar power which is intermittent in nature due to its dependence on natural factors like availability of adequate sunlight.

"Our Flexicycle power plant in Malicounda gives 10% additional output without fuel consumption, and that increases efficiency in a big way. This is the second Flexicycle power plant installed by us in Senegal. We have also installed another one in the Cap des Biches with the IPP ContourGlobal," says Marie-Andrée Truchi, Business Development Manager, Wärtsilä Energy Solutions.

There is no doubt that solutions like Flexicycle power plants will help shape Senegal's energy future in a big way by increasing its energy production while reducing the cost of electricity for consumers and integrating intermittent renewable energy with the grid.

Experts say that going forward, it is countries like Senegal that will make power a pillar for economic development and inspire and lead other African nations to rewrite their energy stories. Political will to bring about change will play a key role. After all, countries don't develop based on crises, abundant resources or plans. They are built brick-by-brick starting with thought leadership and the ability to challenge and change the status quo.

Fuel-flexible power plants are Senegal's solution to reduce electricity cost.

The W50 engines that run on heavy fuel oil will initially power the Malicounda Flexicycle™ plant.

Roatan Electric Company (RECO) provides electricity to the island of Roatan in the Caribbean side of Honduras using their new 28 MW LPG-fired power plant, which was built by Wärtsilä under a fast-track EPC contract in 2016. Wärtsilä's modularised plant design allows for fast track construction. Photo: Roatan Electric Company

LPG – Taking fuel flexibility to the next level

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While the first Wärtsilä LPG power plant has been in operation for some time now, a solution offering liquefied petroleum gas (LPG) with diesel as a backup fuel is the latest development in Wärtsilä's fuel flexibility offering.

With some recent key installations in power plants across Central America and the Caribbean, Wärtsilä proves once again that its engine portfolio has the versatility to run on a variety of different fuels suiting both the needs of its customers and a challenging energy market.

In early 2016, the first of several LPG-powered power plants with Wärtsilä technology went into operation in Central America. A second plant on Roatan Island, Honduras, soon followed. Another plant is due to start operations in St. Thomas in the US Virgin Islands in late 2018.

LPG has its advantages. For instance, while liquefied natural gas (LNG) requires special shipping terminals and cryogenic storage solutions, LPG's primary advantage is its easy accessibility in world markets. It is a global and easily tradeable commodity. In many parts of the world, LPG is used for transportation, cooking and heating. In addition, LPG is also more environment-friendly than heavy fuel oil (HFO).

Today, the lion's share of LPG is sourced from the US, where it is a byproduct of the shale gas exploration bonanza, and from the Middle East. The US supply makes LPG especially attractive in the Caribbean and Central America, hence Wärtsilä's recent LPG plant orders in the region.

This trend is supported by the World LPG Association 2017 market report, which points out how small countries and island nations without access to gas could be a future niche for LPG-fuelled power plants, and describes how LPG will have an increasingly important role to play in the world's energy production.

The first Wärtsilä LPG power plant entered service in Central America in early 2016 and it generates baseload power for industry.

There is growing evidence to suggest that LPG will have an important role to play within the global Power Generation sector in the next 10 to 20 years. As the trend towards renewables continues throughout many parts of the world, and with coal increasingly seen as a power generation source of the past rather than the future, the role of gaseous fuels as a lower-carbon, flexible way to generate electricity has never been more important.

The International Energy Agency (IEA) anticipates 50% growth in the demand for liquefied natural gas (LNG) in the period 2016 to 2040, with much of this growth associated with electricity generation, and a continuation of the trend away from using coal-fired power plants.

Where pipeline infrastructure exists in close proximity to the demand, natural gas is clearly the gaseous fuel of choice. However, many countries do not have an established network of natural gas pipelines. In countries where these do exist, infrastructure is often reserved for areas of high population density or centres of industrial activity, leaving more remote areas with little or no access to natural gas. In such cases, there is a clear opportunity for LPG to provide a solution for power generation – especially when new power plants are necessary to meet increasing electricity demand.

In some cases, governments are looking at using LPG as a 'bridging' fuel in newly built power plants – often with short one-to two-year lead times – but with a longer-term plan to convert to natural gas once the pipeline infrastructure is in place.

Future lies in renewables

The 2017 report continues: "In the future, there is also likely to be an emerging opportunity associated with the use of LPG Power Generation in combination with renewables such as solar PV (photovoltaics)

The construction of a 21 MW LPG power plant for US Virgin Islands' Water and Power Authority is well on its way and is foreseen to be completed in December 2018. Wärtsilä is building the power plant on EPC terms.

and wind power. These 'hybrid' (or micro-grid) projects are likely to be particularly well-suited to remote, or island, locations which currently rely on expensive diesel to meet their power needs."

Wärtsilä's new vision is to lead the world to a 100% renewable energy future. Integration of renewables is a key element of this ambitious vision. This integration requires fast-acting, flexible and efficient backup generation. Wärtsilä's combustion engine technology is superior for this purpose, and a number of peak and grid stability plants have been delivered across the world to facilitate the exploitation of wind and solar power. The US has been the forerunner in efficient renewables integration, where the largest US peak and grid stability plants with Wärtsilä's technology have capacities in excess of 200 MW. Wärtsilä's flexible power generation capacity is a solid foundation for future expansion of renewables.

Wärtsilä's solutions for LPG power plants

With these market conditions, Wärtsilä now has two technologies in its portfolio that have the ability to burn LPG gas. Both technologies are based on the proven Wärtsilä 32/34 frame, launched in the mid-1990s, of which close to 5000 units are already in service in power plants worldwide. In each case, the engine frame and combustion engine technology is the same but the fuel supply system on the 32LG provides new innovations.

The first Wärtsilä LPG engines on the market are of the Wärtsilä 34SG-LPG type, which is essentially a proven Wärtsilä 34SG gas engine with a special tuning. The Wärtsilä 34SG-LPG engines can also be operated on natural gas with only minor adjustments, should gas become available during the lifetime of the plant.

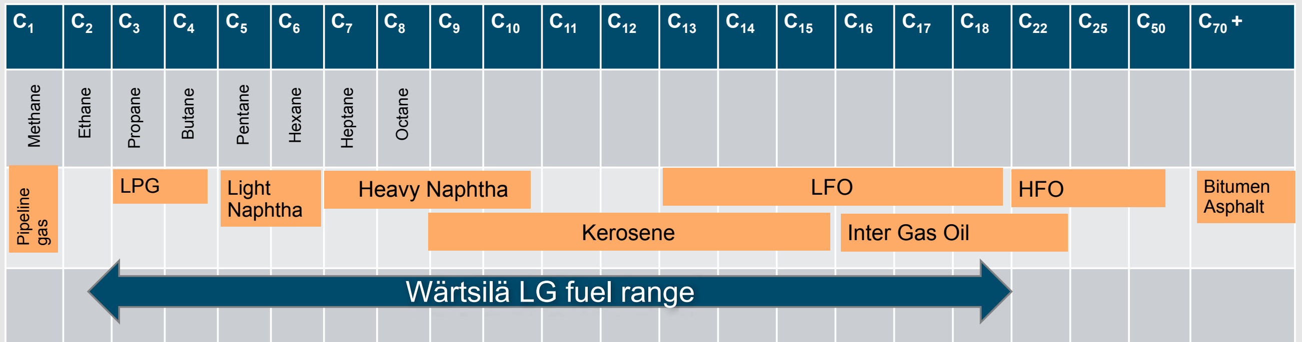
The latest addition is the Wärtsilä 32LG engine, which burns LPG and has the capability to burn diesel as backup fuel in cases where LPG is not available. The Wärtsilä 32LG engine has the benefit of burning propane and butane in any relation and the engine automatically adjusts itself to changes in the fuel supply. Wärtsilä 32LG can also change from LPG to diesel as a backup fuel at the flip of a switch. Furthermore, should the fuel market conditions be favourable, the Wärtsilä 32LG engine has the option to burn a wide range of other fuels such as condensates and naphtha.

The fuel supply and injection system of the Wärtsilä 32LG engine is the real innovation. Although the 32LG system builds on cylinder-specific electronic control and common rail technology developed and further refined by Wärtsilä during the last 25 years, coping with the properties of the wide fuel range of the Wärtsilä 32LG required precision engineering and testing.

In addition to the undisputed flexibility of Wärtsilä's combustion engine plants, the ability to maintain performance with only marginal derating in hot, high and dry sites typical of deserts and high mountains distinguishes Wärtsilä's plants from gas turbine technology. By contrast, other power generation technologies may lose in excess of 30% of the rated capacity due to high ambient temperatures and high altitudes. Furthermore, due to the closed cooling system of Wärtsilä combustion engine plants, water consumption is marginal. Additionally, Wärtsilä combustion engines do not require water for power augmentation at high ambient temperatures or NOx reduction.

	Wärtsilä 20V34SG-LPG	Wärtsilä 20V32LG
Engine frame	Same proven engine frame as used in Wärtsilä 32 & 34 diesel, gas and dual-fuel engines.	
Engine fuel supply system	Identical to system used for Wärtsilä 34SG gas engines. LPG is gasified in external system by heating.	Common rail principle similar to Wärtsilä common rail diesel engines. Liquid LPG is atomised in injection valve.
LPG fuel	Min. 90% propane	Propane and butane in any relation.
Fuel flexibility	Methane (natural gas) or ethane	Light fuel oil, kerosene, naphtha, condensates and other hydrocarbons in the range C_3 to C_{20} in any relation.

The preferred fuel flexibility (natural gas or liquid fuel) in addition to LPG and the composition of the available LPG influences the choice of engine technology for an LPG power plant.



In addition to LPG, the Wärtsilä 32LG engine can burn a wide range of liquid fuels between LFO, kerosene, naphtha and condensates. The engine automatically adjusts itself to changes in the fuel supply as controlled by the operator. Besides using LFO as back-up fuel for LPG, the LG engine fuel flexibility also opens up interesting options for optimising fuel costs in changing fuel markets.

Wärtsilä's unique lifecycle support

When it comes to power generation Wärtsilä is not a mere technology provider. With more than 500 power plant Engineering, Procurement & Construction (EPC) contracts executed, Wärtsilä has an impressive track record of worldwide power plant construction. Furthermore, Wärtsilä's modularised power plant design facilitates fast-track plant construction and also eliminates technical and construction risk to a large extent.

Globally, Wärtsilä has more than 30 GW of capacity in power plants and ships under various types of agreements. The agreements range from simple spare parts supply agreements to maintenance agreements and full operation and maintenance (O&M) agreements. The latter two are common for power plants. Upon engaging Wärtsilä to do the O&M, the plant owner no longer has to worry about staffing the plant, ordering parts and carrying out maintenance work.

When engaging Wärtsilä as an EPC contractor and/or to manage the power plant, plant owners can focus on further optimising and developing their business.

Smart Power Generation with LPG

Wärtsilä's LPG offering is part of the company's increasingly important global strategy for Smart Power Generation, a concept that enables an existing power system to operate at maximum efficiency as well as large-scale renewables integration by effectively absorbing current and future system load variations, providing significant system level savings.

[ENERGY / IN DETAIL]

Landlocked Power Barge and FSRB, loaded using floating hoses.

Wärtsilä's floating storage and regasification barges support LNG growth

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Global adoption of small-scale liquefied natural gas (LNG) could be a reality soon, thanks to Wärtsilä's LNG floating storage and regasification barges (FSRBs). They facilitate access to tricky locations that were once impossible to reach to deliver, store and distribute LNG.

While small-scale LNG has the potential to help solve many of the energy challenges faced by developing countries, complex, off-the-grid locations, lack of infrastructure and the absence of small-scale terminals for delivery, storage and redistribution are the main obstacles to its more widespread acceptance. However, as the capacity to supply LNG around the globe continues to grow, with larger LNG supplies coming from Australia as well as from the United States, both international oil majors and state-owned oil companies are looking for innovative ways to make LNG available for small-scale applications.

The global LNG infrastructure of today consists of large land-based terminals and floating storage and regasification units (FSRUs), which store the LNG and send out gas to large national pipeline networks. This format will not work for more remote areas that are not served by pipelines, nor for those, such as islands in Indonesia or the Caribbean, where any pipeline grid will have to be small scale. Small- and medium-scale LNG infrastructure is the optimal solution to supply energy to such remote or isolated regions.

Missing piece of the LNG puzzle

Even though LNG is often the most cost-competitive energy source in these tricky circumstances, some locations are simply not suitable for establishing an LNG terminal. This may be due to remoteness, a lack of available land, high cost of building, or insufficient infrastructure to support the building of a terminal.

In situations such as these, an FSRB is that crucial piece in the LNG puzzle that has previously not been available as an alternative. Until now, that is.

Wärtsilä has more than 20 years' of experience in designing, constructing and delivering power barges. Its barges are in operation in a variety of global locations from South and East Asia to the Caribbean islands and Central America. Going forward, Wärtsilä will take advantage of this extensive experience and apply it to designing, constructing and implementing a new generation of FSRBs, intended to secure access for LNG to locations where it had previously been impossible or unfeasible to do so.

It's all about flexibility

Using modular designs, Wärtsilä's FSRBs are configured according to the specific project requirements. This modularity also brings flexibility as it enables the barge to be modified for use in a different place or application. Flexibility in an LNG barge solution is what gives competitive advantage to Wärtsilä. Not only can it be implemented with lower capital expenditure (CAPEX) costs and more quickly than a terminal at a remote location, it can also easily be moved to another location if the market for LNG in one place changes over time. Similarly, a second barge can quickly be added to the same location should demand continue to grow.

Permits are often more straightforward to obtain for a barge than for a land installation, enabling a faster project implementation. The FSRB can be delivered from a shipyard within a clear and controlled timeframe and budget, with highly controlled quality, compared to a terminal that is subject to local, sometimes arbitrary, construction risks, delays and quality issues. The controlled schedule and budget significantly reduce the risk of the FSRB project, making it much easier to achieve funding. Last but not least, it is easier to secure financing for a movable, re-sellable asset than it is for one at a fixed location.

Small- and medium-scale instead of large-scale LNG

These days, most floating regasification of LNG is performed by FSRUs. A typical FSRU carries anything from 140,000 m^3 of LNG and up, which it supplies to an existing gas pipeline network, such as a national gas grid.

The FSRB, on the other hand, is a smaller-scale solution, storing LNG volumes ranging from 7,500 to 30,000 m^3. While an FSRU can sail the seas, a FSRB instead fulfils the same purpose as a small, land-based terminal would. It is stationary, usually situated at the shoreline, or within a few hundred metres of the shore, and only moves if it is decommissioned and transferred to another location.

In addition to lower capital costs, an LNG barge is also more cost efficient than an FSRU from an operational point of view. The barge is remotely operated, requires no crew, and is only visited by operators for inspections and maintenance.

