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NEW HULL SHAPES FOR MERCHANT VESSELS(U) DEFENCE
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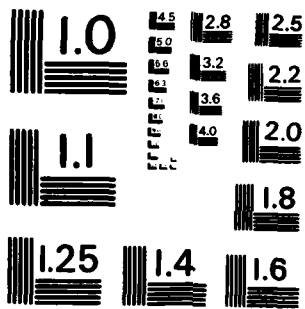
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NEW HULL SHAPES FOR MERCHANT VESSELS.

Åke Williams

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From the beginning of the 1970's ship technology developed towards ever greater freight capacity and installed engine power. These trends have now been halted. One is returning to previous sizes and speeds, but the types of vessel are new. The competition from shipyard and shipping company groups means, however, that ever more has to be squeezed from these new designs, in particular from the operating economy aspect.

Both before and after the change, intensive work has been done to find the optimum hull shapes. Regarding the question of operating economy, marine hydrodynamic research has contributed with new economical hull shapes, without which to-day's vessels would use 10 - 20% more fuel. The work is now continuing, partly by trying generally to force down the fuel consumption even further, partly by finding suitable hull shapes for to-morrow's vessels, for which ever more stipulations and limitations must be taken into account, not least with regard to vibration in the vessel's hull and discomfort at sea and in navigable channels.

Some examples collected from the development work of recent years at the National Shipbuilding Experimental Establishment (SSPA) at Gothenburg.

If one considers the world's merchant fleets in terms of the individual vessels' dead weight and engine power, one finds that the greater part of the stock of vessels occurs within certain narrow bands, Fig. 1.



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The development of the recent decades towards ever larger tankers and bulk-carriers, as well as towards ever greater machinery power (for container and roll-on/roll-off ships) has followed, if possible, even narrower bands. The growth came to a halt with the oil crisis a few years ago. The tanker had then exceeded the half million ton mark with regard to deadweight. Container ships with engine powers greater than 100,000 H.P. had already been delivered.

The previous trends in the size and engine power of merchant vessels have thus been interrupted. Previously normal, fairly small units of tankers and bulk-carriers (product tankers, "handy-sized" bulkers, etc.) are now once again pertinent. Container and ro-ro ships are now given reduced design speeds, as a result of the drastically increased bunker oil prices, but the shape of the new vessels will not be the same, the types of vessel will be different and more economical.

Hydromechanics.

Propulsion economy.

The previous rapid increase in merchant vessels' sizes and machinery power gave rise to energetic research efforts, e.g. within the field of hydromechanics. This concerned deciding how the future mammoth vessels would be propelled. Similarly it was important to supervise in a correct manner engine powers, which had until then only occurred in warships, in the then projected container ships (of the third generation).

In the new situation, when e.g. the bunker oil prices are many times higher and the demand for trouble-free propulsion has increased, the need for hydrodynamic research work is greater than previously. The additional demands which must be made on the new vessels and the new spheres which hydrodynamics must cover will not

be mentioned here. It is however clear that the work towards achieving ever more operationally economical hull shapes must be intensified. It is not enough to rely on results already obtained in the form of systematic hull shape series and variations of the latter. To better illustrate the importance of the hull shape and with it the engine power in the broad economic context, it is worth looking for a moment at those factors which affect a vessel's profitability. A very general example of such a study, prepared before the oil crisis, is to be found in Fig. 2. In conjunction with the oil crisis, the importance of the hull shape has of course been radically accentuated.

If one looks at how a specific improvement of a factor can reduce the required freight rate (RFR), the freight factor is the most important, as expected, and almost inversely proportional to RFR. Other dominant factors are building costs and weight of steel. A ten percent improvement in the vessel's service life or running costs, on the other hand, produces a reduction in RFR of only one percent. The factor which is relevant here consists of the required engine power (corresponding approximately to a combination of frictional and wave resistance). Its relative effect on RFR is almost as large as e.g. the vessel's total building cost.

The speed-resistance relationship.

Economical speeds.

How severely can the vessel's hull be "compressed" hydrodynamically? One of the decisive limitations is the wave propagation around the vessel (here expressed by means of the so called residuary resistance coefficient) which increases rapidly with increasing speed, Fig. 3.

Before wave propagation has called a halt to an increase in speed, one, perhaps two, "economical speeds" have been passed. The classical term "economical speed" in theoretical shipbuilding has no more to do with ship economy than the fact that it indicates certain relative speeds (speed relative to length, Froude number) where we have favourable wave interferences and consequently locally lower resistance.

