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Methodology Article

Multi-Hull Small-Sized Missile Ships: Solution Tree

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Abstract: Multi-hull ships, especially – ships with small water-plane area, are very effective as small-sized, especially fast, “capacity-carriers” i.e. vessels, which are designed for needed area of decks or inner volume, [1], for example – contemporary battle ships. Selection of type of small-sized missile ship is described in the dependence on pre-design conditions and technical solutions, including the corresponded solution tree. Two examples of examined alternatives are described more detail, including the ship with doubled achievable speed.

Keywords: Small-Sized Ship, Multi-Hulls, Ship with Small Water-Plane Area, Seakeeping, Designing, Solution Tree

1. Introduction

One must keep in mind that modern warships is "carriers of capacity", in general terms. This means that their dimensions are not defined primarily by payload mass, but by deck area needed to accommodate the armament and crew (taking into account all areas required to manage ship and maintenance of systems and devices). Typically, the combat mono-hull ships with a steel hull and superstructure have the payload within 10-15% of total tonnage, rarely exceeding 20%.

Especially great needs in fairly large deck area (primarily-top) from naval ships with aviation armament, which today includes, most notably, unmanned aircrafts.

In addition, an important operational qualities of a naval ship are the achievable speed and the ability to maintain it in waves. If the first comes at the expense of modern power plants, the second almost does not depend on the available capacities of the power plant and is determined in main by the characteristics of seakeeping.

Also note that speed in waves is decreased (or heading relative waves is changed, that lengthens the route) to provide the levels of seaworthiness characteristics required for safety of navigation and the possibility of functioning of all subsystems of the ship, especially the hull and the crew. Thus, today the naval ships should have a sufficiently large area decks, maximum high seaworthiness, including speed in waves, and high performance.

All these qualities are easier achieved when using various multi-hull ships provided than with traditional mono-hulled. The advantage of multi-hulls from seakeeping point of view is most evident at small and middle displacement.

The ships with small water-plane area showed their essential advantages compared to all traditionally shaped vessels. Summarizing, we can say an object with small water-plane area has the same seaworthiness as the mono-hull of 5-15 times larger tonnage (depending on the degree of water-plane smallness).

For example, in Figure 1 and 2 are compared the data on the amplitudes of the pitching and rolling of traditional ships with a displacement of 1000 and 3000 tons (a corvette and a frigate) and the 600-t twin-hull ship with small water-plane area, SWATH, designed in the 70-ths (according to model tests in a towing basin of Krylov Shipbuilding Research Center, St. Petersburg, USSR). All ships without motion mitigation.

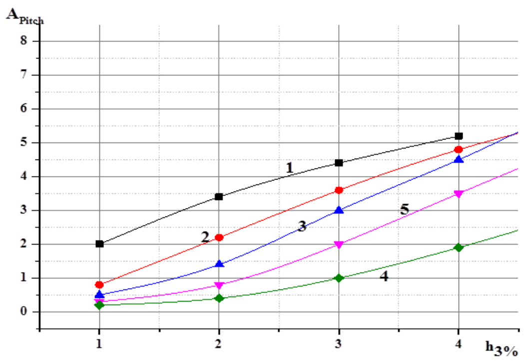

Figure 1. *Pitch amplitudes in head waves: 1-corvette, 1000 tons, 12 knots; 2-600-t SWATH, following waves, 10 knots; 3-the same, head waves, 10 knots; 4-the same, 18 knots; 5-frigate, 3000 t, 15 knots.*

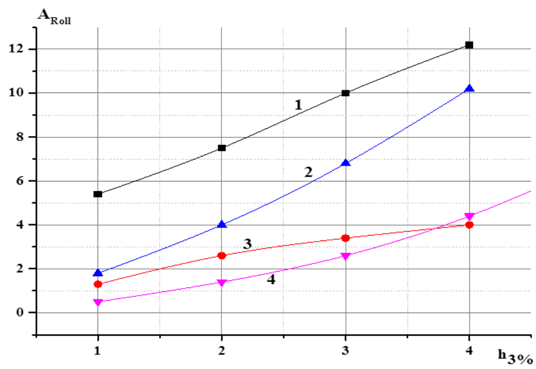

Figure 2. *Roll amplitudes at side waves: 1-corvette, 1000 tons; 2-frigate, 3000 t; 3- SWATH, 600 t, 10 knots, 4 - the same, 18 knots.*

Obviously not only the advantage of amplitudes, but the reverse is towards mono-hull-dependence of pitching from speed: growth of SWA ship speed leads to a decrease of the amplitude of motions. So for these ships power reserve really triggers the growth speed of the waves-unlike mono-hulls, where it is impossible to implement because of the need to reduce speed to maintain the desired level of seaworthiness.

