# Mean velocity and moments of turbulent velocity fluctuations in the wake of a model ship propulsor

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Pod drives are modern outboard ship propulsion systems with a motor encapsulated in a watertight pod. The motor's shaft is connected directly to one or two propellers. The whole unit hangs from the stern of the ship and rotates azimuthally, thus providing thrust and steering without the need of a rudder. Force/momentum and phase-resolved LDA measurements were performed for inline co-rotating and contra-rotating propellers pod drive models (see Fig. 1).

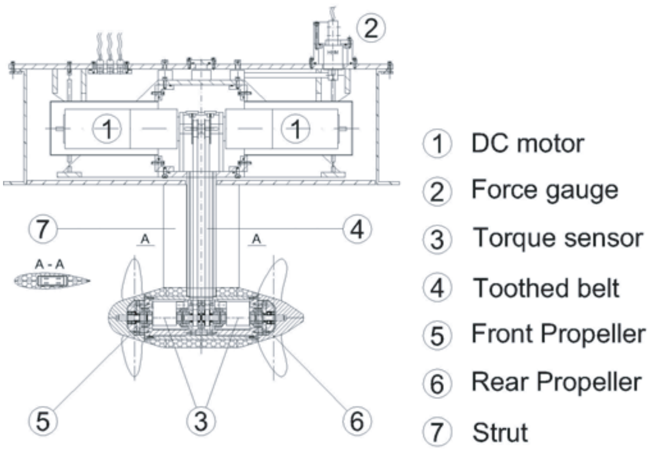


**Fig. 1** Pod drive model and water tunnel balance

The measurements permitted to characterize these ship propulsion systems in terms of their hydrodynamic characteristics. The torque delivered to the propellers and the thrust of the system were measured for different operation conditions of the propellers. These measurements lead to the hydrodynamic optimization of the ship propulsion system. The parameters under focus revealed the influence of distance between propeller planes, propellers' frequency of rotation ratio and type of propellers (co- or contra-rotating) for the overall efficiency of the system. Two of the ship propulsion systems under consideration were chosen, based on their hydrodynamic characteristics, for a detailed study of the swirling wake flow by means of laser Doppler anemometry.

A two-component laser Doppler system was employed for the velocity measurements. A light barrier mounted on the axle of the rear propeller motor supplied a TTL signal to mark the beginning of each period, thus providing angle information for the LDA measurements. Measurements were conducted at four axial positions in the slipstream of the pod drives models (see Fig. 2). The mean velocity field was computed by phase averaging of the recorded instantaneous velocity. The results show that wake of contra-rotating propeller is more homogeneous than when they co-rotate. In agreement with the results of the force/momentum measurements and with hypotheses put forward in the literature (see e.g. Breslin and Andersen (1996)), the co-rotating propellers model showed a much stronger swirl in the wake of the propulsor.

In addition the second-order moments of turbulent velocity fluctuations were computed. The anisotropy of turbulence was analyzed using the anisotropy tensor introduced by Lumley and Newman (1977). The invariants of the anisotropy tensor of the wake flow were computed and were plotted in the Lumley-Newman-diagram. These measurements revealed that the anisotropy tensor in the wake of ship propellers is located near to the borders of the invariant map, showing a large degree of anisotropy. These results will be presented and will be discussed with respect to applications of turbulence models to predict swirling wake flows.

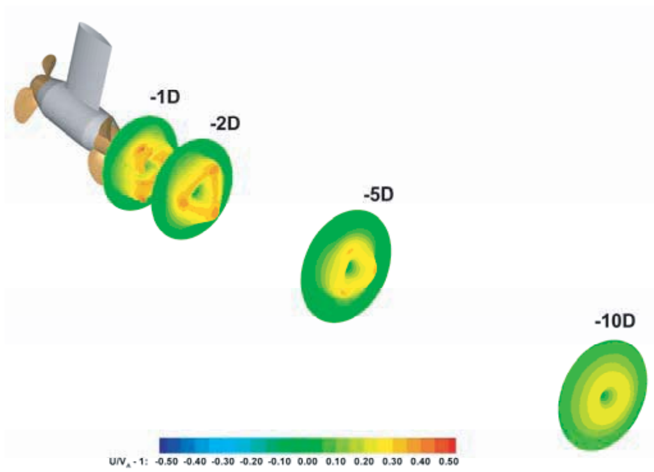


**Fig. 2** Axial mean flow development in the wake of a co-rotating propellers pod drive model

## References

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Lumley, J. L., Newman, G. R. (1977) The return to isotropy of homogeneous turbulence. Journal of Fluid Mechanics, vol. 82, pp 161-178