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Outrigger Ships: Two Concept Designs.

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Abstract-- **Brief description of multi-hull ship types, specificity of ships with outriggers, selected (as the base of comparison) built outrigger ship, concept designs of two type of outrigger ships: with traditional and with small water-plane area main hulls.**

I. 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 more or less widespread at the last ten-year periods.

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].

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 enough)
- in general, absence of more or less narrow prototypes for early stages of designing. [2]

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. [3].

The first result 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. 3. Roll period of SWA ships is about twice bigger, than the same period of comparable mono-hulls with the same initial transverse stability, [4], because of bigger mass moment inertia relative the longitudinal axe, left part of Fig. 1.

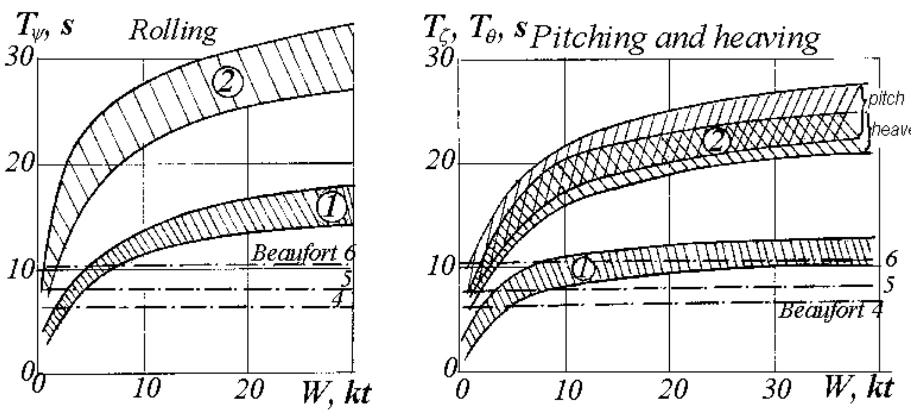

Fig. 1. Natural periods of motions of: 1 – mono-hulls, 2 – SWATH, as compared with average wave periods at Beaufort 4, 5, 6 (dot-dashed lines).

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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.

It must be noted, 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.

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).

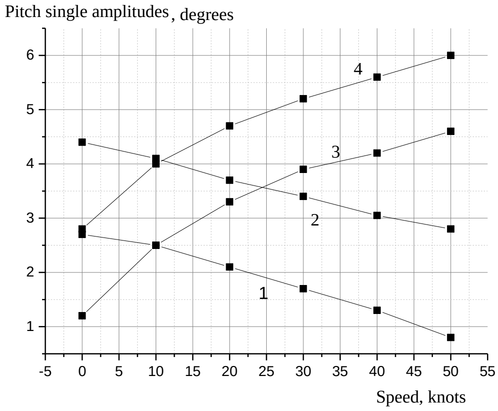

Fig. 2. An example of pitch single amplitudes in head waves of two ships, displacement 4000 t: 1- catamaran (a ship with two traditional hulls), Sea State 5; 2 – the same, Sea State 6; 3 – duplus (a ship with two SWA hulls), Sea State 5; 4 – the same, Sea State 6.

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 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.

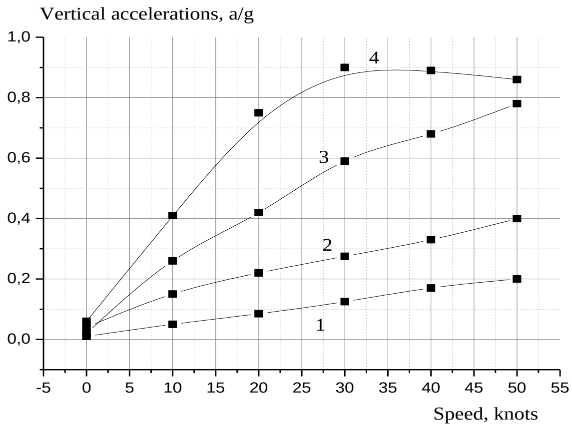

Fig. 3. An example of pitch accelerations in head waves of the same ships: 1 – catamaran, Sea State 5; 2 – the same, Sea State 6; 3 – duplus, Sea State 5; 4 – the same, Sea State 6.

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. And the duplus has nothing speed restriction by the standard at both states of sea.

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.

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The main problem of SWA ships is an evident contradiction between low enough longitudinal stability and the demands of damage trim. Most effective method of the contradiction avoiding is filling in some end apartments by fire protected watertight foam. The list of filled in apartment can be defined by damage attitude calculations.

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.

II. Base Option

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

Fig. 2. 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 about 50 kn, standard displacement 2750 T, full displacement 3100 T, range 4300 nm at 18 kn, two gas turbines LM 25000, two diesels MTU 20V8000, crew 40 +35, 1 x 57 mm gun, 24 Hellfire missiles, helicopter Seahawk MH-60R/S, 2 drones MQ + MQ8C fire Scouts.

Steel hull structure, light metal superstructure.

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.

III. Concept Designing

3.1 Previously solutions [4].

Some technic solutions were selected before beginning of variant designing of the alternative ships with conventional and SWA main hull.

The standard used for US Navy seems most simple and convenient for all types of ships: heel no more, than 10 degrees, at rest and for side wind of speed 100 knots (for unrestricted region of exploitation) or 50 knots (for restricted ones).

Both outriggers ensure the transverse stability.

Some restrictions of the overall dimensions are not known, except of draft at full displacement, but without of water ballast, the design draft is supposed equal to draft of the built ship.

3.2. Preliminary added assumptions:

- number of inner decks in the above-water platform N_1 = 2;
- height between the inner decks of above-water platform h_D= 3 m;
- part of total platform weight in the full displacement at zero approximation w_P = 0.7;
- relative volume of apartments for engines in the above-water platform (v_E =0.05 for diesels, 0.1 for gas turbines), the main engines and ship electric station are placed in the main hull gondola;
- relative part of displacement supply, system, equipment weight in the value of full displacement at the first approximation (w_S = 0.20);
- specific outlay of fuel on economy speed, kgf per a kWt at a hour, including lubricating oil outlay (q_F is approximately about 0.235 for diesels, about 0.3 for gas turbines);

– the weight of primary engines (gas turbines with cylindrical gears and high-speed diesels), will be defined by engine catalogues after power definition; weight of shafts, propulsors, electric station will be taken into account by engine weight correction by coefficients of about 1.5 for diesels, about 2 for gas turbines;
– relative volume of a superstructure on the platform $v_{SS} = 0.2$;
– relative length of outrigger $l_A = L_O/L = 0.5$.
– specific weight of platform metal structure per a cubic meter of the platform inner volume $q_W = 0.065$ t for steel structures.

Concept designing is based on the assumption on steel hull and superstructure.

3.3. Initial data.

The minimal needed initial data for outrigger ship designing are:

– needed payload P = 400 t, needed deck area S_D= 8500 sq m;
– height between decks in the above-water platform h_D= 3 m;
– full and economy speeds v_S= 50 knots (at full displacement), v_E= 18 knots;
– range R = 4300 nm at economy speed.

3.4. 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.

IV. RESULT ANALYSIS

Evidently, all 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.

V. CONCLUSIONS, RECOMMENDATIONS.

Design algorithm based on the needed deck area gives narrow enough overall dimensions at the first approximation. Material of hull structures, steel, is the reason of bigger full displacement of the designed ships in a comparison with the base ship.

Evidently smaller relative water-plane area of SWA ship means the defined advantage in motions at head waves.

Both designed options are recommended for further designing.

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