FUTURE NAVAL TANKERS - BRIDGING THE ENVIRONMENTAL GAP - THE COST EFFECTIVE SOLUTION

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SYNOPSIS

The impending introduction of international legislation against single hulled tankers, IMO MARPOL Annex I regulations 13G and 13H, is driving commercial tanker operators to replace much of the older tanker and product tanker fleets with new construction double hull vessels. Whilst there is little fundamental change in the basic modern products tanker design from its predecessors, some of these new tankers are also including other design features to minimise hazards that may lead to environmental accidents and to improve operating efficiency and costs. The pressure to adopt the commercial regulations for naval tankers is increasing in many countries as the potential negative publicity associated with an oil spill from a naval vessel would be significant. The longer life of the naval tanker and the extended procurement timescales compared to the short lived commercial tanker also leads to the adoption of innovation in tanker design being driven by the commercial sector.

This paper discusses a family of affordable naval replenishment vessels developed by a joint design team drawn from commercial Norwegian ship designers Skipskonsulent and UK based naval designers BMT Defence Services. This family of designs draws on the wide experience of the two companies, offering the pull-through of the best commercial tanker design practise into the naval environment. The family of ships are scalable in size and capability through careful design of systems allowing capability growth.

INTRODUCTION

Few in the business of ship design have not been aware of the debate and subsequent legislation covering the withdrawal of the single hulled oil carrier and its replacement by the doubled hulled tanker. Since the introduction of the US Oil Pollution Act in 1990 and the revised IMO MARPOL Annex I regulations, commercial operators have moved to replace older single hull tankers with double hull tankers ahead of the final phase-out date in 2010.

This replacement programme is well underway with significant numbers of double hull product and crude carriers being built predominately in China and other mostly Asian ship builders as well as in smaller numbers in Europe and South America.

However, the impact of the single hull phase-out programmes of MARPOL Regulation 13G and OPA90 has been slower to appear in the world’s navies, with few double hull replenishment tankers entering service and replacement programmes likely to extend beyond the 2010 deadline. This slow adoption of the new rules is an inevitable consequence of the longer service lives and slower procurement rates in the naval sector; an average naval tanker could expect to serve for thirty years, suggesting that by 2010 only vessels build in 1980 or before would normally be the subject of replacement, some tens years prior to the first regulations governing the introduction of double hulls.
CHANGING ENVIRONMENTAL AND OPERATIONAL REGIME

MARPOL 73/78 Annex I was amended through adoption of Regulation 13F that requires all future tankers greater than 5,000 tonnes deadweight shall be provided with a double hull (or an alternative arrangement). Starting in 1995, Regulation 13G began the process of applying double hulls to existing tankers and a phase-out schedule for single hulled vessels was begun. The schedule has been progressively revised in light of a number of high profile incidents, such as the M/V ERIKA incident in 1999. The key date affecting vessels of the size and type operated by navies is the final 2010 deadline for the phase out of Category 2 and 3 tankers.

A review of the world’s naval replenishment tanker fleet quickly demonstrates that many of the vessels predate the current double hull legislation. In the first instance, the introduction of new regulations would not necessarily be of concern to many navies, who are able to claim exception from the regulations through their national statutory processes.

Today many navies are facing more scrutiny of their operations, particularly with respect to Health and Safety and Environmental Protection. There is also a very real issue that a vessel could be refused entry to waters and ports overseas on the grounds of non-compliance. So it is that many of the Navies currently operating single hulled tankers have come to the conclusion that they should seek compliance, if not by 2010, then at the earliest possible time thereafter.

EVOLVING THE COMMERCIAL TANKER

The design of the latest commercial product tankers have evolved greatly in recent years, specific drivers behind this being:

- Introduction of the double hull and bunker tank location legislation;
- New regulations and penalties associated with operating tankers in “sensitive” areas;
- The search for improved operability and reduced running costs.

A significant change that is occurring in commercial tanker design is the increasing adoption of twin screw designs. The introduction of twin skews is a response to increasing concern of oil pollution through loss of steerage and the increasing number of Special Areas and Particularly Sensitive Sea Areas (PSSA) defined through IMO, Reference [1].

