Reducing Fuel Consumption In Shipping Via Propulsion Efficiency

Alternative Methods To Reduce Resistance and Improve Propulsion

Shipping is vital to the world economy there is no question on that. 95% of the world's goods are moved by sea.

Economically shipping has been to date an essential and efficient means of goods transport. But environmentally the future of shipping raises some serious concerns that could throw the shipping sector into flux.

A shift in environmental consciousness has resulted in stringent regulations from MARPOL Annex VI, the International Maritime Organisation (IMO), as well as others that aim to restrict **sulphur emissions to 0.5%** and reduce **greenhouse gas emissions by 50%** by 2020 and 2050 respectively.

The impact of these impending regulations has resulted in a significant rise in fuel prices. And with current fuel costs accounting for as much as 60% of total operating costs ships need to seek new means to reduce their fuel consumption. Otherwise, they risk high fuel costs cutting into their profits and harsh consequences from the regulators for failing to comply.

To address these issues a solution that is being explored further are **energy-saving devices** that help reduce fuel consumption and therefore, cut costs.

Energy-Saving Devices To Improve Shipping

Efficiency

There is a considerable range of energy-saving devices available for ships that focus on the optimisation of ship design, or make use of and improve upon, certain elements already in place.

When fully integrated with primary propulsion these devices aim to improve the hydrodynamic interaction of the flow around the hull and/or the propulsion efficiencies of the propellers. In turn, reducing fuel consumption and emissions under the correct circumstances.

Want to know more about fuel alternatives in the marine industry? Read our blog: The Shipping Industry's Slant On Alternative Marine Fuels

The implementation of these devices is primarily dependent on the ship type, size, and operational purpose. Some devices may be incompatible with other already placed modifications, some may not. These devices are being integrated through retrofits to the existing fleet or incorporated into new shipbuilding and design.

Ultimately these energy-saving devices intend to reduce fuel consumption by addressing two main aspects of ship efficiency:

1. **The improvement of propeller propulsion effectiveness**
2. **Reducing hull frictional resistance**

Improving Propulsion Efficiency With PIDs

The majority of propellers available for marine vessels fall under three classes - fixed pitch propellers, controllable pitch propellers, and ducted propellers.

Ultimately propeller efficiency comes down to having a favourable wake flow and low energy losses from propeller rotation.

Various devices have been designed to recover as much of this rotational energy that often gets lost, and to promote favourable wake flow to obtain maximum thrust from the propeller and therefore save energy and reduce fuel consumption.

Propulsion improving devices (PIDs) are different ducts, fins, nozzles, bulbs or other modifications made to the hull or propeller in order to improve efficiency.

Alterations take place in front of the propeller as pre-swirl devices that aim to improve the propeller inflow conditions. Or behind the propeller as post-swirl devices which are used to recover parts of the rotational energy in the propeller slipstream.

Pre-Swirl Devices

Pre-swirl devices are hydrodynamic appendages to the hull ahead of the propeller that generate a wake flow opposite to that of the propeller. This improves the angle of the flow onto the propeller blades which in turn experience this as an additional blade loading, increasing the thrust.

The pre-swirl rotating flow also counteracts the rotation flow induced by the propeller, reducing the kinetic rotational energy in the flow behind the propeller, leaving less rotation in the final slipstream.

Pre-swirl fins and stators

Pre-swirl fins and stators are sets of fins or blades arranged directly in front of the propeller which adds to the ship's resistance instead of increasing forward thrust.

However, what they do is generate an asymmetric swirl from the blades which creates a more favourable wake in which the propellers can rotate, thereby increasing efficiency.

Grothues fins, also known as Grothues spoilers, are small curved triangular plates welded on both sides of the hull in front of the propeller and above the propeller axis.

Their function is to straighten the flow before it enters the propeller plane. They do this by deflecting the flow down so that it is re-directed axially towards the propeller, improving the propeller efficiency. They may also provide a limited amount of thrust as a result of the redirection of vertical flow components in the horizontal direction.

However, when the Grothues spoilers are not in the correct position their effect is actually a negative one as there is an increased risk of flow separation, skin friction or parasitic drag. Even if they are in the correct position Grothues spoilers have a drag of their own that may outweigh the gain in propeller efficiency that they ideally provide.

Accelerating ducts

One of the oldest examples of propeller energy-saving devices is the Kort Nozzle ducted propeller.

