HULLS AND PROPELLERS

AIR CAVITY SHIPS AND THE DIFFERENT TYPES OF PROPULSORS USED WITH THIS TECHNOLOGY.

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ABSTRACT

The paper briefly states the research studies on application of artificial bottom cavities for reduction of hydrodynamic resistance of ships. The paper also considers specific features of different types of ship propulsors used in air cavity ships.

There are several methods of adapting a vessels's hull to improving performance, reduce fuel consumption and lower emissions such as optimizing the hull shape, dimensions,
Displacement and block coefficient to reduce the vessel's resistance to movement through the water. Air cavity ships utilize air to reduce the drag and frictional resistance of a hull. The method involves injecting air into a specially designed air cavity in the underside of the hull which effectively reduces the hull wetted area and frictional resistance of the hull surface.

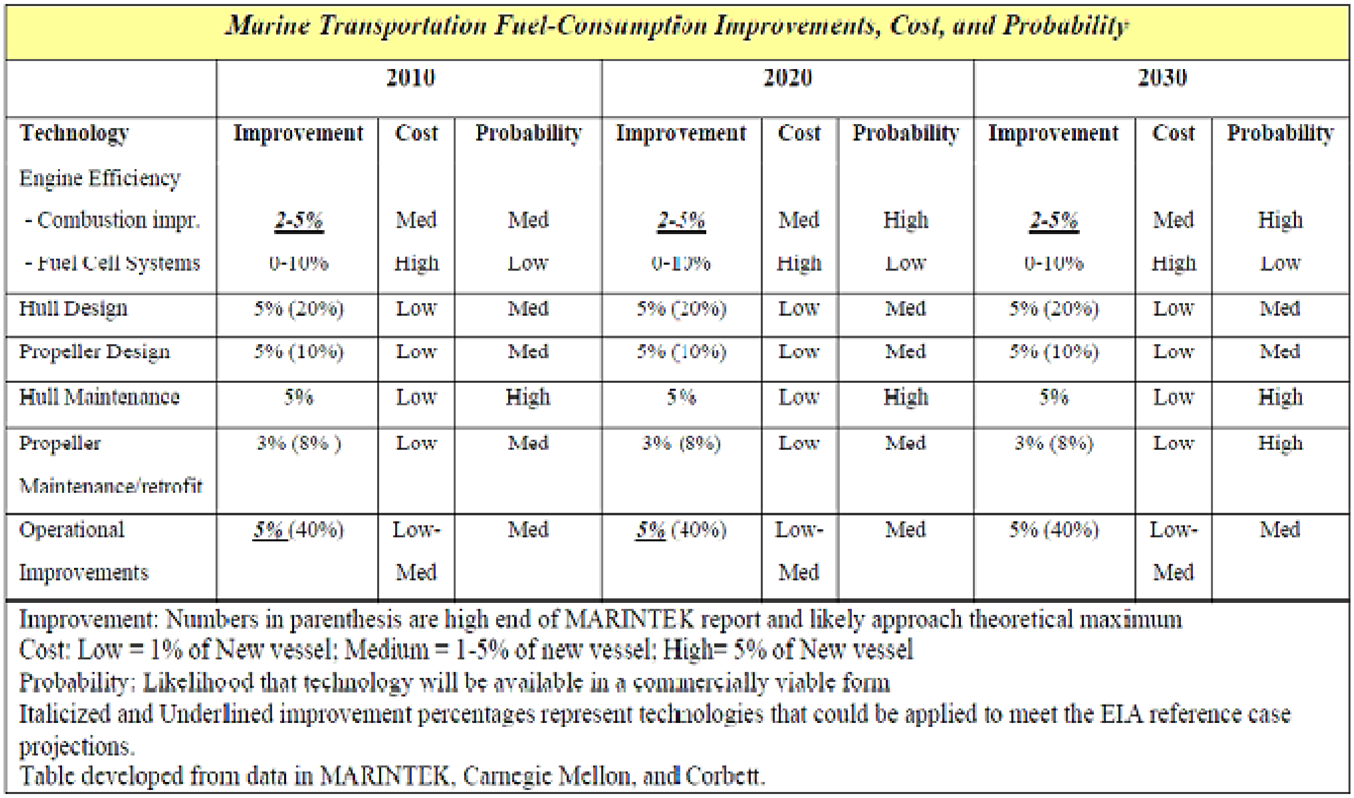
KEYWORDS: Air Lift, Air Cavity, Hydrofoil, Boss cap fins

