Fuel saving by hydrodynamic design

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Soaring fuel costs and the growing need for sustainability has caused an unprecedented demand for a reduction in fuel consumption. Report asks if fuel consumption can be reduced further, and if so, by how much?

The focus of MARIN propulsion research is on further exploration of possibilities to improve propulsive efficiency. One option is to reduce the margins of cavitation nuisance for the benefit of efficiency.

When speaking about measures that can be taken to improve the hull performance, the reduction of the wave and frictional resistance are the main aspects. To minimise wave drag, special attention has to be paid to the design of the bulbous bow and the fore and aftbody shape.

The design of the bulbous bow should lead to optimum interference between the wave pattern of the bulbous bow and the forebody. Optimisation work is conducted by means of CFD computations such as MARIN's potential flow code RAPID. In the past, the bulbous bow was mainly optimised for the trial speed and design draught but off-design conditions are becoming ever more important considering the current fuel price,. The operational profile of the ship has to be taken into account in an early stage and the bulbous bow has to be developed for an often, lower design speed, a wider range of operating speeds and draughts. Of course, the possible drag penalty at the trial conditions has to be minimised.

When optimising the aftbody optimisation for low power requirements, the shape of the buttocks and the transom stern have to be carefully investigated. Additionally, the effect of ducktails, trim wedges or flaps (and sometimes interceptor plates) will be studied by means of model experiments. Resistance reductions of approximately 5 to 10% are often achievable.

Currently, there is a focus on frictional drag reduction in research. Modern anti-fouling paints and a good quality hull (smooth welding etc.) play an important role in reducing drag. Air lubrication is promising for ships with quite a large wetted surface and a large flat bottom. MARIN is involved in applied research projects on air lubrication (PELS I & 2, SMOOTH), as well as more fundamental research into the very mechanisms of air lubrication.

Evolutionary developments

When speaking about increasing the efficiency of the propulsor system, there have been two developments: evolutionary and revolutionary.

Although propellers are regarded as reasonably efficient in transforming mechanical engine power into thrust power with efficiencies mostly in the range of around 70% , significant energy losses are still incurred.

Propeller efficiency that can be attained in practice is limited by the conditions imposed by the shipowner and the hull. The propeller diameter for example, is restricted by the operational draught restrictions, allowing for minimum propeller-hull clearances. This clearance is typically set at a fixed percentage of the diameter (often some 20-25%), as to ensure acceptable vibrations in the aftbody. This same constraint on vibrations causes a limit to the radial loading distribution of the propeller as well, also limiting efficiency.

Another limit is posed by the cavitation erosion criterion, requiring a certain minimum blade area but thereby also increasing the frictional losses of the propeller. The number of blades has for practical blade numbers, hardly a bearing on efficiency. The most important excitation frequencies are well outside the natural frequency of the propeller-shaft-engine system and the resonance frequency of the superstructures. Reducing the number of blades could however, in some cases where the rotation rate is fixed, be beneficial because of the significantly higher efficiency of these propellers due to their larger optimum size.

MARIN is working towards exploiting the niches in the propeller-hull design space for improvement of the efficiency at equal levels of comfort (pressure fluctuations) and safety (erosion risks). One example is its participation in the CRS project, ECONSHIPS, in which a tool is developed for a new energy loss analysis and consequent minimisation of losses for the propeller in the "behind ship" condition. Another example is the coupled hull-propeller optimisation through CFD studies such as the recent coupling between the propeller panel code PROCAL and the hull RANS code, PARNASSOS, was successfully tested for its capability to produce realistic propeller induced pressure fluctuations. This capability is necessary to optimise propeller-hull efficiency with regard to vibrations in the aftbody.

MARIN invests in these tool developments because it believes that the overall propulsive efficiency of conventional propeller driven hulls can be improved by 5 to 10%, if the joint propeller-hull design is optimised and the margins against cavitation are used more effectively.

This article has given a sneak preview into evolutionary developments of the propeller-hull design but MARIN is not losing sight of the potential of revolutionary propulsors. Examples of which are fishtail propulsion and auxiliary kite propulsion, which bear the promise of improving fuel consumption by some 20 %. MARIN

1 This excludes the typical inland waterway efficiency which is more of the order of 50%