Easier regasification

When it comes to the process of delivering LNG to land-based applications in its gaseous form – through the process known as regasification – the FSRB is a differentiator. While FSRUs typically use seawater to heat the LNG to convert it into gas, the FSRB can make use of heat sources onshore, from a power plant for example. Hot water or steam is fed into the regasification module on the barge, where it is cooled while gasifying LNG, and returned to the heat source. In this way, the system performs double work, gasifying the LNG while also cooling the power plant or industrial unit, thereby reducing overall energy consumption. Because of the higher heating media temperatures, the FSRB regasification module is more compact and cost efficient.

If there is no heat source available onshore, the FSRB may also use ambient air vaporisers as a regasification solution for small-scale LNG. Mounted on the barge itself, the vaporisers transfer heat from the air to LNG to transform it into gas. This is a more self-contained process than with seawater, the use of which is restricted in many coastal locations as changing the temperature of seawater can have a negative impact on marine ecosystems.

A key advantage of the on- or near-shore FSRB is that it can also send LNG to shore in its liquid phase. This can be used to load LNG trucks or ISO containers, which will then further extend the small-scale LNG delivery chain to the local region and beyond.

Wärtsilä supports growth of small-scale LNG

Wärtsilä is deeply committed to supporting the establishment of LNG as an enabler of sustainable power generation of the future. With its knowledge of LNG technology and extensive experience of delivering power projects with a full Engineering, Procurement & Construction (EPC) scope, Wärtsilä is also uniquely positioned to provide the missing piece in the LNG puzzle, identify and implement feasible solutions in situations where there are currently no solutions, and provide the know-how, equipment and infrastructure needed to facilitate growth of the small-scale LNG market around the world.

Wärtsilä's new hybrid solar PV and storage solution.

Hybrid solar, a new era in baseload solar

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Renewable energy solutions like hybrid solar are taking the lead in the world's energy production as cost-efficient storage solutions steadily improve.

When people talk about hybrid energy solutions, there are usually three alternatives. The first involves engine hybrids where a solar photovoltaic (PV) plant is added to a diesel plant for added capacity. The second solution involves adding energy storage (using batteries) and PV to an existing diesel plant, also for added capacity. And the third option, which the world will see more of in the coming years, is a pure solar hybrid plant coupled with the latest in energy storage technology.

This last solution, a hybrid solar PV and storage solution, was unveiled by Wärtsilä in Munich, Germany, in June 2018 at the annual Intersolar Europe conference, a major international event for the renewable energy industry.

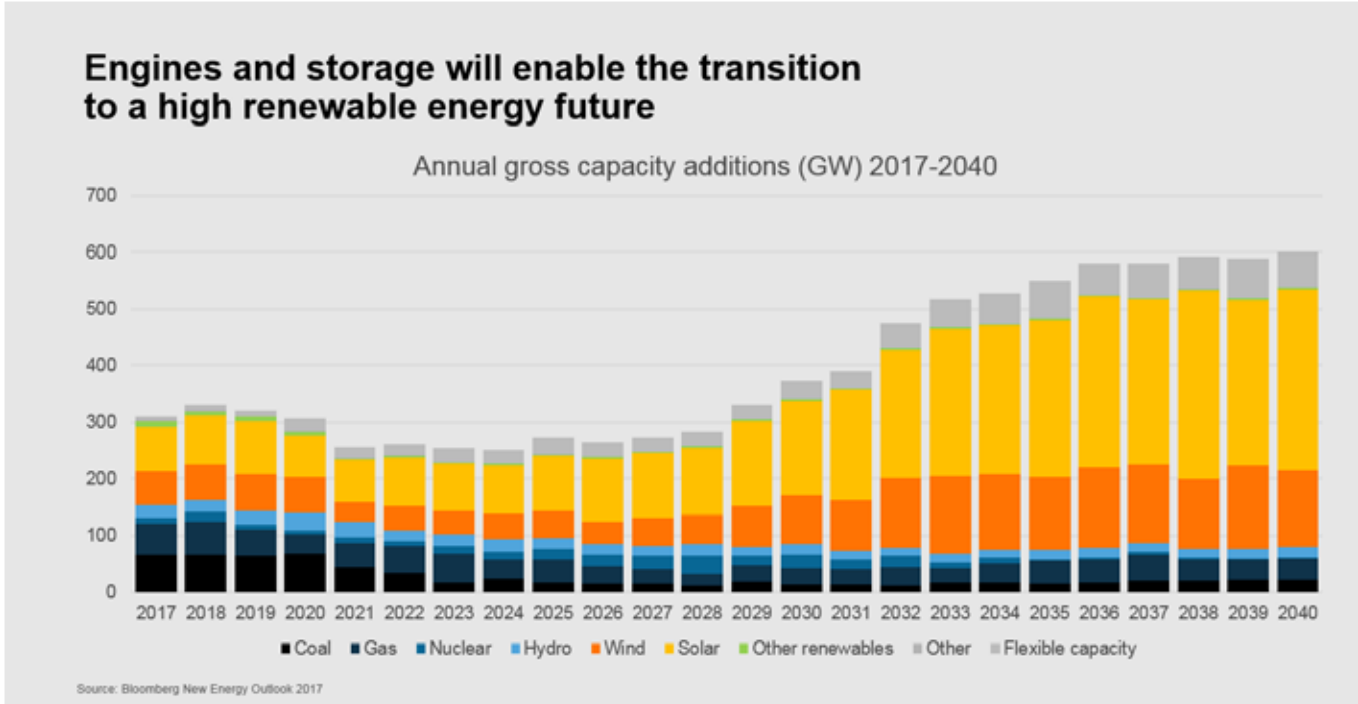
Renewables as baseload

The buzzword for this solar PV and storage energy solution is "renewables as baseload", an energy production scenario that not only is climate-friendly and increases system resilience and efficiencies but also can be supported by a power producer's existing grid infrastructure, hence setting a new hybrid standard.

The trend worldwide is very clear. Renewable energy sources, like PV, are being installed at a record rate around the world to accommodate the need for a cleaner energy mix and a growing world population and urbanisation. According to the International Energy Association (IAE) and its World Energy Outlook 2017, a city the size of Shanghai is added to the world's urban population every four months. And by 2040, the total global energy generation capacity is forecasted to increase by 60% and renewable energy sources will make up more than 45% of that total. With growing production volumes and continuous innovation, the cost of renewable energy technologies is improving and in many cases already represent the most feasible alternative.

In another recent market outlook, compiled by Bloomberg, which forecasts global energy sources between 2017 and 2040, coal, gas and nuclear power will progressively diminish while solar and other renewables will gain massive traction (see the graph on page 17).

To achieve this added penetration of climate-neutral renewables in the global energy sector, it is crucial for the industry to optimise system performance in every aspect of power generation across the board.



Market outlook for the next two decades.

DC–AC–DC

Wärtsilä Energy Solutions is doing exactly this by reengineering some of the critical parts of the PV power generation ecosystem including storage. And it involves fine-tuning the software and hardware to optimise system performance and market participation, and maximise customers' return on investment.

To make renewables the new baseload of power generation means applying many of the same engineering principles to PV generation as is already done to fossil-fuel-based methods, all the while taking into account the traditional energy usage fluctuations that apply during any given day. The trick, though, with PV is that the energy is generated in DC current and needs to be converted to AC current. This is of course handled by a traditional power inverter but when batteries, which are also DC-rated, are added to the mix, the situation gets additionally complex.

One challenge is an energy efficiency loss of about 15% in the 'round trip' between DC to AC and back to DC to recharge the batteries. Or put another way, the batteries which get charged in DC current must also be able to discharge into the AC grid which requires a novel use of converters and inverters.

The real GEMS

In the quest for the best available technologies, Wärtsilä in 2017 acquired Greensmith Energy, which develops GEMS, an advanced energy management system, currently in its fifth generation, enabling new and modern monitoring, and operation of energy generating and storage applications. Greensmith Energy makes use of the latest advancements in power electronic technologies, battery and storage technologies, as well as machine learning and cloud computing to harness renewable energy and optimise it for the grid.

One of the main stalwarts of Wärtsilä's Hybrid Solar solution and GEMS is the usage of bi-directional inverter technology to seamlessly integrate PV panels with the grid. Powered by GEMS software, this highly integrated system enables dispatchable energy on demand.

More to the scenario

A major possibility with this solar hybrid set-up is its ability to perform both the energy shifts while offering ancillary services for grid stability support. This double duty or services stacking enables increased revenues and improved feasibility. Shifting energy matches the needs represented in a typical electrical usage scenario – lower usage during the day, higher at night when people come home from work.

While Greensmith's GEMS platform is used to optimise this complicated load forecast operation, which also takes into account other parameters such as market pricing, market conditions and even weather conditions down to minute-by-minute forecasts, it also includes web and cloud-based computational analysis allowing for intelligent revenue stacking. And by making energy storage an on-demand functionality, the overall lifetime of the batteries and PV plant is extended.

All of this taken together means that the current advances in hybrid solar technologies offer a growing, viable and future-proof energy production system that is also CO_2 neutral for both power developers and regulated utilities.

Evaluating internal combustion engine's performance

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An internal engine combustion performance may vary greatly from the values stated in its catalogue. It is therefore recommended to ask for more site-specific information from the vendor to have a better understanding of the expected performance of the machinery.

Comparing the output and efficiency values of different machines seems like a straightforward task. After all, what could be difficult about tallying different numbers and telling which one is higher? Well, it is not so simple when it comes to evaluating engines.

The efficiency of power generation equipment depends on a variety of factors, many of which are site- and application-specific. To make things more complicated, equipment suppliers often define their efficiency values for different reference conditions that are difficult to interpret for anyone other than specialists.

How the differences occur

There are many factors which affect the actual performance of power generation machinery. The most obvious ones are the ambient conditions and the fuel quality. This means the actual performance of the equipment, when installed on site and commercially operated, will deviate greatly from the catalogue values. Those deviations will naturally have different characteristics, even for very similar equipment, depending on the design. This means that, say, even if machine A is more efficient than machine B in nominal conditions, it will not necessarily still be the case under actual site conditions.

To make things more complex, the nominal values are also often expressed for different sets of conditions or with different assumptions which may or may not be explicitly stated. This makes a realistic comparison, of the site performance for different engines, complex and time-consuming.

At a certain stage, it will inevitably require obtaining a more comprehensive data set from the equipment supplier that goes way beyond the single table given in a catalogue sheet. Yet, understanding certain general principles may facilitate early evaluation of equipment's capabilities, even just with the information on the catalogue. Here, we take a closer look at those principles and its applicability to internal combustion engines.

Ambient conditions

Combustion engines are among the technologies most resilient to ambient environment changes. Nonetheless, at very high temperatures, the performance figures get affected. As a rule of thumb, it may be assumed that the performance parameters will be identical or very close to the nominal values for up to 30 to 35°C. Above that, the performance may get marginally impaired, both in terms of efficiency and output. Humidity also affects the performance. The higher the relative humidity, the lower the temperature at which the engine performance will start to deteriorate. The engines may also be sensitive to air pressure reduction related to high altitude.

Typically, catalogue parameters for engines are stated for the ISO 3046 conditions: an ambient temperature of 25°C, relative humidity of 30%, and an ambient pressure of 100 kPa. This means they are representative for operations in temperate to cool climates, with possible exceptions of the hottest or coldest days. However, for more extreme climates, especially for extremely hot and humid cases, derating and efficiency deterioration has to be always considered.

The load

It is obvious that the efficiency of an engine depends on its load. This is particularly important for plants which are not expected to operate at full load for a considerable amount of time. Fortunately, in case of larger plants, combustion engine power plant allows one to achieve partial loads by shutting down individual gensets while keeping the others as close to the full load as possible. Nonetheless, sometimes, it will be necessary to operate the engines at partial loads due to other considerations (e.g. maintaining spinning reserve), and the efficiency will inevitably reduce. It may be noted though, that the efficiency curve of an engine is typically much flatter than that of other machinery.

The power factor

An alternating current generator generates not only active power but also a certain amount of reactive power. This is typically described by a value called the power factor (or, p.f.). The p.f. is a ratio between active

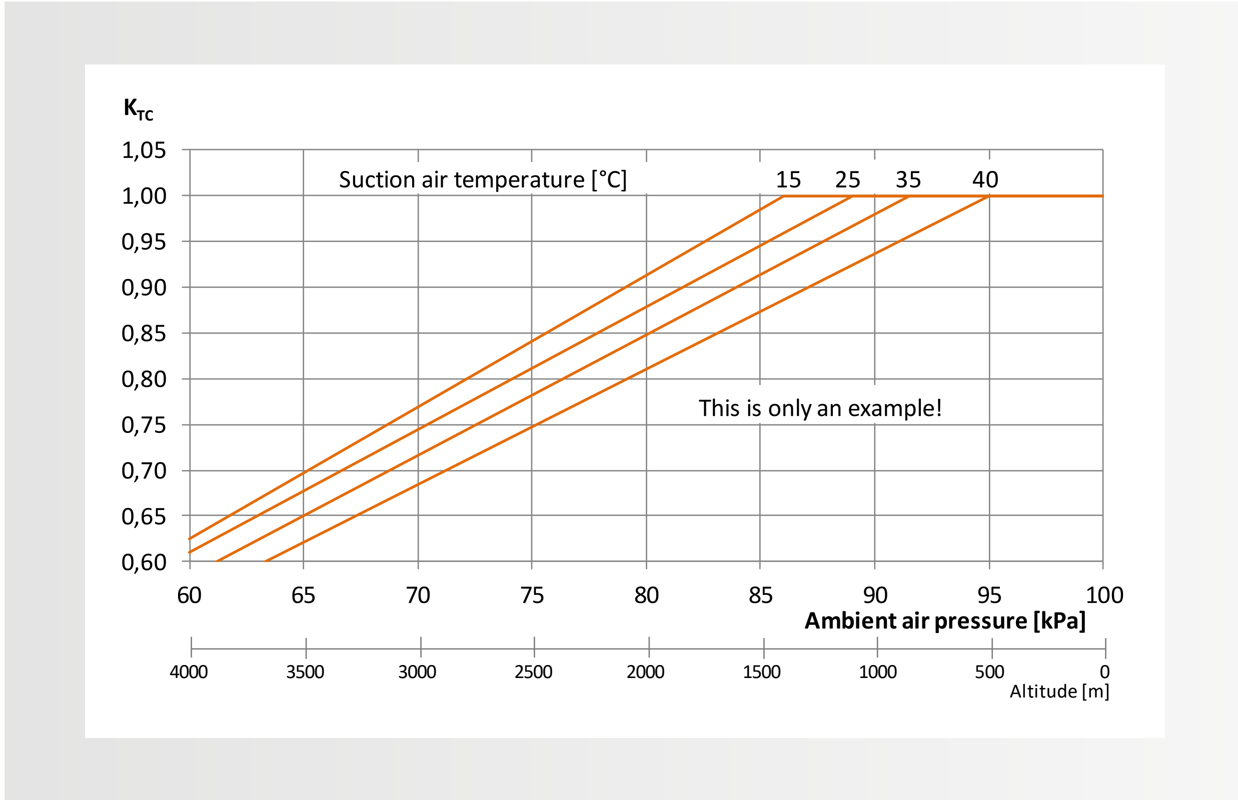

Fig. 1 - Ambient air pressure and temperature may affect engine output. Note that in the case of higher temperatures, derating starts already at lower altitudes. This shows how important it is to use complete information on the site conditions.