In addition to an improved propulsive efficiency resulting from dividing the installed power between two plants, full redundancy in the propulsion plant is achieved. Hence, the ship can be operated with a critical failure in one of the propulsion lines. Maintenance can also be performed, with a complete shutdown of one of the propulsion engines/plants, without having to take the vessel out of service or off-hire and hence no loss of revenue is incurred. Additionally, water and fire tight sub-division may be arranged on the centreline, resulting in two separated engine room compartments that will provide redundancy with regard to flooding and fire.

The hullform should ideally be arranged as a “Twin-skeg” hullform, such as the example shown in Figure 1, as this would contribute positively to the propulsive efficiency, because of a higher hull efficiency due to higher mean wake and also a higher relative rotative efficiency compared to an open shaft twin screw system.
A twin skeg hull form will also allow for a fuller hullform in the aft ship, compared to an open shaft hullform, i.e. the LCB can be shifted towards aft, without having a large negative effect on the ship resistance. It can instead improve the ship resistance characteristics because the foreship hullshape can be made more slender.

![Figure 1 - Twin Skeg Hullform](image)

The twin skeg hullform and the reduced size of the propulsion engines on each shaft compared to a single engined vessel allows for locating the engines further aft in the engine room/hull. The length of the engine room can thereby be reduced which results in a larger cargo capacity. Additionally, by using medium speed engines, further space may be saved and an easier arrangement and installation are achieved.

Finally, a small number of commercial tankers are now being built with diesel electric propulsion to gain the potential operating savings these offers, something more normally associated with warships or cruise ships rather than bulk carriers.

**KEY DIFFERENCES IN COMMERCIAL AND NAVAL TANKERS**

**Service Speed and Hullform**

The commercial products tanker generally has a maximum speed of 14 or 15 knots and the hullform is optimised to provide the maximum cargo volume at these speeds. The naval replenishment ship needs to consider the ability to operate with faster warships and to not become the limiting factor in task group deployment times. Analysis of the operational patterns of naval replenishment ships show large variations in power loads, RAS/FAS operations with speeds of 12 to 14 knots, in combination with a high sustained transit speed requirement typically in the region of 18 knots, with a maximum speed of about 20 knots.

This implies that the naval tanker requires a high sustained transit speed and has a more dispersed operating speed profile compared to a commercial tanker. At this range of service speed and operational conditions, with a large span in required power output, it is essential to have a power production plant that is economical and efficient over the whole speed range.

There are of course many factors involved in the analysis of the most efficient power production and propulsion plant, of which fuel cost is one, but fuel cost is not the determinant factor in this case. A variation in fuel cost tends to shift the optimum point for the minimum break even freight rate, in terms of cost per ton of cargo transported, upwards or downwards along the speed scale, but since the operational speeds are given for a naval tanker, the main issue is to optimise power plant for dominant operating conditions.
The increased service speed of a replenishment tanker with a maximum speed of about 18 knots will of course also require a more slender hull form than for a commercial tanker with a service speed at about 15 knots. This is demonstrated by Figure 2 which shows a range of length - beam ratios for commercial and naval tankers.

![Figure 2 - Length / Beam Ratio for Commercial and Naval Tankers](image)

To increase the ship speed and installed power with a conventional single propeller propulsion system, the propeller diameter must be increased significantly, which may be difficult due to hullform and draught restrictions. If the propeller diameter is not increased, it will lead to a lower propulsive efficiency, due to higher revolutions and a higher loading on the propeller.

For this reason, it is very appropriate to adopt the twin shaft arrangement with the power divided between two propellers; these may have a larger diameter and lower revolutions compared to the propeller load and reduced power density. Hence, propulsive efficiency will be significantly improved.

**Replenishment Systems**

The most obvious element of the integration of the replenishment systems is the provision of the abeam replenishment stations with their associated masts. Their integration into a design is not a significant issue provided that the integration into the structure is considered. Whilst the loads are not considerable in relation to the primary hull loads, there is scope for fatigue cracking due to the cyclic loading of the masts and hence a suitable structural integration must be designed and appropriate materials selected.

