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REDUCTION OF GHG EMISSIONS FROM SHIPS

Prediction and verification of CO_2 emission savings with wind propulsion systems

Submitted by Comoros and RINA

SUMMARY

Executive summary:	This document presents the key findings of a Joint Industry Project on the performance assessment of wind propulsion systems and associated regulatory issues, including EEDI.
Strategic direction, if applicable:	3
Output:	3.7
Action to be taken:	Paragraph 2
Related documents:	MEPC.1/Circ.815, MEPC 62/INF.34, MEPC 74/INF.39, MEPC 75/INF.26 and MEPC 76/7/31

Introduction

1 This document presents the detailed findings of the WiSP JIP in relation to improved performance calculation methods and verification of wind propulsion in the context of regulations on EEDI (and EEXI).

Action requested of the Committee

2 The Committee is invited to note the information provided in this document.

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ANNEX

Details on the Calculation of the Delivered Power by Wind Propulsion System

Performance of wind propulsion in EEDI (and EEXI)

1 A key objective of the WiSP Joint Industry Project was to develop improved and transparent prediction methods. Although the scope of the methods was not constrained for use in the EEDI (or EEXI) context, the starting point was MEPC.1/Circ.815. It is so far the only industry standard for the prediction of wind propulsion performance. However, it lacks critical details on how to carry out performance predictions. This results in considerable uncertainty in performance prediction when following that framework. An improved performance prediction methodology has been developed, as discussed below. Numerous case studies were performed using several reference vessels, including many systematic changes in modelling for different wind propulsion systems (Rigid Sails, Flettner Rotors, etc.). The main reference case vessels are shown in Figure 1.

			
"WASP-Ecoliner" 11850tΔ general cargo concept with Dynarigs	"MHTC" 4041tΔ coaster concept with rotors	"New Vitality" 306751 tdw tanker sailing with airfoils	"Maersk Pelican"[1] 109647 tdw tanker sailing with rotors

Figure 1: Main reference case vessels

2 The results from these studies were used for the development of recommended methods for prediction of performance of wind propulsion in steady conditions. The methods were tested using the reference case vessels; the selected methods show good accuracy when compared with the most accurate prediction methods applied with wind propulsion. At the same time, complexity was not increased unnecessarily. The recommended modelling includes several complexity levels (Tiers). Tier 1 is very similar to the perceived intent of MEPC.1/Circ.815, and it appears to be suitable for ships with relatively small wind propulsion power. The more complex Tier 2 is intended for ships with substantial wind propulsion power. For those ships it was found that methods that would be permissible in MEPC.1/Circ.815 resulted in too high $C0_2$ emission savings. Such ships require modelling at a higher level of detail. For instance, the additional drag due to sailing a drift (leeway) angle needs to be accounted for. As shown in Figure 2, the selection of the Tier 1 and 2 methods depends on a variety of aspects that are related to specific physical phenomena. This selection is based on specific design particulars combined with a prediction at the lowest complexity level.

[1] Has been renamed to "Timberwolf"

