Universität Rostock

Traditio et Innovatio

LEHRSTUHL FÜR
MODELLIERUNG
UND SIMULATION

Universität Rostock | Fakultät Maschinenbau und Schiffstechnik |
Leitung Prof. Dr.-Ing. Nikolai Kornev D 18059 Rostock, Albert-Einstein-Str. 2

Description of the master thesis
Student: ???????
Supervisor: Professor Nikolai Kornev

Rostock, 5th of April, 2017

Development of the mathematical model describing the motion of foil supported catamaran at different sea state conditions.

1. Aim of the work.

The aim of the work is the exploration of the potential of hydrofoils to damp the longitudinal oscillations (heave and pitching) of fast catamarans. The idea is to retrofit existing fast catamarans by foils to improve the seaworthiness. Various previous investigations showed that the foils have positive influence on seaworthiness. In the Master thesis by Ivan Popov [2] done at LeMoS in 2015 was shown that an optimal foil can reduce the acceleration by 20 percent. The questions to be answered in this study are as follows:

- What is the optimal foil configuration?
- How big is the influence of foils on the accelerations and oscillation amplitude at different sea states?
- What is influence of foils at calm water conditions?
- Is it worth economically to retrofit the existing catamarans?

The following model should be developed

- Simulation of 3DOF dynamics using the hydrodynamic model based on the concept of added mass. The model is well described in [1] and [2].

2. Development of the model.

The model [2] should be extended to take the wave influence and hydrofoil into account. Description of the extensions is given below (see also [2]).

2.1 Modelling of forces due to incident waves

The wave ordinate is inserted into the formula for the ship submergence (see page 10 [1]):

$$h = (l - \xi_0 - \xi)\alpha + y_w$$

$$y_w = A\sin\left(K(x_{cg} + \xi) + \omega t\right)$$

The wave number K, frequency and wave amplitude A can be found from relations

$$K = \frac{2\pi}{L_w} \qquad \omega = \sqrt{Kg} \qquad \frac{2A}{L_w} \approx \frac{1}{20}$$

The formulae (8) and (9) from [1] are modified to take the waves into account as follows:

$$\dot{h} = U_0\alpha - \dot{y} - \xi\dot{\vartheta} + \dot{y}_w$$

$$f = \rho_w k(\beta)\left(2h\dot{h}(U_n - \dot{y}_w) + h^2(\dot{U}_n - \ddot{y}_w)(2 - \cos\beta)\right)$$

Forces due to waves are calculated from the formulae

$$Y_{wave} = \int_{-\xi_0}^{l-\xi_0} f_{\mathbf{w}}(\xi)\mathrm{d}\xi$$

$$M_{wave} = \int_{-\xi_0}^{l-\xi_0} f_{\mathbf{w}}(\xi)\xi\mathrm{d}\xi$$

$$f_{\mathbf{w}} = \rho_w k(\beta)\left(2h\dot{h}(\quad - \dot{y}_w) + h^2(\quad - \ddot{y}_w)(2 - \cos\beta)\right)$$

$$Y_{wave} = \frac{Ak(\beta)\rho_w\vartheta_0^2\begin{pmatrix} (2-\cos\beta)l_0^2K^2\omega\cos(\xi_0K - Kx_{cg} - \omega t) \\ -2(2-\cos\beta)l_0K\omega^2\sin(\xi_0K - Kx_{cg} - \omega t) \\ +2(2-\cos\beta)\omega^2\cos(\xi_0K - l_0K - Kx_{cg} - \omega t) \\ -2(2-\cos\beta)\omega^2\cos(\xi_0K - Kx_{cg} - \omega t) \\ -2K^2U_0^2\cos(\xi_0K - l_0K - Kx_{cg} - \omega t) \\ +2K^2U_0^2\cos(\xi_0K - Kx_{cg} - \omega t) \end{pmatrix}}{K^3}$$