However, for the pre-design selection of one or more types of missile ship, which it is advisable to examine in more details, the participants in this choice should be as precise as possible to understand the needs of the Navy, as well as how their provision will affect target the operational characteristics of ships of various types. You cannot confine itself to interaction designers with the customer only the earliest design phase. This interaction should be constant for the preliminary stages, and is available on all subsequent because at all stages of designing alternative technical solutions arise that affect the results of the design.

It is proposed to consider the sequence of pre-design solutions for example small-size mono-hull missile ship, insofar as she has a small displacement and cost, and therefore can be replaced by a new type of ship without much upheaval the foundations of shipbuilding ☺.

2. Pre-design Solutions

The built missile mono-hull of design number 21631 is the source of the main initial data. Initially, interest to this purpose the ship was called the emergence of the issue: is speed doubling of such ship useful from a tactical point of view? Let's say, for the fastest approach at a distance equal to the range of missiles-and a quick exit out of the reach of retaliation? The defeat of sea targets up to 300 miles at speeds up to 50 knots can be useful in the above sense.

Without substantially increasing the speed of the transition to one of the new types of ships, as a minimum, would result in a more or less (depending on type) visible increase seaworthiness, which is especially useful for small vessel.

More high seaworthiness, together with increased deck area, will further take aircraft armament (drones) and use it quite efficiently.

Further considered the possible restrictions and requirements that might determine the choice of the types. It should be noted that, in order to ensure comparability of all variants have the same inner decks of the hull connecting platform, as of the noted mono-hull. In addition, it is assumed the same set of weapons, i.e. its mass, when choosing the dimensions as payload.

The solution tree of the pre-designing is shown by Fig. 3.

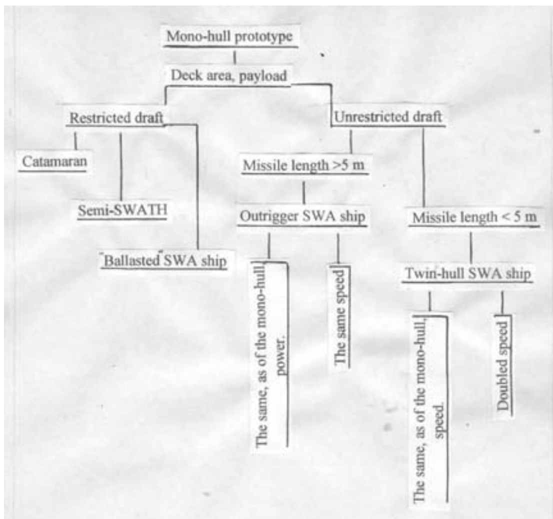

Figure 3. *Solution tree of multi-hull alternatives of the mono-hull small-sized missile ship.*

2.1. Consider Possible Restrictions on Dimensions of Alternative Vehicles

The most "expensive" ship size, length, of multi-hulls usually is significantly less than that of traditional ones. It is clear, therefore, that there is no limit on the length of the alternatives.

However, the draft from the original vessel was clearly limited, and the impact of the circumstances should be considered.

The same draft can be achieved: - by a catamaran (double-hull ship with traditional shape of hulls); - by SWA ship with a special selection of dimensions; - by so named “semi-SWA ship” (when the bow parts of hulls have small area of waterline, and sterns have usual shape, that allows to conveniently place the power plant(s) with practically any desired power).

A. Catamaran will be better than the traditional version because of the larger relative area of decks, bigger initial transverse stability and smaller the amplitude of roll (with approximately equal accelerations of roll, that you can provide a rational choice for the dimensions).

B. A small draft of a SWA ship can be ensured, if the height of its gondolas (the main under-water displacing volumes) will be accepted equal to draft at full displacement. At the draft is equal to height of gondolas, such SWA ship will be used in calm water, or in a harbor, and small enough water ballast will be taken for improve of seaworthiness by bigger draft. Ballast volume when this is almost half of the full volume of struts from the gondola to the above-water platform.

In this case, the height of the main engines may be greater than the height of the gondolas. This will force either to replace it to the above-water platform or significant width of above-gondola, in strut, engine compartments (but too small length of strut ends can lead to unacceptably big entrance and exit angles of strut waterlines, that will increase the towing resistance.) It is clear that increases the width of struts means increasing the area of waterline, that will lead to a worse seaworthiness.

Transfer the power plant to the platform means more complex and expensive transmission of power to the propulsors, i.e. or inclined shafts, or angular gears, or electrical or hydraulic transmission. All this makes it more difficult and costly SWA ship with strongly variable draft.

C. The same result - increasing the area of waterline and the consequent decreasing of seaworthiness-will take place when using semi-SWA ship.

Thus, rigid limitation of precipitation in the source data will limit the number of types, form or configuration options, see the left part of Fig. 3.

It should be noted that all ships with limited draft should be water jets -as the original traditional ship.