[ENERGY / IN DETAIL]

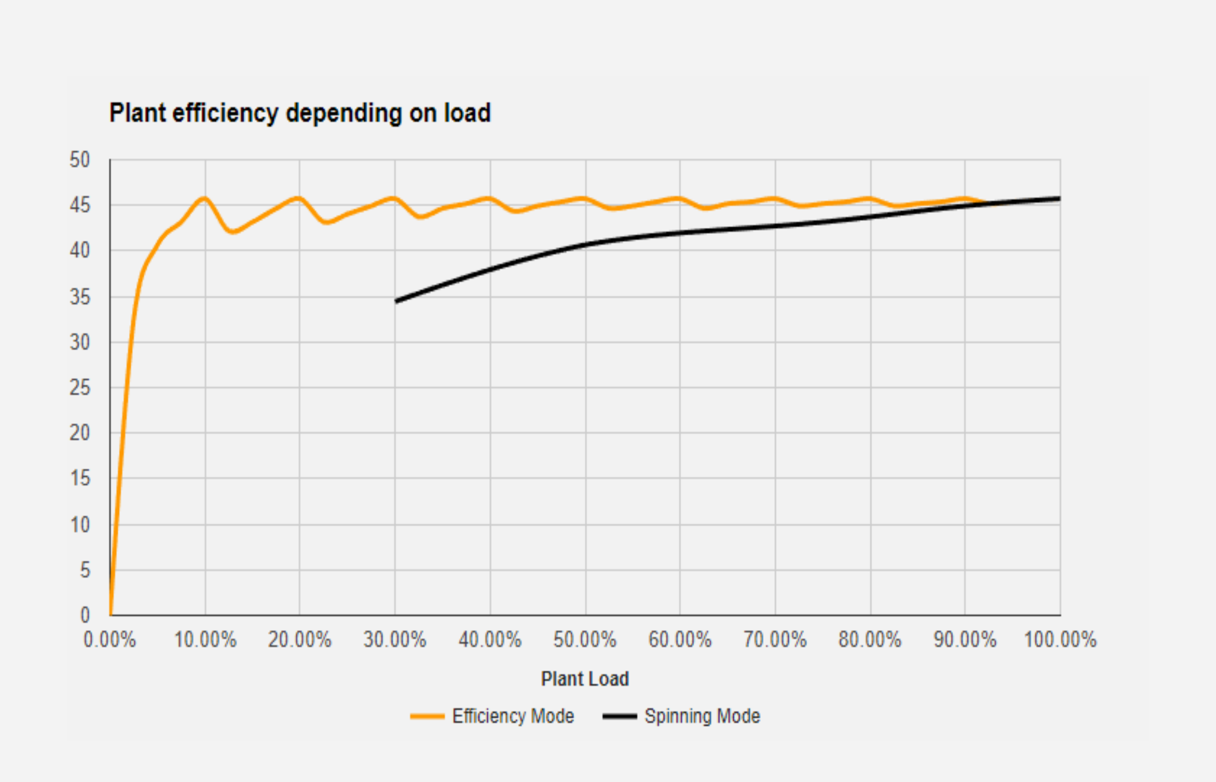

Fig. 2 - One of the outstanding features of the combustion engine technology is the flat load-efficiency curve. This diagram shows such curves for a ten-engine plant operated in two different ways. Orange curve represents the load control by shutting down individual engines while keeping the others at nearly-nominal load. The black curve represents a situation where all the engines are unloaded together, as is the case with plants which need to maintain a spinning reserve.

power and the apparent power. The highest value of the p.f. is 1.0 and it corresponds to a purely resistive load. This is also the value when a generator, and therefore a genset, reaches its highest efficiency. In many cases, power factor equal to 1.0 is used as a point to define nominal parameters published in the equipment data sheets. On the other hand, in some other catalogue data, performance is defined for a relatively low value of 0.8, which is a typical generator design parameter.

Unfortunately, in real life, the power factor never sticks to those idealised values. In most applications, it is somewhere between 0.90 and 0.95. This means that if the nominal efficiency for the generator set is defined at p.f. = 1.0, the actual value will always be lower. And, if the nominal value is defined at p.f. = 0.8, then in real situations, it will be higher than what is given on the catalogue sheets. It is obvious here that if the values for two different machines are defined for two different power factors, they will not be comparable.

Emission optimisation

As in case of any other fuel combusting technology, internal combustion engines generate a certain amount of pollutants. In the context of performance, the most important group of pollutants are the nitrogen oxides, or, NOx.

NOx generation is an inevitable by-product of the combustion process, and therefore cannot be completely eliminated. However, there are methods to reduce it. In fact, the most recent environmental regulations require us to adopt such measures. There are two ways of doing it: the primary and the secondary methods. The primary methods focus on preventing the generation of the pollutant while the secondary ones involve cleaning the exhaust gases.

Modern combustion engines may use both primary and secondary NOx abatement measures. Secondary methods do not affect the performance of a generator set. The primary ones do, as optimisation of the combustion process to lower emissions carries a certain efficiency penalty.

Normally, the catalogue data for a generator set is given for machinery optimised to achieve its maximum efficiency, and therefore relatively high NOx emission. Gas engines are typically designed to meet a NOx target of 500 mg/m^3N defined at reference oxygen content of 5%, also sometimes described as "TA-Luft" level, from a name of a 2002 German emission standard. Unfortunately, this standard is already outdated, and, in many jurisdictions, more stringent emission control is necessary.

Most gas engine designs can be optimised to meet stricter emission levels with primary methods, typically down to either "½ TA-Luft" or even lower, to 200 mg/m^3 at 5% O2 (75 mg/m^3N when expressed for 15% oxygen level). This corresponds to the current EU Industrial Emissions Directive. Such emission optimisation typically leads to a reduction of efficiency by some 1.0-1.5 percentage point. Of course, it is also possible to use an engine with higher efficiency, and SCR flue gas cleaning. Or a certain combination of both measures. The optimal solution is selected based on a project-specific techno-economic analysis, where the increased generation cost caused by the engine optimisation is weighed against the investment and operational costs of an SCR system.

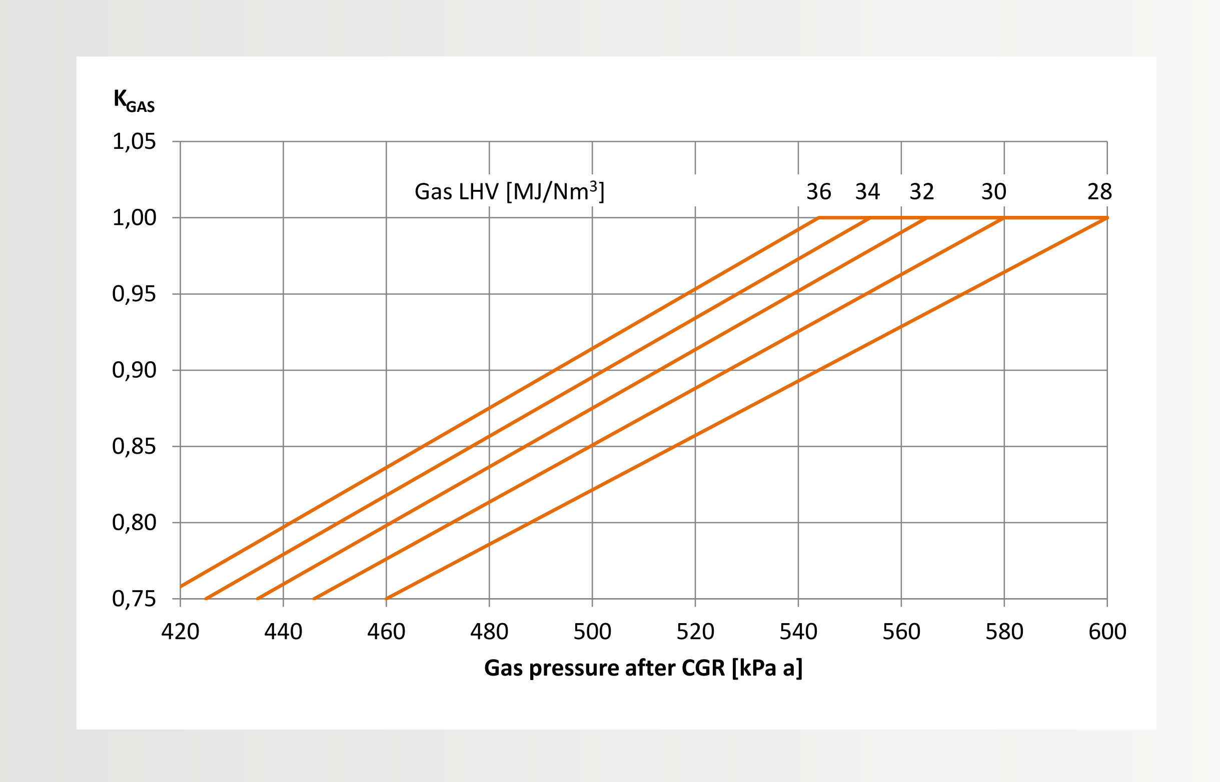

Fig. 3 - Derating of a gas engine is due to the fuel gas lower heating value. Note that, to some extent, LHV drop may be compensated with a higher gas supply pressure.

Wear and tear

Like any other machinery, combustion engines also suffer from wear and tear and the engine performance deteriorates during operation. Fortunately, this deterioration, in most cases, is fully reversible during overhauls when the engines are brought back to their nominal parameters. Here, it is important to point out that in most designs the deterioration only affects the efficiency while output stays at nominal levels. Nevertheless, remember that the average efficiency of an engine plant will somewhat be lower than the nominal values specified for actual site conditions. The magnitude of that deterioration depends on the engine design and its maintenance programme.

Fuel properties

Typically, combustion engines can tolerate a wide variety of fuel qualities and properties. Nonetheless, there are limitations. Some of these are absolute, in which case it is not possible or safe to operate an engine below or above a certain value. Others are conditional, which means that exceeding them is permitted but it may cause some derating or degradation in engine efficiency. Typical cases include the heating value or the methane number. Exceeding the minimums for those will lead to a certain reduction in output or efficiency.

Therefore, it is crucial to verify whether the considered fuel is within the standard specification. Otherwise, ask the vendor for performance figures that are valid for the particular fuel type.

Tolerance

This is the trickiest issue, which even many engineers may be unfamiliar with. Often in data sheets or catalogues, among conditions for which data is specified, you may encounter a statement like "ISO tolerance", "tolerance as per ISO 3046" or "tolerance 5%". It is directly related to a standard ISO 3046 'Reciprocating internal combustion engines – performance'. This standard stipulates that "unless otherwise stated, a higher [fuel] consumption of + 5% is permitted for the specific fuel consumption declared at the declared power."

This means that if any fuel consumption value is stated "with ISO 3046 tolerance," an engine may, in fact, have a fuel consumption up to 5% higher, and still technically meet the specified value. By extension, any efficiency declared with "ISO tolerance" may be 5% (note: not percentage points, but per

Fig. 4 - Some of the larger engine designs, such as this Wärtsilä 50SG or other Wärtsilä designs, are equipped with oil and water pumps are driven directly by the engine shaft. In some other designs, where the pumps are powered electrically it leads to an increase in the internal fuel consumption of the plant.

cent) lower. For example, a generating set with a declared efficiency of 48.0% "with ISO tolerance" may, in fact, reach only 48.0/1.05 = 45.7%. In fact, it is more than likely that it will only reach such value. Historically, this tolerance was indeed provided to account for differences between individual engines leaving the production line. However, with modern manufacturing methods, these differences are, for the most part, a thing of the past. Now the concept of tolerance is – sadly – used to provide exaggerated efficiency values in many publications. Unfortunately, this is also a pitfall for those not familiar with the peculiarities of the engine business. It also creates a threat of comparing apples to oranges, when one data sheet contains 5% tolerance, and another does not. Thus, whenever a tolerance value is not explicitly stated, it is a good practice to ask the vendor to provide an explicit statement on tolerances, as the difference of 5% (that is, some 2.0–2.5 percentage points, depending on the design) is far from insignificant.

Net output and engine-driven equipment

In the case of engine technology, the own electricity consumption is not very large. However, considerable differences may be caused by different designs. This is mostly because of pumps. Every engine needs some pumps to operate: typically, these are lubricating oil pumps, cooling water pumps and – if the fuel is liquid – fuel pumps. The difference is that in some engine designs, typically larger medium-speed engines, the pumps are driven mechanically by the engine shaft. This means that their energy consumption is "taken care of" even before the electricity is generated. But for some other engines, especially smaller high-speed designs that utilise electrical pumps, it will increase the own consumption of the plant.

Own consumption may also be affected by ambient conditions. This is because in most engine power plants, the waste heat is ejected through the radiators driven by electrical fans. Those fans, which are typically the largest consumers of electricity at such a plant, have their speed controlled to ensure proper cooling of the cooling water. The hotter the ambient air, the airflow needed is higher, which also increases the electricity consumption. As the actual consumption depends on site-specific conditions and plant configuration, it is normally not a parameter stated in catalogues. Therefore, it is recommended to ask for an estimated value from the vendors.

Conclusion

The bottom line is that "nominal" parameters, taken straight from a catalogue, almost never represent values that are achievable in actual site conditions even when all equipment is new.

While in certain cases (temperate climate, full load operation, no need for emission optimisation of the combustion process), it is relatively easy to convert catalogue parameters to values attainable in site conditions without extra knowledge. In other applications this will not be possible without asking vendors for further information.

This means higher catalogue efficiency of a certain engine type may not necessarily mean that the site efficiency of the design will be superior to its competitors even if the catalogue parameters are expressed for identical conditions.

Eventually, performance will have to be defined for specific operating conditions. It is therefore recommended to ask for more data points at the feasibility study stage of a power plant. This will make sure that the expected equipment performance is realistic for the considered site.

Disclaimer

All values given in this article, particularly on diagrams, are only meant as an illustration of certain phenomena. They do not represent any particular product or design.

AI makes experts more curious and proactive

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Unparalleled expertise on one of the widest portfolios in the marine industry makes Wärtsilä a partner to many customers. Thanks to advancements in the field of AI, we are now able to identify anomalies and potential failures in real time. Therefore, we can now provide the same expertise more proactively, shifting focus away from troubleshooting towards proactive support and optimisation.

In the asset management domain, systems designed to detect anomalies and potential failures are referred to as condition monitoring, or CM, systems. Some CM systems use specific techniques such as thermography and vibration analysis for rotating equipment. These techniques are effective, but their applicability is limited to specific failure modes. By far, however, most CM systems rely on rules based on engineering knowledge. Both rules and the engines that evaluate them have been improved incrementally over the years to, for example, consider more parameters and conditions, or to be run more frequently. For every issue that needs to be detected, an engineer needs to design a rule that can detect it.