The example Fig. 3 shows the resistance ratios for refrigeration vessels, which are a class of vessel which has for many years been built with lengths between 120 and 160 m within a block coefficient range of 0.50 - 0.55. Previously one kept to first economical speed. Under the motto "speed creates freight", the speeds at sea were subsequently forced up, so that speeds are now generally set at second economical speeds. Vessels A and B were built in the fifties and sixties respectively. Despite its considerably higher speed, vessel B has in fact a lower wave propagation resistance. Meanwhile the hull shapes for refrigeration vessels had been improved in their actual performance, so that, if vessel B had been built with lines corresponding to A, the engine power required would have been fully 15% more.

Hull shape development - tankers and bulk-carriers.

When tankers and bulk-carriers were growing at their fastest, one began asking oneself seriously how much longer the classical hull shape could be used. So here, afterwards, when the intense development has slowed down, one may well state that large fundamental changes were prompted. The bows have in general been given a vertical cylindrical stem with large radii, which is easy to build, saves on the ship's length and is hydrodynamically justified. Kockums was the first Swedish shipyard to build these bows.

More experimenting has been done with the stern, in most cases however with the retention of the *main* classical principles of design. Two different ways of shaping the stern have however been observed.

In the first case, Fig. 4, the stern is divided into two rounded skegs, also called gondolas, each of which accommodates its machinery with shaft and propeller. Good resistance characteristics and high propulsive efficiency can be achieved in this way.

Another way of proceeding, when it comes to improving the propulsion characteristics, is to allow the water to flow vertically right up to the propeller and to give the latter a freer location, Fig. 5.

Götaverk's hydrodynamic study relating to shallow draught vessels can be mentioned as an example of the work within this sphere at SSPA, paid for by STU funds. Very good results were obtained for a basic vessel with "spoon-shaped" bows, Fig. 6, and a stern in accordance with the "single-skeg" principle, Fig. 7.

Hull shape development - container and ro-ro ships.

In the same way as the increase in size causes problems for tankers, the increased engine powers signify worries for the designers of container ships. Should one, two or three propellers be chosen? What must the stern look like in each case? And what must the rest of the underwater hull look like when speeds approach 30 knots?

The above questions shall not be answered here. An interesting question can however be taken up, namely how high a speed and power can single propeller propulsion manage? It is clearly just as much a hull shape problem as a pure propeller problem.

A hull shape according to Fig. 8 (high power shape") gives the propeller such favourable operating conditions that the

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margins against cavitation and vibration are considerably improved with by and large retained propulsive efficiency.

For the present work is in hand with hull shapes for medium size ro-ro ships, where stability and cargo-handling requirements are great. It is then a matter of getting vessels to function well hydrodynamically as well.

Propulsion problems.

Each hull shape studied at SSPA is given certain assessment coefficients after tests have been carried out. One such coefficient concerns required engine power (SHP) and is called the hull shape's "quality grading". This expresses the relationship between the particular vessel's SHP and SHP for a single propeller standard vessel from SSPA's series with the same main dimensions, displacement and propeller. A more correct designation is perhaps the power relation coefficient, "engine SHP vs standard".

For the large vessels with many sea days per year, it is principally a matter of forcing down the fuel consumption.

A frequency test relating to the large vessels' (1 300 m) of required SHP compared to standard, Fig. 9, shows that the best hull shapes can have as much as a 10 - 15% lower power requirement than standard hull shapes.

Mean values and distribution of the power relation figures can be quoted for certain typical stern shapes, Fig. 10. As can be seen, the twin propeller, twin skeg stern occupies a special position. The Uddesvall Shipyard's prospective ULCC of 485,00 tons d.w. has successfully been designed in accordance with this principle. The best vessel within the range quoted for twin skeg vessels has an almost 15% lower required SHP than standard. Ship A and Ship B
/ show

show two well known Swedish vessels, namely Broström's SVEALAND and Grånge's TARFALA respectively. Each and every one of the vessels should be regarded as representing the best in their class.

The propulsion problem for the fast container and ro-ro ships certainly also concerns fuel economy, but for these vessels it is perhaps above all important to reduce the vibration from the propeller(s). The pressure pulses on the hull are in many cases so great that damage will result.

Interference from the propeller can be considerably reduced by changing over to the so called high power shapes (Fig. 8), Fig. 11. In addition, it is probable that the high power shapes can have a considerably higher value admissible for the amplitude of the pressure pulsations, on account of smaller hull surfaces close to the propeller.

Certain common hull shape variants.