RECENT RESEARCH IN HULL FORM DESIGN

We think the more likely changes in ship design will involve the form of the hull. Conventional ships operate in what is known as the displacement mode, pushing aside a volume of water equal to the volume of that portion of the ship's hull that is submerged. The displaced water creates frictional drag as it slides past the hull and also forms a wave cycle whose period is dictated by the speed of the ship. The length of wave from peak to peak is dictated in turn by the speed of passage, with higher speeds producing longer waves. When the length of the wave is roughly equal to the length of the vessel, the vessel is effectively trapped in a trough between two crests and can only travel at the speed of those crests. Most ships cannot effectively climb their own bow waves, so the length and speed of those waves imposes an upper limit on ship speed known as the hull speed. Once a ship begins to overtake its own bow wave it can effectively go no faster in normal circumstances.

Unconventional hull designs include super slender hulls, multi-hulls, air cavity types, planing and semi-planing hulls, hydrofoils, SWATHs, SLICEs, hovercraft, and surface effect vessels.

Marine Transportation fuel - consumption improvements, cost and probability



Marine Transportation Fuel-Consumption Improvements, Cost, and Probability

	2010			**2020**			**2030**		
Technology	**Improvement**	**Cost**	**Probability**	**Improvement**	**Cost**	**Probability**	**Improvement**	**Cost**	**Probability**
Engine Efficiency									
- Combustion impr.	*2-5%*	Med	Med	*2-5%*	Med	High	*2-5%*	Med	High
- Fuel Cell Systems	0-10%	High	Low	0-10%	High	Low	0-10%	High	Low
Hull Design	5% (20%)	Low	Med	5% (20%)	Low	Med	5% (20%)	Low	Med
Propeller Design	5% (10%)	Low	Med	5% (10%)	Low	Med	5% (10%)	Low	Med
Hull Maintenance	5%	Low	High	5%	Low	High	5%	Low	High
Propeller Maintenance/retrofit	3% (8%)	Low	Med	3% (8%)	Low	Med	3% (8%)	Low	High
Operational Improvements	*5%* (40%)	Low-Med	Med	*5%* (40%)	Low-Med	Med	5% (40%)	Low-Med	Med

Improvement: Numbers in parenthesis are high end of MARINTEK report and likely approach theoretical maximum
Cost: Low = 1% of New vessel; Medium = 1-5% of new vessel; High= 5% of New vessel
Probability: Likelihood that technology will be available in a commercially viable form
Italicized and Underlined improvement percentages represent technologies that could be applied to meet the EIA reference case projections.
Table developed from data in MARINTEK, Carnegie Mellon, and Corbett.

AIR CAVITY TYPE SHIP HULL

Air cavity ships have the virtue of resembling ordinary displacement hulls in all but one respect. The bottom of the hull is flat rather than V-shaped and is provided with side and rear walls for containing a pressured air mass which is pumped into the resulting cavity. Approximately 5% of the ship's power is required to maintain the cavity, but the drag reduction is on the order of 50%.

Air-cavity ships (ACS) are advanced marine vehicles that use air injection at the wetted hull surfaces to improve a vessel's hydrodynamic characteristics. The concept of drag reduction by supplying gas under the ship's bottom was proposed in the 19th century by the famous scientists Froude and Laval. However, many attempts to implement this idea in practice have failed because this process is not as straightforward as it seems.

