Hybrid and electric tug viability: the future's bright

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Q&A Summary

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How long does it take to fire up the second engine? Do you sail with only one engine when working in the proximity of the 'target' vessel?

GT | Starting sequence for the engines featuring the Wartsila patented "electric start" is similar to the traditional starting sequence and is performed in the range of few seconds

ES | Damen RSD-E Tug 2513 is equipped with two electrically started Caterpillar C32 back-up generator sets. Because the vessel has a DC electric system synchronising is not neccessary and the generator sets can be started and on line very quickly.

Does the hybrid set up use FPP (fixed pitch propeller) or CPP (controllable pitch) and reason why one is chosen over the other?

JS | For the smaller (64-ft), conventional Damen 1907, we are using FPP in kort nozzles.

GT | The Wartsila HY can feature both FPP and CPP propulsion systems. The importance in the propulsion selection is to understand the related implication in FPP or CPP installations in the available vessels' operating modes, such as the possibility to charge/discharge the batteries or on the "Boost Mode" while both batteries and engines are operating simultaneously.

ES | Damen uses FPP in diesel, hybrid and fully electric rudder propeller tugs instead of the more complex and vunerable CPP system. In all mentioned propulsion configurations the FPP speed can be controlled from zero up to maximum. Hydrodynamic losses of CPP at reduced pitch compared to FPP at reduced speed are bigger than the efficiency gain you can achieve by producing the same power with your propulsion system at a higher rotational speed.

How is the mechanical & hybrid mode working?

JS | Both the conventional mechanical system and the hybrid system are working as intended. We have had very few (if any) problems thus far.

GT | The Wartsila HY features several different operating modes. Mechanical mode is intended the time when the hybrid tug performs its operations by utilising the main engine(s) similarly to is what done in a traditional tug. Hybrid Mode is instead a mode when both the main engine(s) and the electrical equipment is utilized simultaneously, including batteries. One of the usual features in this mode is the peak shaving, where the engine is working in a very stable conidstions and each and every peak in power/torque is absorbed by the batteries.

ES | The fully electric zero emission Damen RSD-E Tug 2513 is equipped with two 1.5 mWh battery packs, two 1-mW generator/FiFi sets and two 1.8 mW electrically driven rudder propellers. Batteries are charged with shore power and deliver all required energy during normal (un)berthing operations in the harbour with a maximum bollard pull of 70 tons. Generator/FiFi sets are only started to perform FiFi (fire-fighting) operations or operations where an extremely big autonomy is required with a maximum continuous bollard pull of 40 ton.

What's the price of this hybrid? How much higher as compare to conventional?

JS | The addition of a Logan FlexaDrive "Full Hybrid" package nearly doubles the installed cost of the 2000 HP conventional propulsion system of the Damen 1907.

ES | The sales price of the fully electric zero emission Damen RSD-E Tug 2513 is approximately twice the sales price of a normal diesel Damen RSD Tug 2513. This additional CAPEX has to be earned back by the reduction in OPEX as a result of the use of electricity instead of diesel fuel and the reduction in maintenance. The local electricity price and the local fuel price are very important for the business case. This means that authorities have to provide cheap green electricity in the harbour to realise their zero emission goals.

How many years do batteries last

JS | There are no batteries required for use of the Logan FlexaDrive hybrid system.

GT | This is very much dependant on operating principles, as usually batteries manufacturer ensures amount of cycles and not years of operations. As an indicative figure, we usually speak of about 10 years lifetime.

ES | Expected lifetime of the LTO batteries in this application is approximately 30.000 cycles. The vessel can perform 2-3 average (un)berthing jobs in the harbour on a full battery. In a normal port the vessel will be charged one time a day and in an extremely busy port the vessel might be charged three times each day. This means 1,000 cyles a year is the worst case scenario. As a result the life time of the batteries is at least 30 years and approximately equal to the lifetime of the vessel.

What is the battery technology in use, service life and cooling system for batteries (air/water)? Which is the preferred cooling system?

GT | There are several available batteries technologies currently on the market, featuring both air and water cooled systems. Both cooling systems have benefits and drawbacks. In the latest time it seems the water cooled principle is getting the market preference both for the possibility of controlling to a higher degree of precision each cell's temperature and for improving the batteries space requirements.

ES | Damen uses an Echandia air cooled battery system consisting of Toshiba SCIB battery modules based on LTO battery technology. The battery systems are situated in an isolated, temperature controlled battery room. Watercooling is not needed for the battery system, because (dis)charge powers are low compared to the installed energy storage capacity.

What is the cost differential in OPEX and CAPEX for hybrid tugs vs diesel tugs? What are the savings in fuel versus a diesel tug?

JS | Although we have not had the Damen 1907 Hybrid tugs in service for a full year yet, thus far we are seeing a 30% to 50% fuel savings. The OpEx will depend largely on the utilisation year to year. We have also taken into account the extended life cycle costs of maintenance and overhaul on the main diesel engines.

