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Two Outrigger Ships with Various Main Hulls: Structure Mass Estimation

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Abstract: *Brief description of multi-hull ship types, specificity of ships with outriggers, the main results of concept designing of two type of outrigger ships: with traditional and with small water-plane area main hulls; the initial assumptions for structure mass estimation. Estimation result description: the difference of external loads (because of smaller motions) between two fast ships with various main hulls and with outriggers of conventional shape can`t be noticeable at the stage of concept designing, if the minimal thickness of plating was selected initially. Only the later stages of designing can show the influence of decreased motions to the structure mass for various shape of the main hulls.*

The next stages of designing of the examined ships are recommended.

INTRODUCTION

Twin-hull ship with identical hulls of traditional shape, catamaran, was the first type of multi-hulls, which was applied periodically from Ancient Ages. The type was widespread enough applied from the second half of twentieth century.

Ship with one bigger (main, central) hull and two smaller side hulls, outriggers, is the second type of multi-hull ships, which is used periodically since 1990-th.

As lot of multi-hulls, the outrigger ships usually have nothing near enough prototype for designing. It means, straight calculations of technical and exploitation characteristics is the most convenient method of approximately prediction for dimension selection at the early stages of designing.

All multi-hull ships and boats differ from mono-hulls by some common specificities, and each type of multi-hulls differs from the other types by own specificities [1], [2], [3], [4].

Specificity of multi-hull ships (MHS) in a comparison with mono-hulls:

- great number of types and shape options with various characteristics;
- bigger relative area of deck;
- more or less higher seaworthiness;
- any needed initial stability without any restriction of a hull aspect ratio;
- big above-water watertight volume;
- possibility of wet deck slamming;
- sufficient influence of transverse external loads on strength;
- possibility of sufficient changing of draft by small enough water ballast (if the water-plane area is small).

Multi-hulls can consist (fully or partially) from two various type of hulls: traditional ones or the hulls with small water-plane area, SWA ships (SWATH for two hulls).

Small water-plane area is the reason of highest achievable seaworthiness from all types of ships, except vessels with deeply submerged controllable foils.

The first result of small (or even decreased) water-plane area is sufficient decreasing of indignant forces and moments of waves. The second result is smaller enough longitudinal stability of SWA ships. It means about twice bigger natural period of pitch and heave, right part of Fig. 1. Roll period of SWA ships is about twice bigger, than the same period of comparable mono-hulls with the same initial transverse stability, because of bigger mass moment inertia relative the longitudinal axe, left part of Fig. 1.

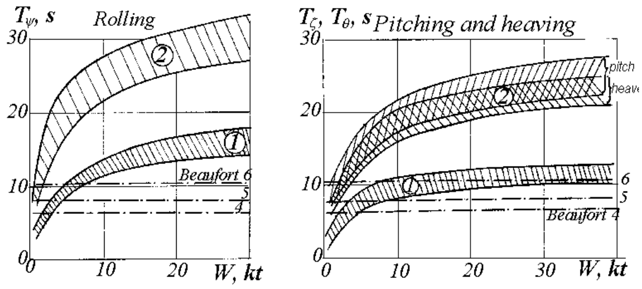

Fig. 1. Natural periods of motions of:

1 – mono-hulls, 2 – SWATH, as compared with average wave periods at Beaufort 4, 5, 6 (dot-dashed lines).

In its turn, bigger own periods of motions mean the resonance conditions at following waves and narrow headings in general, not at head waves, as of mono-hulls. SWA ship motions at following seas can have big enough amplitudes, but small enough accelerations, if there is not especially bigger damping, usually – by added motion mitigation foil, passive or active ones.

Outrigger ship with SWA main hull usually must have some pair of motion mitigation foils: three pairs, if the outriggers are at the middle, two pairs – if at stern.Total area of active foils is about 10% of the total water-plane area, with 2/3 part at stern.

The active mitigation foils – as any motion mitigation systems – are more effective at SWA ships, because the mitigation forces and moments are comparable with decreased indignant action of waves. If the motion mitigation is needed at rest, the mitigation tanks activated by air are the best method of mitigation. Today such system is applied at the Russian mono-hull supply ship for roll mitigation. The previously noted decreased longitudinal stability of SWA ships ensures pitch mitigation by such tanks too.

In general, seakeeping of a SWA ship is about the same, as of mono-hull of bigger displacement at 5-15 times (in the dependence from achieved decreasing of relative water-plane area).

