Journal of Traffic and Transportation Engineering 3 (2015) 289-292
doi: 10.17265/2328-2142/2015.05.004

Multi-hulls: Slamming, Upper Deck Wetness and Dimension Selection

Victor A. Dubrovsky
BaltTechnoProm Ltd., St. Petersburg 192283, Russia

Abstract: Some types of multi-hull ships are researched more or less, and some types of them are applied today. The slamming (wave shocks to hull structure) and the wetness of upper deck are common problems of seaworthiness of all sea-going ships, but all multi-hulls differ by the additional possibility of wet deck slamming. Slamming and wetness are the sufficient restrictors of ship operability at sea, therefore, ship dimensions, which are connected with these phenomenon, must be selected carefully for maximal seaworthiness of multi-hulls. If the wave level exceeds the local height of board, deck wetness is generated. The shock of a structure by wave means one-time exceeding of threshold values by two random processes: the vertical displacement of water level relative to ship and the speed of the displacement. The formula for prediction of coincidence frequency is shown. Standards of number of slamming and wetness are selected for definition of the permissible vertical dimensions of hulls. As an example, the results of some calculation of the minimal clearance (the distance between the design water-plane and wet deck) of two catamarans are shown. A strong dependence of the needed clearance from the relative beam of a hull is shown. The carried out data are recommended for the selection of a catamaran minimal clearance at zero approximation.

Key words: Vertical clearance, multi-hull ship, slamming, wetness, relative displacement, displacement velocity.

1. Introduction

Today, a lot of types of multi-hull ships are researched more or less [1], and some types are applied more or less widely [2]. All multi-hull ships differ from the corresponded mono-hulls by better seaworthiness, but the degree of the advantage depends on the ship type. Multi-hulls with SWA (small water-plane area) ships have the best possible seaworthiness from the displacement and semi-gliding vessels [3].

Slamming (shocks of hull structure by waves) is a common problem of all sea-going ships. But the problem of the traditional (mono-hull) ships is in main hull bottom slamming. The additional problem of multi-hull ships is slamming of the wet deck (the bottom of the above-water structure, which connects the hulls).

Upper deck wetness or "green water" (water volume on the upper deck) is a common problem of all sea-going ships. As with slamming, it is an important restrictor of the operability at sea. Usually, both phenomenon are observed in head or bow waves. Both phenomenon, slamming and "green water", depend on the ship motions and vertical dimensions. Both phenomenon are most often at various places of a ship: a bottom slamming is observed at hull(s) bow(s), wet deck slamming—most often at the bow end of the above-water structure, "green water"—at the bow part of the upper deck(s).

Hull bottom slamming is a more important problem with multi-hull ships of traditional shaped of hulls. Ships with small water-plane area are exposed much less than the hull bottom slamming because of relative bigger draft and sufficiently smaller motions.

The paper presents most physically-based method of some dimension selections for permissible seaworthiness and sailing safety. The corresponding dimensions are: vertical clearance (the distance between wet deck and design draft), minimal design draft at bow and board height at bow perpendicular.

Corresponding author: Victor A. Dubrovsky, Ph.D., research fields: researching and concept designing of multi-hull ships and boats. E-mail: multi-hulls@yandex.ru.

Sometimes, the other points on the upper deck can be important for various purposes of ships, for example, fishery or science boats, etc. At the case, wetness of the working places on the upper deck must be predicted by the method described below.

2. Physical Base and Calculation Method

Both phenomenon, slamming and wetness, can be described in main by their possibility or by number per unit of time—usually per a hour. Evidently, the second characteristic is more convenient because of simplicity of measurement at full-scale tests.

The "green water" begins, when the wave level is equal to the board height at the examined point. But the equality means a zero initial height of water on the deck. For actual generation of the "green water", a slightly bigger height of above-water board can be supposed. For example, the difference can be supposed equal to 10% of local height of board H.

The number of "green water" cases (N_{GW}) can be defined by the following equation [4]:

$$N_{GW} = (3{,}600 \times \omega_Z/2\pi) \times \exp-[(1.1 \times H)^2/(2 \times D_Z)] \quad (1)$$

where:

$\omega_Z = (D_V/D_Z)^{1/2}$;

D_V: the dispersion of vertical velocity of level displacement (m^2/s^2);

D_Z: the dispersion of level displacement (m^2);

H: local height of the above-water board (m).

Each shock of slamming means simultaneous exceeding of thresholds of two random values: (1) the vertical displacement of the wave level relative the ship; (2) the velocity of that displacement. If only level height is exceeded, no slamming shock exists.

