EEXI Simulation Demonstrator

Cape Horn Engineering

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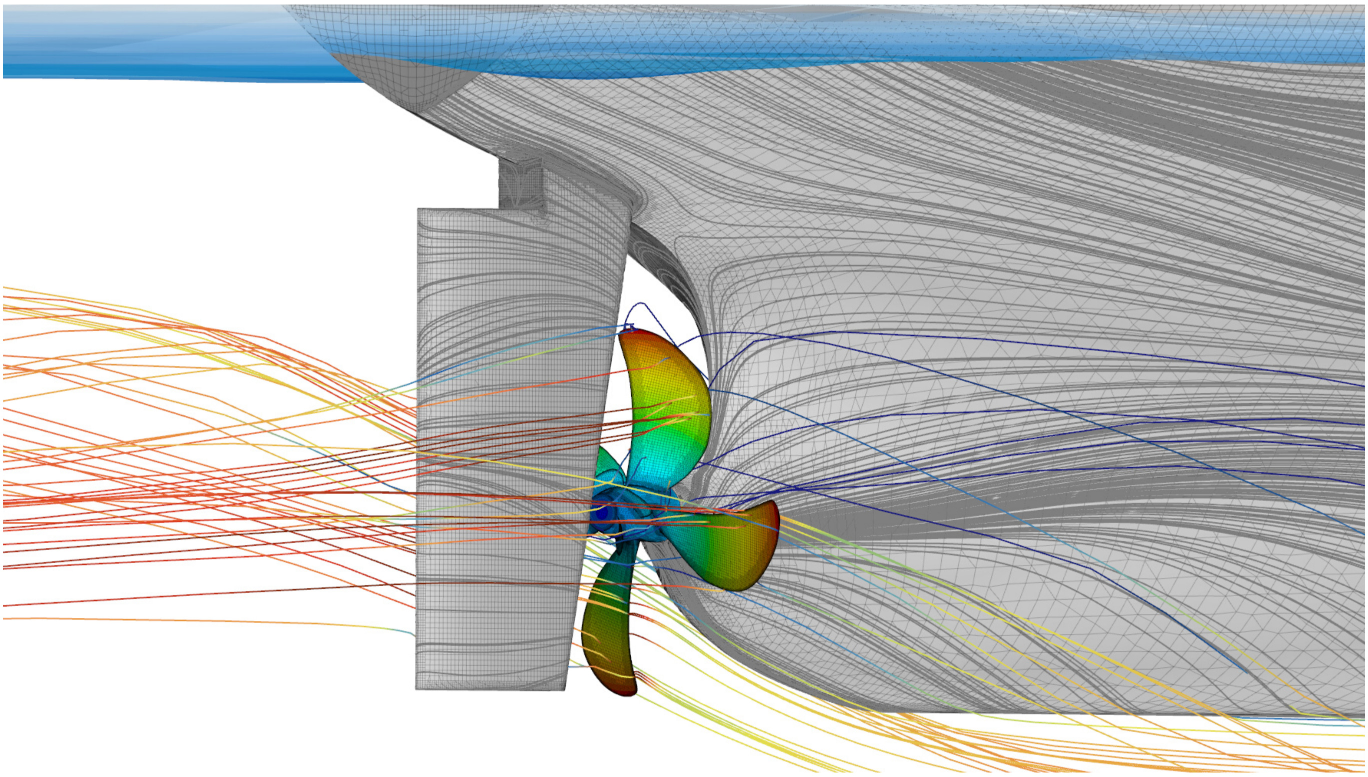


Service Description

Global efforts to reduce the environmental impact of the shipping industry have accelerated rapidly in recent years, with new measures by the International Maritime Organisation (IMO), such as the Energy Efficiency eXisting Ship Index (EEXI), and Energy Efficiency Design Index (EEDI) for new designs, set to come into force in January 2023.

From 2022 the IMO accepts Computational Fluid Dynamics (CFD) as a mean to provide the vessel reference speed needed in the EEXI/EEDI calculation. Prior to this, only towing tank tests were accepted with numerical simulations seen as a secondary option "under special circumstances".

