Wave Foils on Concept Ship ReVolt

Eivind Finne Riley
Dept. Marine Technology, NTNU
Specialization: Hydrodynamics
Advisor: Sverre Steen, Co-advisor: Eirik Bøckmann

Introduction

- ReVolt is a concept container ship designed by DNV GL Research and Innovation. The concept is fully autonomous and electrically driven.
- The purpose of ReVolt is to develop a cost-effective and environmentally friendly shipping alternative to container transport on Norwegian roads. ReVolt has a calm water brake power of only 50kW at 6 knots.

Purpose of thesis

- The battery pack of ReVolt has to be sufficiently large to complete a trip in the worst sailing conditions ReVolt might encounter.
- The added resistance in wind and waves is high compared to the calm water resistance of ReVolt. This means a large battery pack must be fitted to endure all conditions.
- The purpose of this thesis is to fit ReVolt with "wave foils", using the wave and ship motions directly to produce thrust and dampen ship motions, and hence decrease the CAPEX and OPEX cost of ReVolt.
- An irregular sea is simulated in MATLAB, and the foil performance is tested in a vast array of sea states with different wave headings and ship speeds. Effects of foil stalling, finite foil span and unsteady lift is included.

ReVolt and the wave foil

Fig. 1: ReVolt [3]

The wave foils are fastened to the hull by struts. Foil folding mechanism is shown in Figure 2.

