MULTI-ENGINE CONCEPTS FOR DIESEL PROPULSION

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Abstract
The coastguard vessels of many nations are presently poorly suited to the current demands of the role of an Offshore Patrol Vessel (OPV). On the one hand, existing vessels designed prior to the introduction of the 200-mile zone may not have the endurance required or the seakeeping capabilities. On the other hand, corvettes are not a cost-effective solution for protecting the 200-mile zone. Given these circumstances, OPV designs with a lean crew have now been designed to match the new challenges. The vessels have a range of 5,000 to 7,000 nm at speeds of between 12 and 16 knots. At cruise speeds they combine cost effectiveness and endurance and can operate at high speeds for limited periods. A comparison of conventional two-engine propulsion arrangements with four-engine power-packs developed in a joint venture between MTU and RENK shows the most important effects of different propulsion options on the ship and her performance.

Context
Conventional OPV propulsion configurations comprise a twin-shaft arrangement with each propeller driven by a medium-speed engine through a reduction gearbox. Just one engine can drive the vessel at cruising speed, with the other trailing, either with a stationary shaft and feathered propeller or with a non-driven rotating propeller. There will always be a drag effect exercised by the non-driven propeller. If the single engine is to be run up to full revolutions when at cruise, then a reduction ratio is needed that is different to that required for full revolutions at full speed. This calls for a double-path gearbox.

If a single gearbox reduction is adopted, the propeller blade is at full pitch and the engine is running at a point of the torque-speed curve which is away from the full-power point. If the engine is not sequentially turbocharged this will usually lead to a worse specific fuel consumption and thus worse economy. If the engine blade angle is fined off to move the engine point to better economy, this leads to worse propeller efficiency. In either case, there is a worse outcome for either engine or propeller efficiency at cruise speed.

The four-engine concept sought to avoid the shortcomings of the standard approach. Each propeller shaft is driven by two high-speed engines through a single- or double-reduction gear. Specifically for this application, RENK developed its ASL 2 x 104 gearbox which, along with the engines, is mounted on a common raft to save assembly time at the shipyard and space in the ship.
The most important advantages of the Power-Pack arrangement

In 2009, MTU-RENK introduced the OPV Power-Pack concept which attempts to offset the drawbacks of the conventional arrangement. Each propeller shaft is driven by two high-speed engines through a single- or double-reduction gear.

The higher gearbox reduction ratio would involve slightly higher losses but at cruise speed, one engine would run on each shaft thus avoiding the need to trail a shaft. The high-speed engines are Sequentially Turbo-Charged (STC) and allow for better economy and better torque across the whole engine speed range. Thus at cruise speed the engine can be located away from the smaller optimum load range as per the conventional design and can run at a good part-load efficiency. This allows the propeller pitch to be optimal for this speed and thus the overall effect should be better than the conventional.

Although they have good part-load efficiency (i.e. specific fuel consumption) relative to its full load performance, the high-speed engines’ efficiency at full load is not always as good as that of a slower-speed engine.

Comparison: two- and four-engine options

A theoretical comparison of the different arrangements reveals how each of different options can be most suitable depending on fuel costs, engine support costs and the ship’s operating profile.

Space and Weight Savings

It is estimated that the four-engine design is about 30 tonnes lighter than the two-engine design. This is principally due to the 44 tonnes for the smaller engines versus the 73
tonnes for the larger engine. The four-engine design is estimated to have a smaller volume as the engines are both lower and shorter than the twin-engine design although the raft as a whole will be wider. Since almost all the auxiliary components are onboard the raft, upkeep on the smaller engines can be carried out by engine exchange. Components such as cooler, filters, hydraulic valves, sensors, controls, and pumps are mounted on the gearbox. The larger torque envelope of the STC engine allows for more engine operating flexibility and fewer restrictions on low-speed operations. The bespoke gearbox provides scope for engine input forward or aft.

**Engine Costs**

For the assumed ship speed profile, the four-engine design consumes 3.8% more fuel per year or 165 tonnes. This is £83k or €94,000 at £500/tonne. For this study, engine support costs are related to the engine rating through the factor £10/MWh. Thus an 8,000 kW engine costs £80/hour to run and a 4,000 kW engine costs £40 per hour. Whilst this figure is much higher than quoted by engine suppliers it does go some way to reflect the factored cost of infrastructure for the ship owner in terms of spares, ILS and the staffing required ashore. The figure is clearly representative yet would need to be subjected to sensitivity analysis. It does not consider the impact of higher running speeds on the Time Between Overhauls (TBO) or the relative ease of maintaining smaller engines in-situ or through upkeep by exchange.

![Figure 2: Annual Engine Support Costs for each Option](image)

On this basis, the four engine design has running costs which are about 70% of the two engine design. This does not include a factor for the markedly different number of engine cylinders.
Conclusions
The four-engine Power-Pack has footprint benefit in terms of length and on the basis of the assumptions in this study, an overall engine support cost benefit. There are no discernable differences in the endurance fuel requirement though the four-engine design has a worse range above the endurance speed.

The provision of four engines will make for a more available propulsion arrangement even if there is a high chance of any one engine failing. However, the Power-Pack has a more complex gearbox arrangement to allow for single and combined engine operations.

The Power-Pack design can be installed into the ship with fewer interfaces to the ship’s own systems: this is desirable for the shipyard. However the whole raft has to be inserted into the hull early in the build and this may affect cash-flow and work-in-way issues. The choice of design needs to reflect the ships operating profile as this can have a major bearing on the match of main machinery to ship usage.

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