Cape Horn Engineering has been lobbying for many years for CFD simulations to achieve the accredited status necessary to become the preferred method to demonstrate the ship performance. There are many reasons why running a CFD programme is superior to utilising towing tanks. Not only are there huge time and cost benefits, fundamental to any project, but CFD also benefits from running simulations in a 1 to 1 scale, removing any errors or uncertainties when applying scaling effects from model scale to full scale.

One of the default methods accepted by IMO for calculating the EEXI/EEDI reference speed is to use an empirical formula that takes into account the ship type and installed power. This is a quick and dirty procedure, however this speed will be conservative since the formula includes a penalising margin factor. Thus, it is beneficial to calculate a precise reference speed with CFD as this will aid compliance and makes the vessel more commercially viable.

Cape Horn Engineering has specialised in EEXI/EEDI calculations based on high-fidelity RANS CFD. Today we can offer EEXI/EEDI calculations in a very efficient and cost effective manner, having developed validated workflows and Best Practice Guidelines in conjunction with a leading classification society (Lloyds Register). These workflows have to comply with a strict set of directives and recommendations from the International Towing Tank Conference (ITTC) and the International Association of Classification Societies (IACS).

The ITTC recommendations are concerned with the "Quality Assurance in Ship CFD Application" and describe how the Validation and Verification (V+V) process has to be performed. They also set the requirement for the organisations delivering the CFD results to formulate and document their own version of Best Practice Guidelines.

The IACS guidelines outline the process for determining the reference speed for use in the EEXI calculation. The guidelines establish a set of criteria which the CFD organisations need to fulfil for the "Demonstration of Qualification" and also detail how the validation and calibration of the CFD results has to be demonstrated and documented for each new project.

The Demonstration of Qualification requires that the CFD organisations have conducted Verification and Validation on a set of comparable ships and that they can demonstrate this with supporting documentation. See following sections to read more on this.

In general the EEXI calculation consists of 2 phases; the Verification and Validation to determine a "valid correlation factor", and the computation of the new speed-power curve for the EEXI certification at full scantling condition. The first phase is needed to assess the numerical and modelling uncertainty. Depending on the vessel in question, it can be conducted using existing measurement data from model tests or from sea trials, with sea trials being our preferred option. Sea trials are usually performed at draft ballast. The CFD simulations have to be performed for at least one of the conditions documented in the sea trials, usually the one that is closest to the EEXI condition, for example for 75% MCR. The difference between the simulated results and the measured ones then has to be assessed, to determine the 'modelling uncertainty'. This is also known as the "Validation" process. This difference will be used as a correlation factor to shift the speed-power curve in the full loaded condition to be computed in the second phase.

At the same time, for the same condition, the spatial discretisation (mesh density) and the temporal discretisation (time step used to advance the simulations) have to be varied systematically to determine the 'numerical uncertainty'. This process is also known as the "Verification" process. The spatial and temporal uncertainties are combined to form the total numerical uncertainty. The uncertainty from the sea trials also need to be considered, and if the correlation between CFD and measurements fall within the combined numerical and experimental uncertainties, the solution is considered to be "valid" and the correlation factor can be used in the second phase, see also section below on Verification and Validation.

Finally, after the V+V process is proved to be valid and the speed-power curve is determined, taking into account the correlation factor, the vessel reference speed "Vref" can be interpolated for use in the EEXI formula. This whole process has to be documented following the IACS guidelines for submission to the classification society who will act as the "Verifier" and issue the corresponding EEXI certificate to the vessel.

A similar process will be followed in case the vessel undergoes modification to improve her performance, for instance by installing Energy Saving Devises (ESDs) like asymmetric stern bulbs, nozzles or fins in front of the propeller, fins in the propeller boss cap etc. The CFD V+V will be conducted for the same conditions in the sea trial, usually without the ESDs, and then using exactly the same simulation setup the EDS will be included to calculate the new, improved speed-power curve for the EEXI condition. Thus, CFD is the best way of assessing and demonstrating the savings to improve the EEXI certificate of vessels.

Cape Horn Engineering has experience demonstrating performance improvement using energy saving devices. Furthermore, we have specialised in Wind Assisted Ship Propulsion (WASP), using devices such as wing sails, suction sails, Flettner rotors, or any other wind-powered devices. In the case of WASP, the IMO guidelines dictates that in case that more than one device is installed on deck the forces produced by the devices should take into account their interactions. At Cape Horn Engineering we have specialised in computing such interaction models, making used of advanced machine learning techniques.

