

# Minimising fuel consumption

During the last four decades the loading capacity of container ships has increased from a few hundred TEU for the first full container ship to more than 9000 TEU for the most modern vessels now in operation. Over this period of development numerous design and construction problems associated with the increasing size of the vessels and their propellers were overcome. The demand for sufficient stability, higher speeds and low vibration levels has led to new hull forms specific to this type of vessel.

Under the pressure of rising fuel costs – the price for the OPEC Reference Basket (ORB) increased by a factor of 2.7 in the last five years (see Fig 1) and is still going up – an old virtue came back to the focus of ship designers, owners and operators – optimisation of the whole system to minimise the fuel consumption under actual environmental conditions. One approach is the application of energy saving devices, another the optimisation of the way the vessel is operated.

Very large container ships suffer from several specific hydrodynamic problems due to their pure size and the special transport profile, such as propeller cavitation and erosion, rudder cavitation and erosion, and parametric rolling. They are discussed in detail in the HSVA paper entitled *The Challenge of Very Large Container Ships – A Hydrodynamic View* presented at PRADS 2004.

## A broader approach

An actual problem for container ships of any size is the very high power and fuel oil consumption at the speed required for regular container line services. But the higher the speed the higher the fuel consumption.

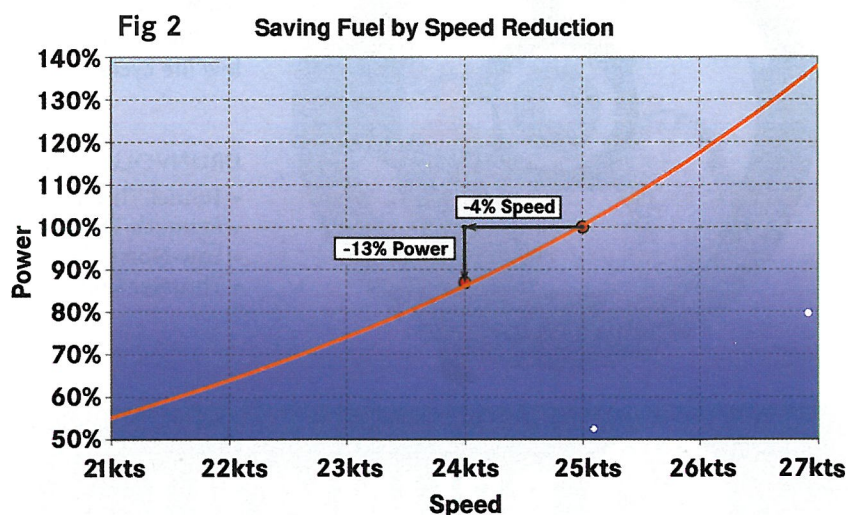
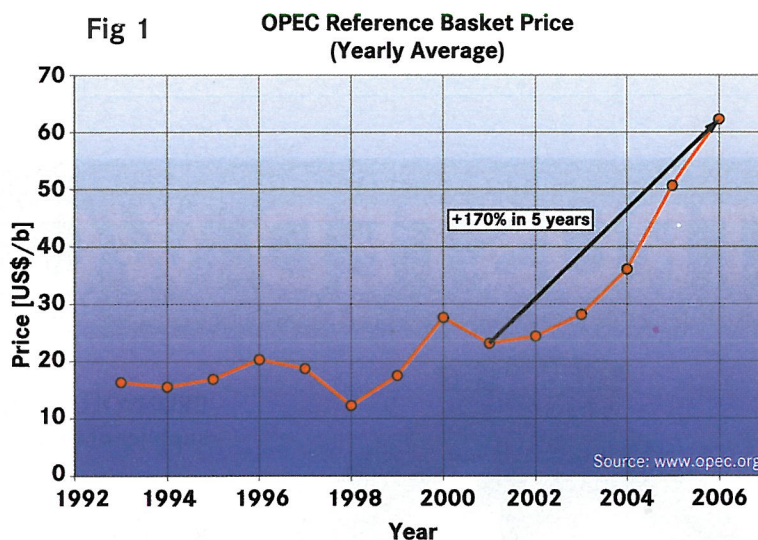
Nowadays some shipowners already operate their fleet at speeds lower than those for which the ships have been designed. For a large container ship this means that a reduction of the speed from 25kts to 24kts (-4%) results in a reduction of the power and fuel consumption by about 13% (see Fig 2).