The shock number per hour (N_S) is defined by motion and height of vertical clearance by the following equation [4]:

$$N_S = [(3{,}600 \times \omega_z)/2\pi] \times \exp[-d^2/(2 \times D_Z) + v_0^2/(2 \times D_V)] \quad (2)$$

where:

d: the distance from the examined point of the wet deck to the design water-plane;

v_0: threshold value of the velocity, usually, it is supposed as 3.5 m/s.

A comparison of Eqs. (1) and (2) shows that the number of wetness cases is bigger than of slamming shocks—for the same distances $1.1H$ and d. It means that the first value must be bigger than the second, if the case numbers are equal.

These equations show frequency but not intensity of the slamming shocks. The shock intensity depends at the surface shape and structure. If the acceleration of the wet deck $\delta^2\zeta/\delta t^2$ (m/s^2), relative to the water level, is known, and the slamming pressure (tf/m^2) can be obtained as follows [1]:

$$p = k(i)\cdot(\delta^2\zeta/\delta t^2) \quad (3)$$

where:

$k(i)$ is an empirical coefficient;

i is the bottom inclination angle relative to the horizon (Fig. 1) [1].

Today, there are no official standards of slamming and wetness frequency. Very different standards were proposed by various specialists [5]. The permissible number of "green water" depends from the ship purpose, i.e., from crew activity on the upper deck at sea. The difference of the proposed standards of slamming is smaller.

These standards selection is the first problem of the based calculations of vertical dimensions of multi-hulls.

The base of the calculation is measured or calculated data on relative displacement of wave levels at specified points. Corresponding seakeeping tests must be carried out with the models without wet decks because of wet deck position influence on the level measurements.

The calculation result of slamming possibility is the dependence of shock frequency and wetness from wave height and (varied) vertical dimensions. It provides a good base of the clearance or local height of board selection. If the needed clearance is impossible because of the other design demands, the intensity of slamming shocks can be decreased by some special development of the wet deck structure (for example, Ref. [1]).

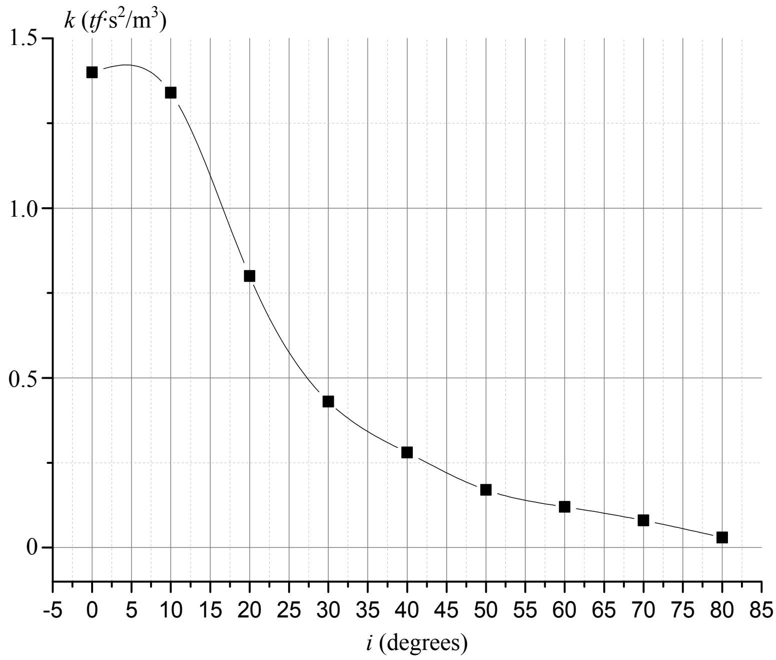

Fig. 1 The empirical coefficient *k* versus angles of surface inclination relative degrees.

3. Examined Options and Calculation Results of Slamming

Today, usually 20 shocks per hour is supposed as a permissible maximal value of slamming, as a rule—for the hull bottom. The same standard is supposed for the shown calculations. Evidently, the same calculations can be carried out for the other standard of shock frequency.

Today, there is not sufficient and systematic data on the catamaran motions, including relative displacement of water level. Some data on mono-hull motions were applied for the example of calculations for catamarans. It implies the following assumption: Catamaran motions are approximately the same, as the motions of a mono-hull of the same length, displacement, shape, as a hull of the catamaran. Evidently, it means the interaction of hulls is taken as a negligible one.

On that basis, the data of motion of systematic models of Series 60 [6] were used for calculations. The initial data of two hulls with $L/B_1 = 8.5$, $B_1/T = 2$ or 4, $C_B = 0.55$ (where, L—hull length, B_1—beam of a hull, T—design draft) were used. The test results are shown in Fig. 2 as the dependence of relative vertical clearance from the relative height of wave of significant height.

