SIEMENS DIGITAL INDUSTRIES SOFTWARE

Energy saving devices: A cost-effective and energy-efficient solution for the marine industry

Alejandro Caldas, Constantinos Zegos & Chris Craddock
Lloyd’s Register

SIEMENS

Introducing energy saving devices

In order to reduce fuel costs and comply with increasingly stringent environmental regulation on emissions of air pollutants such as SOx, NOx, and CO_2, ship owners and operators are constantly looking for innovative, energy-efficient, and cost-effective solutions. One popular solution is to employ Energy Saving Devices (ESD) in order to improve the hydrodynamic performance of vessels through active or passive flow control. Such devices fall into two categories:

1. Those that aim at reducing the resistance of the vessel;
2. Those that aim at improving the propulsion performance. This can be achieved through improvements of the propulsion system itself, for example with Propeller Boss Cap Fins (PBCF), or through the use of systems that improve the hull-propulsion interaction, such as pre-ducts.

This article focuses on the second group of devices. Although the advantages of applying those technologies are clear, a few challenges need to be overcome in the design process.

The case for CFD

The two main challenges with designing ESD's are as follows:

1. Since the performance of ESDs is strongly linked to the Reynolds number (Re), their design cannot be based on scaled models in a ship model basin, where the difference in Re is usually two orders of magnitude.
2. ESD design should be robust, i.e. improving the performance over the operating profile of the ship and not only for one condition. This forces designers to investigate a large number of operating points in order to ensure that the device is effective across the operating profile.

The use of Computational Fluid Dynamics (CFD) applied to the design and assessment of these devices is vital since it allows the computations to be carried out at full scale (same Re). In addition, a wide range of solutions can be investigated without having to construct any physical model of the device.

Case study

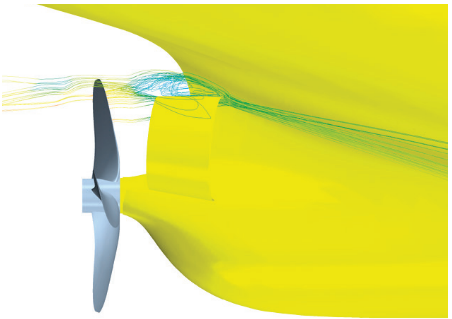


Figure 1. Flow behavior around the duct in scantling draught (13.3 m draught)

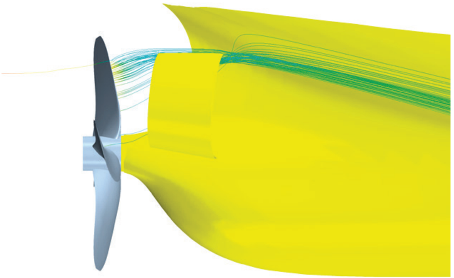


Figure 2. Flow behavior around the duct in ballast draught (6.73 m draught)

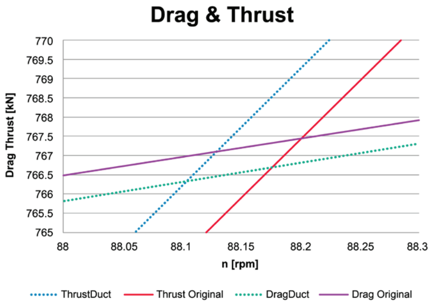


Figure 3. Using the pre-duct - Comparison of drag and thrust versus rotation rate for the original and modified designs in design draught

A case study of a 60,000 DWT bulk carrier was carried out. Three types of ESDs were tested using Simcenter™ STAR-CCM+™, namely pre-ducts, twisted rudders and PBCF. Those devices improve the overall performance of the vessel by interacting with the propulsion system, thereby reducing the amount of rotational losses. The effect of each ESD on the propulsion performance and on the hull-propulsion interaction was calculated for six operating points, including three draughts (ballast, design and scantling), and two speeds per draught.

Pre-ducts

In order to find the best pre-duct design for the 60,000 DWT bulk carrier, the duct geometry was fully parameterized using the CAD tools in Simcenter STAR-CCM+. A total of seven parameters were used to define the duct: diameter, relative position (two constraints), contraction angle, length, thickness, and profile shape.

As can be seen from the streamlines shown in Figures 1 (scantling draught) and 2 (ballast draught) for an initial design, the performance of the duct was found to be relatively sensitive to the hull draught. In scantling draught, the duct is not aligned with the flow, resulting in a turbulent wake and loss of rotational energy. This can lead to a bad performance of the propeller and even cavitation. In ballast draught, however, the flow remains aligned to the duct, resulting in a better performance of the propeller.