This is practical for existing ships but for newbuild ships a broader approach to fuel saving should be selected. A reduction of the design speed allows the selection of a smaller main engine which costs less. Additional

Hilmar Klug\* and Friedrich Mewis\* discuss current hydrodynamic trends and developments and present exemplary results from model tests performed at the Hamburg Ship Model Basin (HSVA)

■ Fig 1: Oil price history

■ Fig 2: Reduction of speed saves fuel oil



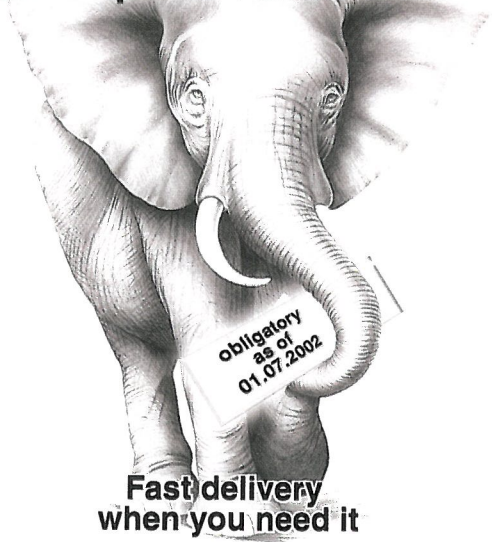


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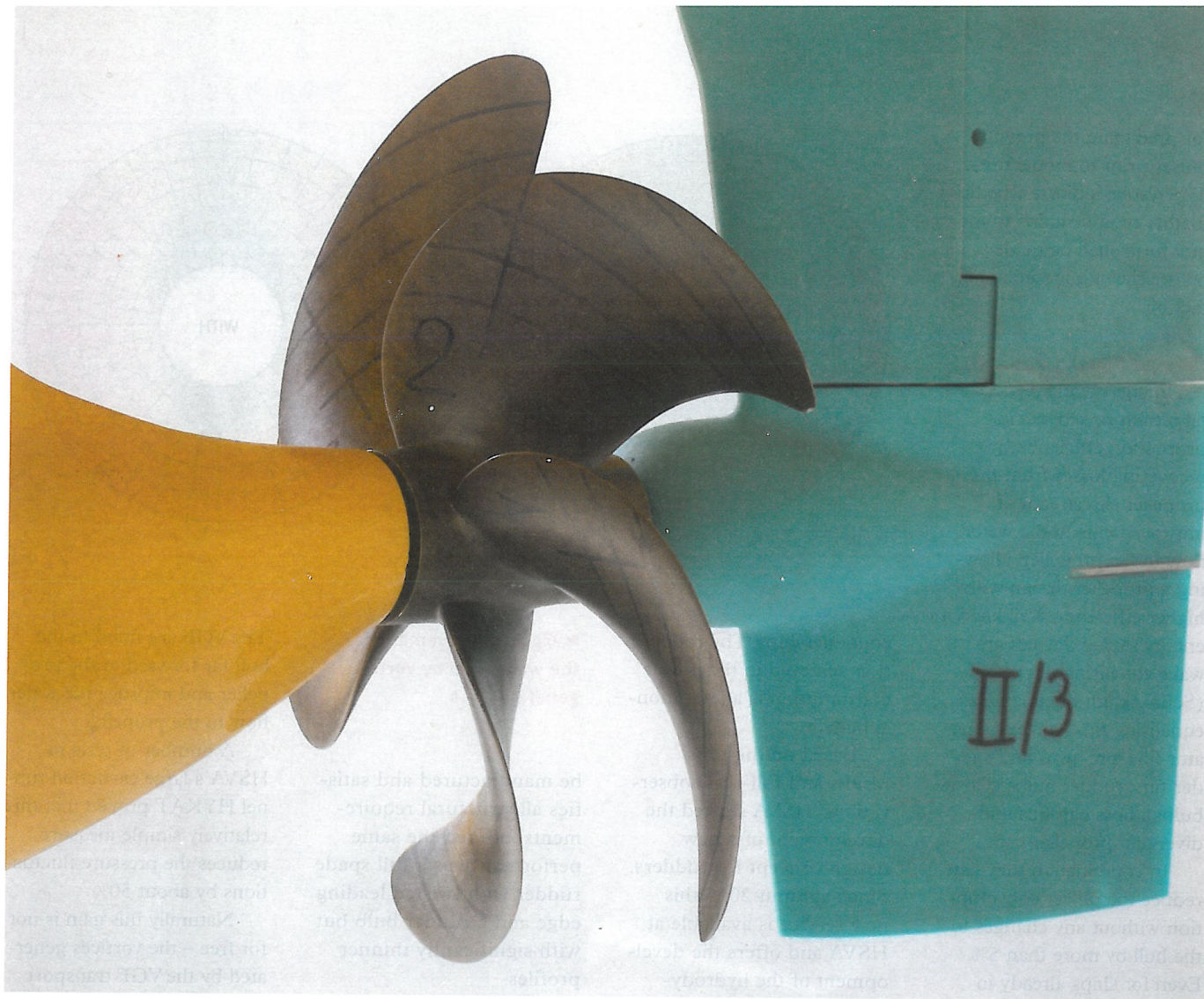
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gains in economy can be achieved easily when all aspects of ship hydrodynamics are taken into account (eg higher propeller efficiency due to lower load and risk for erosive cavitation).