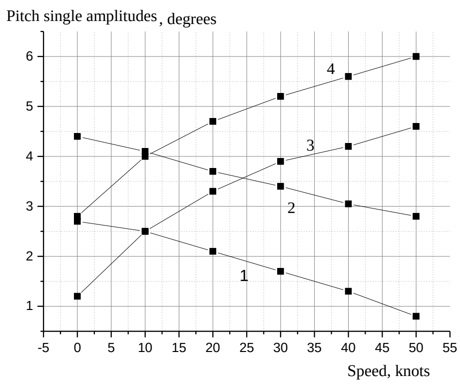

Fig. 2. An example of pitch single amplitudes in head waves of two ships, displacement 4000 t: 1- catamaran (a ship with two identical traditional hulls), Sea State 5; 2 – the same, Sea State 6; 3 – duplus (a ship with two identical SWA hulls), Sea State 5; 4 – the same, Sea State 6.

Various dependence of speed is evident: pitch of the SWA ship drops with speed growth. If the pitch standard is 4 degrees, the SWA ship has nothing restriction of maximal speed by pitch; and the ship with traditional hulls can`t have speed bigger, than about 32 knots for Sea State 5 and bigger, than 10 knots for Sea State 6.

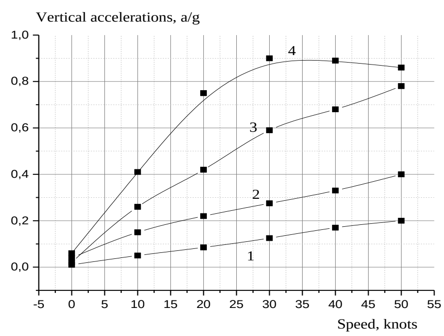

Fig. 3. An example of pitch accelerations in head waves of the same ships: 1 – catamaran, Sea State 5; 2 – the same, Sea State 6; 3 – duplus, Sea State 5; 4 – the same, Sea State 6.

If the acceleration standard is 0.4g, the catamaran can have speed about 17 knots at Sea State 5 and about 10 knots – at Sea State 6.The duplus has nothing speed restriction by the standard at both states of sea. Practically it means: the twin-hull 4000-t SWA ship is "all-weather" one.

It must be noted the main SWA ship advantage from seakeeping point of view, decreased or small longitudinal stability, is a sufficient disadvantage from damage trim point of view. It means the need of partially filling of end apartments by fireproof watertight light foam. Some end apartments of a new Russian frigate are filled by foam today.

Most simple draft variation is a specificity and possible advantage of SWA ships, because the needed water ballast is equal to (relative small) volume of thin struts. Bigger draft is effective for sailing in waves, and smaller draft – for harbors and shallow waters of any kinds. Such effective draft control can be ensured by the same mitigation ballast tanks activated by air.

Evidently, better seaworthiness, i.e. smaller amplitudes and accelerations of motions, mean smaller external loads of any kinds; therefore, structure mass can be decreased in a comparison with traditional shape of hulls.

All outrigger ships with SWA main hull and usual shape of outriggers have bigger relative water-plane area, as the other SWA ships, because the usual outriggers have relative big water-plane area. It means such outrigger ships have slightly worse seakeeping, as "pure" SWA ships.

There are two groups of outrigger ships: with traditional main hull and with SWA main hull. These ships with traditional main hull and outriggers differ from the ships with small water-plane area (SWA) main hull by sufficiently higher role of main hull in transverse stability ensuring and by smaller longitudinal motions.

The examined below ships are "capacity-carriers", i.e. they need for relative big area of decks.

1. Initial assumptions.

1. The specificity of geometry of the outrigger ships allow to take the main initial assumption: longitudinal motions in bow waves depend in main from the main hull shape; and transverse motions in side waves depend in main from shape, dimensions and position of the outriggers.

   The assumption allows the application of two various rules of structure designing for the estimation of structure mass of the outrigger ships: "Rules for the classification of trimarans"

[5] for designing of the transverse structure and "Guidelines for construction of small water-plane are twin hull craft" [6] for designing of the longitudinal structure and plating.

2. Besides, the relative influence of outriggers to the longitudinal bending moment is supposed approximately the same for any shape of the main hull.
3. The minimal number of the main loaded bulkheads of the above-water structure for both options includes two transient and two longitudinal bulkheads, as the example is shown by Fig. 4.