Deep physical understanding of multiphase laws is required to achieve a positive outcome. Based on the results of systematic research, several successful ACS's have been created and found practical application during the past decade.

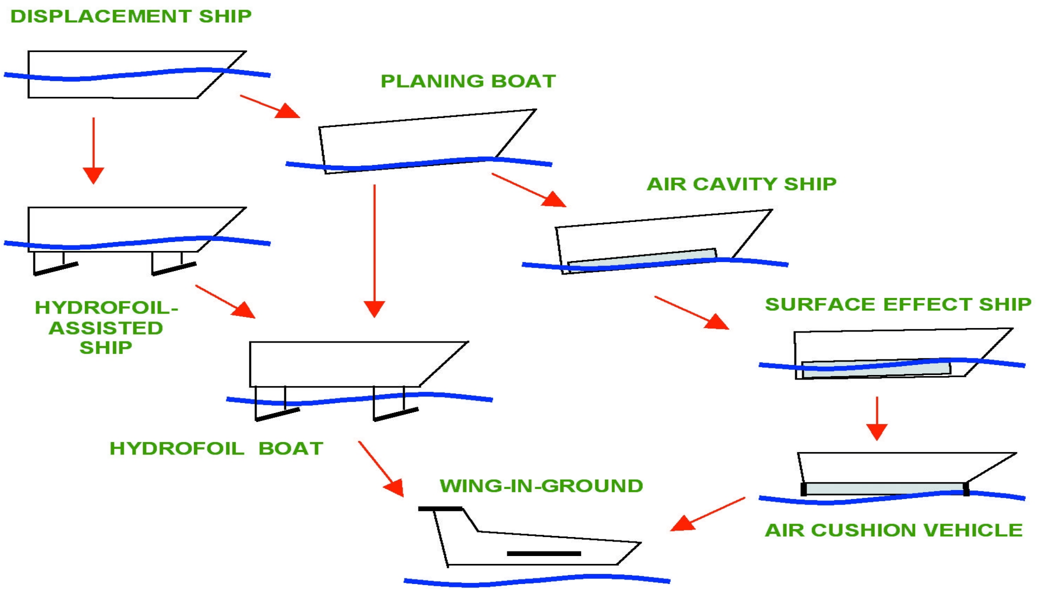


Fig. 1 - The position of the ACS among other ship types

The position of the ACS among other ship types is shown in Fig 1 characterizing the degree of water-hull contact. The basic type of ship operates in a displacement mode. At sufficiently high speed and with suitable hull lines, a boat can glide over the water surface. Air can be injected under the bottom, significantly reducing wetted hull area and consequently hydrodynamic resistance. This type of ship corresponds to the A C S, and the phenomena of generating a gas layer at the submerged hull surface is called artificial cavitations or air lubrication. A similar and more familiar concept is the surface effect ship (SES), where air is also pumped under the ship's bottom. Such a vessel usually has flexible bow and stern covers enclosing the space between twin hulls. The next ship type after the SES is an air cushion vehicle with no permanently submerged parts.