Demonstration of Qualification

Table 1 below summarises the recent EEXI projects completed by Cape Horn Engineering. For confidentiality reasons some of the vessel names have been omitted and the main particulars slightly changed. They are in chronological order and as the modelling techniques improve, we obtain more accurate results.

Table 2 gives the comparison of our CFD resistance tests results at model scale with recent high quality towing tank measurements performed at SINTEF Ocean in Norway for the Bulk Carrier SOBC-1 Benchmarking project.

As can be seen in the tables, correlation factors of less than 2% are achievable for the full scale vessel, and even less when replicating the exact towing tank test conditions.

Table 1: Comparison CFD with Sea Trial at Full Scale

Vessel	Type of Simulation	LOA [m]	Delta Delivered power	Delta RPM	Delta Torque
General Cargo Regal	Rotating Propeller	149.30	2.92%	1.79%	1.00%
General Cargo Regal	Virtual Disk	149.30	3.35%	2.24%	1.13%
Bulk Carrier XXX	Rotating Propeller	190	2.10%	1.89%	-
LNG Tanker XXX	Rotating Propeller	300	1.01%	1.20%	-

Table 2: Comparison CFD with Model Tests at Model Scale

Vessel	Type of Simulation	LOA [m]	Delta Resistance
SINTEF Ocean Bulk Carrier SOBC-1	Model Scale Resistance	6.25	0.05%

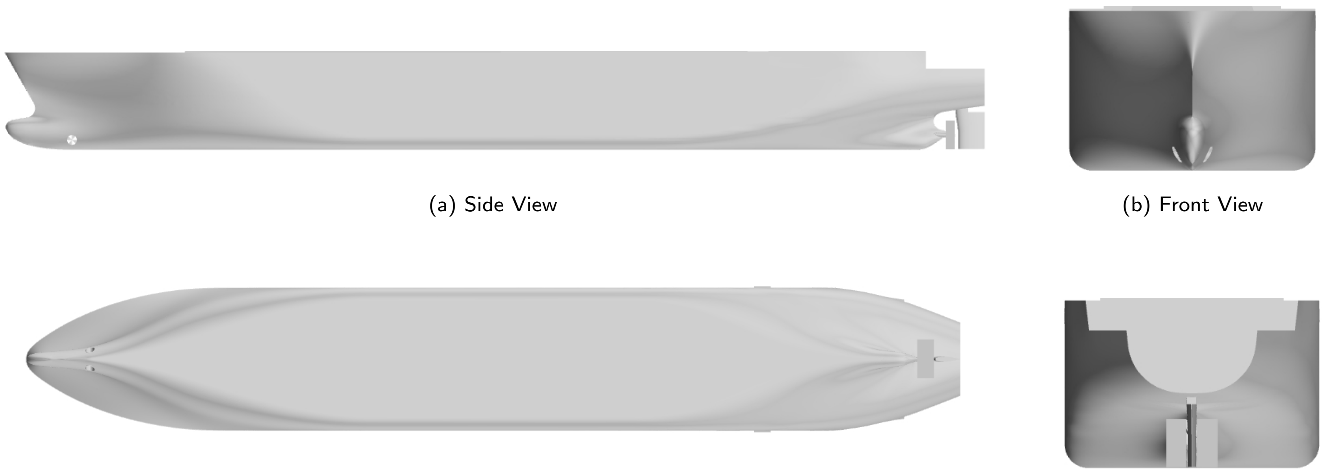
Example of a Verification and Validation Study

Here we present as an example the V+V study for the 300m LNG Tanker XXX using the rotating propeller for self propulsion simulations. A full EEXI V_{Ref} study was conducted for this Tanker with a full assessment of the numerical and modelling errors undertaken.

Some of the vessel particulars are given in Table 3 and Figure 1 displays the vessel geometry in different views. In the simulations the model included the superstructure and tanks on deck to account for the aerodynamic effects, these have been removed in the images. Some information has been redacted.