When processing such a large amount of material about hull shapes as SSPA has available, it is possible to produce e.g. what significance certain common hull shape variants have for the propulsion. Fig. 12 thus shows the typical result in SHP (increase/reduction) of certain special deviations from a best single propeller standard shape. Constructive measures are to introduce a stem bulb and, on rounded vessels, a so called cylindrical stem. On a fast ro-ro ship, a well dimensioned bulb can reduce the power requirement by fully 15%. Similarly it has recently been possible to show that so called single- and twin-skeg sterns will reduce the power requirement by 5 - 10%.

In many cases, where it is a question of a dry-cargo ship, the deviations from the "best" hull shape has had to do with the

/ loading

loading time. If the cargo spaces are given a shape which is particularly convenient for stowing, this will mean hard bilges and shoulders in the bows and stern. For the exemplified typical ro-ro ship, this will mean up to 20% more SHP.

Many vessels have been built with bulbs and cylindrical stems, even more have been tested, but it is nevertheless difficult to get a grasp of the whole. Experiments have largely taken place unsystematically. Fig. 13 shows an attempt to gain a combined picture of the situation. Similarly, in the previous diagram the horizontal columns represent the typical result of the various measures, but here with the additional fact that it concerns favourable assumptions. The improvements with bulbs shown for large tankers and bulk-carriers by no means apply to all vessels in the size class. Many tankers are sailing around to-day with large expensive stem bulbs which by no means pay for their existence.

The vertical cylindrical stem is, as opposed to the bulb, not so sensitive to changes in speed and draught. It also retains its resistance-reducing characteristics at the relatively low speeds which large tankers have. For these vessels, one is fully justified (from the hydromechanical point of view) in exchanging the bulb for a cylindrical stem, which is of course also cheaper to build.

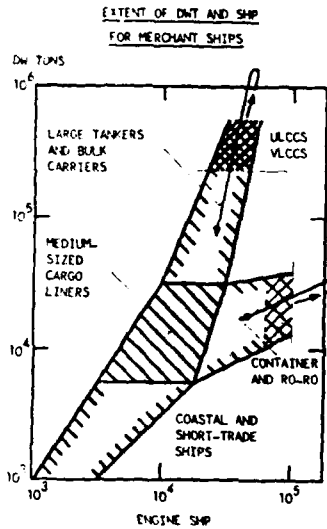


Fig. 1. Range of merchant vessels' freight capacity and engine power.

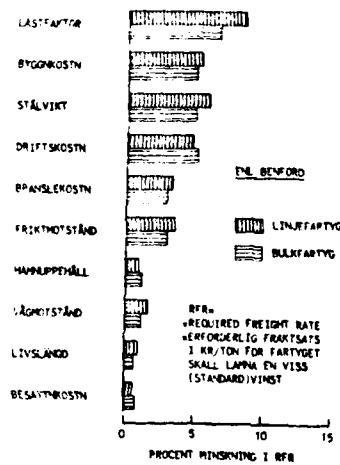


Fig. 2. Reduction in the necessary freight rate as a result of an 80% improvement of various building and operating factors (diagram produced before the oil crisis).

Freight factor	
Building cost	
Steel weight	<u>According to Benford</u>
Operating cost	Liner
Fuel cost	Bulk-carrier
Frictional resistance	
Maintenance	
Wave resistance	RFR = required freight rate
Service life	in kr/ton for the vessel
Manning cost	shall earn a specific
	(standard) profit

Percentage reduction in RFR

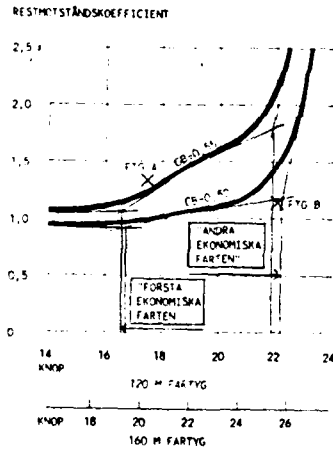


Fig. 3. "Economical speeds" for 120 - 160 m freighters with standard hull shapes.

The second economical speed

The first economical speed

Knots

120 m vessel

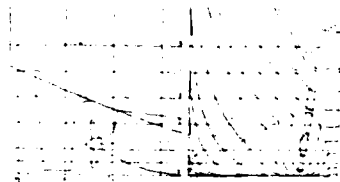


Fig. 4. SSPA tanker/bulk-carrier. Twin-skeg stern.

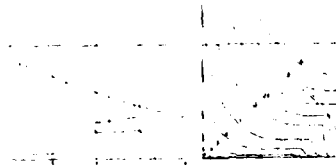


Fig. 5. SSPA tanker/bulk-carrier. Stern with "free" location of propeller.