GT | This is a fairly general question and, as such, difficult to answer. What can be said is that the CapEx vs. OpEx basics see the payback time of a hybrid tug installation in the range of three years, despite being very specific to the application's operating principles.

ES | The sales price of the fully electric zero emission Damen RSD-E Tug 2513 is around twice the sales price of a normal diesel Damen RSD Tug 2513. This additional CAPEX has to be earned back by the reduction in OPEX as a result of the use of electricity instead of diesel fuel and the reduction in maintenance. The local electricity price and the local fuel price are very important for the business case. This means that local authorities have to provide cheap green electricity in the harbour to realize their zero emission goals.

Joe, how do you achieve the emission reduction because you are running diesel engines in all operating modes? Also in hybrid mode your small high speed engines are running.

JS | We significantly reduce emissions (but do not eliminate them entirely). The reduction is the result of hybrid operation, whereby the 800 kW main diesel engines are shut down, and the vessel is utilising minimal power for electric propulsion from only one 99-kW diesel genset. This is significantly more efficient. The specific fuel consumption of diesel engines is higher when they are operated at low load. Running main engines when not required burns unnecessary fuel and adds running hours. By configuring the plant to operate only the diesels required for a a given operational scenario, the vessel burns less fuel and creates fewer emissions.

Joe: It is interesting that the batteries are cut out. Has this been investigated for larger power applications and what are they challenges in achieving this?

JS | The populsion and power generation configuration of a hybrid system should be dependent on the vessel's operational profile. While batteries can be beneficial in some situations, they also are a significant contributor to the CAPEX and OPEX of a vessel. We analysed the duty cycle of our tugs and determined that for our operations, the addition of batteries would not significantly reduce fuel consumption and emissions, and further, would not provide a desirable ROI. From a technical perspective, the use of large energy (battery) storage systems on ships is feasible and in fact has been done previously by our integration team. When deploying energy storage systems on vessels the key challenges to overcome, in addition to the cost, are typically related to the safe operation of the batteries in a marine environment, as well as size and weight of the systems. It should also be noted that storing energy that is produced on the vessel by diesel generators does not mean zero-emission, nor does using power from shore sources.

On the ship's bridge, is it clear in that mode the ship is? (Diesel / Electric / Hybid / ...in every instance, so the captain knows what he / she can expect from the ship.

JS | Our system has a number of Human Machine Interface (HMI) panels that provide the vessel's operators, both on the bridge and elsewhere, an overview of the system's configuration at any given time. It also shows energy flows and alarms. These have purposely been designed so that key information can be read at a glance, without the requirement to search through menus or sub-screens.

ES | For the captain operating a fully electric zero emission Damen RSD-E Tug 2513 is the same as operating a normal diesel RSD Tug 2513. Main engines are replaced by electric engines and during all normal (un)berthing operations in the harbour their are no mode changes. Fuel bunkering is replaced by charging the batteries. For fire-fighting operations the captain still has to select the fire-fighting mode. Only difference is that the captain has to start the back-up generators for special operations were an extremely big autonomy is required.

It is well known that electricity and water do not mix. What challenges are there in terms of safety and legislation for electric/hybrid technologies in a tug?

JS | Electrical switchboards and equipment are always present on modern vessels. While unique in configuration, the hybrid systems we deploy on our tugs are comprised of components that are certified for purpose and approved for use on marine vessels. Additionally, even when the vessel is not under Class or other regulatory rules, we always design and manufacture our systems to meet the most stringent industry regulations (Class/IEEE etc). Parallel hybrid systems are a mix of mechanical and diesel electric systems, both of which are well known and understood from a safety and legislative point of view. However, the incorporation of large battery systems has required new rules and regulations to be developed. Even so, there have been incidents.

ES | Damen uses L-drive rudder propellers with an electric motor on top instead of electric pods. This way all electric equipment is situated inside the ships hull and not in the water. The amount of redundancy in the electric propulsion system is at least the same as the amount of redundancy in a normal diesel propulsion system. A hazard study is performed and the electric system inside the RSD-E is compliant to all applicable rules and regulations of BV and LR. The electric system in the RSD-E Tug is different from electric components/systems for land-based and automotive applications on the following points; higher IP values used, thicker cables used, designed for longer life time, designed for more extreme conditions, more redundancy.

Approximate total weight of battery bank?

ES | Approx. 40 tons

How about the life cycle costs of a hybrid cost in relation to a conventional one? especially considering the lifecycle of batteries?

JS | As the hybrid plant we deployed in this instance does not have batteries, the components in our systems have a designed lifecycle that is equivalent to or exceeds the other systems and equipment on the vessel. As such, maintenance and component replacement do not contribute significantly to maintenance costs. Any additional hybrid related maintenance is certainly offset by the reduction in running hours, and associated maintenance, of the diesel engines.

ES | Damen Hybrid with LTO batteries charged from shore on average harbour tug operating profile; 40-50% higher CAPEX. OPEX reduced by exchanging 15% of the fuel consumption into electricity consumption and reducing maintenance costs by 50% reduction on running hours of the main engines. The local electricity price and the local fuel price are very important for the business case. In general, it is very difficult to make a business case based on an average harbour tug operating profile.

