Wind Energ. Sci. Discuss.,
https://doi.org/10.5194/wes-2019-100-AC4, 2020

WESD

Interactive comment

Interactive comment on "Exploitation of the far-offshore wind energy resource by fleets of energy ships. Part A. Energy ship design and performance" *by* Aurélien Babarit et al.

Aurélien Babarit et al.

aurelien.babarit@ec-nantes.fr

Received and published: 30 April 2020

Dear Anonymous Referee,

Thank you very much for reviewing our manuscript. We greatly appreciate your comments and suggestions. We have revised the manuscript accordingly. Please find below our point-by-point responses to your suggestions and concerns. We hope that you will find our responses satisfactory .

1: The Farwind concept is an interesting, multidisciplinary one that proposes to produce fuel in the open ocean. The ship uses Flettner rotors to produce the propulsive force

Printer-friendly version

Discussion paper

tomove the ship and underwater turbines to generate electricity which is then used on-board to produce hydrogen and then methanol. The methanol use CO2 as a feedstock, but that is produced elsewhere and brought on-board separately. The Farwinder is one a set of generally similar concepts in which a fuel is made on an unmoored ship. In other variants the ship may be propelled by wingsails or wind turbine thrust; electricity may be made by a wind turbine on the ship, and the fuel produced could be simply hydrogen itself or ammonia. The Farwinder is unique in that it proposes to use Flettner rotors and produce methanol.

Answer: Yes, there have been other energy ship proposals. Please note that in reply to comment #1 of Shane McDonagh, we have added in the revised manuscript a short discussion and pictures of the other energy ship proposals in the introduction.

2: The proposal at this stage is still quite conceptual. Each of the steps will need validation, as will the performance of a complete system. The paper would benefit from discussion of a few points in more detail.

Answer: Yes, we agree that validation is needed, first for the subsystems and then for a complete system. However, one has to start somewhere, and we believe that theory is a good starting point. Indeed, if a concept does not work in theory, how could it work in practice? Moreover, in respect to validation, please note that, following the preliminary results, we have already built a 1/14-scale prototype which we tested on a river last summer (see picture below). We measured a power production of 75 W for a wind of 5.6 knots, which corresponds to a generated power of approximately 1 MW at full scale (21 knots wind speed). It is in agreement with theoretical and numerical results. These results will be published soon. The next step is to replace the Bermuda rig of the test platform by Flettner rotors to achieve a more representative proof-of-concept. This is on-going. Finally, note that the need for validation is already mentioned in the conclusion of the paper “Other challenges include the development and validation of the key subsystems (water turbine, autonomous power-to-methanol plant, control systems for autonomous navigation)”.

3: The authors indicate that the sideways force on the hull is insignificant and implicitly would result in little power loss due to motion in the sideways direction. Further justification is needed of that.

Answer: We have developed an advanced numerical model which takes into account sideways force (that model has not been published yet). Results show that the drift velocity is smaller than 10% of the forward velocity provided that the ship is equipped with appropriate appendages (centerboards of total surface area in the order of 10 square meters).

4: There has been other work considering the use of wind turbines, wingsails or Flettner rotors for saving fuel on cargo vessels. Those concepts are somewhat different in that the purpose of the turbines or rotors is to augment propulsion on vessels of relatively high drag rather than to produce fuel, but there is enough similarity that it would be worth discussing them. Examples of such work are Wind Turbine Propulsion of Ships by Bøckmann and Steen (2011) and Drift Forces – Wingsails vs Flettner Rotors by Kramer, Steen and Savio (2016).

Answer: We believe that your comment points out to the fact that there are other wind propulsion technology available which may be used for the energy ship concept. As the revised version of the manuscript includes a discussion and pictures of other energy ship proposals which include other wind propulsion subsytems (wingsails, soft sails, kites), we believe that it is somehow addressed. Moreover, we think that adding a discussion on for wind-assisted ship propulsion technologies in this paper could cause more harm than good, as it could be confusing for the reader. Finally, please note that we have throroughly investigated those options in a separate study, which lead us to the selection of Flettner rotors. This study will be the topic of a separated paper (in preparation).

5. The question of the similarity and differences between the Farwinder means of wind energy extraction and a conventional wind turbine is an interesting one and merits

some discussion.

Answer: The paper already includes a discussion on the optimal induction factor, which can be very different for an energy ship in comparison to a wind turbine; and results for efficiency. We are not sure what aspects you suggest to further discuss (see also our answer to your comment 18).

6. It could be argued, in fact, that the concept is actually a variant of the Madaras rotor power plant of the 1930s. In that plant, Flettner rotors also provided the propulsion and the electricity was generated at the level of the platform through the motion created by the force from the rotors. See, for example, Analysis of the Madaras Rotor Power Plant: an alternate method for extracting large amounts of power from the wind, by Whitford et al. (1978).

Answer: Thank you for pointing out the Madaras rotor power plant, we were not aware of this concept. However, as we are not the inventors of the energy ship concept (it was patented in 1982) and for sake of clarity and conciness, we think the paper should focus on its main objectives which are to provide answers to the following research questions: "what is the energy performance of this technology? Can it produce significant amounts of energy? What is the overall energy efficiency? (see also answers to your comment 4 and our answer to anonymous referee #1).

7: Some additional suggestions to consider are the following p.2, line 32: The wind resourceis strongest in the "open ocean" instead of "at sea", otherwise the advantage of FAR-WINDers operating in a stronger wind resource far-offshore is not evident.

Answer: Corrected, thank you for the suggestion.

8: p. 2, line40: "not neither" should be corrected to "neither"

Answer: Typo, corrected, thank you.

9: p. 4, line 86: At what scale are these CO2 methods feasible?