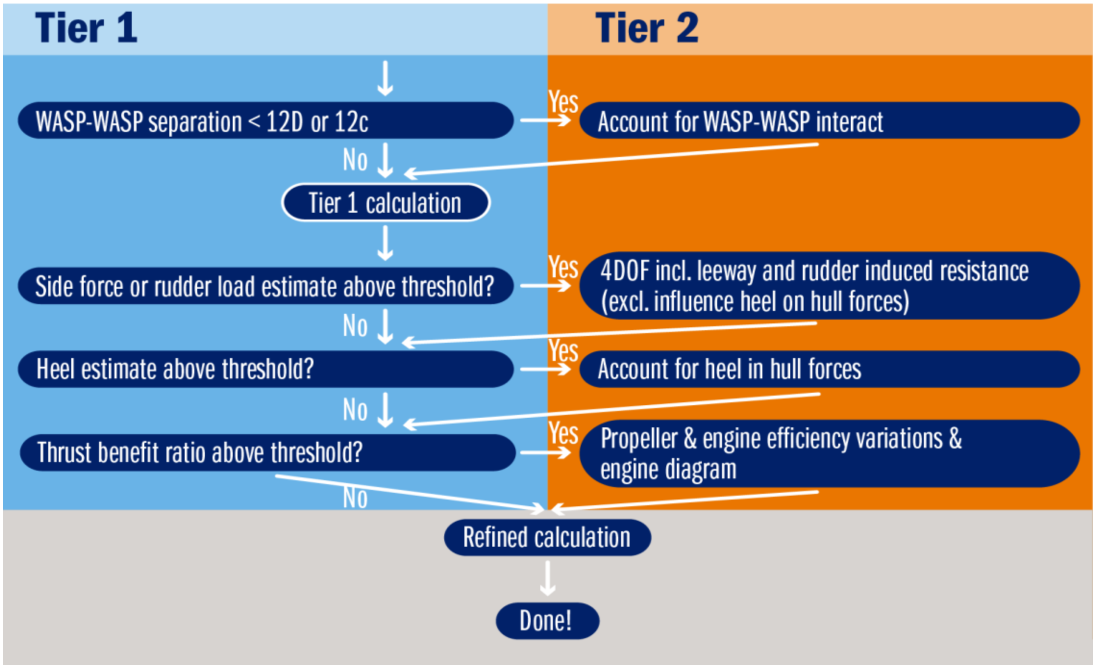

Figure 2: Modelling tiers and selection

3 Figure 3 shows resulting CO_2 emission savings (derived from the calculated fuel savings) at the two Tier level methods, with Tier 1 very similar to what would be permissible in MEPC.1/Circ.815. The savings compared to the same ship without wind propulsion are plotted against the relative contribution of wind propulsion. No benefits of voyage optimisation (speed or course) are included. The results show that for the smaller installations on New Vitality and Maersk Pelican, there is not much difference in savings in absolute terms. Thus, it is judged that Tier 1 modelling is appropriate for those vessels. However, for MHTC and WASP-Ecoliner there is a substantial gap. It was found that certain aspects need to be evaluated at Tier 2 level. Those vessels show a significant increase in losses related to for instance additional resistance on the hull and rudder, as well as a limitation in fuel savings due to realistic engine operations and an increase in specific fuel consumption at part load if a single combustion engine is used for propulsion.

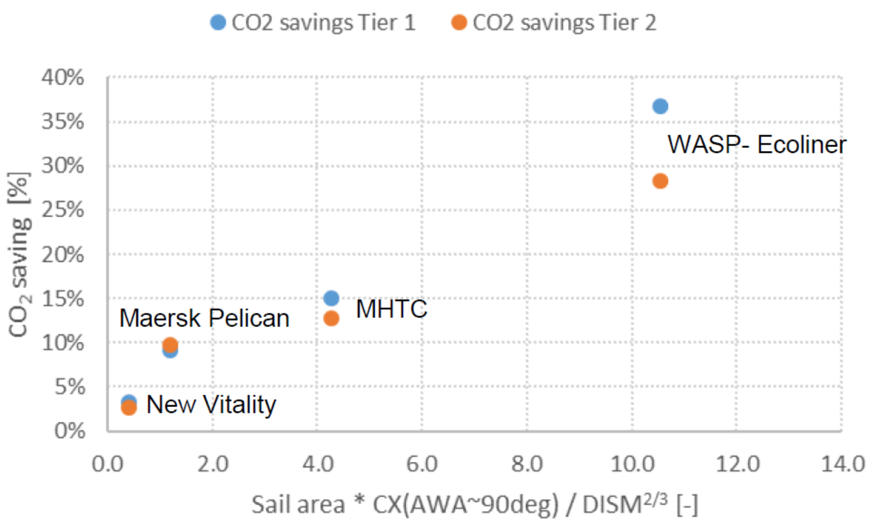

Figure 3: Overall worldwide CO_2 savings for the two modelling Tiers, versus the relative thrust contribution in (apparent) beam wind

4 Taking MEPC.1/Circ.815, as a starting point, the recommendations for Tier 1 modelling contain the following important additional specifications:

- Not allowing negative thrust on the propeller (assuming that regeneration with the propeller is generally not possible on conventional ships).

- Including windage of the ship itself. The base EEDI only accounts for wind due to ship speed. The additional consideration of "true" wind will not only lead to thrust with wind propulsion; it will generally also lead to increased drag on the ship itself.