Guilio: The PTI/PTO is a very vital link in the HY-tug and would have the maximum running hours. What is the reliability of the this equipment, time between overhauls, how easy is it to maintain and how quickly can it be swapped out?

GT | The PTO/PTI is indeed the "link" between the mechanical part of the installation and the electrical part of it. Nevertheless it must be remembered that the Wartsila HY system is designed in a way that, should the PTO/PTI stop working, the tug can be operated in the traditional way, ensuring the same safety, reliability and economical performance of a tradition tug. The PTO/PTI is an electrical rotating machine with an extremely high level of reliability and low maintenance requirements.

What is the price for a full electric Damen tug in comparison to a conventional tug?

ES | The sales price of the fully electric zero emission Damen RSD-E Tug 2513 is around twice the sales price of a normal diesel Damen RSD Tug 2513. This additional CAPEX has to be earned back by the reduction in OPEX as a result of the use of electricity instead of diesel fuel and the reduction in maintenance. The local electricity price and the local fuel price are very important for the business case. This means that local authorities have to provide cheap green electricity in the harbour to realise their zero emission goals.

How do you see the growth of batteries charging facilities for vessels in the ports around the globe?

ES | In general, more big shore connections are being placed around the world in ports where it is not allowed for vessels to use their own generator sets, but cold ironing is mandatory. For the RSD-E Tug 2513 Damen can provide a 1.5 MW shore charging facility that can be connected to a 690 V-60 Hz input from shore.

How can a full electric tug achieve high bollard pulls for 1% of operations when high BP is required? Can there be all-electric propulsion escort tugs?

GT | The tug design principle for which a fully electric tug can be designed is, in principle, the same as for a hybrid tug or a conventional tug. As such, the maximum bollard pull will be achieved and, independent from the maximum power, the propulsion system can create and the thrusters can absorb; nothing different from any other tug. At the same time, having batteries producing an output power similar to an engine is rather difficult with current batteries technology

ES | The Damen RSD-E Tug 2513 can deliver the maximum bollard pull of 70 tons for at least 30 minutes only on batteries, for at least one hour on batteries plus generator sets, and the vessel can deliver continuously a bollard pull of 40 tons on the generator sets alone. For normal (un)berthing operations the vessel can be used as zero emission tug on batteries alone. During escort tug operations and other operations where bigger autonomy is required the IMO Tier III compliant back-up generator sets run continuously to generate basic power supply up to 40 ton bollard pull and batteries only deliver additional power to boost up to 70 ton bollard pull.

Is Wartsila aiming to have a fully electric tugboat? same as Damen?

GT | Traditional propulsion, hybrid or fully electric is a decision consequence of the decision on which performances the vessel should achieve and, as such, are all viable. With today battery techonology, a fully electric tug will have the negative aspects of having a high CapEx, a reduced endurance, a reduced bollard pull and a high onborad space requirement for batteries. As such, the hybrid propulsion system is currently the one providing the most advanced performances not comprising the vessels economical and technical viability.

Damen: 0% fuel on ship. Onshore: 0-100% fuel, depending on the energy-supplier...

ES | There are fuel tanks and two IMO Tier III compliant back-up generators/FiFi sets installed on the Damen RSD-E Tug 2513. These generator/FiFi sets are installed to be able to perform FiFi operations and other operations where a bigger autonomy is required. The generators/FiFi sets can also be used to charge the batteries in the emergency situation that shore power is dead. As a result the towing operation is not depending on the availability of shore power. At this moment not all shore power is generated in an environmentally friendly manner, but we hope that this will change in the near future.

What are the projected maintenance cost for batteries?

GT | Batteries have basically zero maintenance requirements. The most relevant item to be considered is the batteries lifetime as, as such, once batteries lose their performances they usually must be simply replaced.

ES | Expected lifetime of the LTO batteries in this application is around 30,000 cycles. The vessel can perform 2-3 average (un)berthing jobs in the harbour on a full battery. In a normal port the vessel will be charged one time a day and in an extremely busy port the vessel might be charged three times each day. This means 1,000 cyles a year is the worst case scenario. As a result the life time of the batteries is at least 30 years and around equal to the lifetime of the vessel.

Damen: Maintenance cost for battery is not included in your presentation especially if you take it for more than 10 years.

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Great Lake: Is there any engine RPM limitation for variable speed generator? What is the power of this genset when engine runs at idle?

JS | The variable speed generators are able to contribute electrical power to the switchboard from engine idle through to full RPM. As can be understood, the output of the generator is dependent on rotational speed. This is compensated for by the gear ratio of the PTO, as well as the selection of generators that are designed to deliver rated output at lower speeds (more electrical poles). To ensure that we meet the vessel's operational requirements, we size the generator so that it delivers the necessary kWs throughout its speed range.

Erik: What is the percentage of power loss during charging and discharging batteries?

ES | Approx. 3% loss in batteries during (dis)charging.