Consisting of a screw propeller surrounded by a non-rotating duct which allows an increase inflow to the propeller (additional thrust load) - thus improving propeller efficiency.

Still actively used on vessels, however only for those that require high thrust and travel at slow speeds. This is due to the nozzle adding drag as speeds increase.

The **Schneekluth Wake Equalising Duct** and the **Mewis Duct** are both examples of adaptations from the Kort Nozzle design which have been developed to handle larger vessels.

Schneekluth ducts are added to the hull in front of the upper part of the propeller, it consists of two aero foils halfring ducts and is used to create a more uniform inflow into the propeller. It does this by accelerating the flow in the top part of the propeller disc, while minimising the amount of flow separation at the after body, generating additional trust, achieving a much more uniform wakefield, and improving hull efficiency.

A **Mevis duct** is the combination of a wake equalising duct and an integrated pre-swirl fin. The duct straightens and accelerates the inflow and the fins reduces slipstream losses resulting in an increase in propeller thrust.

Post-Swirl Devices

Post-swirl devices condition the flow at the aft end of the propeller to minimise slipstream losses.

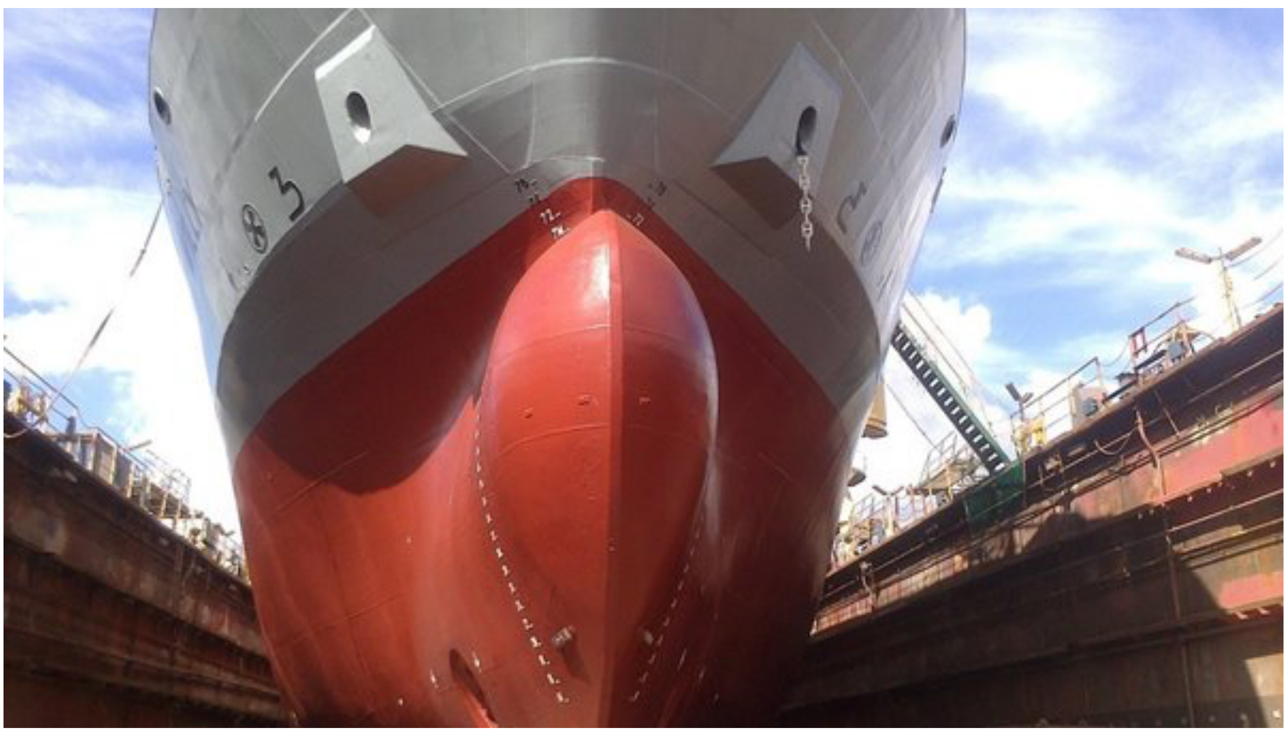
This often means converting the rotational flow created by the propeller to axial flow. Or, in other situations it is a matter of suppressing detrimental flow characteristics (such as the propeller hub vortex) or diverting it to improve rudder efficiency.

