Investigating the Effect of Propeller Location with the use of CFD

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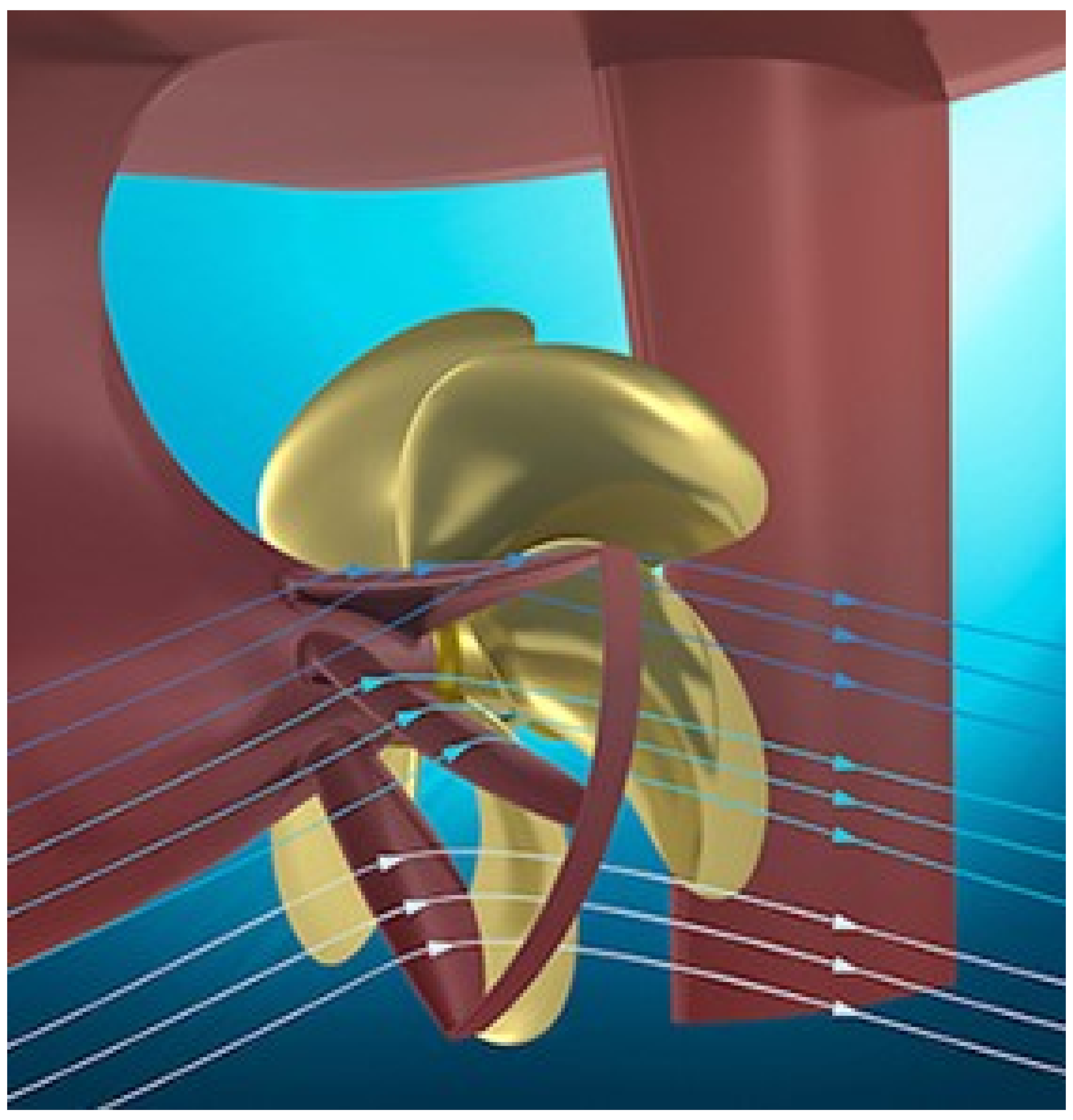
Case description

The propeller location is rather constraint in its position. However, there is possibilities of moving the propeller a certain distance upstream or downstream. Therefore, with the help from the CFD software FineMarine (FM) and propeller analysis software AKPA it is possible to evaluate how the propeller will perform while adjusting its position.

The performance is highly dependent on the inflow fluid regime. Therefore, the adjusted flow introduced by a Pre-Swirl Stator (PSS) shall be investigated with respect to the propeller position. The PSS orientation may also be tuned to fit the operating propeller at a given location. Thus, the PSS orientation shall also be investigated with respect to hydrodynamic performance.

PSS - Working Principle

The working principle of a PSS is to recover rotational losses at the propeller location. This is done by decreasing the rotational kinetic energy losses and increasing the axial kinetic energy [1]. Thus resulting in higher thrust. The flow is manipulated by introducing a swirling flow in the opposite direction of the rotation of the propeller. Wärtsilä has created their own PSS called EnergoFlow, illustrated below, stating it may cut consumption up to 10% [2].