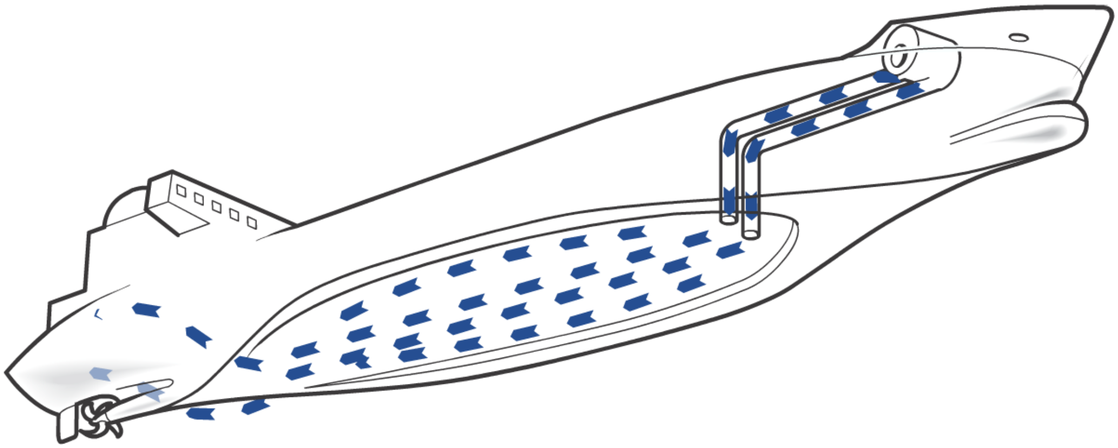


Fig. 2 – Air Cavity formed under the bottom of fast ACS

ACS FEATURES

- air cavity ships are already produced in series
- 15-40 per cent drag reduction is achieved
- less than 3 per cent of the total ship power is needed to support the air cavity
- low wash wake is generated due to smoothed pressure gradients in the presence of the air cavity
- overloads in rough seas are reduced due to a damping effect of the air cavity
- fouling growth on the hull in warm seas is lessened due to decreased wetted surface
- ACS is a convenient platform for effective landing and shallow-water operations
- protected or special propulsors may be required for ACS.

THE CONCEPT

The ACS concept is based on successful usage of bottom ventilation (artificial cavitations). A gas is supplied underneath a special profile, so that a steady air layer is generated which separates a part of the bottom from contact with water, therefore reducing hydrodynamic resistance. Drag reduction achieved on a full-scale ACS is within 15-40 per cent, while the power spent on the cavity maintaining gas flow is always less than 3 per cent of the total propulsive power of a vessel. Pressure inside the cavity is higher than atmospheric, providing additional support for the ship's weight. Although the ACS principle seems similar to an SES, there are significant differences. First, there are no flexible seals on an ACS. The air layer is contained by solid hull parts, which not only prevent air leakage from the cavity, but also influence the air cavity characteristics. Secondly, the

