New concepts in ferry propulsion

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The demands for lower bunkering costs and reduced greenhouse emissions have become two of the main drivers in the field of ferry design. In competing with other modes of transport, the existing well-proven solutions might not be the most effective.

Wärtsilä is conducting continuous development to meet the need for lower power demand and fewer emissions. In striving for these goals, Wärtsilä has during recent years proposed a number of innovative propulsion solutions for ferries. The latest in this series of ferry propulsion development concepts is presented herewith.

By combining the positive experience and very high propulsion efficiency of the podded contra rotating propeller (CRP) concept, with the advances in thruster technology and ship design, a new propulsion machinery concept has been developed. The concept features a direct driven controllable pitch (CP) propeller, and a contra rotating propeller behind it mounted on a pulling mechanical thruster. The machinery has been configured to keep the initial cost low by avoiding expensive electric pods and drives, and by going to a simple mechanical drive of the forward propeller using a large bore main engine. A novel machinery and cargo ramp arrangement has been developed to facilitate also very large main engines, which are too high to fit under the main deck.

Both fuel consumption, and therefore also exhaust emissions, can be reduced by more than 10% with this new concept. Overall, the new concept offers a very attractive economic solution that represents state-of-the-art propulsion technology, while relying on well proven and reliable components.

STRIVING FOR LOWER FUEL CONSUMPTION

During the last couple of years, the shipping industry has witnessed a significant increase in fuel prices. The price has fluctuated both up and down, but is in general at a much higher level than in the past. Expectations are that prices will remain high and may continue to increase. This has led to a situation where the fuel cost has become even more significant to the total operating costs of a ferry.

At the same time, the public is focusing more and more on climate change, and the pressure on the industry to reduce greenhouse emissions is becoming ever more evident. The EU has set a target to reduce CO₂ emissions by 20%. The shipping industry must be ready to meet this challenge.

Both of these factors emphasize the increasing importance of fuel efficiency. Low consumption has, of course, always been a target to strive for, but these latest developments mean that ship owners not only should, but indeed have a real incentive in seeking low consumption solutions.

Looking beyond the conventional

The conventional large displacement ferry machinery used today is usually based on twin shaft lines, with twin
CP propellers driven by two or four medium-speed diesel engines. This arrangement has proven itself as both functional and reliable. However, the shortcoming to this propulsion set-up is that the long shaft lines below the hull, together with the other appendages, give rise to high resistance. Therefore, if an alternative solution that eliminates the need for shaft lines can be found, lower power demand could be achieved.

The appendage resistance of a ferry can be as high as 10-15% of the total resistance. Furthermore, the risk of pressure side cavitation at low speed operation is always apparent with CP propellers, which are needed in this type of mechanical propulsion. The engines are also run at low load while manoeuvring and during slow speed operation. This is not desirable from the point of view of engine performance.

Ferries need good manoeuvring characteristics since they have frequent port calls and while in port, need short turnaround capabilities. Twin shaft lines with twin rudders offer quite good manoeuvring performance, but some ferries still need more side thrust than can be generated with the rudders alone, so additional tunnel thrusters are installed in the stern. Single screw arrangements are quite rare in modern ferry tonnage.

Medium-speed 4-stroke diesel engines dominate the ferry market. Only very few ferries have 2-stroke diesel engines, which are otherwise the most common type of engine in large cargo vessels operating over long distances on the open sea. The popularity of the 2-stroke engine for cargo vessels is based upon its low maintenance demand, low fuel consumption and on its reputation for high reliability.

The main reasons why 2-stroke engines are not used in ferries is because the large cross head engines do not fit beneath the main cargo deck. This means that there would need to be an engine trunk on the main cargo deck to house the 2-stroke engine. This trunk would interfere with cargo handling over the stern, and would reduce the available lane meters (freight capacity). Space is a design issue for ferries as they are considered to be volume-critical, rather than weight-critical vessels.