As machinery becomes more complex, more issues may occur, and more rules are

[MARINE / IN DETAIL]

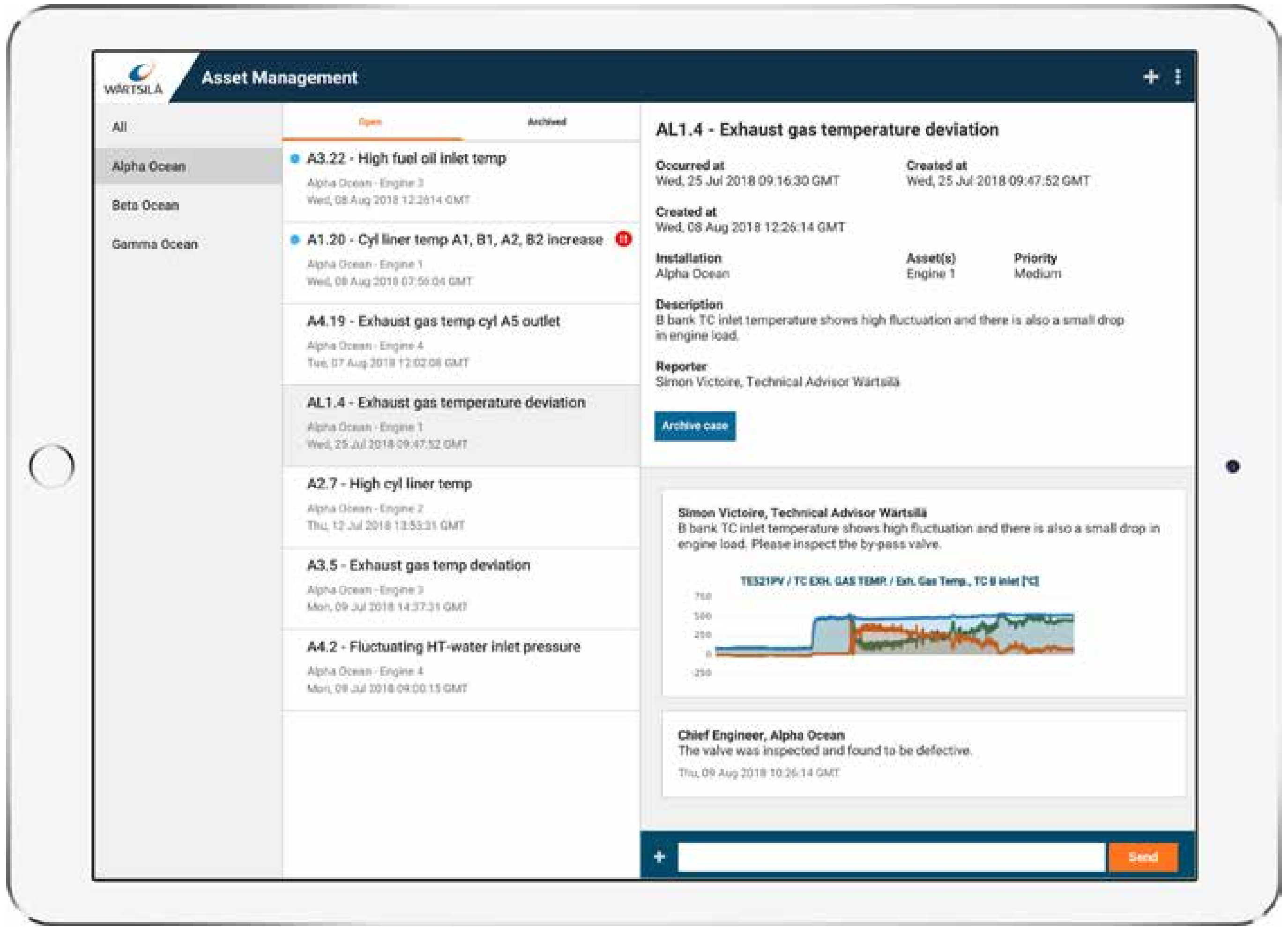


Fig. 1 - Anonymised example of an anomaly reported to a chief engineer.

Fig. 2 - Enlargement of the data snapshot included in the reported anomaly (see Fig. 1).

needed to monitor the system. The better a traditional CM system becomes at detecting issues, the more numerous and complex the rules become. Eventually the system becomes difficult to maintain and, in some cases, unreliable. Furthermore, engineered rules are specific to one kind of machinery. Monitoring another kind of machinery entails creating a completely new set of rules.

Often actual failures occurring in the field trigger the creation of new or better rules to detect those previously unknown or misunderstood failure modes. Hence, in practice it can take years for a CM system to reach maturity, meaning it is able to detect critical failures.

For engines, Wärtsilä has a good CBM (Condition Based Maintenance) service available. Its rules and formulas have been improved and refined for many years, and it is able to detect many critical failure modes in a timely fashion. Nonetheless, like other systems that rely on rules, it takes considerable effort to maintain, and expanding the current approach to other equipment types would be cumbersome.

Fortunately, thanks to advancements in the field of artificial intelligence and technologies such as Google's TensorFlow, we are now on the verge of a paradigm shift, where we move from:

- engineering rules to self-learning ML algorithms
- point solutions to holistic solutions
- experts crunching data to experts supporting customers
- periodic reports to real-time collaboration
- reactive troubleshooting to proactive support and optimisation.

Because the ML algorithms automatically analyse all incoming data in real time, the equipment experts can focus fully on supporting the customer rather than creating rules, crunching data and making reports. By combining raw processing power of an AI with the deep understanding of equipment experts we can create the CBM system of the future and support our customers much better.

Equipment knowledge remains critical

Compared to a human being, a well-trained AI is superior at detecting anomalous behaviour. Whereas it might take a human being several days to go through a month of machinery data, with varying results, an AI might process it in less than a minute with reliable results.

Unfortunately, AIs today do not yet have the capability to interpret the anomalies. They cannot determine whether an anomaly is a precursor of a severe failure or a less problematic defect, which has no effect on machinery performance, such as a broken sensor. This is where the equipment expert comes in. With knowledge and experience in engineering and troubleshooting an equipment expert can review the anomaly and provide a recommendation to the operator.

If the anomaly detected by the AI indicates a valid issue, the Wärtsilä expert

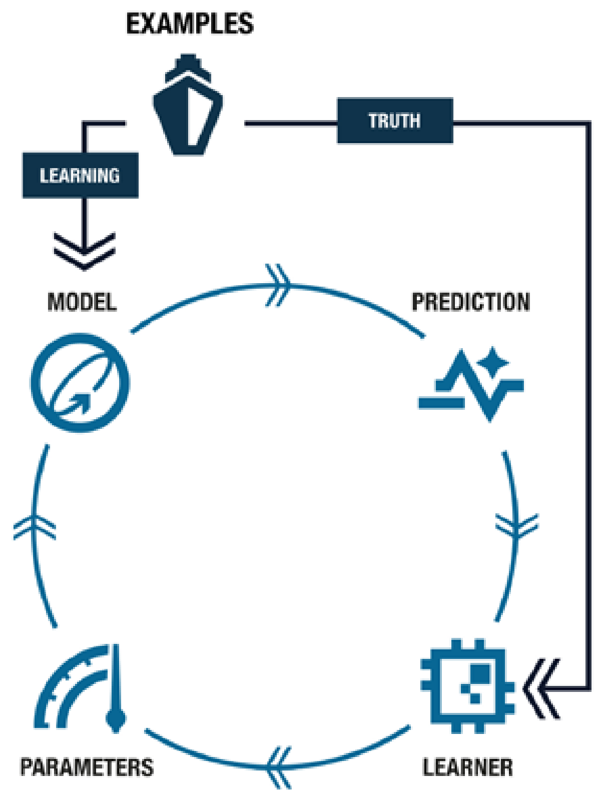
Engine room of the Royal Caribbean cruise vessel Allure of the Seas.

MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE EXPLAINED

The term 'artificial intelligence' or AI dates back to 1956 and is attributed to John McCarthy, a Stanford researched working in the field of computer science. AI is the ability of a machine or a computer program to learn. The concept of AI is based on the idea of building machines capable of learning like humans and then be able to think and act on the basis of those learnings.

The terms machine learning and AI are often used interchangeable but they are not the same. AI is a broad concept while machine learning is a common application of AI in today's industry. In machine learning (ML), algorithms are created that use computational methods to help the machine gather and therefore "learn" information directly from data without relying on pre-set logic, such as the rules created by an engineer. ML algorithms adaptively improve their performance as the number of samples available for learning increases.

The AI referenced in this article consists of several such ML algorithms. Typically, a ML system consists of three major parts: the model which makes the predictions, the parameters used by the model to weigh different inputs and the learner which adjusts the parameters based on the ability of the model to predict the right outcome. A simple overview is included on the right.



can notify the onboard crew the moment it occurs, thus preventing the situation from worsening.

Teaching the AI

It is also possible that the AI makes a mistake and finds an anomaly which is in fact normal equipment behaviour, or it can miss an event in its entirety. This is where one of the main strengths of machine learning comes in play: its ability to continue improving even when in active use. By pointing out the mistakes of the AI, the expert can teach the AI to correctly assess similar cases in the future.

When doing predictive maintenance on engines, the learning capability of the AI shines. A challenge with combustion engines is that every engine is unique due to its environment, load characteristics, the way piping is mounted and other factors. Whilst it might be too labour-intensive to create a single rule set for each engine, it takes virtually no effort to train an AI for each engine. This makes it possible to fine-tune the algorithms for each engine, making it possible to handle engine-specific differences without sacrificing accuracy.

Data-driven approach to go beyond point solutions

A rule-based approach relies on engineering knowledge of how components within machinery interact. Creating an AI, however, is fundamentally different. When an AI is fed with sensory data it learns the relationship between measured signals. Whenever one of the signals deviates from what the AI has learned as normal, this is considered anomalous and flagged as a potential issue.

Such a data-driven approach has the advantage that the same method can easily be applied on different types of equipment. From combustion engines to HVAC systems, if it is equipped with sensors, an AI can be trained to detect anomalies with minimal configuration.

Better decisions through collaboration

The traditional method of communication in CBM systems has been periodic reporting. This makes sense in a setup where the expert spends a lot of time on analysis and addresses each installation one by one, typically in a monthly cycle. When the ML algorithms crunch the data, however, the expert can focus on diagnosing anomalies and providing recommendations to the customer.

In such a setup, the monthly reports no longer make sense. One would be tempted to resort to e-mails and phone calls, but such would ignore the fact that there are dozens or even hundreds of machineries onboard a ship or on a power plant. A better alternative is to use a collaboration application that allows cases to be reviewed in context.

An overview of the analysis software and the collaboration application are included on pages 26–27 (Figures 1 and 2).

After the equipment expert has diagnosed a potential issue and included its recommendations it becomes visible in the collaboration application. The expert then collaborates with the operator to resolve the issue. It's a two-way street, and the operator can also request a second opinion from the expert on issues experienced at the site.

Wärtsilä has engaged in a small-scale pilot with Royal Caribbean Cruise Lines (RCCL). RCCL is a front-runner when it comes to the adoption of new digital technologies. Thus far the ML algorithms and the assigned experts have been able to detect all potential issues in a timely manner, allowing the crew onboard to take timely preventive and optimisation actions.

With the acquisition of Puregas Solutions, Wärtsilä has a foothold in the burgeoning biomethane market.

Wärtsilä welcomes new branches to its family tree

AUTHORS: Alexander Farnsworth, Isabelle Kliger, Anne Salomäki

Puregas Solutions' CApure technology.

Virtual gas pipeline.

With the acquisitions of Guidance Marine and Puregas Solutions, Wärtsilä is widening its umbrella of services to dynamic positioning sensor solutions and biogas upgrading technology. Take a look at how they boost Wärtsilä's existing offering.

The Wärtsilä family's two latest members, Puregas Solutions and Guidance Marine, hail from Sweden and the UK respectively. While Puregas Solutions specialises in manufacturing biogas upgrading technology, Guidance Marine's expertise lies in dynamic positioning sensors.

Puregas Solutions strengthens Wärtsilä's gas processing portfolio at a tipping point: the global biogas market is expected to expand at an annual rate of over 6% in terms of volume until 2023, based on an estimate by Transparency Market Research (TMR), a global market intelligence company.

Guidance Marine, in turn, complements Wärtsilä's portfolio with its sensor solutions for dynamic positioning and other vessel control systems, such as collision avoidance and remote-controlled operations. Its principal markets are oil and gas and offshore, where its sensor technology is crucial to oil production platforms, drilling rigs, floating production storage and offloading units, and the vessels that serve them.

Keeping an eye on the value chain

Puregas Solutions manufactures and supplies Biogas Upgrading Plants to the bioCNG market. BioCNG is compressed biomethane from the anaerobic digestion of organic waste, and it can be used similarly to regular LNG. The company's unique CApure upgrading process recovers 99.9% of the available methane from raw biogas.

Technology and solutions for the manufacturing of bioCNG were not part of Wärtsilä's premium offering before. With this acquisition, a whole new and quickly growing market opens up, as major energy players are becoming increasingly interested in biomethane.

Biomethane is essentially the same as LNG or natural gas, as each gas is made up of about 99% methane. However, natural gas is a non-renewable fossil fuel. Biomethane on the contrary is produced in so-called anaerobic reactors from a constant supply of farm manure, process waste, household organic waste, food waste and energy crops.

A win-win

Puregas Solutions' prefabricated modular plants are used in agricultural, food waste, waste water treatment and organic waste applications. In most instances, the bioCNG made with Puregas Solutions' CApure technology is used to power city buses. The biomethane can also be injected into the gas grid or in some cases liquefied to bioLNG.

Due to the growing need for more renewable natural gas production, and countries like the US, France and Italy adopting the technology, Puregas Solutions is a win-win for Wärtsilä. Step by step, biomethane is becoming a global trend with growth at around 15% per year.

One of the major selling points of Puregas Solutions' CApure technology is that it achieves the highest methane recovery with a so-called methane slip of less than 0.1%. The high recovery rate translates into maximised revenue with extremely low waste.

SceneScan is the first targetless laser position reference sensor.

The RadaScan system is a long-range, high precision radar sensor.

Guidance Marine: New technologies on the radar

Through the acquisition of Guidance Marine, Wärtsilä can now offer state-of-the-art dynamic positioning solutions for various vessel types, including cruise ships, yachts and ferries, which also require safe and precise positioning and manoeuvring capabilities.

Guidance Marine applies two complementary sensor-based position measurement technologies to deliver best-in-class positioning performance. Both the laser and radar sensor, known as CyScan and RadaScan, have crucial roles to play in an all-round, reliable Dynamic Positioning solution.

The company is also working on two so-called "targetless" technologies – one laser-based and the other radar-based – that will eliminate reliance on these failure-prone targets. While the laser-based version, known as SceneScan, has already been released, the radar-based system requires longer development time.

Meet CyScan and RadaScan

Guidance Marine's CyScan is a high-performance local position laser sensor suitable for use in close-range operations on both fixed and mobile offshore structures.