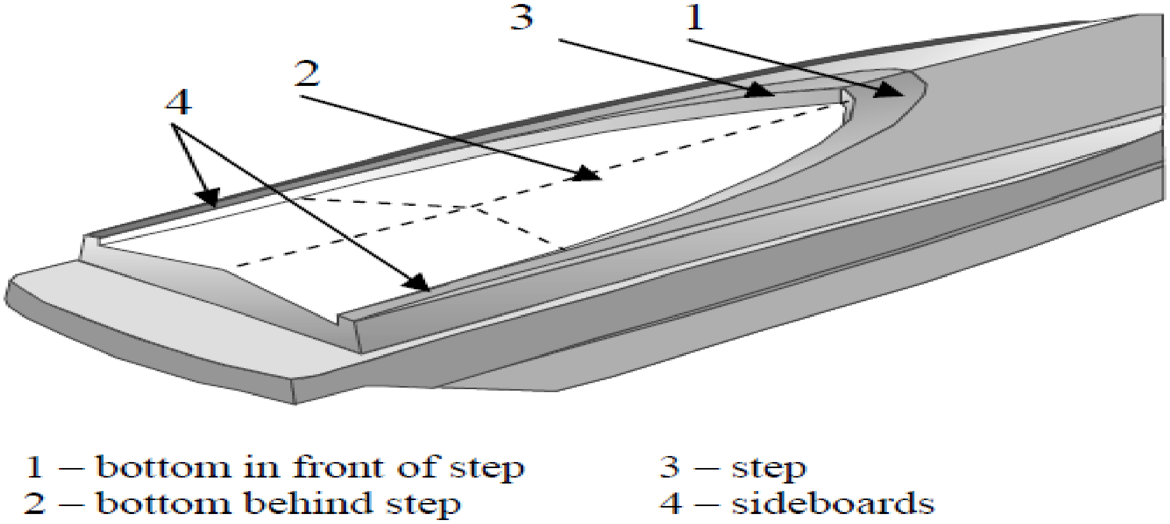


Fig. 3 - Scheme of the Planing Boat on Artificial Cavity

To use the artificial cavitation effectively, a ship bottom profile should be chosen to provide air to cover a large bottom area at low energy expense for air supply. There are three important components of the bottom structure on a fast ACS: a step forming the cavity surface, planing sidewalls (skegs), which also protect a cavity, and a special section near the transom that provides smooth closing of cavity surface to the hull. The determination of geometrical parameters of these structural components is the main task of ACS design. An air cavity is formed in the bottom recess by supplying gas through the nozzles using fans. The important physical properties of cavitating flow aimed at reducing drag can be illustrated using a simple example of the flow behind a wedge attached to a horizontal wall in the presence of gravity, as shown in Fig 4.

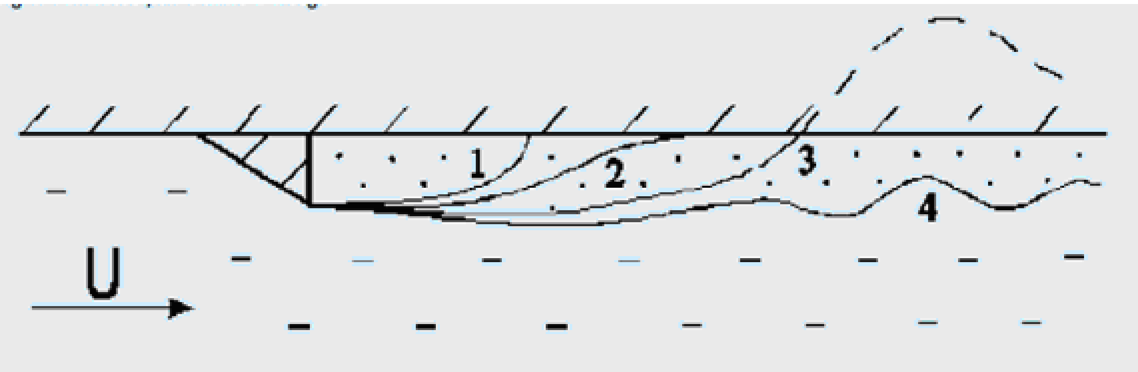
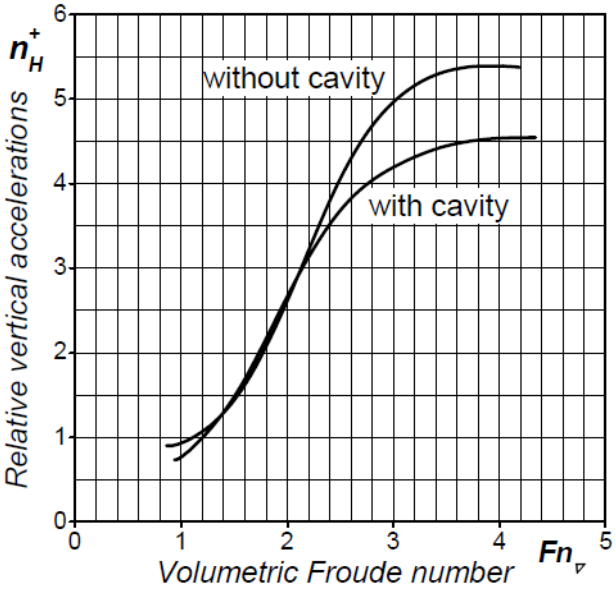


Fig. 4 – Ventilated flow behind a wedge

A characteristic feature of cavity 1 is the formation of a pulsating re-entrant jet in the tail part of the cavity, while the cavity boundary close to the wedge remains stable. This flow is similar to usual cavitation and ventilation with a positive cavitation number in the absence of a horizontal wall. Shape 2 is associated with a flow mode when no re-entrant jet is present, and the tail of the cavity attaches smoothly to the plate. In this case, the cavity-maintaining gas flow, as well as the cavitation drag, is theoretically equal to zero.

