# Limitations of RANS flow predictions for propeller-rudder interaction

## MARINE 2023

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### ABSTRACT

Industrial state-of-the art flow prediction for propellers relies on RANS[1], both for the propeller in open-water condition and when it is operating in a wake, or when its interaction with hull and/or rudder is considered. The flow is largely steady, in the rotating frame-of reference, for the open-water condition, while interactions with other components break this symmetry and induces significantly more unsteady flow.

The recent progress in large-eddy simulation for propellers, see e.g. [1,2], provides reference data on a much higher level of detail than what has been previously available. This allows for a more detailed assessment of the potential shortcomings of RANS for propeller flows.

In the present study, a configuration consisting of the 7-bladed INSEAN E1658 propeller operating upstream of a rudder with a NACA0020-profile is considered. RANS simulations, 2nd order accurate finite volumes with wall-functions and a $k-\omega$ model, are carried out testing both a rotating frame of reference and a rotating mesh. The results are compared in detail, including the flow and turbulence, with LES results of [1].

Two types of potential limitations of RANS are in focus. First, the turbulence modelling of RANS leads to larger modelling error which is reflected in the mean (both normal average and phase-average) flow, force and torque quantities. For the main performance characteristics of the propeller, these discrepancies are generally quite small, whereas for any flow feature affected by separation RANS often performs poorly. Second, as the LES resolves essentially all important flow scales, it is expected to provide a significantly more accurate prediction of any second- and higher-order statistics of the flow. The paper will investigate this aspect in detail, first analysing the discrepancies of the predicted turbulent kinetic energy field, and then identifying the differing behaviour in regions affected by flow separation.

### REFERENCES

[1] A. Posa and R. Broglia, “LES study of the interaction of a propeller with a downstream hydrofoil at incidence”, 34th Symposium on Naval Hydrodynamics, Washington DC, USA, June 2022.

[2] A. Posa, R. Broglia and E. Balaras, “The wake structure of a propeller operating upstream of a hydrofoil”, Journal of Fluid Mechanics, Vol. 904, A12, December, 2020.

[1] RANS = Reynolds-Averaged Navier Stokes equations.