Answer: We don't fully understand your concern here. Is it whether it would be possible to supply enough CO_2 to the energy ships? If yes, one can arguer that direct air capture has virtually unlimited potential.

10: p. 4, line 86: "indirectty" should be corrected to "indirectly"

Answer: Typo, corrected, thank you.

11: p.4, line 92: "remaining" should be "remainder"

Answer: Corrected, thank you.

12: p. 4, line 100: Figure 2 indicates that the Flettner rotor is providing energy (from the wind, which ideally should be shown as coming from the side) to the FARWINDer; the arrow should be pointed in the direction of the FARWINDer motion. There is external energy source responsible for the rotation of the rotors; that should also be included in the figure.

Answer: We have modified the figure to take into account your comments. However, we did not change the direction of the arrows for the work as the intention is to show the energy flows and not the direction of the physical forces.

13: p. 6, line 131: It is not clear in what plane As lies. It is also referred to as the "sail" area, and referred to as the"rotor" elsewhere in the paper.

Answer: As follows the usual definition for a lifting profile. It is the projected area.

14: p. 6, line 138 "propeller of the turbine" is a misnomer; a propeller induces a greater velocity at the rotor plane and the turbine induces a lesser velocity; it is the water turbine's rotor that is being referred to

Answer: Corrected, thank you for the suggestion. Please note that we have changed propeller to rotor everywhere that it was necessary.

15: p. 6, line 139: "according to the" should be corrected to "according to"

Answer: Corrected, thank you for the suggestion.

16: p. 6, line 143 It would be helpful to provide a background and a figure to aid in clarifying the rotor disk area and momentum theory to the reader.

Answer: As it is a well-known theory to the readership of the Wind energy science journal, we don't think that it is necessary. Morever, we have provided a reference for the momentum theory. See also our answer to comment 3 of Shane McDonagh.

17: p. 6, line 150: It is unclear under what conditions the form factor k is neglected

Answer: It is very standard practice in naval engineering to neglect the form factor in a first approach, as it is usually a few percent.

18: p. 7, line 153: What range of the Reynolds number does this formula ac-count for and what is an approximate Reynolds number for the FARWINDer?

Answer: this formula is valid for Reynolds typical for ships, i.e 10ˆ6 – 10ˆ9. In rated conditions, the Re number of the FARWINDer is 10ˆ8 – 10ˆ9.

19: p. 7, line163: There is no need to introduce a new variable Pp since it is equal to PT.

Answer: Typo, corrected

20: p. 7, line167: The optimal axial induction factor 0.04 is dependent on the configuration of ship,turbine, and other parameters not fully explicated. It can vary depending on the hydroturbine, hull, and Flettner rotor configurations.

Answer: Yes, the optimal value of 0.04 is for that particular energy ship design. For another design, it would certainly be different. However, what is important here is not the particular value of the optimal induction factor, but the fact that it is very different from that for fixed turbines (1/3). Nevertheless, to clarify, we've modified the text from "It is clear from Fig. 5 that the optimal induction factor is approximately 0.04" to "For this exemple, one can see in Fig. 5 that the optimal induction factor is approximately

0.04”

21: p. 9, line 210: “Manoevring” should bespelled “maneuvering”

Answer: Typo, corrected

Interactive comment on Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2019-100, 2020.

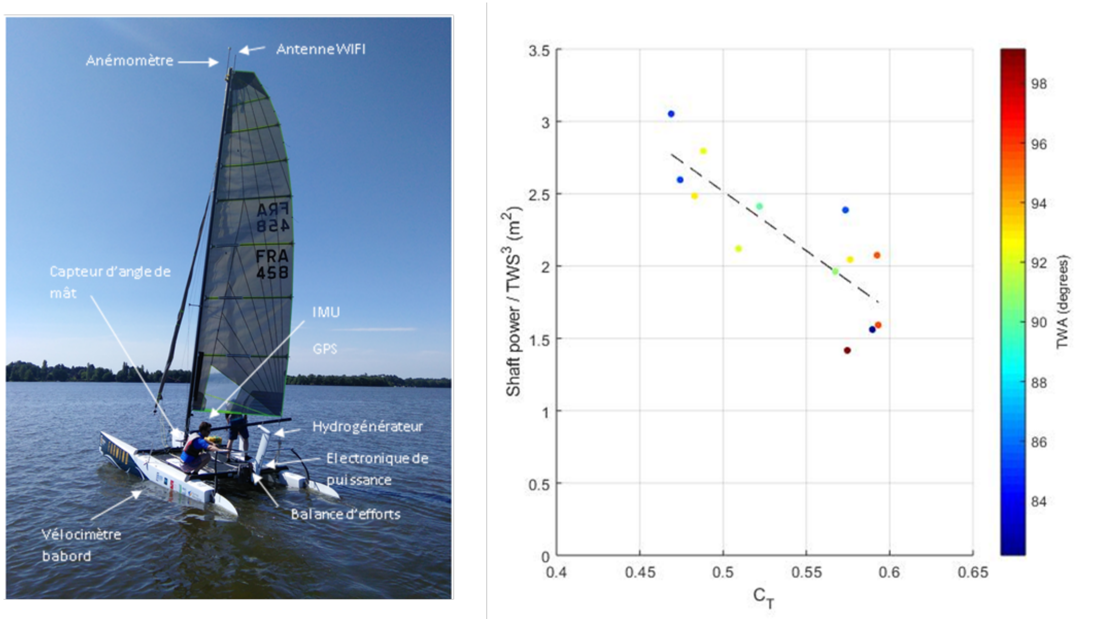

Fig. 1. The FARWINDer prototype. Right: measurement results for the power production as function of the thrust coefficient of the water turbine