Pressure inside the cavity exceeds that in the undisturbed flow, making the cavitation number negative. The peculiarity of shape 3 is that in theory the cavity pierces the plate at its aft end (as shown by the dashed line). During tests, strong pulsations are observed all over the cavity in this case, as in overventilated flows with positive cavitation numbers. This regime is realised at high gas consumption. The formation of an unclosed cavity 4 is also possible under certain conditions; however, the power needed for air injection is too high to make this regime attractive for practical drag reduction. Thus, the flow mode that produces cavity 2 is the most promising. As shown by calculations and verified in experiments, the cavity length in this case scales as the flow velocity squared. Cavity geometrical characteristics, and a cavitation number corresponding to this most favorable situation, are called the limiting parameters. Successful ACS's are designed to operate in this regime.

The idea of drag reduction by air lubrication is also applicable to relatively slow vessels, such as tankers and cargo ships. However, due to the stability limit on cavity dimensions, a different arrangement of air cavities must be employed. If the ship length is large and its speed is not sufficiently high, an entire bottom of the vessel cannot be covered by a single cavity. This explains unsuccessful attempts to reduce drag by supplying gas through only a single nozzle in low speed regimes. Several air cavities (up to 7-8) must be created on a slow ACS operating in a displacement mode.



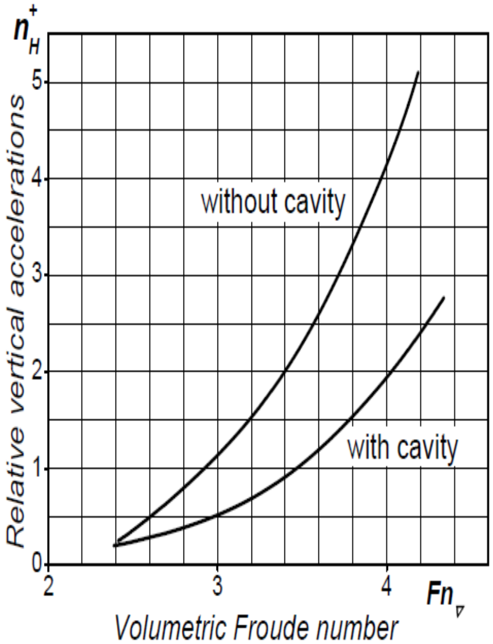


Fig. 5 - Results of comparative model tests of a 32-ton planning craft in head waves in sea state 4.

Fig. 6 - Results of comparative model tests of a 32-ton planning craft in follow waves in sea state 4.

Figures 5 and 6 show the results of comparative model tests of a 32-ton planing craft in head and following waves in sea state 4 (significant wave height 2 m, wave length 35 m). Two options were tested: model with initial (smooth) hull lines and The test data show that the air cavity provides reduction in heave accelerations by 10 ~ 50%.

The sea-keeping performance of air-cavity boats is comparable with the fixed-hydrofoil ships. It is not surprising that the cavity improves sea-keeping performance because a significant part of the rigid bottom surface subject to wave effects is covered with easily compressed air preventing the waves to impart their energy to hull.

Improvements in Propeller Efficiencies

Over the years, a variety of propeller designs has appeared and been manufactured. Each design has its own benefits, characteristics and drawbacks. These designs have been refined with experience and with the emergence of new design tools. Operators have their own preferred types of propellers. Some consider three bladed propellers to be more efficient than four bladed propellers and have cited improvements in fuel consumption as a result of changing.

Some of the most relevant propeller designs are briefly described below:

☐ **Fixed Pitch Propeller (FPP)** -This covers the major proportion of propellers and design types and sizes, ranging from propellers for small powerboats to those for large tankers and bulk carriers. These propellers are easy to manufacture

☐ **Controllable Pitch Propeller (CPP)** - This is more flexible than a Fixed Pitch Propeller due to flexibility of its control and ability to change blade pitch rather than propulsion efficiency. It has found most application on ferries, tugs, trawlers, and fisheries because of the improved maneuverability compared to that provided by a FPP. However, its manufacturing cost is higher than that of a FPP. It also requires more maintenance.