Fig. 6. GV shallow draught vessel. Bows.

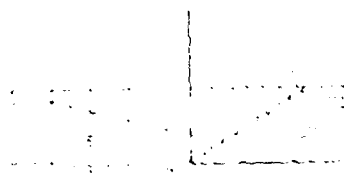


Fig. 7. GV shallow draught vessel. Stern.



Fig. 8. SSPA container ship "high power shape". Stern and propeller.

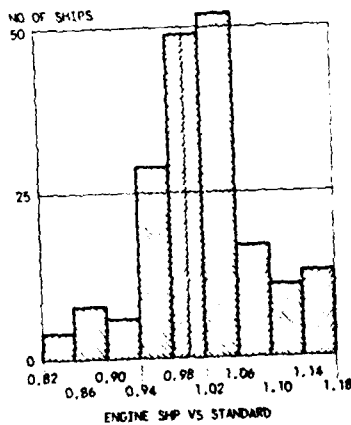


Fig. 9. Distribution of "SHP relative to standard" for single-propeller vessel. L = 300 m.

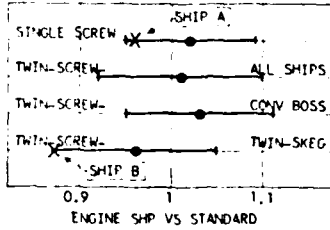


Fig. 10. Mean and spread of "SHP relative to standard". L 300 m.

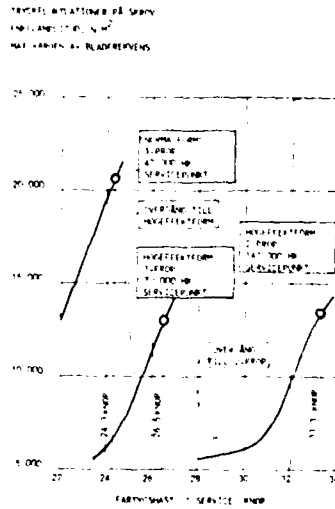


Fig. 11. SSPA container ships. Standard shape and high power shapes.

Pressure fluctuations on hulls measured in SSPA's large cavitation tunnel.

Pressure fluctuations on hull
Single amplitude, N/M^2
Max. value of blade frequency

Standard shape
1 prop.
43,000 H.P.
Operating level

Change-over to
high power shape

High power shape
1 prop
70,000 H.P.
Operating level

High power shape
2 props.
147,000 HP
Operating level

Change-over to 2-prop.

Speed in service, knots

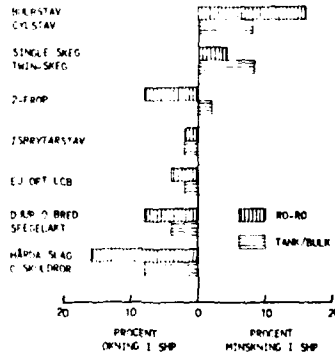


Fig. 12. Increase and reduction in the SHP required, as a result of the effect of different shape variants.

Bulb stem
Cylindrical stem
Single-skeg
Twin-skeg

2-prop.

Ice-breaking stem

Non-opt. LCB
Deep and broad
Mirror stern

Hard bilges
and shoulders

Ro-ro

Tanker/bulk-carrier

Percentage increase
in H.P.

Percentage reduction
in H.P.

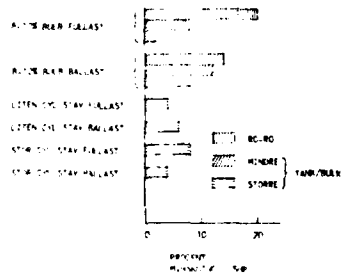


Fig. 13. Reduction in the SHP required, as a result of the effect

of bulb and cylindrical stems.

8-12% bulb, fully loaded

8-12% bulb, ballasted

Small cylindrical stem full load

Small cylindrical stem, ballast

Large cylindrical stem, full load

Large cylindrical stem, ballast

Ro-Ro

Smallish) tanker/

Largish) bulk-carrier

Percentage reduction in SHP

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Abstract From the beginning of the 1970's ship technology developed towards greater freight capacity and engine power. These trends stopped around 1976 and designers are returning to previous sizes and speeds, but with new types of vessels. Competition between shipyard and shipping company concerns means that these designs have to be more cost effective in terms of operation. Much research has been undertaken to establish optimum hull shapes. Hydrodynamic research has contributed new, economical, hull shapes which produce fuel savings of up to 17 per cent. Work aimed at producing suitable hull shapes for future vessels and decreased fuel consumption is discussed.			

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