References

[1] van Terwisga, Tom: *On the working principles of energy saving devices*, Proceedings of the Third International Symposium on Marine Propulsors. Launceston, Tasmania, Austrailia (2013)

[2] Voermans, Anton *Experimental determination of hydrodynamic loads on the Wärtsilä pre-swirl stator EnergoFlow and validation of a prediction methodology for design loads*, (2019)

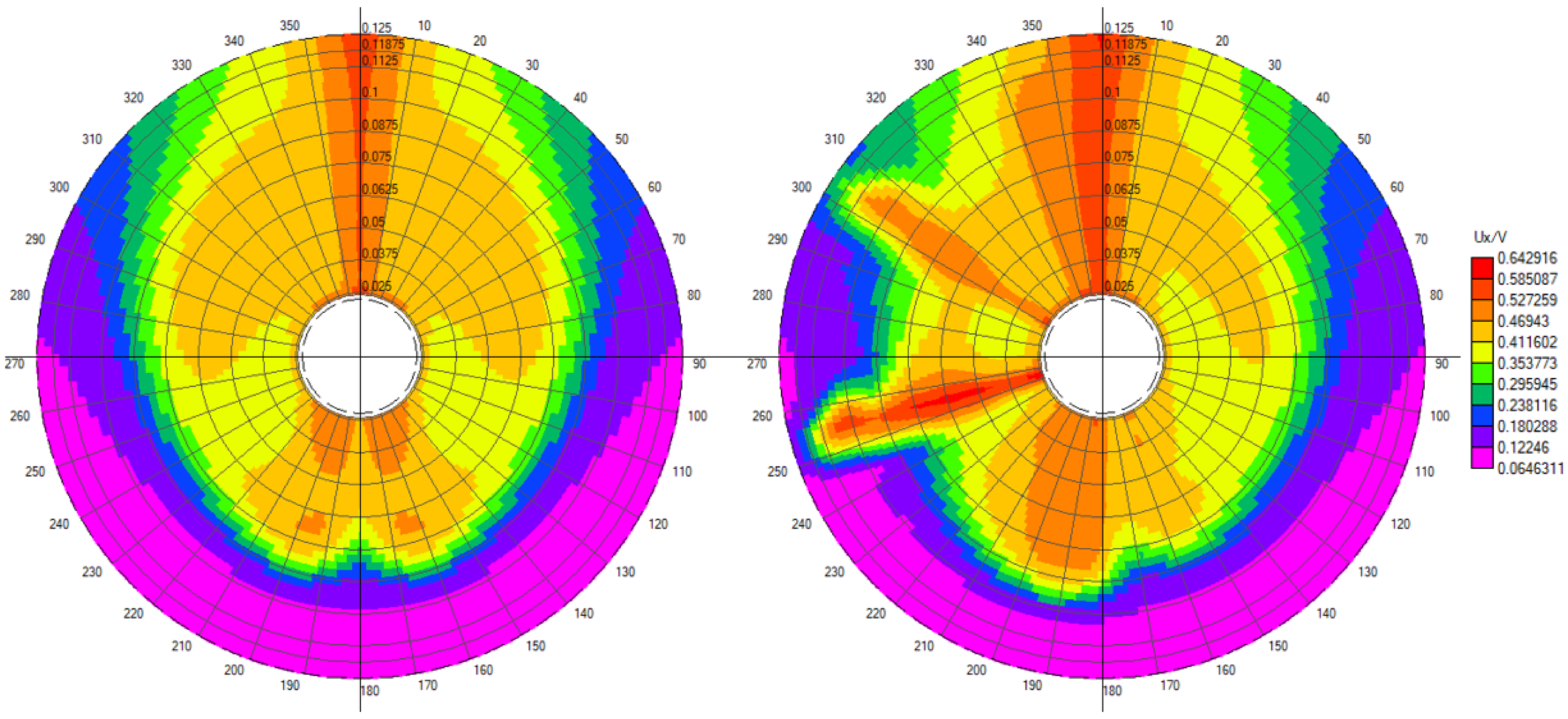
Acknowledgements

This research study is conducted as a part of my master thesis at NTNU Marine Technology in co-operation with SINTEF and the NorSingProp project. I would like to thank Professor Kourosh Koushan, Eloise Croonenborghs and Fengjian Jiang for endless support through the study.

Propeller Location Analysis

The wake field obtained at the propeller location is of high importance in the design process of a propulsive system. Studying how the propeller perform aft of a naked hull and with the presence of a PSS it is often seen power savings up to 4% for the latter. On the other hand, introducing such devices in the vicinity of the rotative disc may introduce other problems such as cavitation. Therefore, numerical methods is utilised to extract the nominal wake field at the different propeller locations. The nominal wake field for both naked hull (left) and with the PSS (right) at the original propeller location is presented in the figure below. The presence of the PSS is clearly seen by the higher wake fraction at port side in angular positions 255°, 305° and 345° from hub to blade tip.

By importing the nominal wake field into AKPA the effective wake field and thus the propeller performance may be investigated. The studied parameters is efficiency and required shaft delivered power. As a result of a more chaotic inflow regime the propeller must undergo a cavitation analysis. This is conducted by studying the local pressure coefficient over all chord lengths at all radial positions and compare it with the cavitation inception criteria. The criteria states that cavitation may occur if the local pressure is lower than vapour pressure of the fluid.



Conclusion - Most Optimal Position

The most optimal propeller location is evaluated with respect to visual interpretation of the nominal wake field, obtained hydrodynamic performance coefficients and by conducting a cavitation analysis of the working propeller. The obtained results points towards that the the rotative disc will consume less fuel by moving the location further downstream. This is supported by the visual analysis of the wake field which implies that the working environment is more homogeneous downstream.

Both efficiency in wake and required shaft delivered power decreases as the propeller blade is moved in the downstream direction. Thus the efficiency points towards that the propeller should be placed upstream. On the other hand, delivered power indicates the opposite. The reason for the deviation is that the propeller is not included in the numerical simulation and thus the thrust deduction is not accounted for. Therefore, the shaft delivered power is used as basis for conclusion. Furthermore, cavitation analysis indicates that there is no significant risk of cavitation, illustrated in the figure below. It is seen that the inception criterion $(1 \leq \frac{-C_P}{SGM})$ is not met. The study indicates that the propeller may have a lower fuel consumption at a position further downstream. However, further simulations with the presence of the propeller is encouraged.