As ferries need twin screws in most cases for manoeuvring purposes, and to allow some degree of redundancy, they actually need to have at least two engines. Twin large 2-stroke engines would effectively close up the entire main deck in the stern of the vessel and make cargo handling almost impossible. This fact further contributes to the reasons why we have not seen many ferries with 2-stroke main engines.

**ADVANCED PROPULSION CONCEPTS FROM WÄRTSILÄ**

In recent years, Wärtsilä has put forward a number of new propulsion concepts for ferries. These include, Podded CRP, Wing Pods and Wing Thrusters [2, 3, 4, 5]. These all have one important feature in common in that they have gone away from the traditional twin shaft line set-up, and instead use a propeller mounted on the centre line skeg combined with either one or two azimuthing propulsors.

**The Podded CRP**
The Podded CRP concept features a contra-rotating propeller on an electric pod located directly behind the main propeller in the centre line skeg. The pod propeller is of the fixed pitch (FP) type, while the main propeller is of the controllable pitch (CP) type. Compared to a conventional vessel fitted with twin screws, the Podded
CRP configuration offers better hydrodynamic efficiency. This is mainly due to the following reasons:

- The resistance of the single skeg hull form with a single pod is lower than that of a twin screw hull with two shaft lines.
- The aft propeller takes advantage of the rotative energy left in the slipstream of the forward propeller when it rotates in the opposite direction.
- The skeg offers a more favourable wake than a shaft line, resulting in better hull efficiency ($h_w$).

The improvement in propulsion efficiency is clear, but the level of improvement depends on the vessel in question. The reduction in power demand at the propeller measured in model tests, has usually been in the range of 10-17% better efficiency compared to twin screw vessels. Even higher values have also been reported [6].

The Podded CRP concept has actually been applied in two fast Japanese ferries, and the beneficial features of the concept have been verified in actual operating conditions.

Japanese ferries showcase efficiencies

The first ferries featuring Podded CRP propulsion, the Hamanasu and the Akashia, entered into service in Japan in 2004. These two ferries are operated by the Shin Nihonkai Ferry Line, and were built by Mitsubishi Heavy Industries. The ferries have a service speed of 30.5 knots and a top speed of 32 knots. The ship features a CODED machinery with two 12-cylinder Wärtsilä 46 medium-speed engines in V-configuration, driving a CP propeller, two similar Wärtsilä 12V46 engines driving the generators, and one smaller genset for use in port. The total installed propulsion power is 42.8 MW, with 17.6 MW on the pod and 25.2 MW on the forward propeller (41/59 power split). The ships have been performing very well. A comparison with conventional ships in the Shin Nihonkai Ferry fleet shows that a 20% reduction in fuel consumption can easily be reached. This does not take into account the fact that the new ships are 1 knot faster and take 15% more cargo [1].

Market slow to take advantage

The Podded CRP concept has proved itself in two full scale applications and has delivered better fuel savings than estimated. However, to date we have not seen any surge in new orders. At the same time, there have been plenty of orders for conventional ferry concepts. One has to ask, therefore, why it is that ferry owners are not taking advantage of the opportunity for fuel cost savings.

There is probably not one conclusive answer to this question, but one can speculate as to the possible reasons. One fact is that the CRP is still a rather new concept, despite its operational track record stretching back almost 3 years. Most ferries are ordered in Europe and not all owners have concrete feedback regarding the performance of the Japanese vessels. The ferries on order have also been designed for lower speeds than the two existing CRP vessels. The question among owners is of course, how big the savings will be for a slower vessel.

One of the most important reasons, however, is still likely to be cost. The investment cost of a CRP ferry is higher than for a conventional twin shaft ferry. In particular, the electric pod is expensive and increases the investment costs. Nevertheless, it is easy to show that the CRP will pay for itself within a reasonable timeframe [2, 3].

A higher initial price though, can still be a critical item for owners trying to finance the ship in the first place. Another aspect of the cost issue is the sister ship effect. It is always more expensive for a shipyard to build a prototype vessel, such as the CRP vessel would be, rather than a repeat vessel. Even though many of the ferries on order today seem to be of a new design, they are often based on, and have many similarities to a previous ship. This makes it increasingly difficult for the introduction of any new designs.