Evidently, the influence varied value of the relative beam B_1/T is sufficient. Maybe, changing of the hulls of smaller relative beam to bigger beam will ensure the possibility of smaller clearance, i.e., smaller height of hulls. But such transition means that changing of the design draft of hulls and smaller draft can be a reason of bigger slamming of hull bottoms. Let us check the idea.

As example, for a hull displacement of 1,000 t, the draft of narrower hull will be about 3.7 m, and the draft of wider hull will be 2.4 m. If the vertical displacement is assumed symmetrical, the values can be noted on the *y*-axis of Fig. 2. For Froude number, for example, 0.3, the frequency standard of the bottom slamming, will be achieved at relative height of wave about 0.18 for narrower hull, and about 0.37 for wider hull. It means that, relatively, wider hulls are more effective from both slamming points of view, wet deck and hull bottoms. It must be noted that, for the same frequency,

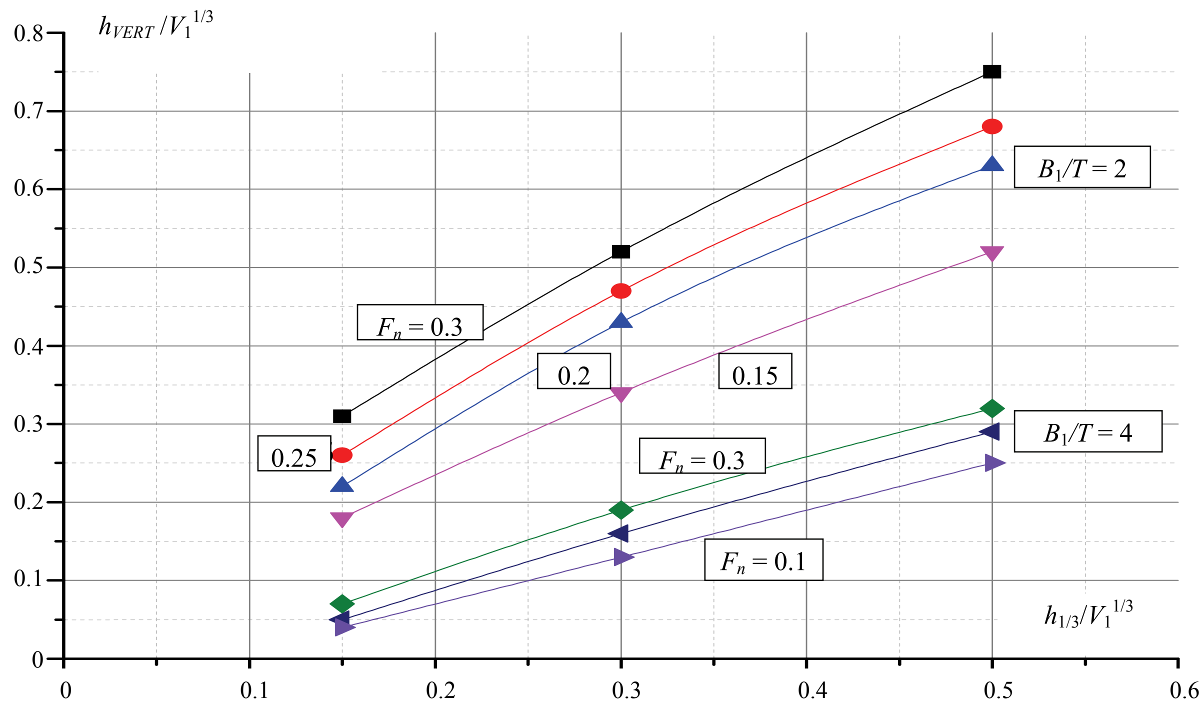

Fig. 2 Calculated minimal relative vertical clearance of two examined catamarans $h_{VERT}/V_1^{1/3}$ versus relative significant height of wave $h_{1/3}/V_1^{1/3}$ (where, V_1 means hull volume displacement).

the intensity of bottom slamming will be lower because the bottoms are not flat, but wet deck is practically flat.

4. Conclusions and Recommendations

Three points can be drawn from this paper:

(1) The proposed method allows the selection of the vertical clearance of any multi-hull ship or checking the permissible local height of board at the needed points based of seakeeping model tests or calculations;

(2) Two various catamarans, as an example, and the calculations show a sufficient influence of the minimum needed clearance (in general, minimum vertical dimensions) from the hull dimension correlation (relative beam);

(3) The calculated results are recommended for selection of a catamaran clearance at zero approximation (before seakeeping tests or theoretical prediction of seakeeping).

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