- Include a specification of maximum operational conditions for wind propulsion systems (to trigger depowering through trimming, reefing, lower spin ratios or suction as relevant for the specific device).

- Description of variation of wind speed as function of height from sea level (the earth atmospheric boundary layer).

- Reference to applicable standards on calculation or testing of hydrodynamic and aerodynamics forces, including for instance consideration of scale effects on Flettner rotor forces and power requirements for active devices.

5 For Tier 2, the most important modelling additions comprise:

- Resolving equilibrium in four degrees of freedom (surge, sway, roll and yaw) including accounting for the additional resistance of hull and rudder(s).

- Accounting for interaction effects in the aerodynamics of wind propulsors with the ship.

- Propulsion, transmission and engine efficiencies as function of its load.

- Make sure that the entire ship and propulsion conditions remain within its operational limits (e.g. engine, heel, rudder angle).

6 The WiSP results on performance modelling will be published separately in a more extensive format than allowed in this Information paper.

Wind probability matrix and a possible simplification

7 As per MEPC.1/Circ. 815, the wind propulsion contribution is to be computed by weighting the Force matrix using a Global Wind Probability Matrix. Common practice in the industry has been to use the MEPC.62/INF.34 global wind probability matrix.

8 This Global Wind matrix accounts for the wind probability across the major commercial shipping routes. Nonetheless, some observations may be traced with regard to the use of a Global Wind Probability Matrix and specifically the one described in MEPC.62/INF.34:

.1 Other INF papers (e.g. MEPC.74/INF.39) pointed out that the global wind probability matrix accounts for routes with both low and high wind probabilities. Commercially it is more profitable to install a wind propulsion system on a ship sailing in routes with higher wind probability rather than lower.

.2 Additionally, it can be stated that a ship equipped with a wind propulsion system may tend to sail on routes deviating from the main routes for which the Global Wind Probability has been derived to maximize the fuel (and CO_2 emission) savings.

.3 MEPC.74/INF.39 demonstrates how using a route specific wind probability matrix allows a bigger reduction of the EEDI rating in comparison to the global wind probability matrix.

9 Referring to paragraph 8, ways to simplify the EEDI calculation pertaining to the use of Wind Probability Matrix were investigated. The investigation was carried out such as to mimic the same logic as for an EET Category A device. Such devices have their efficiency gains demonstrated only for a single operational point.

10 The effect of the following alternatives was investigated:

.1 Using a fixed single wind speed and single wind angle, i.e. only one operational point. This would result in not needing to use a Wind Probability Matrix.

.2 Using a fixed single wind speed but with three or four fixed wind angles with all the conditions having the same probability.

11 These conditions are then considered to be the same irrespective of the wind propulsion systems used.

12 In the WiSP JIP, many systems have been investigated as described earlier. The analysis focused on two vessels: one fitted with Flettner Rotor and another with Dynarigs. For these two cases, the EEDI was computed without wind propulsion (EEDI Baseline), and with wind propulsion using the Global Wind Probability Matrix (MEPC.62/INF.34) and for the different cases listed in paragraphs 9 and 10.

13 Figure 4 shows an example of the EEDI gains with the multiple versions for the case with a Flettner rotor (similar results are obtained with rigid sails). When four angles and the speed of 6.5 m/s are used, the level of gains obtained are similar to those provided by the MEPC.62/INF.34. In this case, wind direction angles of 45, 90, 135 and 180 degrees are considered.