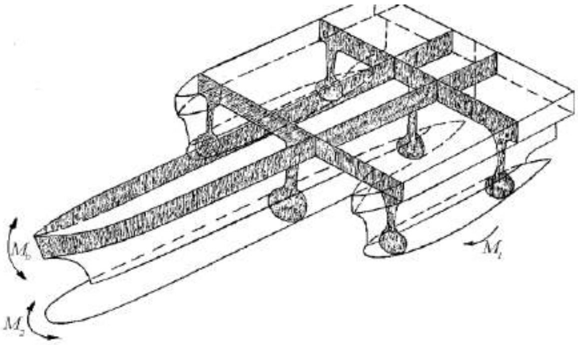

Fig. 4. An example of the minimal bulkhead systems of the above-water platform: two transverse ones from board to board and from deck to bottom, and two longitudinal ones.

4. The same initial exploitation demands are supposed the same for both examined ships and for a built ship, see below.
5. The exactness of calculations corresponds to concept stage of designing, when only overall dimensions of the hull and outriggers are known.
6. Both examined ships have steel hull structures and light-alloy superstructure.

2. Base option.

Littoral Combat Ships of US Navy was selected as the base for an example of concept designing.

Fig. 5. Littoral Combat Ship of US Navy at trials.

Referring to official data, the ship have following main dimensions and general characteristics:

length overall 127.4 m; beam overall 31.6; two gas turbines LM2500; two diesels MTU32.6; design draft 4.6 m; full speed 44 kn; sprint speed 50 kn; standard displacement 2750 t; full displacement 3100 t; range 4300 nm at 18 kn; crew 40 +35, 1 x 57 mm gun, 24 Hellfire missiles, helicopter Seahawk MH-60R/S, 2 drones MQ + MQ8C fire Scouts.

The other needed initial data were estimated by photos of external view and was supposed on the general base of combat and multi-hull ship statistics.

3. Main dimensions and general characteristics of designed ships

(the first approximation) are shown at the following table.

Dimensions & characteristics	Base ship	Traditional main hull	SWA main hull
Overall length & beam, m	127.4 x 31.6	(137, 112, 97) x (27.4, 33.6, 38.8)	
Design draft (full displacement, w/out water ballast), m	4.6	4.6	
Design draft at sea (full displacement, with water ballast), m	-	5.75	
Full displacement (w/out ballast), t	3100	Abt. 4100	Abt. 4350
Power for speed 44 kn and full displacement, MWt *	65	Abt. 88	Abt. 82
Power for speed 50 kn and full displacement	-	Abt. 130	Abt. 120
Main hull water-plane area, sq m	Abt. 915	1335	515; 420; 365
Outrigger area of water-plane, sq m	Abt. 250**	150; 100; 75	145; 95; 70
Relative water-plane area, $S_W/V^{2/3}$	Abt. 5.5	5.25; 5.0; 4.93	2.5; 1.95; 1.65

* in Russian practice, the full speed is defined at full displacement.

** used initial stability standard is unknown.

Evidently, full steel structure is the reason of full displacement increasing in a comparison with built ship. The same design draft is the reason of bigger beam of the main hull of the designed ship with traditional hull shape.

The difference between full displacements of the designed options is small enough, but it can arose at the next stages of designing.

It seems evident the differences between option dimensions are small enough (at the first approximation) : supposed the same relative overall beam means the same overall length and beam for the constant total deck area; about the same full displacements and very narrow values of outrigger dimensions.

Lower values of the residual resistance coefficient of SWA main hull at full speed is the reason of slightly smaller installed power of the ship.

The main difference is smaller at about 2 times relative area of water-planes of the SWA options. It means corresponded decreasing of longitudinal motions at head waves.

4. Brief description of mass estimations.

Smaller vertical accelerations at waves means about twice smaller general loads of the SW ship and smaller needed minimal thickness of bottom plating. But big enough hull depth ensures the needed minimal section modulus even with selected minimal thickness of all plating, and the difference between bottom thicknesses does not affect noticeable to the structure mass.

A more exact comparison can be carried out at the next, more detailed, stages of designing.

Conclusion, Recommendation

The difference of external loads (because of smaller motions) between two fast ships with outriggers can`t be noticeable at the stage of concept designing, if the minimal thickness of platingwas selected initially. Only the later stages of designing can show the influence of decreased motions to the structure mass for various shape of the main hulls.

The next stages of designing of the examined ships are recommended.

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