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Roll Response of a Yacht at Zero Froude Number

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ABSTRACT

Horace Lamb, speaking to the British Association for the Advancement of Science in 1932:

" *I am an old man now, and when I die and go to heaven there are two matters on which I hope for enlightenment. One is quantum electrodynamics, and the other is the turbulent motion of fluids. And about the former I am really rather optimistic*"

This thesis describes the development and validation of a technique for predicting the roll motion of a yacht in waves at zero Froude number. Roll motion is strongly influenced by viscous effects, whereas other ship motions are in the main dealt with satisfactorily by inviscid theory.

Yachts exhibit a characteristic that distinguishes them from most other vessels; they have proportionally much larger appendages, and those appendages are distinctly three dimensional. Computational techniques for solving oscillating viscous vortical flows near the free surface are highly computer intensive and as yet have been developed only for basic geometries and simplified flows.

A time domain numerical model was developed which treated the hull and the appendages separately. Sway induced motion in the flow kinematics was included in the appendage model. The appendages were modelled on the Morison equation, requiring the input of inertial and drag coefficients in both roll and sway for a flat plate undergoing rotational oscillation. There was a dearth of data on the forces experienced by flat plates undergoing rotational oscillation. In order to provide appendage coefficients for the numerical model a series of forced rotational oscillation experiments was conducted in calm water on four flat plates of different shapes. The plates and their motion were scaled representations of a

yacht keel undergoing roll motion. The results were modelled in a form suitable for inclusion in the numerical model, using a least squares regression optimisation.

The development of the numerical model of roll motion of a yacht in beam seas provided valuable insight to the roll prediction problem. The technique of employing data from forced oscillation experiments in the numerical model via a Morison equation formulation has been found to be a worthwhile solution to the problem of modelling rotational oscillation flows. The effect of changes in appendage geometry on roll response were predicted by the numerical model to a level of accuracy sufficient for the model to be useful as an investigative tool in the yacht design process.

The results from the forced oscillation experiments showed that the forces generated by a two-dimensional plate exhibited quite different characteristics from those of three dimensional plates. This confirmed that existing successful 2-D numerical methods were not appropriate for the yacht appendage problem.

For the conditions of the forced oscillation experiments and within the limits of experimental error, the proximity of the plate to the channel bed did not alter the force and moment coefficients of the plate at under keel clearances as low as 2.5%. This was less than the practical operational limit for a sailing yacht at anchor.

Model experiments were carried out in a wave basin on a stylised hull with different appendage configurations to measure their influence on motion response. This confirmed the importance of appendages in roll response and provided validation data under controlled conditions for the numerical model.

Full scale experiments have been conducted on a yacht in waves and in calm water to measure the motion response. The results yielded validation data for the numerical model under realistic operating conditions and demonstrated that the influence of a sail on roll response.

The output from the numerical model showed that the yacht appendages dominated the hydrodynamic inertia and damping. This finding, supported by the full scale and wave basin model experiments, distinguishes the approach required for sailing yacht roll prediction techniques from those used in other craft with smaller appendages.