The effect of the duct upon the propulsion is quantified in Figure 3 for different propeller shaft speeds around the equilibrium point (where the propeller thrust is equal to the hull drag). It appears that the duct has an impact over the hull drag but also over the propeller performance. In this case, a slight reduction of the hull drag and an increase of the propeller thrust for the same rotational speed occurs. The shift of the equilibrium point shows a decrease in rotational speed and hence a reduction of the engine power delivered.

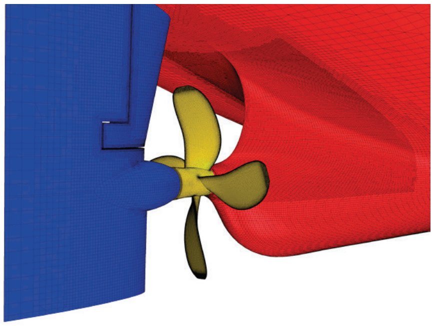


Figure 4. Geometry and trimmed mesh of the twisted rudder with costa bulb

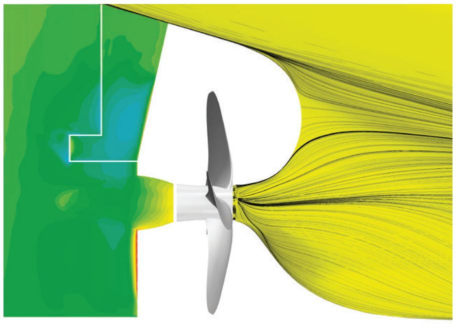


Figure 5. Flow behavior on the propeller and rudder when using a twisted rudder with costa bulb

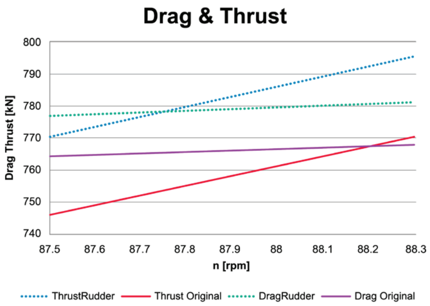


Figure 6. Using the twisted rudder - Comparison of drag and thrust versus rotation rate for the original and modified designs in design draught

Twisted rudder

Similar calculations were carried out for the twisted rudder with costa bulb, whose design is shown in Figure 4. The rudder geometry was also parameterized using the CAD tools in Simcenter STAR-CCM+ and tested over the operating profile previously defined. The design parameters included the rudder profile length, thickness and leading edge camber distribution, bulb diameter and length.

The effect of the rudder geometry on the propulsion performance is illustrated in Figure 5 and quantified in Figure 6. The later indicates an increase of both the propeller thrust and the hull drag (rudder drag included). However, the overall effect is a reduction of the delivered power as the equilibrium point is at lower rotational speed when compared to the original case. In addition, the performance of the device was found to be relatively stable over the operating profile, as can be seen in Figure 10.

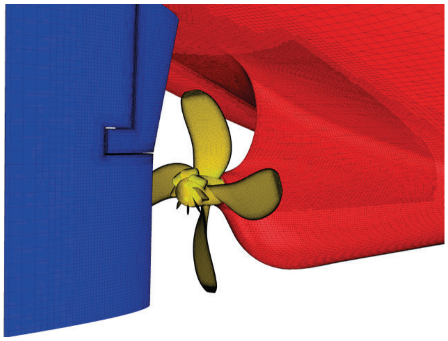


Figure 7. Geometry and trimmed mesh of the propeller boss cap fins

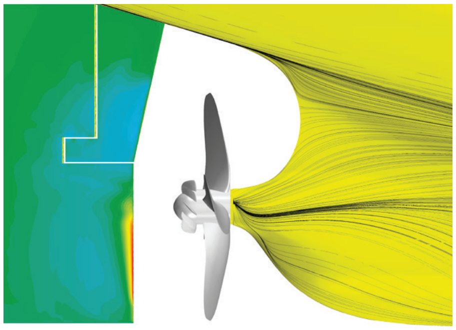


Figure 8. Flow behavior around the propeller and rudder when using propeller boss cap fins