The CyScan sensor measures the range and bearing to retro-reflective targets, allowing for the calculation of vessel position and heading.

CyScan uses so-called passive targets, which do not require power to function. The laser sensor identifies targets with highly reflective surfaces, such as retro-reflective tape or retro-reflective prisms, which can easily and safely be mounted in almost any location. Moreover, these targets require no maintenance, apart from occasional cleaning.

The RadaScan system is a long-range, high-precision radar sensor, with an all-weather operating range of up to 1000 metres. Guidance Marine has also developed a special sensor used exclusively for shuttle tankers with a range of up to 10 kilometres. RadaScan accurately measures the range and bearing of intelligent microwave targets called responders, allowing for the calculation of vessel position and heading. The uniquely coded responders allow the vessel captain to differentiate one responder from another, providing accurate situational awareness.

Despite being powered either by electricity or a rechargeable battery, RadaScan's targets are Explosive Atmosphere (ATEX)-certified as intrinsically safe-for-use in hazardous offshore environments.

Two systems, different advantages

Radar-and laser-based sensor systems come with different benefits and limitations. The principal advantage of radar-based technology is weather-proof operation. Bad weather is common in offshore operations, and thus a sensor system that is not impacted by climatic conditions is crucial. RadaScan is also able to differentiate between targets and therefore deliver enhanced situational awareness.

Despite not being weatherproof, the standout feature that sets a laser sensor apart is its use of passive targets. Retro-reflective targets can be positioned anywhere, with no need for an electric cable or battery. This represents a huge advantage in terms of both safety and convenience for Guidance Marine's CyScan in risky offshore applications, and its range is also significantly longer than that of the radar system.

The single most important driver in the offshore industry is safety. CyScan and RadaScan are two independent systems, and one can never replace the other – both are needed to ensure total safety in a high-risk environment.

The future is targetless

Targetless sensors are set to take the dynamic positioning market by storm. By eliminating the reliance on failure-prone co-operative targets, vessel crews will no longer have to depend on people onboard the rigs.

Guidance Marine's SceneScan utilises a technique called Simultaneous Location And Mapping (SLAM) – a version of the Light Detection and Ranging (LIDAR) technology used by driverless cars to build a picture of their surroundings. As the name implies, SLAM involves building a local map of the vicinity, and then using this map to locate the position of the sensor within it. Based on the weaker reflections returned from the local environment, SLAM technology allows a vessel crew to reference the position of its vessel without the use of co-operative targets.

Meanwhile, the high-resolution imaging radar will use a 24 GHz K-Band microwave source, improving the resolution of the radar image. The innovation has huge potential for autonomous operations, like docking or fully autonomous vessel operation. Guidance Marine is the first company in the world to produce a marine imaging radar at K-Band for non-military applications.

The CyScan system is a local position reference sensor for marine Dynamic Positioning (DP) applications.

Emission legislation changes the game

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Stringent environmental legislation is having an impact on the shipping industry, forcing ship owners to look beyond today's standard solutions. An example of new innovations is Wärtsilä's modular installation system for sulphur oxide exhaust cleaning equipment.

The numbers are clear and unforgiving: The International Maritime Organization's (IMO) Tier III regulations require ships to cut NOx emissions by 80% from the Tier I level within Emission Control Areas (ECAs). On top of this, from 1 January 2020, the sulphur content of fuels used in shipping cannot exceed 0.5%.

Conventional heavy fuel oil (HFO) used by marine vessels contains 3.5% sulphur, meaning ship owners must either buy expensive low-sulphur fuel or install SOx exhaust gas cleaning systems to meet the cap.

Currently, the only way for ships with diesel engines to meet the 80% reduction in NOx in emissions is to install Selective Catalytic Reduction (SCR) units. These units will now be required in all ships with keel laying in the North American Emission Control Areas (ECA) in 2016 and in the North European ECA in 2021.

However, exhaust gas cleaning systems and SCRs increase the cost of both building and operating ships. Operating costs are increasing because of the increased electrical power demand for the pumps and the urea consumed by the SCRs.

Alternatives on the horizon

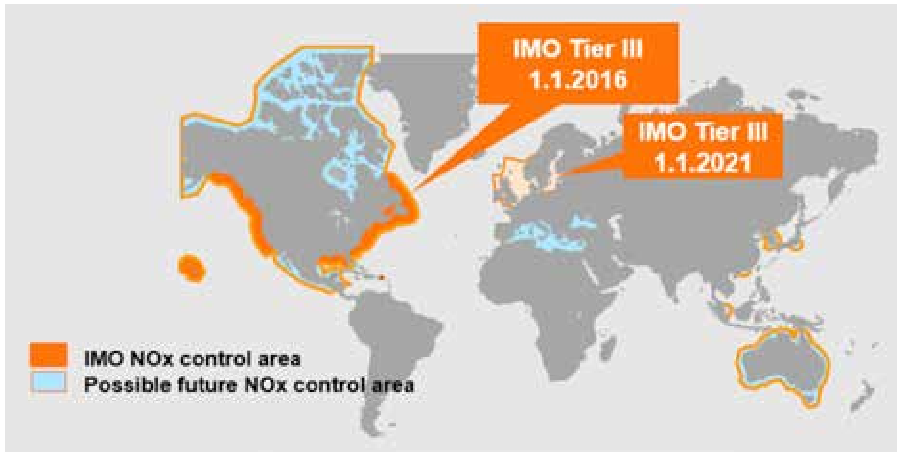
Understandably, ship owners are now keen on exploring new options. Interest in alternative fuels is growing due to the rising cost of diesel oil. Liquefied natural gas (LNG) is looking particularly promising with production increasing by 6% to 8% a year with no sulphur and low emissions.

Gas or dual-fuel engines running on gas have 25% lower CO_2 emissions, while NOx emissions are 85% lower than for a diesel engine. This enables compliance with the IMO Tier III levels without the need for an SCR.

The two bottlenecks for LNG use have been bunkering availability and price. There are barely more than 100 LNG-fuelled vessels, most operating in northern Europe.

However, numbers are predicted to increase to more than 200 by 2019, and ports worldwide are showing an increased interest, which will lead to better bunkering infrastructure.

Despite the benefits of LNG, it's not easy to guess which marine fuel will become dominant, as it can be difficult to predict fuel prices. SOx exhaust gas cleaning systems and LNG are likely to be more economical in new builds than running on low-sulphur fuel, even though the building costs will be higher. LNG-fuelled ships will be the most expensive to build, although costs continue to decrease as the technology becomes more mature.

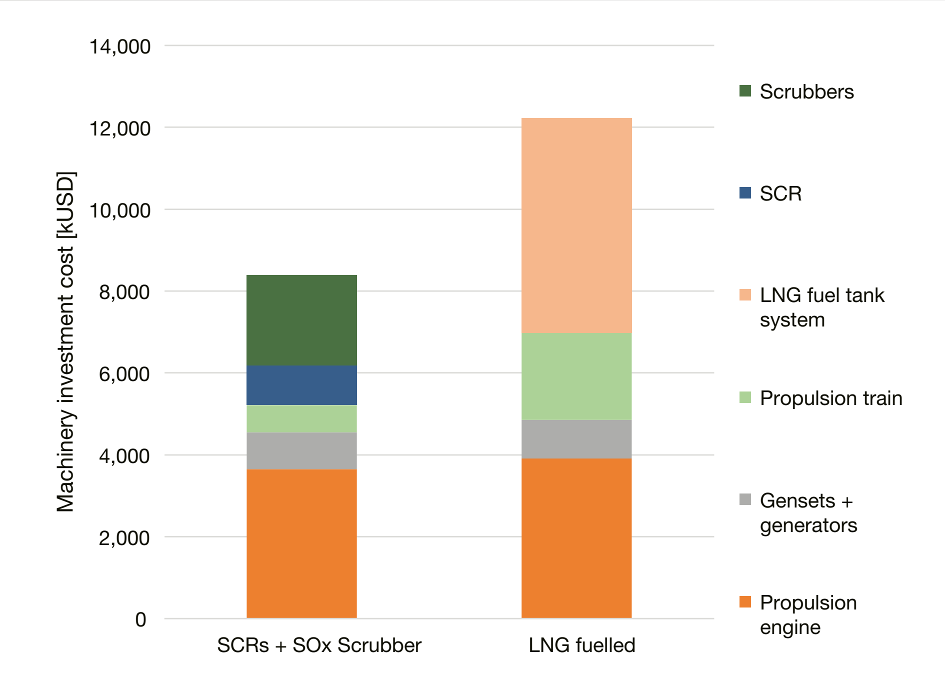


Emission Control Area expansions.

Shortening the queues to dry docks

In preparation for the regulatory changes, Wärtsilä's experts have rolled up their sleeves to help customers meet the new rules. One of these solutions is a modular installation system for sulphur oxide exhaust cleaning equipment, which can be standardised, factory-produced and rapidly installed without the need to enter dry dock.

Thus, the system will allow ship owners to avoid the expected shortage of dry docking slots in the run-up to 2020. There are an



Comparison on investment costs for two machinery alternatives: SOx scrubber with SCRs vs. a LNG fuelled vessel.

estimated 15,000 ships under the age of 10, making them suitable for being retrofitted with exhaust gas cleaning systems. Their owners are all now deciding whether to install a cleaning system and convert their engines to LNG, or pay a premium for low-sulphur fuel, making time in dry docks hard to find, particularly for large vessels.

Wärtsilä's modular system allows customers to retrofit cleaning systems without having to secure dry dock slots or even significantly interrupt their normal commercial operations.

Installation is no hassle

The first generation of marine exhaust gas cleaning systems was installed on ferries and cruise ships, mostly operating in the Baltic Sea and North America. For these ships, inline systems used to replace the ship's silencer were a good option, as most had sufficient space in the engine rooms for the required pumps and piping.

These ships also often opted for open loop systems, which spray seawater into the exhaust and use the water's natural alkalinity to strip out the sulphur dioxide. However, open loop systems are not appropriate for vessels that need to operate in waters such as rivers or estuaries, where there is insufficient alkalinity to strip out sulphur, or in areas where environmental regulations forbid the discharge of acidic water.

Such vessels require a closed loop or hybrid system, where the same water can be used in a cycle, with an alkali added to keep the PH sufficiently high. As a hybrid system has various components, including an alkali tank, several settling tanks, a residence tank, a process tank, a buffer tank, and additional pumps and piping, retrofits can be complicated.

In a traditional retrofit, this equipment is crammed into the engine room wherever there is sufficient space, leading to a mess of pipes and cables. Wärtsilä's system moves most of the equipment into two steel frames which can be mounted on deck, taking the area of three or four 20-foot containers.

Because Wärtsilä uses TEU-based dimensions and the same twist lock system standard for shipping containers, the prefabricated modules can be taken to where they will be installed on container vessels or a specialised truck, and often mounted using existing container cranes at ports.

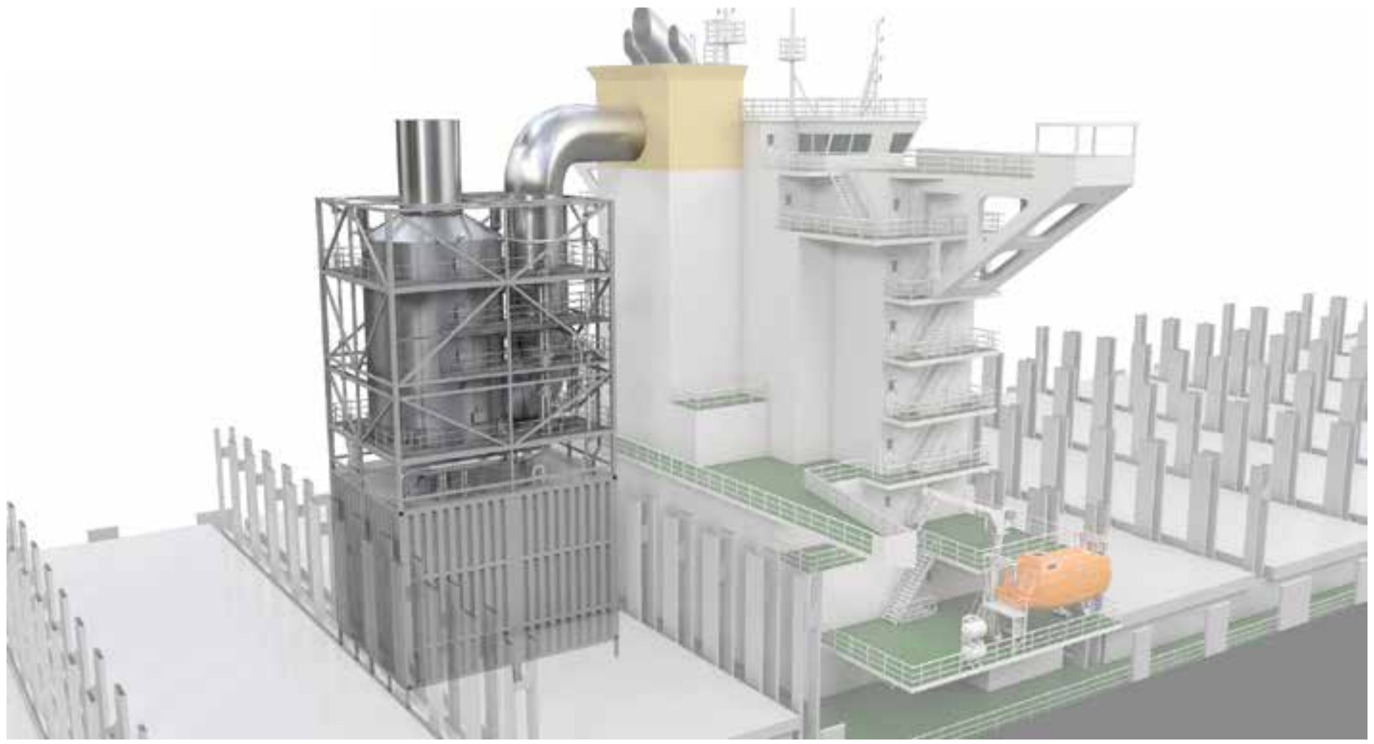
Low Sulphur Fuel, SOx scrubbers or LNG?

It is not easy to guess which marine fuel will dominate in the future, as it is difficult to predict fuel prices.

According to a recent report (IMO MEPC 70/INF.6), the price spread between 0.5% sulphur fuel and 3% sulphur fuel is 130 USD/ton, indicating that the payback time for SOx exhaust cleaning systems will be short compared to running on 0.5% sulphur fuel.

SOx exhaust cleaning or LNG are likely to be more economical in newbuildings than running on low sulphur fuel, even though the building costs will be higher. LNG fuelled ships will be the most expensive to build, although costs continue to decrease as the technology becomes more mature.

IMO is targeting to reduce the GHG emissions by at least 40% by 2030. Using LNG as fuel, together with advanced hull designs and propulsion machinery shows that it is already today possible to meet the IMO target for 2030. Clean ships is not a niche market anymore, but they are about to become main stream.