☐ **Ducted propeller** – These consist of two components, an annular duct having an aerofoil cross section and a propeller inside the duct. The presence of duct reduces the pressure forces induced on the hull; the duct also protects the propeller against damage. Propeller efficiency is increased depending upon the propeller loading and improvements of between 1% and 5% compared to an open propeller are quoted

☐ **Contra Rotating Propeller (CRP)** - This kind of propeller has two coaxial propellers sited one behind the other and rotating in opposite directions. It has the hydrodynamic advantage of recovering part of the slip stream rotational energy which would otherwise be lost to a conventional single screw system which leads to an energy saving about 15% in power. A more detailed description of this propeller configuration is given later in this Section.

Propeller Boss Cap Fins (PBCF)

Propeller Boss Cap Fins are small fins fitted to a propeller's boss cap and are made of the same material as the Boss Cap; they can be easily installed in the same way as the Boss Cap and have been available since the late 1980s. The PCBF was developed jointly by Mitsui OSK. Lines, West Japan Fluid Engineering Laboratory Co. Ltd. and Mikado Propeller Co. Ltd .They have been fitted on Mitsui OSK Lines vessels. Actual measurements on over 60 ships have shown benefits of 4-5% in fuel saving and an increase in speed of about 2%.

Fig. 7 – Comparison Propellers with and without PBCF

The fins are intended to reduce the energy lost into the hub vortex .Without the fins, the flow of water around the propeller generates a hub vortex that wastes almost 10% of the engines energy; the fins help to reduce this effect. Other benefits include a reduction in stern vibrations, reduction of propeller noise and acoustic equipment. The latter makes them particularly suitable for oceanic research vessels. The fins can also be installed on
controllable pitch propellers are used on fast ferries and RoRos which benefit from the
reduction in fuel consumption and increase in ship's speed.
More than 1,500 ships had been fitted with Propeller Boss Cap Fins up to 2008

Kappel Propellers

Propulsion efficiency of a marine propeller can be increased with tip fins. A five year EC funded project under the BRITE-EURAM Programme (BRPR970458) investigated the potential of a concept applied to aircraft wings to improve the performance of marine propellers. The KAPRICCIO project, entitled 'The Kappel propulsion concept –improving energy efficiency and reducing the environmental impact' was completed in 2002. The cost increase in production over a conventional propeller was estimated to be about 20% and the mathematical and physical modeling carried out in the project indicated that it is realistic to expect fuel savings of up to 7% compared with a well designed conventional propeller.

A number of commercial airliners now feature non-planar wings and have winglets at the wing tips giving increased performance from the airfoil wing resulting in improved fuel consumption and a greater operating range. The unique feature of the KAPPEL propeller is that the theory of non planar wings and winglets has been applied to marine propellers and applied to a propeller concept where the propeller blade and "winglet" are designed as one integral curved blade to reduce the energy losses inevitably present at the ends or tips of airfoil devices.

Fig. 8 - The illustration above shows the 14 tonne Kappel propeller unit fitted to the “Nordamerika” of Norden A/S just prior to trials that demonstrated savings of 4%.

REFRENCES

1) SEVENTH FRAMEWORK PROGRAMME SST–2007–TREN–1 - SST.2007.2.2.4. Maritime and logistics co-ordination platform

2) Matveev, K.I., 2005, Application of Artificial Cavitation for Reducing Ship Drag, Oceanic Engineering International, 9(1), pp. 35-413#

3) Matveev, K.I., Air cavity ships are ready for a wider market, http://docs.hydrofoils.org/SAS03.pdf

4) INTERNATIONAL CONFERENCE ON SHIP DRAG REDUCTION (SMOOTH-Ships)
Application of Air Cavities on High-Speed Ships in Russia - A.V. SVERCHKOV