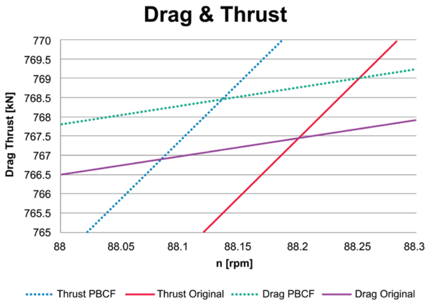
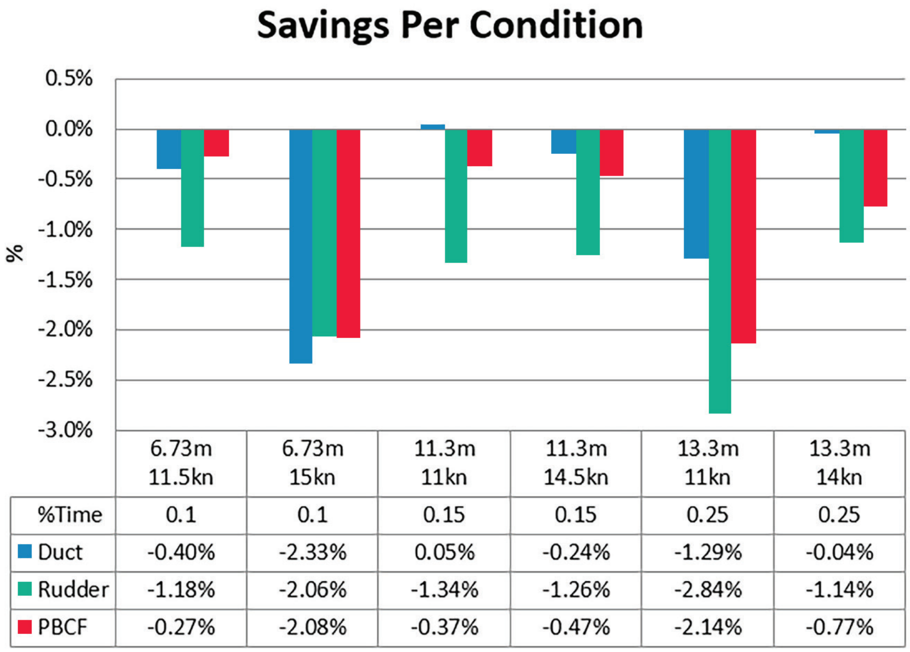


Figure 9. Using the propeller boss cap fins - Comparison of drag and thrust versus rotational speed for the original and modified designs in design draught

Propeller boss cap fins

Similar calculations were carried out for the PBCF, whose design is shown in Figure 7. The PBCF geometry was also parameterized in Simcenter STAR-CCM+ and tested over the operating profile previously defined. The parameters included the profile length, thickness and camber distribution, number of blades and relative position to the propeller.

The effect of the PBCF geometry on the propulsion performance is illustrated in Figure 8 and quantified in Figure 9. The latter indicates an increase in both the propeller thrust and the hull drag. However, as with the twisted rudder design, the overall effect is a reduction of the delivered power as the equilibrium point is at lower rotational speed when compared to the original case.



	6.73m 11.5kn	6.73m 15kn	11.3m 11kn	11.3m 14.5kn	13.3m 11kn	13.3m 14kn
%Time	0.1	0.1	0.15	0.15	0.25	0.25
🟦 Duct	-0.40%	-2.33%	0.05%	-0.24%	-1.29%	-0.04%
🟩 Rudder	-1.18%	-2.06%	-1.34%	-1.26%	-2.84%	-1.14%
🟥 PBCF	-0.27%	-2.08%	-0.37%	-0.47%	-2.14%	-0.77%

Figure 10. This graph shows the percentage of time allocated to each operating point and the overall savings achieved at each of these points using the three types of ESD.

Conclusion

The aim of this study was to analyze the influence of three tailored ESDs on the performance of a new 60,000 DWT bulk carrier in order to select the best option to be fitted to the vessel. The overall savings per condition, as well as the percentage of time spent on each operational condition are summarized in Figure 10. It was found that the twisted rudder with costa bulb was not only the ESD with the most consistent performance, but also the modified design that led to the highest overall power reduction. The analysis also showed that the performance of the pre-duct ESD was the most sensitive to operating conditions. This suggests that this device could give good results for specific conditions but for wider operating profiles such as the one presented the applicability is reduced. Consequently, it would appear that the pre-duct would be best suited for vessels that sail within relatively small draught and speed ranges.

The use of CFD applied to the design and assessment of ESDs is vital since it allows the computations to be carried out at full scale (same Reynolds number). In addition, a wide range of solutions can be investigated without having to construct any physical model of the device.

Siemens Digital Industries Software

Americas: 1 800 498 5351

EMEA: 00 800 70002222

Asia-Pacific: 001 800 03061910

For additional numbers, click here.

About Siemens Digital Industries Software

Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. Xcelerator, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, helps companies of all sizes create and leverage a comprehensive digital twin that provides organizations with new insights, opportunities and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit siemens.com/software or follow us on LinkedIn, Twitter, Facebook and Instagram. Siemens Digital Industries Software – Where today meets tomorrow.

siemens.com/software

84103-D2 8/21 SF