Furthermore, the operational profile of the vessel should be well defined and taken into account in the ship design. It is still common practice that one draught is defined as design draught and all requirements for minimum speed or maximum fuel consumption etc are defined for this single draught ignoring that, in most cases, the ship will operate at other draughts and speeds.

This means that the ship is optimised for conditions at which it seldom sails. A hull design optimised for a range of draughts and speeds should be first choice for

containerships. Such a design will, for example, feature a smaller transom and a bulbous bow suitable for various draughts.

#### Hull lines design

Often the main dimensions for a new containership are selected during the concept design phase. Major changes are seldom made later on. For the speed/power and cavitation performance the selection of the main dimensions are critical as they directly influence the resistance and the wake of the vessel.

A new service provided by HSVA (QuickCheck) gives advice for the proper selection of the main dimensions based on HSVA's large database including resistance, propulsion, wake field, cavitation and pressure fluctuations.

■ **Fig 3: Semi-balanced rudder designed by HSVA featuring twisted leading edge, twisted trailing edge and rudder bulb**

Currently, several projects at HSVA include studies of the position of the longitudinal centre of buoyancy (LCB). Up until now, the LCB for smaller container vessels has been relatively far aft. Today, positions further forward are being investigated.

Driven by the need for a higher number of containers on the hatches and in the holds, the superstructure and the main engine are shifted aft, requiring more buoyancy in the aft body. This may result in flow separations and a poor wake field. For large container vessels hull forms with more forward LCB are developed in order

to improve the inflow to the propeller.

Not new, but for the first time applied in large-scale for commercial projects, is the technology to automatically optimise a hull shape defined by a high number of geometrical parameters taking into a complex target function incorporating not only least resistance at one or more draught(s) and speed(s) but also volume, stability etc. The results of such an automatic optimisation have been confirmed by model tests at HSVA for a medium size container vessel.

While the optimisation of the hull lines is well supported by the application of potential flow calculations, the latest developments in viscous flow calculations today allow the calculation of the wake field as a basis



for predicting the pressure pulses prior to model tests. The results indicate whether further modifications to the hull form shall be made before starting model manufacture.

### Energy saving devices

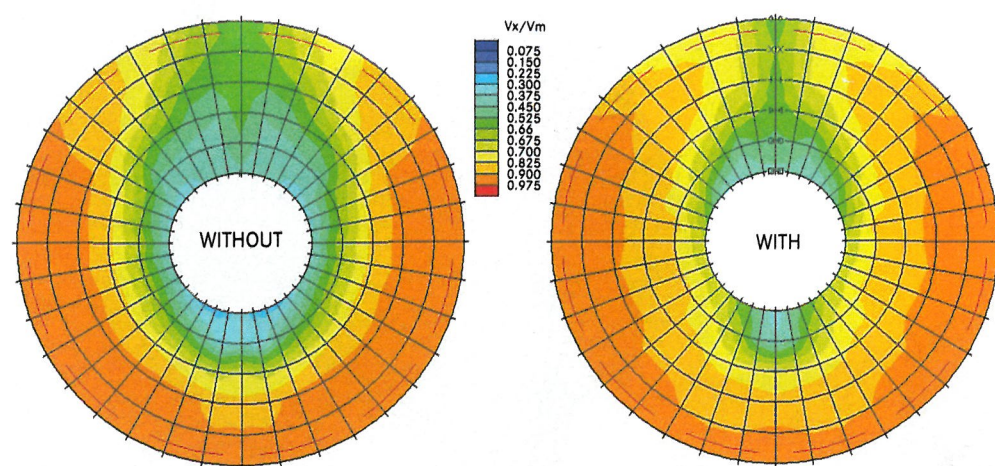
Energy saving devices target improvements in propulsion efficiency by recovering losses from the propeller slip stream or improvements in the water flow to the propeller, allowing a propeller design with higher efficiency. Well known energy saving devices are wake equalising ducts (Schneekluth ducts), wake equalising fins, vortex generator fins, pre-swirl and rudder fins, rudder bulbs (Costa bulbs), boss cap fins and divergent propeller caps.

