Methods for Assessing the Impact of Hydrofoil Deformations on Performance

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ABSTRACT

Hydrofoils have seen a significant increase in use in the high performance sailing world in recent years. Their ability to minimise wetted surface area by lifting a yacht's hull out of the water can lead to significant performance gains as observed in recent additions of the America's Cup. Hydrofoil design is driven by maximising the lift to drag ratio over a range of conditions whilst trying to minimise the manufactured weight. Designing composite foil structures based on ultimate strength can provide valuable weight savings but results in greater structural deformations. Predicting the performance of modern hydrofoils is therefore a Fluid-Structure Interaction (FSI) problem requiring both the fluid and structural responses to be understood. Increases in computational resource have led to numerical techniques which solve both the flow field and the structural deformation of such structures however there is very little experimental data available with which to validate these simulations.

Obtaining experimental measurements of the deformed shape of a hydrofoil is extremely challenging as the structure cannot be tested in isolation but must be exposed to the same fluid loading as it would experience in operation. Recent research at the University of Southampton has developed optical techniques using Digital Image Correlation (DIC) for measuring the full-field deformation of a foil whilst being tested in a wind tunnel [1]. This technique has subsequently been coupled with Particle Image Velocimetry (PIV) to provide synchronised measurements of the fluid flow field and the foil deformation [2]. An overview of how this data has been used to validate coupled CFD and FEA simulations of flexible foil structures will be provided highlighting the benefit of such experimental data for the development of future computational methods.

As the previously published experimental FSI investigations were conducted in a wind tunnel, the fluid dynamic loads are significantly smaller than at the equivalent Reynolds number in water. Therefore, to date these methods have not been applied to realistic foils deforming in water. A low-cost underwater stereo imaging system using Go-Pro cameras was utilised to provide full-field deformation measurement of a foil towed in a towing tank. The measurement accuracy of the system was determined by measuring the displacement of a rigid target translated over known distances. A curved dagger board from a Nacra F20, which was previously tested in the wind tunnel [1], was towed at a range of speeds and at two different angles of attack. The experimental deformations over the tip region of the foil will be presented and the potential value of such systems in the future discussed.

REFERENCES

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