The provision of the winches has to be considered from the point of view of providing safe routes for the lines which are under tension and also the fuel vapour hazardous zone, depending on the choice of winch type. Both hydraulic and electrically driven winches are provided today and it is perceived that many navies are likely to specify electrically driven solutions due to the reduced maintenance loads over hydraulic installations.

To further reduce maintenance loads, where possible, deck equipments and pipes should be below deck and under cover. Figure 3 indicates a possible winch installation; the winches are partly below decks and covered by a portable maintenance cover; due to the hazardous zone above the tanks the winches cannot be placed fully below decks.
Aviation

Whilst only a few navies may consider the use of the platform to conduct warfighting operations, the ability to embark a helicopter for vertical replenishment of stores or personnel movements offers significant advantages, allowing the tanker to provide limited replenishment of stores. It is therefore difficult to conceive a dedicated replenishment tanker design that does not provide at least a flight deck.

However, this represents a significant problem with the commercial design; to maximise cargo capacity the products tanker design seeks to minimise the length of non-cargo carrying hull resulting in short quarter decks aft of a short accommodation block. The incorporation of a flight deck on a commercial conversion has to consider two options; fit a forward flight deck or extend the flight deck over the stern of the vessel. Both of these are credible solutions but are not technically ideal. A forward flight deck is not preferred by pilots and its close proximity to obstructions such as the RAS masts and navigation light mast make for a higher pilot workload. A flight deck extending over the stern (by perhaps as much as 15 metres or more) is structural feasible but prone to slamming damage and higher vertical motions, both of which may limit the operating envelope.

Hence, the purpose designed naval tanker requires a significantly stretched superstructure block to account for the flight deck length and, ideally, space for a Hangar.

Accommodation

Whilst naval accommodation does not normally require the same area allocation as for a commercial vessel, the required complement of a naval replenishment vessel is significantly higher than a commercial tanker. Typically a commercial tanker will be provided with 25 or so berths and can be operated with a complement of less than 20. In comparison, a naval replenishment tanker can have a complement of over 50 and requires between 70 to 100 berths, depending on the level of capability.
Such a large complement can be difficult to comprehend for a commercial operator, but it is a realistic requirement that is driven by both the large manpower required during replenishment operations and the more extensive fire and damage control organisation of a naval vessel. Table 1 indicates comparative breakdowns of complement; in addition to the complement it can also be seen that more additional berths are required for non-complement staff often deployed with naval auxiliaries.

In a number of countries, such as the UK, the replenishment vessels are operated by commercial crews and hence the standard of accommodation has to follow commercial guidelines. Clearly, the increase in berth numbers at a similar standard has a very dramatic impact on the required accommodation footprint. Even where the vessels are naval operated and hence multiberth cabin arrangements may be adopted the arrangement of accommodation becomes a significant driver on the size of the superstructure. Combined with the flight deck and Hangar, it may be expected that a naval auxiliary vessel requires some 25 to 30 metres extra length for the same deadweight to account for the increase in length required aft of the cargo tankage, as illustrated in Figures 4 and 5.
Table 1 - Comparison of Typical Number of Berths

THE AEGIR DESIGNS

Hence, there exists an attractive proposition for the regional navy to consider a purpose built naval replenishment tanker which is derived from the current commercial practises and uses the maximum of design practise pull through to achieve an affordable programme at low risk. Such a design would not necessarily be a direct derivation of an existing design, rather using mature commercial design practise to de-risk the process.

This may best be approached through the direct teaming of commercial and naval designers to pull through the broadest understanding of commercial designs and naval operational constraints. This forms the foundation of the AEGIR design concept. By combining a number of basic design features, which are all being used in the latest commercial tanker designs, a double-hulled naval replenishment tanker series has been developed for international markets.

The designs offer significant environmental protection features, including propulsion and manoeuvring systems redundancy, full protection of cargo and fuel, and economical propulsion and power production in all operational modes and at higher speeds than for conventional naval replenishment tanker designs.

To illustrate the AEGIR family, four designs have so far been developed. Three represent scaleable versions of the Fleet Tanker, the forth a mixed consumable AOR. All share many similar features.

