Modelling mean forces and moments due to waves based on RANS simulations

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ABSTRACT
In order to predict manoeuvrability of ships in seaways a mathematical model for approximating the hydrodynamic forces acting on the ship has been extended for taking into account mean forces and moments due to waves. RANS computations for a twin screw passenger ship in waves of various lengths coming from all directions have been used to determine the coefficients of the mathematical model. The paper shows that a double parametric approach on wave length and encountering angle is capable of reconstructing the mean forces and moments for all considered situations.

KEY WORDS: drift forces, RANS, mean wave forces, modelling, ship flow, manoeuvring, oblique waves.

INTRODUCTION
In the past years it has become common practice to use numerical methods for turbulent flows to predict the manoeuvrability of a ship in calm water. The effect of incoming waves thereby is still neglected in most cases. In order to predict manoeuvrability in waves and - in particular - to estimate the minimum power required to maintain a reasonable manoeuvrability in adverse seaway conditions, it is necessary to quantify the mean wave forces and moments acting on the ship during a manoeuvre.

A classical way for predicting rudder manoeuvres in calm water consists in approximating forces and moments due to ship motions and rudder deflection using a mathematical model. This allows solving the set of motion equations of the ship, assumed to be rigid, with a suitable numerical time integration algorithm. In the present work a mathematical model of Abkowitz type (Abkowitz, 1964) is being extended for taking into account mean forces and moments due to waves, in order to predict rudder manoeuvres of the ship sailing in adverse conditions.

The basic mathematical model for calm water, consisting of hydrodynamic coefficients which reflect the influence of motion and steering parameters on the hydrodynamic forces acting on the ship, has proven to perform satisfactorily for several applications as shown by the Stern and Agdup (2008); Cura-Hochbaum et al. (2008); Cura-Hochbaum and Uharek (2014) in the workshops SIMMAN 2008 and 2014. The coefficients can be determined by means of virtual captive model tests, see Cura-Hochbaum (2006). As a first step towards manoeuvring prediction in moderate long crested seaways, additional terms and corresponding coefficients taking into account the mean effect of the waves are now included to this basic mathematical model.

When taking wave effects into account, two considerably different time scales can be considered. The motion of the ship due to wave forces and moments of first order in the wave amplitude represents the typical seakeeping problem. These forces having usually very large amplitudes but zero mean values cause (relatively) high frequency motions in all six degrees of freedom. For manoeuvring prediction however, it may be a valid assumption that the harmonically oscillating first order forces do not influence the resulting (low frequency) global motions during the manoeuvre, provided that the encountering frequency of the wave does not become too small (Yasukawa and Nakayama, 2009). The only forces and moments to be added to the mathematical model for manoeuvring prediction are thus the non-zero mean values of second (or higher) order forces, also called drift forces.

This extension can be done by a simple approach, where mean wave forces and moments on the ship sailing steadily straight ahead in diverse obliquely incoming individual waves are stored in a database and their values for the current situation are calculated by a multidimensional interpolation from the database information. Another - more elegant - approach is to state a functional relationship between mean forces and all relevant parameters. With the usual assumption that the mean forces and moments due to a single harmonic wave depend quadratically on the wave amplitude ($\tilde{\zeta}_w$), the remaining parameters considered for a suitable description of these forces are the wave length ($\lambda$) or frequency ($\omega$) and the encountering angle ($\alpha$). The following