Table 3: Vessel Particulars

Parameter	Value
IMO Number	XXXXXXX
Launched	200X
Type	LNG Tanker
Length Overall (LOA)	300 m
Breadth	50 m
Design Draft	11 m
Scantling Draft (Moulded)	11.8 m
Service Speed	20 knots
Lightship	30000 Ton
DWT at EEXI Draft	100000 Ton



(a) Side View (b) Front View

(c) Bottom View (d) Rear View

Figure 1: LNG Tanker Geometry

The experimental data used for the V&V procedure was taken from the sea trial report, as supplied by the client. Experimental uncertainty was taken to be the average difference between the two runs completed for each of the sea trial speeds, as no other data was available. This gave uncertainty values that were in line with those of a typical experimental study.

Figure 2 shows a triplet study that was completed to quantify the uncertainty for the spatial and temporal discretisation. Shown in this case are results for propeller RPM. However, similar diagrams are presented to the verifier for propeller thrust, delivered power and dynamic sinkage and trim.

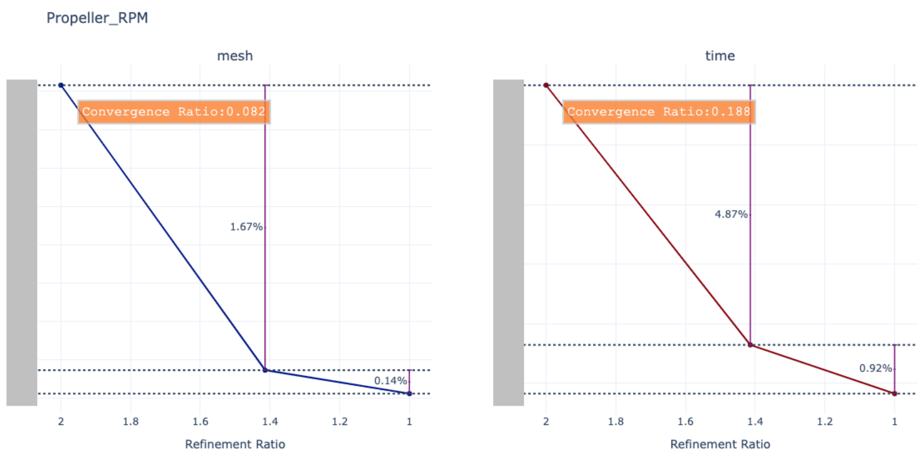


Figure 2: Convergence of Triplet Studies - RPM

The compiled uncertainties are detailed in Table 4. Acceptable levels of uncertainty were found for all parameters, and both the Propeller RPM and the Delivered Power were shown to be Valid as the comparison error is smaller than the validation uncertainty.

Table 4: LNG Tanker Validation Results

	RPM	Delivered Power
Sea Trial Data	XXX	XXX
Sumulation (001_Baseline)	XXX	XXX
Delta	1.05	243700
Comparison Error	-1.2%	-1.01%
Data Uncertainty	0.8%	1.22%
Numerical Uncertainty	1.65%	5.95%
Validation Uncertainty	1.83%	6.07%
Validation	VALID	VALID

The validation of Propeller RPM is presented graphically in Figure 3. In this image the blue point is the sea trial value and the blue error bar are the sea trial uncertainty. The red point is the CFD value and the red error bar is the numerical uncertainty. The difference between the two dotted lines is the comparison error (or difference in the results) and the purple error bar is the validation uncertainty. As the purple error bar is larger than the difference in the dashed lines the simulations are considered valid, according to the ITTC guidelines.

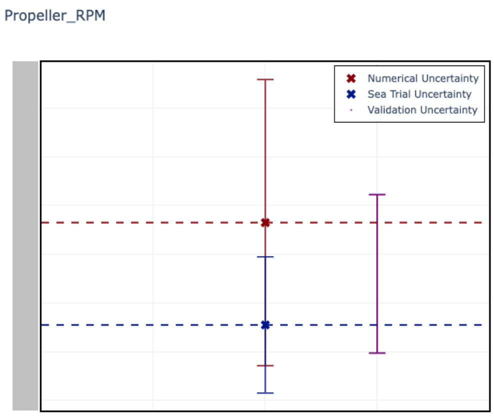


Figure 3: Validation of CFD with Sea Trials