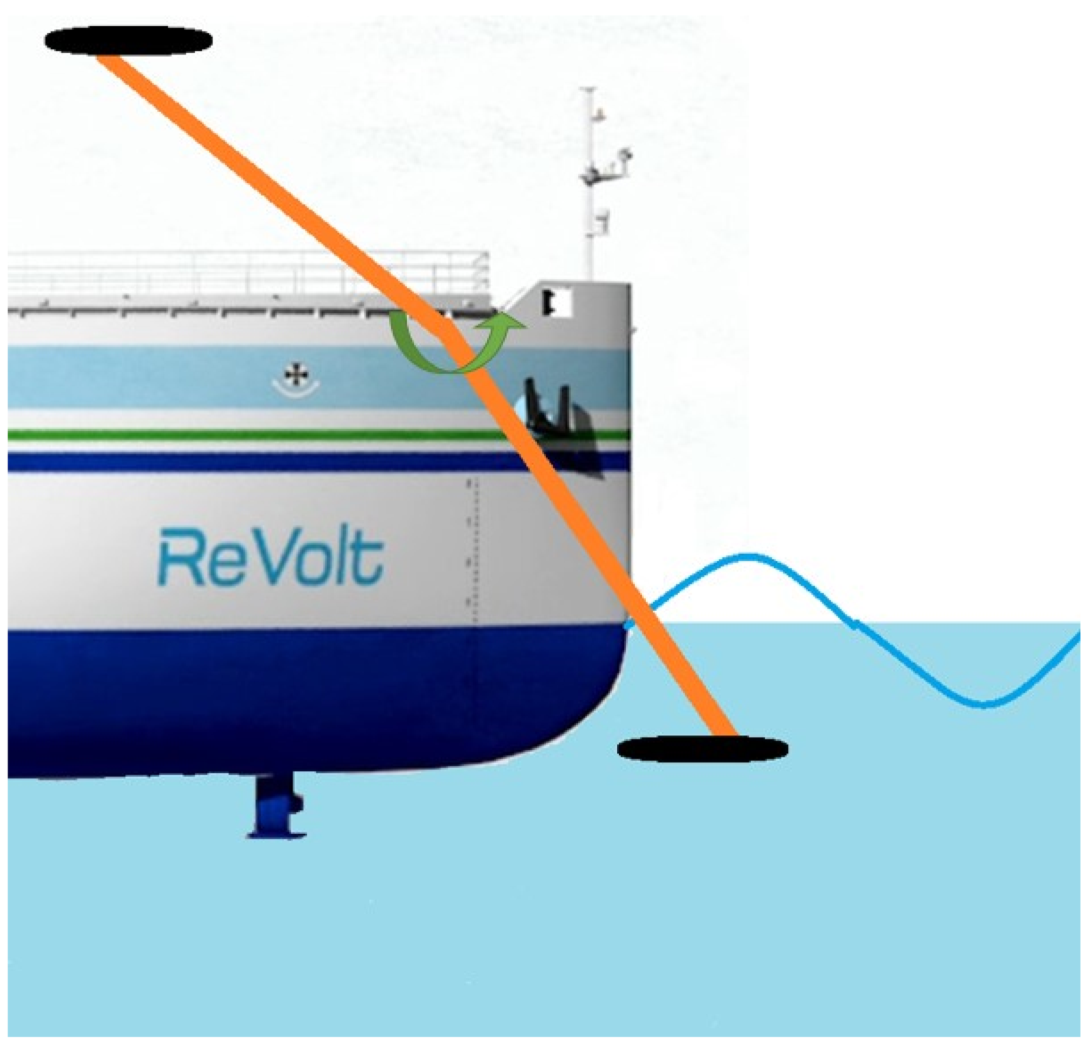

Fig. 2: ReVolt fitted with wave foils [3]

Results for fixed foils

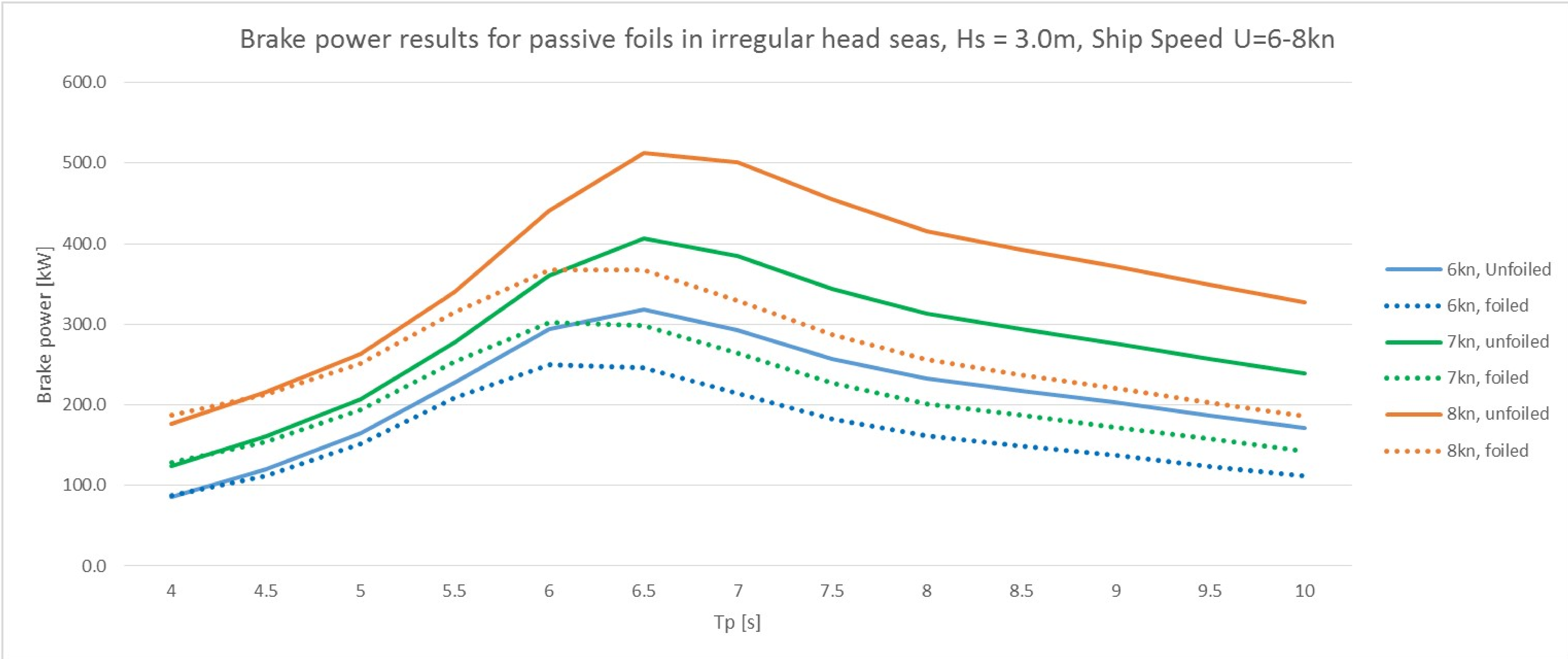

Fig. 3: Savings in brake power

Concept of wave foils

The thrust production mechanism is similar to those of aquatic mammals, creating lift and thrust by oscillatory motion of a foil. Relative vertical motion fluid motion, induced by wave particle fluid motions and ship motions, induce a flow angle of attack on the foils, and thus a lift is created on the foil. This lift will at all times have a component pointing in the forward (sailing) direction, and can thus be decomposed into a thrust component. The lift will also dampen the ship motions.