NEW CONCEPT OFFERS LOWER INVESTMENT COSTS

Wärtsilä has developed a new concept that is relying on the good features of CRP propulsion, while at the same time attempting to overcome some...
The new concept features a Contra Rotating Propeller pair with the forward propeller mounted on the centre line skeg, and the aft propeller on a pulling-type steerable mechanical thruster located directly aft of the forward propeller. When looking from the outside, this set-up looks very similar to the existing CRP arrangement with an electric pod. It also acts in the same way hydrodynamically. However, the difference is on the inside of the thruster. The electric motor is replaced by a mechanical drive system with two 90° bevel gears.

The most obvious benefit of this is that it allows for fully diesel-mechanical machinery, while at the same time significantly lowering investment costs.

**Savings achieved via new machinery arrangement**

The novelty of the new propulsion concept is in the machinery arrangement that makes it both practically feasible for a ferry and also economically superior to all other machinery alternatives on the market today.

The aft thruster is driven mechanically by a medium-speed diesel engine located in the centre of the vessel above the shaft line of the forward propeller. This means that the engine is located higher up than where normally situated in ferries. The engine compartment penetrates the main deck.

The forward propeller is driven in the traditional manner by one or two engines. The engines are located in the centre of the vessel at tank top level.

The machinery forms a very compact package that is higher than normal, but much narrower. The machinery can also be pulled further aft than in a twin shaft vessel, since the single skeg hull form allows the reduction gear to be located further aft. The thruster engine, because of its high location, is also very far aft.

**Machinery also suitable for large main engines**

The new machinery arrangement also provides some new options when it comes to engine selection. The narrow and high machinery is well suited for a large main engine that is higher than normally. The main engines could be, for example, a 2-stroke engine or the very largest medium-speed engine on the market, the Wärtsilä 64.

The new arrangement efficiently overcomes some of the problems associated with high engines in ferries. With a conventional propulsion solution, two large engines would close up the entire beam of the main deck. Since the engines in the new proposal are behind each other, two engines will not take up more than two lanes on the main deck. This is only one more than anyway occupied by the normal engine casing. This means that only very few lane meters are lost on the main deck. In addition, the shorter engine room allows for a longer lower cargo hold, which compensates for the lost lane meters.

**Cargo arrangement is also innovative**

An innovative cargo deck arrangement goes hand in hand with the new machinery concept. A wide ramp from the stern of the vessel to the upper cargo deck can be located on top of the machinery. The fixed two-lane ramp above the engines will utilize the space on the main deck, that would otherwise be lost to the machinery compartments, efficiently. In this way, the entire beam...
of the vessel can be used for loading. The two centre lanes lead directly to the upper cargo deck without any interfering with the loading operation on the main deck. There are three lanes to the main deck on each side of the centre ramp and engine casing. The new cargo arrangement is of course, best suited for ports with only single level loading.

**NEW SHIP DESIGNS MADE**

A few new ferry designs have been made using different machinery solutions. One design is of a ferry with conventional twin-screw machinery, while all the other have a CRP propulsion arrangement but with different main engines. The five machinery alternatives studied are:

- **Twin shaft**, 4 x Wärtsilä 9L38
- **CRP**, 7-cylinder
  Wärtsilä RT-flex60 + Wärtsilä 8L38
- **CRP**, Wärtsilä 16V46 + Wärtsilä 8L38
- **CRP**, 2 x Wärtsilä 8L46 + Wärtsilä 8L38
- **CRP**, Wärtsilä 8L64 + Wärtsilä 8L38

The vessels are designed to offer the same capacity and performance:

- Lane meter 2400 m
- Payload 5150 ton
- Speed 24 knots (15% SM, 85% MCR)

The ship design is kept similar, but the main dimensions are varied to offer an optimized solution. This provides the ideal way by which to compare different machinery alternatives.

It would be wrong to start with a certain hull and then see how much cargo can be fitted into it after the machinery is in place. This is, however, the method often used for similar machinery comparisons, but it represents the wrong approach. It means that one or more of the alternatives are not optimized.

