Abstract

Research on lift-carry-over in hull-keel-centre board configurations, to improve the performance prediction of sailing yachts at Dykstra Naval Architects

This thesis, for the degree of Master of Science in Marine Technology, describes the research commissioned by Dykstra Naval Architects, to graduate at the Delft University of Technology.

Dykstra is regularly designing large classic sailing yachts or motor-sailors, of which the draft is an important design restriction. Therefore, Dykstra is trying to improve the sailing performance by adding lift-generating appendages, without increasing the draft. An example is a retractable centre board, having a big influence on the sailing properties. Predicting the performance contribution of a centre board in a hull-keel-centre board configuration is the subject of this research.

Predicting the performance through commercial VPPs is known to give inaccurate results for yachts with a keel-centre board combination, because these lay outside the scope of the systematic tank test series on which these VPPs are based. Therefore, Dykstra is obtaining all information regarding the performance of the hull through CFD or towing tank tests, after which the centre board is superposed as a lift generating surface.

During the verification of this method for a large yacht with a keel-centre board configuration, it was found that the centre board was working more 'effective' in terms of sideforce and resistance than was expected. This effect has been found in earlier studies as well and is known as the lift-carry-over, defined as the ratio between the measured lift and the theoretical lift of the foil. However, these earlier studies were all conducted on conventional hull-keel configurations of small yachts. The goal of this research is to develop a method to predict the performance contribution of a centre board to yachts with a hull-keel-centre board configuration.

Dykstra wants to keep the ability to superpose an appendage to the data of a hull-keel configuration obtained from towing tank experiments or CFD simulations. This means that a method must be developed to estimate the *contribution* of the centre board, in terms of sideforce, resistance and centre of effort.

Both towing tank experiments and CFD simulations are conducted for this research. The Maltese Falcon is used as the 'case ship'. A towing tank model of the Maltese Falcon was already made and tested at the TU delft in 2002. This model is again subjected to towing tank experiments, with a new keel and two new centre boards, resulting in 9 different hull-keel-centre board configurations. The main focus was on the towing tank experiments, executed in the Delft Hydromechanics Laboratory. Extensive preparations, a carefully constructed towing tank setup and elaborate post-processing resulted in good and useful results. The CFD simulations were then done to validate the results of the towing tank experiments and to gain visual insight in the flow around the vessel. The lift-carry-over on the keel and hull above the centre board can clearly be seen, as well as the influence of the centre board on the circulation in the flow around the underwater body of the yacht.

After post-processing all experimental data, the results of the towing tank experiments are used to develop formulations to predict the performance contribution of the centre board. For as far as possible, existing formulations to predict the lift-carry-over, resistance and centre of effort of conventional yachts, have been reconstructed to make them suitable for predicting the centre board contribution. According to the results from the towing tank experiment, the magnitude of the lift-carry-over was even more than was expected. The measured lift of the centre board contribution was roughly a factor 2 higher than the centre would generate according to Wicker & Fehlner theory.

It was interesting to see that taking this 'extra' lift into account when calculating the induced resistance, this induced resistance would be largely over estimated. This shows that the lift-carry-over does not only have a positive effect on the generated sideforce, but also on the resistance. Furthermore, it was found that heeling the Maltese Falcon model by 15 degrees, yields the same magnitude of lift-carry-over as for the upright conditions. The theoretical aspects prescribing the lift-carry-over reduction due to heel for conventional hull-keel configurations, are significantly less existent for the centre boards in large yachts. This resulted in the conclusion that heeling the yacht has no influence on the lift-carry-over from centre board to keel-hull.

The new prediction methods, derived from the towing tank experiment data, are validated on YACHT1 and Adela. These are existing yachts with a hull-keel-centre board configuration, but both very different. This enabled an interesting examination on the influence of certain aspects of the configuration on the performance of the centre board contribution. All in all, it was found that the predicted centre board contribution corresponded really well to the measured data of YACHT1 and Adela. This provides enough trust to implement the new centre board performance prediction methods in the Dykstra performance prediction tool. Every new design cycle of a yacht with hull-keel-centre board configuration will serve as a validation of the derived performance prediction methods.