Hybrid 60MW Wärtsilä Modular SOx Scrubber Retrofit installation on-board 10,000 TEU container vessel.

NOW, FORGET DRY-DOCKING

Originally developed for a container ship that lacked space in its engine room for the pumps and pipes, Wärtsilä's innovative sulphur oxide exhaust cleaning equipment allows ship owners to ready vessels for the Marpol 2020 sulphur regulations without taking them to a dry dock. This saves time and money and helps avoid a growing shortage of dry dock slots.

This is great news, especially for large vessel owners, considering the run-up to 1 January 2020, is so close. This is the date on which the International Maritime Organization has ruled that the sulphur content of fuels used in shipping cannot exceed 0.5%.

There are an estimated 15,000 ships under the age of 10, and suitable for being retrofitted with exhaust gas cleaning systems. Their owners are now deciding whether to install a cleaning system and convert their engines to LNG, or pay a premium for low sulphur fuel, making time in dry docks hard to find.

Wärtsilä's modular system allows customers to retrofit cleaning systems without having to secure dry dock slots or even significantly interrupting their normal commercial operations. Fitting the equipment in an auxiliary module on deck has more wide-ranging advantages: the system can be standardised, factory-produced, and rapidly installed without entering dry dock.

Avoiding dry-docking also removes the need to empty the vessel of containers, an operation that takes several days and comes with a heavy cost. Moreover, the modular system also brings safety improvements. A conventional exhaust gas cleaning system is normally installed in the ship's funnel, meaning the engine room is directly connected and the risk of being flooded and damaged by seawater or acidic water in the event of a leakage. In the modular system, water leaks harmlessly onto the deck.

Evaluating the validity of full-scale CFD simulations

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Advancements in CFD simulations have made the results comparable to data received from model basins. In this article, we compare how the simulators made by Wärtsilä Propulsion match up to real measurement data, revealing the shortcomings of the ITTC'78 extrapolation method.

Introduction

An important part of the design process of propulsion equipment is determining the performance of the parts. In the past, this could only be done with physical model scale experiments. Now, the numerical flow simulations (Computational Fluid Dynamics, or CFD) have developed to such a level that the simulations can provide similar results.

The advancements in the simulations have been a result of a continuous increase in computing power and improvements in software programs. Validation of the results with available measurement data either from actual sea trials or model scale experiments have contributed towards robust procedures and increased understanding of the occurring flow phenomena.

In this article, we discuss how the CFD simulations, as made by Wärtsilä Propulsion, show a good match with the measurement data.

Since Wärtsilä is providing the actual propulsion equipment to the customers, the focus has been on accurate prediction of the full-scale units. As the majority of the available validation data is based on model scale experiments, comparisons have been made between CFD results at model scale and full-scale. Here, the focus is on the scaling effects of open and ducted propellers.

Historical background

Evaluation of performance of marine propellers has been the field of model test experiments for decades. In order to transfer the results from the tests at small scale to the actual full-scale, extrapolation methods have been developed. The development of these procedures is coordinated by the International Towing Tank Conference (ITTC), where all model test institutes are represented. For the speed-power prediction of a certain vessel, the ITTC'78 extrapolation method is widely used. This methodology is 40 years old, and now some of the weaknesses of the extrapolation method have started coming to the surface.

When the method was developed, data was taken from full-scale vessels with open propellers. For single-screw and twin-screw vessels, the applicability of this method is still good. On the other hand, more recent developments have led to other types of main propulsion devices, like ducted propellers and azimuth thrusters, either with open propeller or with ducted propeller. Moreover, the introduction of several energy saving devices has added another degree of complexity. As a result, the conventional extrapolation method is losing its prediction accuracy.

The ITTC'78 extrapolation method is critically viewed from two sides. First, the deviation in findings at actual trials triggers the viability of this approach. But then, the gained knowledge on the occurring flow phenomena from viscous CFD simulations has provided new insights. Where these new insights get accepted, the consequences for the conventional methods can be reviewed.

■ Fig. 1 - Wärtsilä propulsion product portfolio.

Wärtsilä propulsion product portfolio

The portfolio of Wärtsilä propulsion products can be split into various families.

The shaft-line driven propellers are mostly applied for main propulsion applications. The propellers can be or either Fixed Pitch (FP) type or Controllable Pitch (CP) type. The latter is used often in combination with a four-stroke diesel engine, in order to be able to keep the propeller operational curves within the engine envelope. For various vessel types, such as inland, fishing and dredging vessels, nozzles are applied to boost the performance. At ship speeds above 15 knots, the drag of the nozzle exceeds the additional performance, which limits the application to certain types of vessels and sizes.

A second family is based on bevel gearboxes, where the driveshaft is oriented in a vertical direction. Examples of these units are azimuth (steerable) thrusters and tunnel thrusters. Again, these thrusters can be equipped with fixed pitch or controllable pitch propellers. Which one of the two variants is selected is often related to the layout of the rest of the driveline (E-motor, VFD or diesel engine). For vessel speeds above 30 knots, waterjet propulsion concepts are used. In the waterjet, the power is transferred through a mixed-flow pump into the water. The high pressure is converted into a high-speed jet, which can propel vessels up to 70 knots.

In this article, the occurring flow phenomena for open and ducted propellers were reviewed. It was observed that the Reynolds scaling effects can be different. The thrusters and waterjets performance evaluations were not addressed in this article since this has been addressed in other publications. [1, 2]

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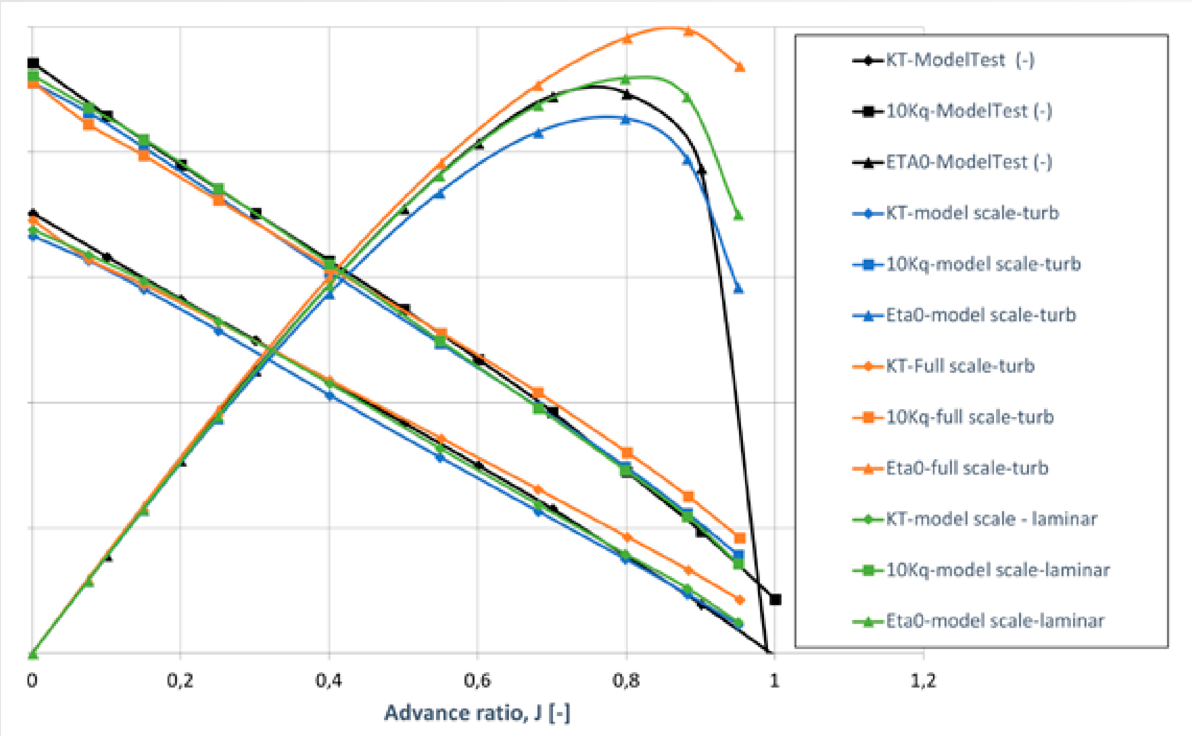

Fig. 2 - Open water performance curves of open propeller: comparison of CFD simulations and model scale measurements.

Open propellers

The first propulsion configuration that will be reviewed in this document is the open propeller. It can be either of fixed pitch or controllable pitch type. As part of the CFD implementation process for propeller performance simulations, Wärtsilä has spent a lot of effort in making comparisons with model scale experiments. By now, the CFD method has been scripted completely, which results in high precision of the simulations. With this automated method, a large number of propellers have been analysed and results have been compared with measurements from various well-known model basins.

A large group of fixed-pitch propellers, with moderate blade area ratios, showed excellent agreement of model scale experiments and CFD simulations, in case the laminar flow regime was activated in the simulations. More details of the CFD simulations and the results are presented in the SMP2017 conference [3].

This phenomenon is clearly visible in Figure 2, where the green line has the best match with the experiments. The fully turbulent case on model scale is shown in blue, which gives a lower efficiency, due to a higher friction factor. The full-scale result exceeds the laminar-transition result by a few percentage points. When this result is compared to the full turbulent model scale result, then the differences due to shear stress become more in line with expectations. From this diagram, it can be concluded that the scaling effect of open propellers is fairly small due to the combined action of transition from laminar to turbulent flow and the reduction of wall shear stress due to increased Reynolds number.

Open propeller in behind-ship condition

The Lloyds Register full-scale CFD test case is a well-known example (see Figure 3), which has been analysed by Wärtsilä as well. Detailed sea trials have been carried out on a single screw vessel with fixed pitch propeller. It could sail with three different propeller RPMs, and consequently it reached three different ship speeds. In the initial workshop, the ship speed reached and the shaft power required were not provided. The task for the participants was to calculate the expected self-propulsion point, thus providing the ship speed and required power.

The validation of the CFD results was then based on the imbalance of thrust and resistance on the one hand and on the required propeller shaft torque on the other. In order to get a good match of the shaft torque, one has to model the propeller properly, but would also have to make sure that the inflow velocity is calculated accurately. The agreement, as shown in Figure 4, is good for all three sailing conditions where the propeller speed of the fixed propeller has been varied, resulting in different ship speeds.

Ducted propellers

CFD simulations of ducted propellers revealed Reynolds scaling effects up to 10%. Since that value exceeds the usually experienced numbers with open propellers, it requires additional research. Figure 5 shows the open water performance of a ducted propeller from model scale measurements and CFD simulations. Accord between the model scale measurements and CFD simulations is important. From the knowledge we have of an open propeller, it is noted that for the ducted propeller simulations, a fully turbulent flow regime should be assumed.

The fact that an open propeller gives the best agreement with a laminar flow regime and a ducted propeller with a turbulent flow regime is already an indication of the Reynolds scaling having different effects.

This scaling problem has been reviewed from another perspective as well. In this approach, the ducted propeller, with small clearance between propeller tip and inner nozzle, is regarded as axial pump [4]. The transfer to the field of axial pump theory opens the door to literature of the last century, where Reynolds scale effects of 7–8% have been mentioned. This closes the gap of the observed scaling effects between the open and ducted propellers.

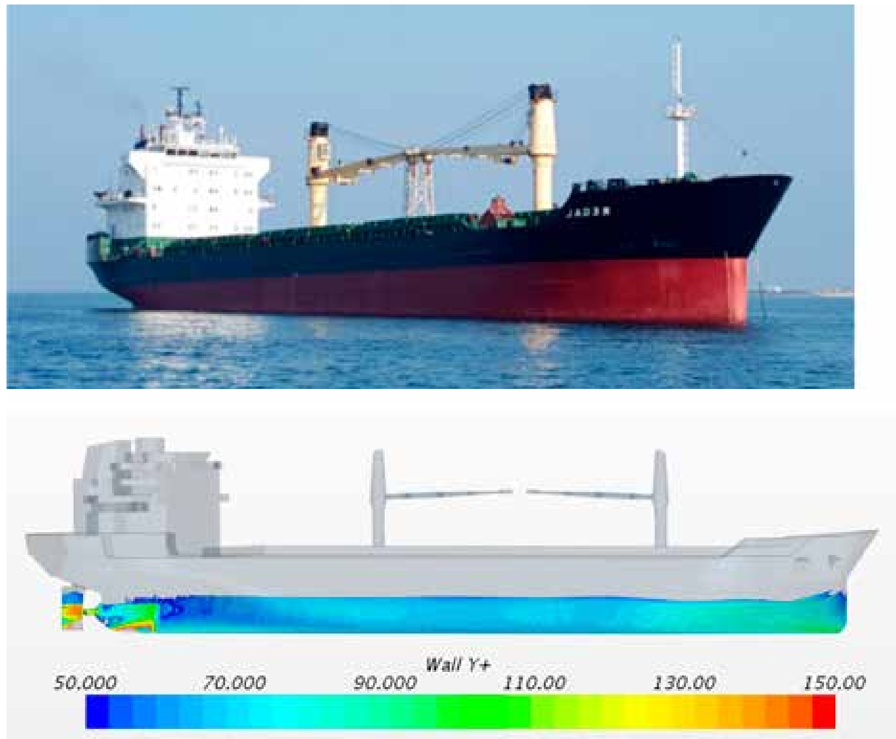

Fig. 3 - Lloyds Register full-scale CFD vessel and CFD model.

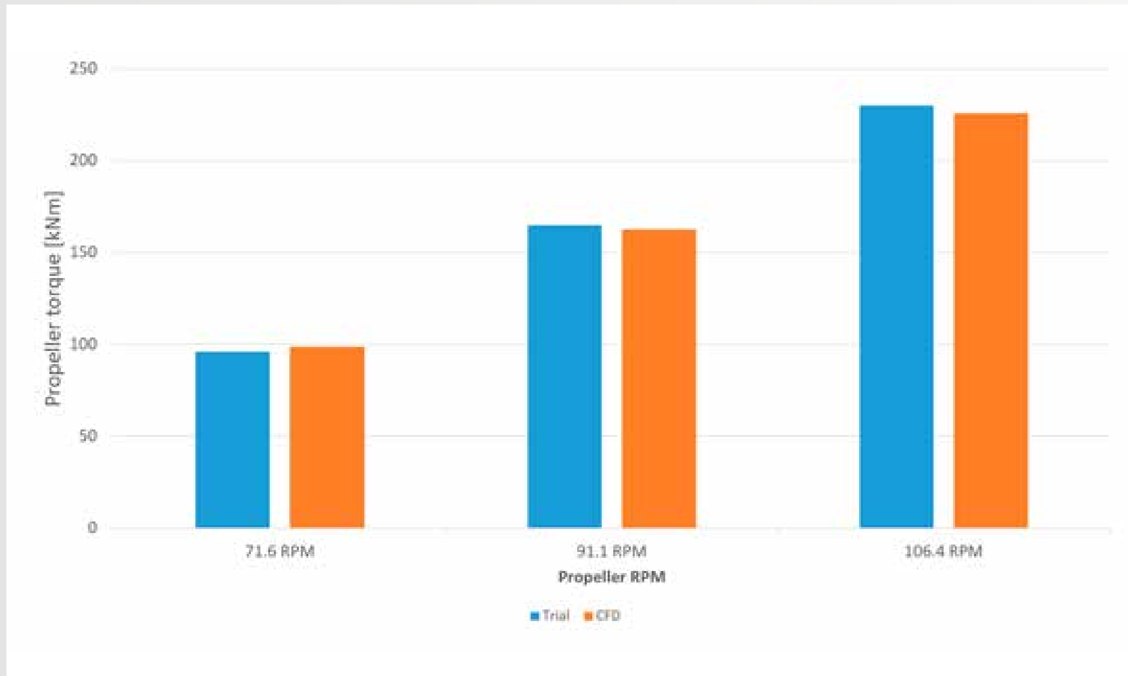

Fig. 4 - Comparison of measured and calculated propeller shaft torque for three different propeller RPMs.