The method used here is to start from the mission of the vessel, and then design a ship to meet this mission. Of course, the principle behind the design process should be similar to arrive at comparable end results.

**RoPax particulars**

The ferry represents a contemporary RoPax vessel with 2400 lane meters for cargo and day facilities, for a limited number of passengers. The main dimensions are presented in Table 1.

The CRP ferry with a main engine below the main deck can have the same dimensions as the conventional twin shaft ferry and still offer the same cargo capacity. There is some reduction in lane meters by way of the thruster engine compartment. However, this is compensated by a larger lower cargo hold made possible by the shorter engine room.

The CRP machinery option with a high main engine going through the main deck, and with the ramp above the machinery, cannot offer the same cargo capacity, unless the length of the ship is increased.

**MACHINERY COMPARISONS**

The different machinery options have been compared with each other as follows:

**Weight**

The CRP machinery option shows an advantage when it comes to weight. Even with the low speed engine, the weight is at the same level as with conventional twin shaft machinery.

**Power demand and fuel consumption**

The power demand of the vessel has been calculated and compared with results from...
previous CRP model tests that Wärtsilä has been involved in. The delivered power demand of the CRP propulsion is about 9.5-11% lower than that of the twin-screw option. The larger saving is achieved with the option having the lower Wärtsilä 46 medium-speed engines, as their weight is 400 tons less, due to the lighter machinery and the small ship.

However, fuel consumption also depends on the transmission losses, as well as the specific fuel oil consumption in each operating mode. The mechanical thruster has higher transmission losses than a conventional shaft line owing to the two bevel gears. On the other hand, this represents only 25% of the total power. The main engine in the CRP options is of a larger type than in the twin shaft vessels. This gives lower SFOC. The total annual fuel consumption is shown in Figure 3. It can be seen that the CRP option (Wärtsilä 16V46) offers the lowest fuel and lube oil costs. The annual fuel and lube oil cost saving with the CRP is about 11-12.5%.

Investment costs
The investment cost of each machinery alternative has been estimated based on equipment offers, and is shown in Figure 6. It can be seen that the CRP machinery with the smaller medium-speed main engine offers the lowest machinery equipment investment costs.

In addition to the machinery, other building costs need to be assessed as well. This has been done with a system model of each vessel. The CRP alternative with the low-speed engine is about 2 MEUR more expensive than the other options, since its hull is about 500 gt larger than the others.

Total machinery related costs
The total annual machinery costs are shown for each alternative in Figure 7. The annual operating costs are calculated based on an assumed operating profile. The investment costs are turned into annual payments over an assumed 12 year period with 6% interest. The investment costs are turned into annual payments over an assumed 12 year period with 6% interest.

All of the CRP options indicate clear savings compared to a conventional twin shaft vessel. The CRP option with the Wärtsilä 16V46 medium-speed engine is the most economical, with an annual saving of about EUR 850,000.

**THE NEW CRP CONCEPT OFFERS A COMPETITIVE SOLUTION**

There is increasing demand for the ferry industry to begin focusing on greenhouse emissions. At the same time, high fuel prices also call for a clear reduction in fuel consumption. A new propulsion machinery concept based on CRP propulsion with a mechanical thruster, can offer a more than 10% reduction in both fuel consumption and operating costs. The nice feature of this concept is that it does not need to be more expensive than a conventional solution despite its superior performance. The investment costs can actually be cheaper depending on main engine selection. The unique arrangement also allows for efficient cargo handling, despite a small penalty in lost lane meters on the main deck. This can however be compensated by increasing the ship size.

This fact is taken into account in the comprehensive economic comparison performed showing that all CRP options indicate clearly superior overall performance. The lowest total cost level is for the CRP concept with the Wärtsilä 16V46 main engine. It has an annual saving of up to EUR 850,000. All in all, the new concept offers a very competitive solution that is a step in the right direction towards a cleaner ferry business.

**REFERENCES**


**Table 1. – Main dimensions of the RoPax ferry.**

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**Fig. 8 – New ferry with mechanical thruster CRP propulsion.**