The most common of these devices are post-swirl fins, wheels, bulbs, and twisted rudder.

Rudder thrust fins, **post-swirl stators** and **asymmetric rudder** all work to deflect the flow from the propeller to turn its rotational components into axial flow.

Rudder bulbs, **Propeller Boss Cap Fin (PBCF)**, and **Divergent Propeller Caps** work to condition the radial distribution of the flow behind the propeller near the hub, to reduce the losses associated with high rotation and the creation of a strong vortex in this area.

The **grim vane wheel** rotates immediately behind the propeller. The vane wheel has a bigger diameter than the main propeller and increases the propeller diameter. The main smaller propeller drives the freely revolving vane wheel fitted on the wake. The inner part of the vane wheel acts as a turbine and the outer part as an “additional” propeller which generates additional thrust. This leads to a substantial recovery of the rotational energy.



Reducing Hull Resistance

The hydrodynamic performance of a vessel depends largely on the frictional and pressure resistance of the hull moving through water.

Pressure reduction can be achieved through retrofit improvements to the shape of the vessel using hull form optimisation techniques. Or, new designs can be developed with the aim to reduce wave resistance already in place.

The largest component of resistance comes from frictional resistance - approximately 70-90% of the total resistance. It requires surface improvement methods such as applying **antifouling coatings**, and **air lubrication techniques** to reduce turbulent flow in the boundary layer.

Hull optimisation is vital to reduce fuel consumption because hull performance directly affects the speed and power consumption of a ship.

Hull form optimisation

As stated viscous (frictional) resistance accounts for the largest part of the total resistance, this is especially true in slower speed vessels. Whereas, for high-speed ships, wave-making resistance makes up a larger component of the overall resistance.

Different **bow optimisations** can improve water flow around the hull and reduce wave resistance.

When developing a full-body hull form such as a tanker, the emphasis is placed on reducing the wetted surface as well as providing a smooth and gradual transition to the propeller.

This encourages the LCB to be as far forward as practical, mitigating wave propagation at the forward shoulder. Employing blunter bow shape is encouraged over finer bows as blunt bows tend to accommodate a smoother transition.

For higher speed hull forms, wave-making is more significant.
In this circumstance, the slender hull allows the LCB to be moved aft while still maintaining good flow into the propeller. This enables a reduced entrance angle and softer forward shoulders. The bulb on a containership will be elongated with finer shape to reduce wave-making resistance.

Hull coatings

One of the simplest methods to reduce friction resistance is to apply a coating on the ship hull that minimises its physical and biological roughness.

Hull roughness depends on the type of coating, the amount of rust, fractures in the coating, and fouling. Some are permanent eg. the weld seams and steel surface, and some are temporary eg. the fouling and deposits that build up.

Marine bio-fouling is defined as the undesirable accumulation of living organisms and biogenic structures on the ship hulls and other submerged surfaces including slime, algae, barnacles, tubeworms and mussels.

These organisms immediately attach to the immersed surfaces and grow until several months after immersion. The ability of marine fouling to settle and grow depends on factors such as salinity, pressure, and nutrient levels as well as the physical properties of the surface such as roughness and colour.

The most common method to not only smooth out the surface but to also minimise the growth of marine organisms is to use **antifouling coatings and paints**.

Antifouling paints prevent the growth of fouling organisms by releasing biocides. However, they were extremely detrimental to the environment and were eventually banned. New alternatives such as tin-free coatings, silicone-based foul release coatings, hydrophilic marine antifouling coatings, and hydrophobic foul-release coatings have appeared on the market to address this concern.

Something as simple as hull coatings are said to be capable of saving fuel consumption on average 5%.

Air Lubrication

Air lubrication techniques are gaining awareness as an alternative method that effectively reduces frictional resistance by improving the viscous behaviour of the water in contact with the hull.

This is done through the injection of low-pressure air into the boundary layer of the wetted surface to either develop a microbubble interface, or form an ‘air cushion’ or ‘blanket’ between the hull and the water.

An automated system will regulate the compressors generating air bubbles at the required pressure and rate to pass continuously beneath the ship’s surface with outlets symmetrically on both sides. The system ensures a uniform layer of air bubbles which reduces the drag and resistance between the ship and the water.

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