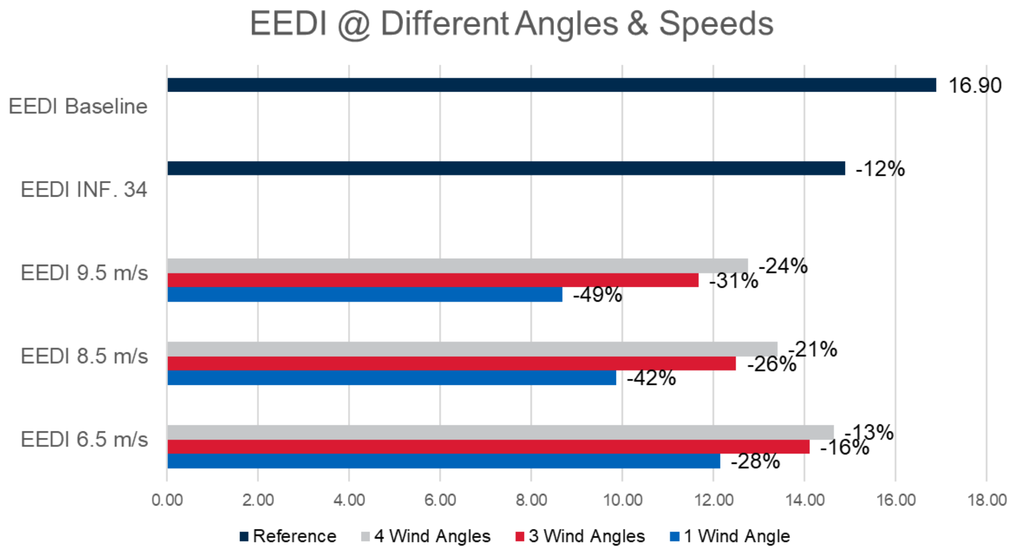

Figure 4: Application of different EEDI calculation procedures for a Flettner Rotor system.

14 Results suggest that it is possible to find a combination of one single speed and four wind angles that provides EEDI results similar to the procedure based on MEPC.62/INF.34. Interestingly, the wind speed of 6.5 m/s that provides the best match, is close to the speed with highest wind probability in the MEPC.62/INF.34 Global Wind Probability Matrix.

Sea Trials for Wind Propulsion

15 Full scale trial procedures are governed by the ISO 15016:2015 Guidelines for EEDI determination. The ISO guidelines scope covers test runs to confirm the vessel's speed in EEDI conditions (in calm water) based on model test predictions at the design stage. Hence, the prescribed trial environment and process are not suitable for evaluating any wind propulsion system. Even when a fitted wind propulsion system is not operating, its presence may result in deviations from the earlier speed/power prognosis due the added windage, among others.

16 A possible adaptation of the ISO 15016:2015 procedures has been considered to allow for the assessment of wind propulsion. This goes as follows:

- The vessel would be trialled without the wind propulsion system active to determine the Power Speed curve (full blue line in Figure 5) at sea trial draft (according to 15016:2015). WASP is to be considered as not-installed, hence corrections for windage are needed.

- Dedicated trials are carried out with the wind propulsion system active. Provided that the system performs as expected, the process should result in a new Power Speed curve (full red line in Figure 5).

- Correct the sea trial measurements for the EEDI draft based on pre-calculations / model tests, resulting in the dashed blue and red lines.

- Finally, correct the Power-Speed for the system ON curve from step 3 to the EEDI wind speed of [18] kn (to be defined at a later stage), achieving the final Power Speed curve (dotted green line in Figure 5), which gives $VREF_{EEDI}$ at P_{WASP_EEDI}.

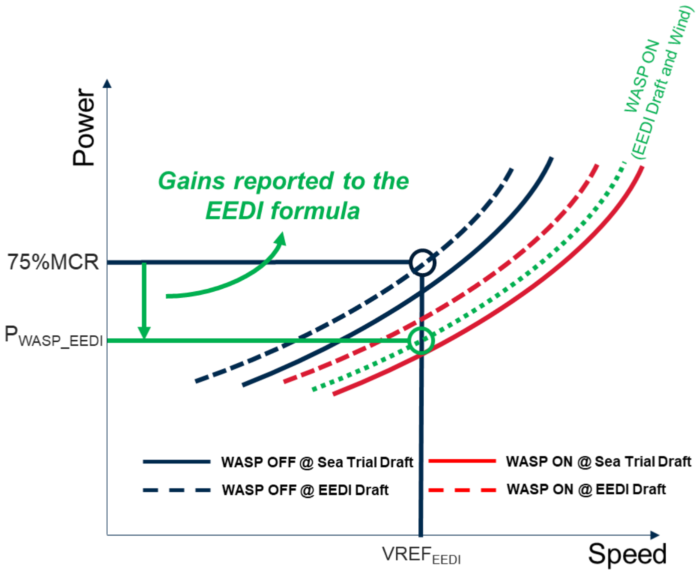

Figure 5: Power Speed Curves derived based on proposed sea trials

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