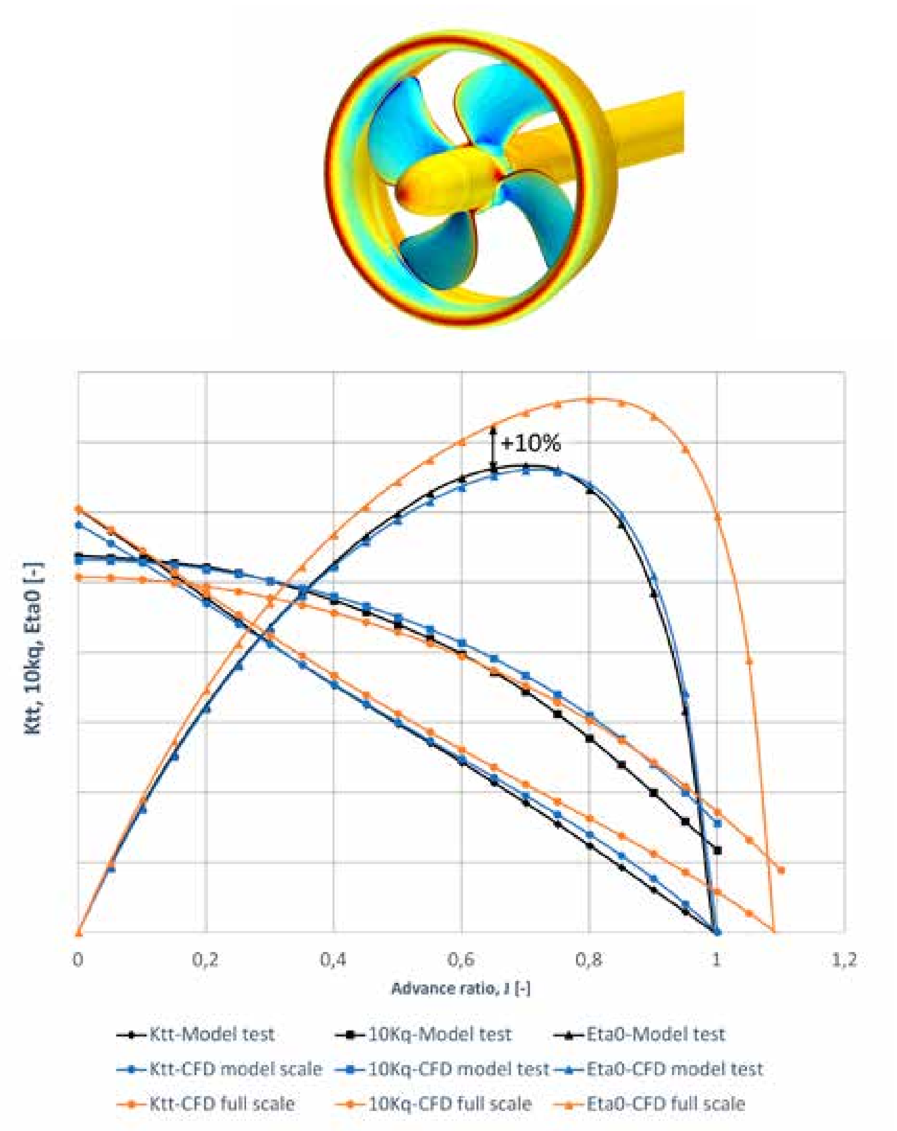

Fig. 5 - Open water performance curves of ducted propeller – comparison of CFD simulations and model scale measurements.

Ducted propeller in behind ship condition

Even though a fairly large Reynolds scaling effect of ducted propellers in open water condition has been found and explained, by definition, it does not mean that this scaling effect will be visible in same amount when the ducted propeller is placed behind the ship.

A confirmation can be found in Figure 6, where a full-scale trial data is compared with three different speed-power prediction methods as well as a dedicated CFD simulation of the complete vessel in calm water.

The blue line represents the performance prediction of the model basin based on the ITTC'78 method. In this method, the measured model scale open water performance is used. The solid green line is calculated in a similar way, but here the calculated open-water curve of the ducted propeller is used at as a model scale. The remaining interacting factors like wake-fraction and thrust-deduction were kept identical.

The difference between the green line and the dotted red line is the use of the full-scale open-water curve, which gives about 10% additional efficiency (see Figure 6).

With this approach a reasonable accord is found between the range of measured trial conditions. This indicates that the interacting factors are relatively insensitive to the Reynolds scaling effects.

The full-scale CFD simulations of the complete vessel have been made for 13 knots sailing speed (marked with the green dot). The calculated power requirement matches well with the sea trial data. Results from the CFD simulations are shown in Figure 7 and Figure 8.

Effects of dynamic sinkage and trim are taken into account in the simulations to have as accurate a resistance as possible. This sinkage and trim is derived from the simulations with free surface and calm water. Local details like the nozzle connection bar are taken into account as well, as shown in Figure 8.

From the current results, as presented in Figure 6, it can be concluded that a reasonable prediction can be made, as long as the full-scale open-water performance curve is used and the CFD simulation of the complete vessel measurements is spot on.

On the other hand, the shortcomings of the standard ITTC'78 method are clearly visible with the offset over the whole range of sailing conditions. Results of the calculated wave pattern and the streamlines along the aft-ship are shown in Figures 7 and 8.

Concluding remarks

For the actual vessel performance prediction, a 40-year-old method is still commonly used in combination with model scale experiments. With the introduction of numerical flow simulation methods, the door has been opened to direct full-scale simulations. Comparison of the numerical results at model scale and full-scale has revealed the shortcomings of the ITTC'78 extrapolation method, and moreover, the full-scale CFD results have shown better agreement with actual full-scale vessel trial data. Whether the decision to eliminate the extrapolation method and move on to full-scale CFD stimulation is right or not will be further justified in the future by making comparisons with the sailing fleet.

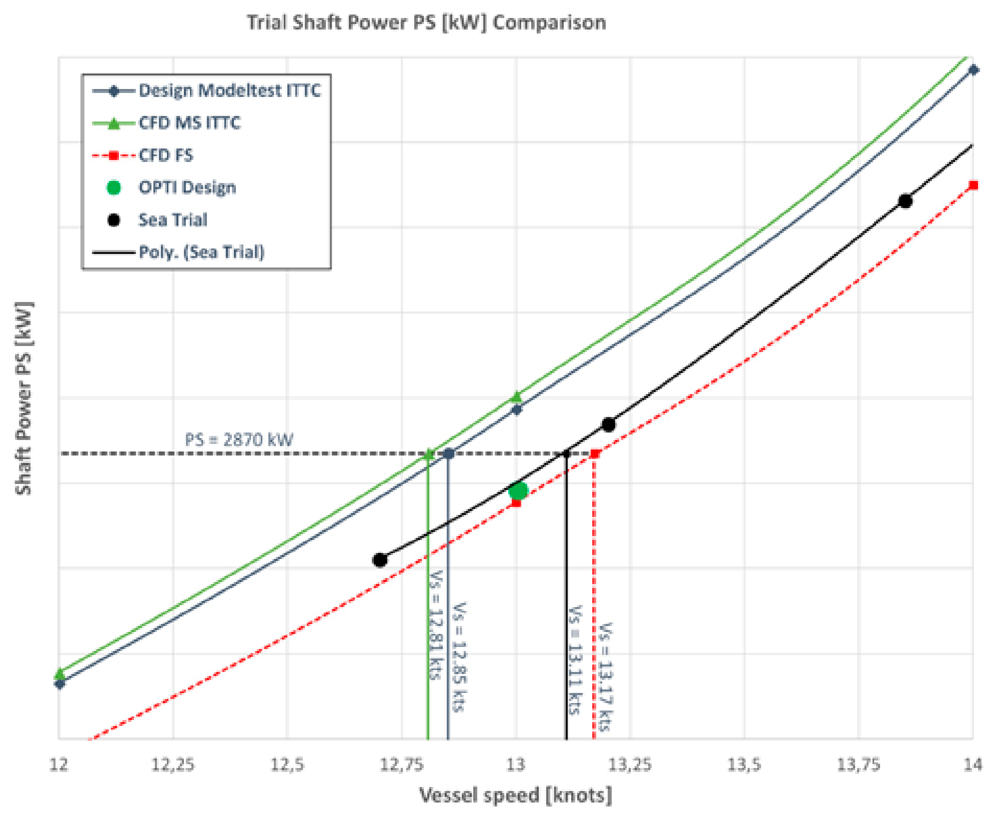

Fig. 6 - Speed power curves for tanker with ducted propeller.

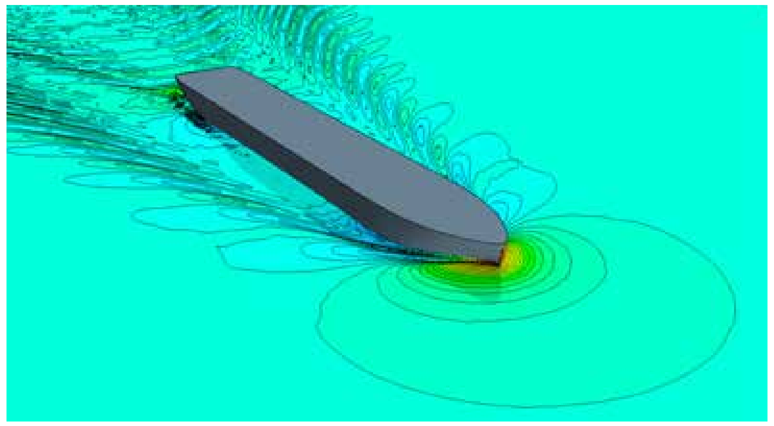

Fig. 7 - Wave pattern at 13 knots.

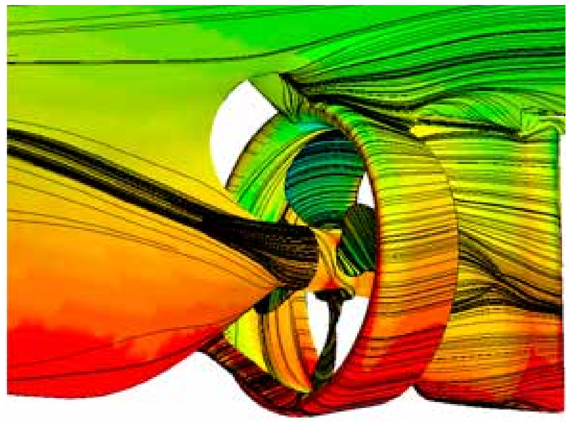

Fig. 8 - Limiting streamlines at aft-ship.

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Wärtsilä makes auto-docking safe and sustainable

AUTHOR: Alexander Farnsworth

The successful testing of Wärtsilä's auto-docking system, steered principally by software, show that autonomous driving technology can be used to minimise fuel consumption and boost the safety of docking.

Fluttering winds and eddying currents can throw off even the most experienced helmsman. It is no surprise then that some of the latest developments in dynamic positioning – keeping a crane ship still in the high seas, for example – and autonomous driving technology have evolved together to allow a ship to automatically dock in a harbour. The docking manoeuvre is probably one of the most precarious operations a ship can undertake.

In the small world of auto-docking, Wärtsilä Marine Solutions and its Dynamic Positioning Inc. (DP) subsidiary in San Diego, California, are leading the pack, and making waves, so to speak.

Their prototype auto-docking system was successfully tested on the Norwegian RoRo passenger ship Folgefonn, first out in the open water on a simulated dock in January 2018, and then again successfully in the Stord harbour in Norway in April 2018.

"We've translated our offshore DP expertise into a new and exciting potential market – ferries and maybe cruise ships. It fits very well into Wärtsilä's overall 'smart marine' strategy," says Thomas Pedersen, Managing Director of Wärtsilä DP.
"The plan is to submit the auto-docking functionality for regulatory approval to make automated docking a vital part of new offerings for the ferry and other markets."

Auto-docking simply means a ship is programmed with all the variables of its approach to a dock – wind speed, weight, pitch, roll, current, depth and so on – to perform the manoeuvre automatically in the most efficient and safest way possible, within oversight of a captain, of course, but steered principally by software. By making docking as efficient and sustainable as possible, fuel expenses are also minimised.