Wavefoils may be installed in a fixed position, or they may be rotated in order to achieve the optimal angle of attack. Rotational control is done by a spring spring system controlling the pitch displacement of the foil.

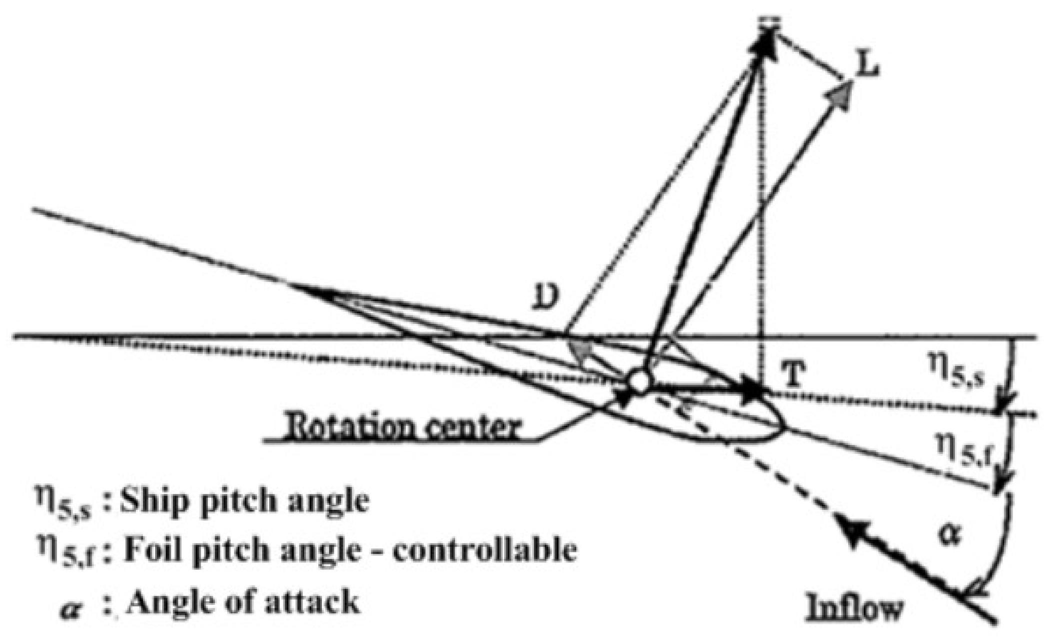

Fig. 4: Lift and thrust resulting from inflow angle [2]

Pitch control of the foils will produce thrust more efficiently than a passive, fixed foil in high sea states due to foil stalling avoidance. However, for lesser sea states, fixed foils are more efficient. Wave foils are only beneficial when the waves are sufficiently long, and when the wave height is sufficiently large. For all other sea states, the foils must be stowed away to avoid additional drag imposed from the foil and struts holding them in place.

Several folding mechanisms have been proposed. A folding mechanism where the foils are fixed to struts have been chosen, due to the low complexity in folding mechanism and the little modifications needed to be done to the hull for this mechanism.

Active foils

Results for active foils are not yet ready, but is generally expected to surpass the performances of passive foils for Hs > 3.0m due to stalling avoidance.

Conclusion

- Wave foils are not a new concept, and various attempts at implementing them have been made throughout the past 150 years. It has not, however, been a commercial success yet. The difference in this thesis is the approach seeking to reduce CAPEX costs. This is very relevant for battery powered vessels, as batteries are associated with a large cost today. This is not the case for vessels burning fossil fuels, as installing larger fuel tanks are significantly cheaper than installing a larger battery.
- Wavefoils seem to be very efficient at reducing the energy demands for worst case conditions. Brake power for a ReVolt with and without wave foils installed is shown in Figure 3, for a small sample of the sea states examined, indicating that significant benefits can be found.
- Thus, the CAPEX of ReVolt could decrease significantly with wavefoils fitted. The OPEX can also be expected to decrease.
- Preliminary cost analysis shows a reduction of dimensioned battery pack capacity by 20-25%, corresponding to a CAPEX cost decrease of 1.0-1.25 million USD per ship built, using a battery price of 1000USD/kWh.

References

[1] Brian Amberg: *LaTeX Poster Template*, `http://www.brian-amberg.de/uni/poster/`

[2] Christian Thomas Borgen: *Application of an active foil propeller*, Dept. of Marine Technology, NTNU, Norway (2010)

[3] Stock photos of ReVolt from DNV GL