Effect of Shaft Inclination on the Flow Field around two Marine Propellers

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ABSTRACT
The objective of the present study is to investigate, by means of velocimetric measurements, the flow field generated by two marine propellers running with inclined shaft configuration. The two propellers represent two alternative designs for the same application, mostly differing for the radial load distribution adopted. The presence of shaft appendages is considered as well, thus simulating a typical twin screw vessel configuration. Measurements have been carried out on two different scaled model of the propellers in the cavitation tunnel of UNIGE using Laser Doppler Velocimetry (LDV) and the acquired data have been post-processed applying the ensemble average technique. The tests have been performed with and without propellers in order to characterize the propeller inflow and the effects of the struts and shaft on the incoming flow field. The complete 3-D flow field has been measured considering one transverse section downstream of the propeller, focusing on the near field wake and a longitudinal plane containing the propeller shaft as well. Acquisitions have been made at longitudinal plane extending from -0.25D till 1D. Results allow analysing the main characteristics of the flow field, including the evolution of its main structures. The effects of non-uniform inflow conditions caused by the oblique flow and the appendages are analysed focusing on the axial and tangential velocity of the flow field.

KEY WORDS: Velocimetric measurements; cavitation tunnel; inclined shaft; marine propeller; LDV.

INTRODUCTION
The inflow characteristics have significant influence on the performance of rotor systems and their resulting flow fields. The interaction of non-uniform inflow conditions with the functioning of these systems can deteriorate their performances by producing unstable dynamic loads (Huang et al., 2021), noise radiation (Robison and Peake, 2014), and fatigue stresses (Stevens and Meneveau, 2017).

For marine propellers, the non-uniformity of inflow is a result of hull wake. The characteristics of incoming flow have a significant impact on cavitation dynamics and its side effects, which may include efficiency loss (Kerwin, 1986), cavitation erosion (Abbasi et al., 2022), hull pressure fluctuations (Ge et al., 2020), and radiated noise (Tani et al., 2017).

The interaction of the propeller with the non-uniform inflow is highly dependent on the characteristics of the hull and the propeller configuration adopted on the marine vehicle.

Experimental flow measurements are considered as a reliable tool to study the detailed flow dynamics of the flow field and interaction of non-uniform inflow with the flow. In addition, they provide valuable data for development and validation of theoretical or numerical models. The flow measurements by velocimetric techniques have been successfully used to get better understanding of some complex flow problems in naval architecture. In the literature, several experimental studies have been conducted to study the features of the flow field around different propellers (Di Felice 2004; Felli et al., 2006; Felli et al., 2018). Propeller wake characteristics of CLT propeller has been experimentally investigated using LDV measurements (Bertetta et al., 2012). The results highlighted the particular vortical wake structures associated with the end-plate. Felli et al., (2009) experimentally studied the flow field around a propeller–rudder configuration through time resolved flow visualizations and LDV phase sampling measurements. In another study, the propeller wake evolution and instability for three different configurations of the E779a propeller, with a different number of blades have been studied experimentally (Felli et al., 2008). The effect of propeller suction on the inflow, the inter-blade flow and the slipstream evolution were analysed on nine transversal sections of the wake using LDV. Felli (2021) investigated the underlying mechanisms of interaction between the propeller wake and a non-lifting wing using velocimetric measurements. The results demonstrated that interaction between the propeller tip vortexes and the wing occurs through a three-stage process, approaching phase, vortex penetration phase and reconnection phase. Although different aspects of non-uniform inflow conditions have been studied experimentally in detail in literature, there are only few experimental studies concerning the oblique flow conditions or the complete twin-screw configuration with appendages.

The aim of the present study is to investigate the flow field around two propellers, working in typical twin screw configuration using LDV measurements in model scale. The two propellers are alternate designs of propeller designed for the same application, mostly differing for the radial load distribution adopted. The overall flow field behaviour is studied, considering average flow and ensemble average, along with the effect of inclined shaft on two propellers.