Fleet Tankers

The three Fleet tanker designs span the deadweight range of ocean going replenishment tankers, with deadweights of 10,000 tonnes, 18,000 tonnes and 26,000 tonnes. Figure 6 illustrates the principle characteristics of the family.
Replenishment

The design features tensioned span wire rigs for the transfer of fluids; DIESO, AVCAT and Fresh Water. The larger AEGIR 18 and 26 designs features locations for up to four rigs and the smaller AEGIR 10 locations for two rigs. The equipments for the replenishment system (hydraulic or electrical power systems, air systems for the tensioning system) are located in the deck house below the replenishment control station. The latter is conventionally arranged, between the rigs with maximum visibility for the operators. A stern refuelling rig is also provided on all the designs, located below the flight deck.

Aviation

A flight deck is provided for a 10 tonne medium helicopter. On the AEGIR 18 and 26, a Hangar is also provided to allow deployments on the vessel for short periods. The provision of a flight deck on a commercial conversion is possible though not ideal; provision of a hangar space is essentially impossible without complete redesign of the superstructure. Their inclusion in the AEGIR design from the outset is a feature that adds significant potential.

Propulsion System

The propulsion plant is arranged with medium speed engines, controllable pitch propellers driven via reduction gearboxes, as this allows for optimum propeller revolutions to be selected because reduction gearboxes are fitted. Shaft generators are provided on each shaft in additional to dedicated diesel generators. Finally, bow thrusters are fitted, which is now common place on commercial and increasingly naval tankers.
In all normal operation one or both of the shaft generators will be used to supply the ship with electrical power, and during discharge operations, one of the plants can be used to supply power to discharge cargo. During manoeuvring operations the shaft generators may also supply power to the bow thrusters. This means that installed auxiliary power can be reduced to a minimum, whilst maintaining safety and emergency response.

In addition to the full redundancy achieved with a twin engine/twin screw plant, this allows the propulsion plant to be arranged in a way such that both propellers can be driven with one engine, using one shaft generator as a motor, thereby providing full manoeuvrability even with the failure of one main engine. Additionally, the vessel may be run on one engine allowing maintenance of the other or if a reduction in service speed/power is used to reduce engine hours.

Alternatively, a higher auxiliary power may be installed. This power can than be used to boost the propulsion power by using both shaft generators as motors, taking power from the auxiliaries, supplying the propellers together with the main engines, in maximum speed sprint mode. This would be in cases when higher service speed then the normal service speed is required.

**Mixed Commodity AOR**

For the navy that requires more stores support at sea, the AEGIR 18R is a multi-commodity AOR based on the same hull as the AEGIR 18 and is shown in Figure 8.

The principal change is the introduction of a cargo hold of 1350m$^2$ in place of the aft most cargo tanks. A reduced fluid cargo of 12,000m$^3$ is provided. The cargo hold may be configured as required, but nominally would carry refrigerated stores, dry provisions and ammunition. Its location aft of the tank section principally offers reduced vulnerability to the deep cargo munitions, removing them from the forward part of the hull where collision with another ship or other obstruction is most likely.

The superstructure has also been extended forward over the cargo hold. This provides space adjacent to the cargo lift servicing the hold for the reconstitution of replenishment stores prior to conducting a RAS. The extended superstructure also offers significantly enhanced accommodation with 180 berths provided.

Replenishment is conducted by four duel use solid/liquid rigs and by VERTREP for solid stores. A central clear route is provided from the superstructure along the RAS deck, with a widened route beneath the replenishment control office.
CONCLUDING REMARKS

Over the coming decade, navies will have to address how best to meet the international regulations governing tanker design. For many regional powers, there will continue to be a need for replenishment tankers to support extended operations but the double hull legislation will make the purchase of non-compliant second hand vessels unattractive.

The choice between a new build naval replenishment tanker and converting a commercial vessel requires careful consideration of the costs, timescales and required capabilities. The emergence of new, affordable naval replenishment tanker designs, such as the AEGIR, offers the potential to introduce new vessels which exploit the latest commercial design practices and may be considered low risk due to the maturity of these features within commercial vessels. However, significant improvements in capability are possible through the incorporation of features such as flight decks and extended accommodation from the outset, and this makes these designs more attractive than the commercial conversion, particular as the price of commercial tankers continues to be very strong in the second hand market.

REFERENCES

1. IMO Resolution A.927(22).