$$M_{wave}=\frac{-Ak(\beta)\rho_w\vartheta_0^2\begin{pmatrix}(2-\cos\beta)\xi_0 l_0^2K^3\omega^2\cos(\xi_0K-Kx_{cg}-\omega t)\\-(2-\cos\beta)l_0^2K^2\omega^2\sin(\xi_0K-Kx_{cg}-\omega t)\\-2(2-\cos\beta)\xi_0 l_0K^2\omega^2\sin(\xi_0K-Kx_{cg}-\omega t)\\-6(2-\cos\beta)\omega^2\sin(\xi_0K-l_0K-Kx_{cg}-\omega t)\\-4(2-\cos\beta)l_0K\omega^2\cos(\xi_0K-Kx_{cg}-\omega t)\\+2(2-\cos\beta)\xi_0K\omega^2\cos(\xi_0K-l_0K-Kx_{cg}-\omega t)\\-2(2-\cos\beta)l_0K\omega^2\cos(\xi_0K-l_0K-Kx_{cg}-\omega t)\\+6(2-\cos\beta)\omega^2\sin(\xi_0K-Kx_{cg}-\omega t)\\-2(2-\cos\beta)\xi_0K\omega^2\cos(\xi_0K-Kx_{cg}-\omega t)\\-2\xi_0K^3U_0^2\cos(\xi_0K-l_0K-Kx_{cg}-\omega t)\\+2l_0K^3U_0^2\cos(\xi_0K-l_0K-Kx_{cg}-\omega t)\\+2K^2U_0^2\sin(\xi_0K-l_0K-Kx_{cg}-\omega t)\\+2\xi_0K^3U_0^2\cos(\xi_0K-Kx_{cg}-\omega t)\\-2K^2U_0^2\sin(\xi_0K-Kx_{cg}-\omega t)\end{pmatrix}}{K^4}$$

2.2 Forces on hydrofoils

Slope on angle of attack is corrected to account for the free surface effect according to formula

$$C_y^\alpha(h)=C_y^\alpha\Big|_{h=\infty}\left(1-\frac{\tau^2}{2}\right),\quad \text{where}\quad \tau=\sqrt{4h^2+1}-2h$$

Derivative $C_y^\alpha\Big|_{h=\infty}$ is calculated from

$$C_y^\alpha=\frac{2\pi\lambda_f}{2+\sqrt{\lambda_f^2+4}}$$

Where λ_f is the aspect ratio.

Force on foils

$$Y^\alpha=\frac{1}{2}C_y^\alpha\rho_wU_0^2S_f$$

$$Y_{foil}=\frac{1}{2}C_y^\alpha\rho_wU_0^2S_f\left(\vartheta+\vartheta_0+\alpha_{sf}-\frac{\dot{y}}{U_o}\right)$$

can be just added to the hull forces determined from the model [1]. The influence of the hull is neglected. The moment on the hydrofoil is equal to the force multiplied by the arm.

Additionally, the model [1] should be extended by consideration of added mass and resistance of hydrofoils. The method for added mass can be developed using the book [3].

3. Working steps

1. Overview of the literature.
2. Analysis of the model [1].
3. Development of the code.
4. Development of the model [1] to take the waves and hydrofoils into account.
5. Consideration of the hydrostatic forces in the model [1]
6. Design of optimal foil configuration.
7. Report

4. References

1. Kornev, N., Kleinsorge, L. & Migeotte G. (2010). Dynamics and stability of racing boats with air wings. International Journal of Aerodynamics, Vol. 1, Issue 1, pp. 28—51.
2. Ivan Popov (2015). Дипломна работа Симулационно моделиране на динамичното поведение на състезателен катамаран. Bachelor thesis, Rostock, Varna (in Bulgarian).
3. Korotkin A.I., Added Masses of Ship Structures, Springer, 2009.
4. Tanvir Mehedi Sayeed, Heather Peng, Brian Veitch, and Randy Billard, Numerical simulation of fast resque crafts in waves and its application in a training simulator. The Journal of Ocean Technology, Vol. 8, No. 4, 2013, 41-63.
5. Benjamin Friedhoff and Alexander Tide, GEOSIM MODEL TESTS OF A HARD CHINE PLANING CRAFT ON DIFFERENT WATER DEPTHS, *10th International Conference on Fast Sea Transportation FAST 2009, Athens, Greece, October 2009*

Supervisor:

Prof. Dr.-Ing. N. Kornev