In combination they can reduce the power consumption without any changes to the hull by more than 5%. Even for ships already in operation some of the devices can be very beneficial, but the effectiveness of such measures needs to be proven by model tests.

### Rudder design

Early in 2005 the first very large container vessel fitted with a rudder featuring a twisted leading edge entered service. Many others followed *Savannah Express*, built by DSME and fitted with a TLKSR-rudder from Becker Marine Systems.

The decision for the twisted rudder was supported by a comprehensive test campaign at HSVA, including CFD calculations, ship powering, cavitation and manoeuvring tests. The intention for the development of the rudder with twisted leading edge was to reduce risk of rudder cavitation and cavitation-induced erosion due to the very high flow speeds in the propeller slip stream of very large



■ Fig 4: Improvement of the wake field by vortex generator fins

containerships. The reduction achieved in the power consumption is an additional benefit.

Based on the tests results and full-scale observations, HSVA started the development of a new design concept for rudders. Since autumn 2005 this new service is available at HSVA and offers the development of the hydrodynamic design for a rudder based on the results of calm water tests (resistance, self-propulsion and wake field measurement) and viscous flow CFD analysis of the rudder geometry and profiles.

The optimum twist of the leading edge is found in an iterative process. The twisted leading edge can be combined with a twisted trailing edge and/or a rudder bulb. Designs for full spade and semi-balanced rudders are available. Rudder horns might be twisted, too. Comparative tests for a 5000 TEU container vessel proved the effectiveness of the new rudder designs.

The new design, a semi-balanced rudder with twisted leading and trailing edges and a rudder bulb (see Fig 3), which was developed together with the customer in order to ensure that the rudder can

be manufactured and satisfies all structural requirements, offered the same performance as a full spade rudder with twisted leading edge and a rudder bulb but with significantly thinner profiles.

Compared to a conventional semi-balanced rudder without rudder bulb designed for this vessel, the ship with the twisted rudder and rudder bulb had about 4% lower power consumption, which equals to a gain in speed of about 0.3kts.

### Vortex generator fins

Modern containership design often features the superstructure far aft and located more or less directly above the propeller, which is the main source for structural vibration excitation. This leads to relatively full aft bodies with often unsatisfactory wake field, resulting in unacceptable pressure fluctuations and vibrations.

If the main dimensions and the hull shape cannot be changed (which should be the first choice), vortex generator fins (VGF) are a very effective measure to reduce the pressure fluctuations.

The VGF are fitted to the hull far forward of the propeller and improve the water flow to the propeller.

A number of tests in HSVA's large cavitation tunnel HYKAT proved that this relatively simple measure reduces the pressure fluctuations by about 50%.

Naturally this gain is not for free – the vortices generated by the VGF transport water from the outer boundary layer to the inner one in the upper part of the propeller disc equalising the wake field (see Fig 4). However, these vortices contain rotational energy which is taken from the ship. An increase of the power consumption by about 2% has to be expected.

### Ship operation

Containerships have a high ballast water capacity in order to ensure sufficient stability for all loading conditions. The ballast water can also be used to influence the trim of the vessel.

Since modern hull lines often feature a very wide transom which is quite deeply submerged, especially at scantling draught, small changes to the trim can result in a significant change in power consumption/achievable speed.

At HSVA, speed differences of about 0.3kts have



been measured between the best and the worst trim condition at design draught (= about 3% difference in power, CV 8500,  $\pm 1$  m trim). Other ship types such as ferries, ro-ro vessels and general cargo vessels can be even more sensitive to trim variations.

### Conclusions

Driven by rising fuel oil costs and new requirements for (lower) ship speed, development of the hydrodynamic design of container vessels has entered the next level of optimisation. Shipowners and operators pay more attention to the optimisation of the projected vessels beyond the limit 'good enough'. The new target is 'as good as possible'.

Ship model basins all over the world work hard to find the optimum solution for each single vessel taking into account the special needs and boundary conditions. Hull lines are optimised using automatic soft-

ware tools, model tests and, last but not least, the vast experience of a ship model basin's staff.

With the large tests facilities (the cavitation tunnel HYKAT and the 300m long towing tank with completely modernised control and measuring systems) and committed experts, HSVA is

taking part in and driving the development of cutting edge technology in the field of hydrodynamics, such as the development and optimisation of energy saving devices recovering losses from the propeller slip stream.

With focus on reduced fuel consumption, guidelines for ship crews are developed

giving advice on how the vessel should be trimmed in order to achieve maximum efficiency, resulting in reductions of operational costs with very little investment. ■

\* Hilmar Klug is Project Manager and Friedrich Mewis is Director (retired) at HSVA

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