An innovative ship

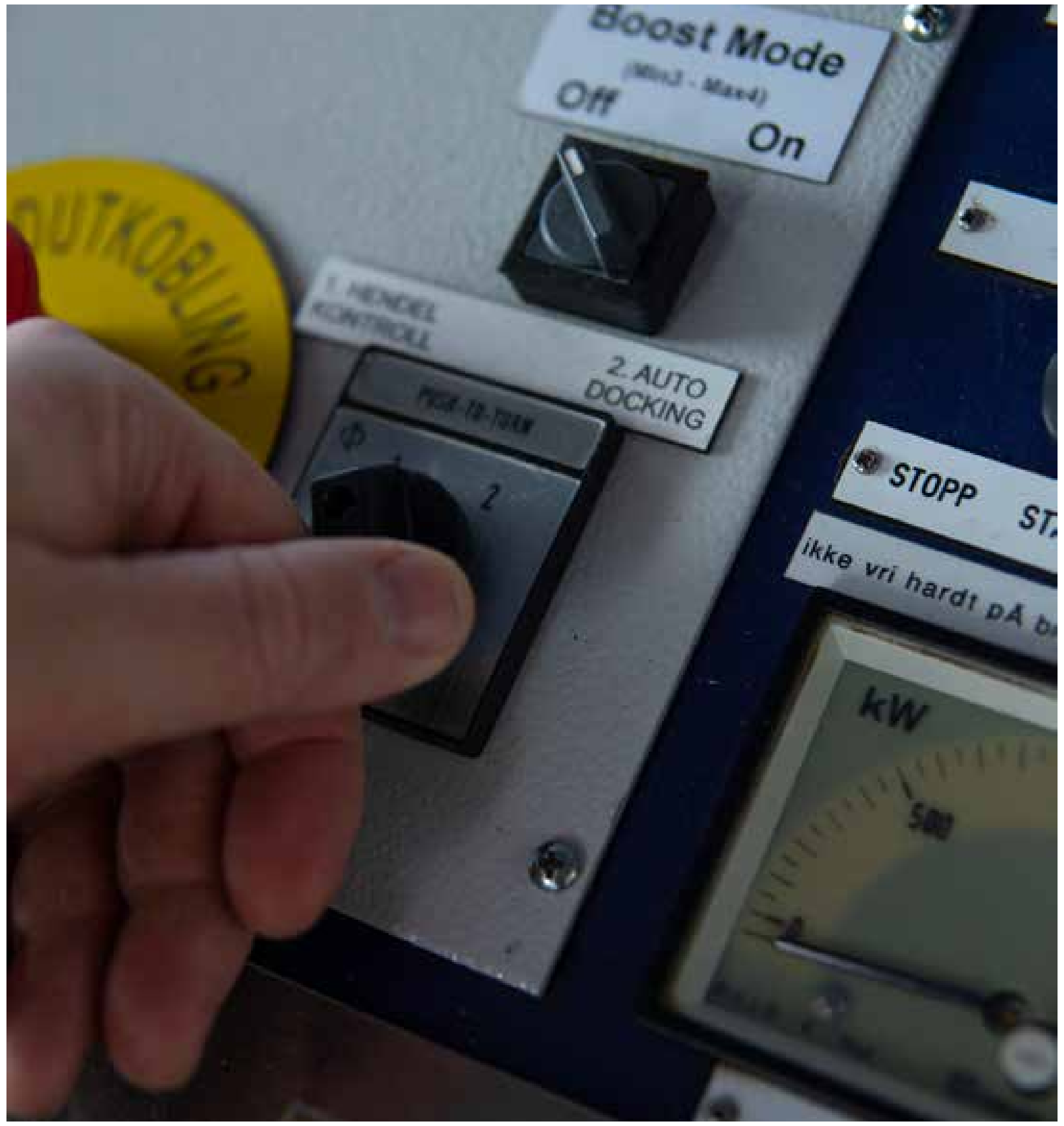
The Folgefonn is a novel ship even without auto-docking. A double-ended, 85-metre-long, 1182-tonne hybrid-powered passenger and car ferry servicing Jektevik-Hodnanes, Norway, the Folgefonn carries 76 cars and 300 passengers. It is owned by Norled, which operates 45 car ferries across Norway, and was built as a diesel-powered ferry in 1998. It was retrofitted into a hybrid diesel/electric vessel in 2014 with the help of Wärtsilä's wireless inductive charging technology, both on land and aboard, allowing it to charge its batteries without cumbersome cables. Folgefonn is also using vacuum docking technology (Cavotec) in which suction keeps the ship at the dock, eliminating ropes or lines.

Part of the auto-docking research performed by Wärtsilä is also being funded by the Norwegian maritime authorities.

"Wärtsilä Norway and Norled have both received grants from Innovation Norway, an investment fund, to test auto-docking and integrate it with the existing hybrid energy system," says Ingve Sørfonn, Senior Technical Officer E&A, Wärtsilä Marine Solutions. "For many years, the Power Conversion organisation in Stord, Norway, has worked with the Folgefonn ferry on numerous innovations including electrical operation, land-based charging, data transfer and induction charging. With auto-docking, the total docking and charging sequence will now be automated."

A natural evolution

Pedersen adds, "The Folgefonn was already equipped with our inductive charging technology, and the owners were very receptive to auto-docking. These efforts are part of the industry's overall desire to



One of the first steps in full autonomous shipping is auto-docking.

automate more of a vessel's movement."

Extensive testing of the system was key to making the ship's environmental sensors interface with software to precisely control the ship's propulsion systems. This work – sequencing and calibrating thrusters, for example, and developing a user interface – is what makes Wärtsilä Dynamic Positioning a leader in the field.

"We finished the Folgefonn tests and gained much valuable test data, plus more general experience, which was useful for updating our overall auto-docking methodology," says Pedersen.

In both tests, the Folgefonn ship was taken off its regular ferry service during planned repairs and made available to Wärtsilä DP engineers.

Smart Marine Ecosystem

Auto-docking and other automated functions are a part of Wärtsilä's much wider Smart Marine Ecosystem strategy, unveiled in November 2017, which will focus on "intelligent vessels and smart ports", among other initiatives.

"The world is moving towards a future that is more and more connected, and nowhere is this more apparent than in the shipping sector. The opportunities offered through smart technology will foster a new era of collaboration and knowledge sharing with customers, suppliers and partners," says Roger Holm, President, Wärtsilä Marine Solutions.

Andrea Morgante, Head of Digital, Wärtsilä Marine Solutions, adds, "At Wärtsilä, we are fully engaged in developing 'intelligent' vessels since we consider such technologies to be vital to maintaining a profitable future for our customers."

Says Pedersen in conclusion, "Auto-docking is just a new application built on the dynamic positioning capabilities we have had over many years. It is one of the first steps in fully autonomous shipping."

The Folgefonn carries 300 passengers and 76 cars.

Rosario Sommonte, Manager, Strategic Purchasing (left) and Gabriele Giraldi, Strategic Purchaser, Wärtsilä Italia, presenting the results of a 3D printer: a crankcase cover and an oil nozzle.

Wärtsilä aims to be at the top of the 3D printing world

AUTHORS: Sami Anteroinen, Anne Salomäki

Digital revolution in manufacturing technology is largely believed to lie in additive manufacturing. One example of this is 3D printing of items based on digital models, which enables, for instance, the tailoring of parts and rapid manufacture on demand. Wärtsilä wants to launch a world-class 3D metal printing Research Centre and create a strong ecosystem that combines industry excellence with academic muscle.

The city of Vaasa in Finland could well become a global stronghold for ambitious additive manufacturing – if Wärtsilä succeeds in its plans to create a world-class Research Centre for 3D metal printing excellence on the west coast of Finland.

Steering the project along, Wärtsilä's Innovation Expert Juho Raukola believes that the potential of 3D metal printing is enormous – and that 3D has the power to usher in a brand new era in manufacturing.

"3D metal printing is on the verge of making a big breakthrough in the 2020s," Raukola says.

As a matter of fact, even the upcoming Research Centre is only a part of a bigger puzzle: Wärtsilä has plans for additive manufacturing and 3D printing to go systemic across the organisation. In fact, it has already started testing the waters.

"We are now starting our journey with 3D metal printing of spare parts. The first 3D printed materials are in production and we will soon deliver them to the market," says Rosario Sommonte, Manager, Strategic Purchasing at Wärtsilä Trieste, who believes that this rapid development of 3D metal printing opens new opportunities for Wärtsilä.

Establishing a 3D printing Research Centre in Vaasa, however, is no small feat – and the project is still in its initial phases. Raukola envisions that the actual, physical construction of a brand-new Research Centre could kick off in 2019 or 2020. Once the Centre is up and running, all of Wärtsilä's operations will be able to tap into that knowledge base.

Talents wanted

The project is carried out as a collaboration between big companies, like Wärtsilä and ABB, local metal industry subcontractors and schools, such as Vaasa University of Applied Sciences and University of Vaasa. Raukola comments that it is important to combine versatile industry muscle with academic reach in this project.

"For example, the metal shops in the region have been lacking resources to push 3D printing, but within this ecosystem, they can have access to new tools and contribute."

Local schools are involved, too – and the reason is obvious. Raukola says that creating a talent pipeline is crucial for the overall success of the project: once the students of Vaasa University of Applied Sciences, for example, get familiar with modern 3D printing techniques, they will provide a homegrown labour force for the Centre.

"3D printing is so cutting edge that nobody is really teaching it in schools yet. We want to collaborate with the schools in order to recruit graduates with knowledge of 3D printing tools and the ability to make the components that the industry needs."

Jorma Tuominen, Director of School of Technology at Vaasa University of Applied Sciences, has kept an eye on the development of 3D printing since the late '90s – and admits to being surprised by the rapid pace of development in recent years.

Tuominen is excited about the project, as the school wants to be a strong contributor in the emerging alliance.

"Now it seems that the technology has suddenly evolved tremendously," he notes. "During the next five to ten years, there's really no telling what 3D printing can achieve – the possibilities are amazing."

The project also has some very powerful backup from Sweden, thanks to the innovation hub AMEXCI bringing together some of best expertise from top Nordic companies.

3D branching out to new dimensions

Wärtsilä and its partners aren't the only ones venturing into 3D printing. Research Team Leader Pasi Puukko from VTT Technical Research Centre of Finland says that the utilisation of industrial 3D printing started mainly in three industrial domains: aerospace, automotive and medicine.

"Each of these sectors has somewhat specific drivers and reasons to use this technology," he says. "For aerospace, it is lighter structures and fly-to-buy ratio; for automotive, fast prototyping and tooling; for medicine, patient specific instruments, guides and visual models."

Since the costs of additive manufacturing has come down, 3D utilisation is now about to branch out to new sectors: energy, gas & oil, consumer products, and more recently, also marine. Puukko notes that the marine sector does not benefit much from lighter components – and the same stands for the other above-mentioned drivers, as well.

"Thus, new types of drivers need to be found in order to make this technology reasonable in the marine sector. Those could be, for instance, better performing components – like components which have optimised liquid or gas flow – or part consolidation where you use one part instead of 10, or digitalised spare parts."

"Remarkable potential"

In April 2018, VTT succeeded in 3D printing a smart metal shaft using a new overall process management chain: 3D printing, sensor technology, wireless data transfer, and condition monitoring all came in the same package. The new manufacturing methods will, hopefully, enable the creation of new business models and provide a competitive edge in developing artificial intelligence.

VTT experts believe that the most intense competition in technological development within this sector concerns smart solutions. There is widespread investment in R&D, but few have succeeded in developing a working solution in which sensors form a functional part of a 3D printed metal structure.

Puukko is of the opinion that this recent Proof of Concept shows remarkable potential, for example in condition-based maintenance (CBM). One can make more accurate measurements in situ and gather more reliable data, since sensors can be located more easily on the right spots.

"It fits very well in applications where conditions are harsh, since sensing elements and wiring are embedded inside the component."

Farming with a Ferrari?

VTT wants to continue this development with companies that see potential in the additive manufacturing technology for their own business. One such company is certainly Wärtsilä, as it started experimenting with 3D printing around 10 years ago. There was already definite interest towards metal-based 3D printing at the time, and, in 2013–2014, there was a major R&D project exploring the opportunities.

However, as exciting as the technology is and as rapidly as its possible applications are expanding, 3D metal printing is more expensive than traditional manufacturing. Hence, it makes no sense to try to make use of the method everywhere.

"It's like a farmer who's using a new Ferrari to plough his field," Wärtsilä's Raukola explains. "Sure, you can do it, but it's hardly smart."

WÄRTSILÄ CONNECTS THE DOTS TO THE FUTURE

The market is being re-shaped by new ways of collaboration and smart technology. Our strong development in product offering combined with know-how and vast installed base gives us a unique platform to lead the industry's transformation towards a Smart Marine Ecosystem through the use of high levels of connectivity and digitalisation. We have the vision, a strong legacy and the expertise of our people. We continue to develop products and services together with customers, for the benefit of our customers. By doing so we will be shaping the industry together.

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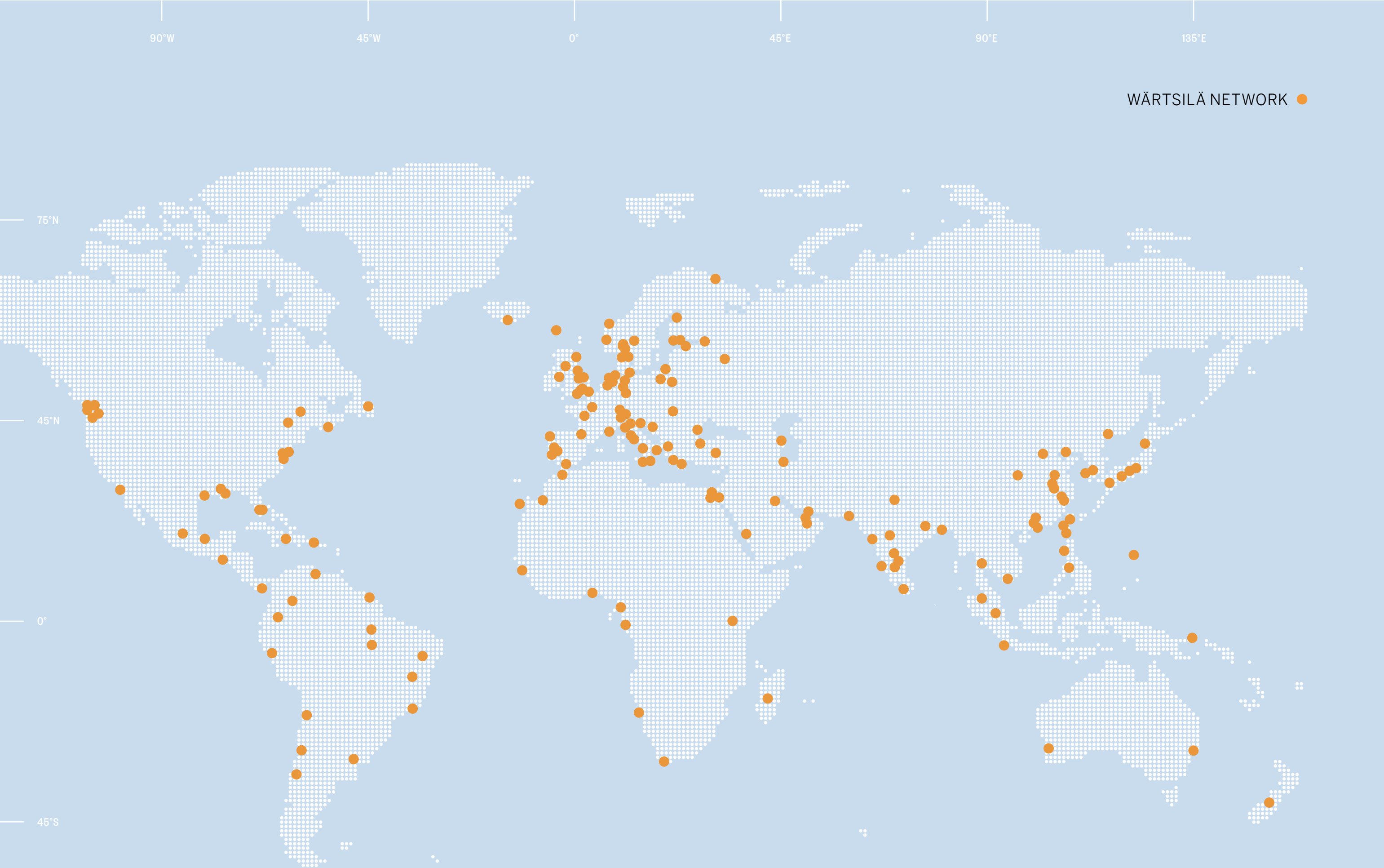

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