If there are nothing dimension limitations, the other options are considered below, the right part of Fig. 3.

2.2. Missile Dimension Influence

The main condition that affects the selection type in this case is the height of the main missile launcher. If this height is greater than 5 m, which will not allow to place them within the above-water platform, and the most convenient option is the SWA hull with outriggers; while launchers are linearly placed in the superstructure above the main hull (and in its strut). At the case, the parts of the above-water platform between the main hull and outriggers will be additional structure protection of the launchers.

A. The outrigger option can have the same main engine as the initial mono-hull, and a propeller as the main propulsor because of bigger draft. Then you can expect decrease achievable speed on calm water. However, at the expense of reducing the loss of speed in waves, the average speed in a marine environment can remain virtually the same.

B. As more warships, typically you can use twin-shaft power plant; it means the possibility of the same speed on calm water, as the single-shaft mono-hull, as due to power growth and by increasing the propulsive coefficient while increasing the area of two propulsors compared to one (with the same ship draft). The increase in the total propulsor area allows using the propellers instead of the more expensive and complex water jets. In this case, also the average speed at sea will be higher than that of a single-shaft prototype.

C. Finally, can be provided at approximately 2 times higher achievable speed of the twin-hull SWA ship [2], [3] in a comparison with the traditional prototype-understandable, with a corresponded increase in power and full displacement of the vessel.

All of these options may have additional weapons that should be taken into account as in the original largest payloads, and the magnitude of the necessary area of decks.

Thus, depending on the customer's needs can be considered the following alternatives to small-sized missile vessel:

A. With dimension restriction:
- catamaran;
- SWA ship with strongly varied draft (for calm waters and for sea conditions), with power plant in the gondolas or in the above-water platform;
- semi-SWA ship (with bow parts of small area of water-plane and traditional lines of sterns);

B. Without dimension restriction:
- SWA ship with outriggers for the same range of speeds that traditional ship, single-shaft or double-shaft;
- twin-hulled SWA ship with doubled, compared with the traditional ship, full speed.

For the example below briefly shows the main results of an indicative selection of dimensions and the expected characteristics of the two latest versions of ships.

3. The Initial Data

Noted mono-hull prototype has a full-load displacement 949 t, maximum length of 74.1 m, width 11 m, hull height 6.57 m, draft of 2.6 m, speed 25 knots at power 7.35 MW and one water-jet.

Hull draught 6.57 m can correspond to 1 or 2 inner decks; for avoiding of deck lack, let us suppose 2 inner decks. Then the area of internal decks, without the second bottom floor, is approximately 1300 sq. m.

Take the mass of the payload equal to 15% of total tonnage, i.e. approximately 150 tons.

The stated values of speed and power source in research project believe.

4. Options Do Not Have Restrictions on Draft

Minimum overall width of the options shall be determined by the next request to the initial transverse stability: heel at rest no more than 10 degrees if the side wind has a speed of 100 knots (which corresponds to an unlimited navigation area, usual condition for US Navy) [4], [5].

4.1. SWA Ship with Outriggers

When placing missile launchers near the midsection will adopt the same accommodation outriggers (to increase the structure protection of the main armament of the ship). This placement of outriggers is optimal for the economy speed [5].

The special algorithm of SWA ship designing [6], [7], [8] allows to select the main dimensions and general characteristics at zero approximation, see below.

Overall width this option is determined by the above requirement for initial transverse stability.

Estimated general arrangement of outrigger SWA ship with outriggers is shown by Figure 4.

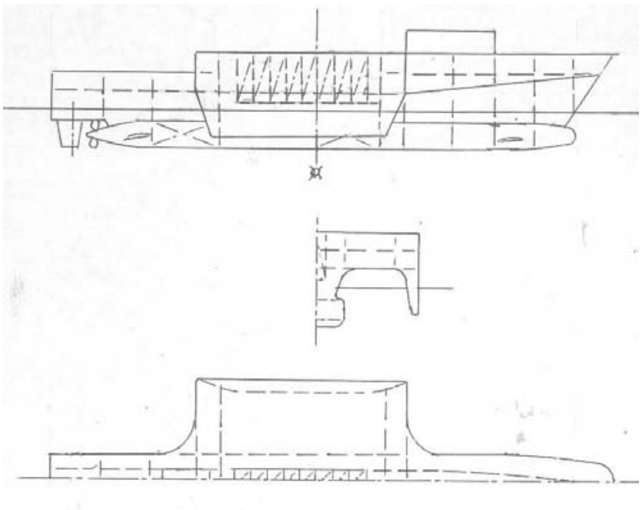

Figure 4. *Approximate general arrangement of SWA ship with outriggers.*

4.2. "Semi-Gliding" SWA as the Missile Ship with Doubled Full Speed

For a substantial increase in the speed of a SWA ship, you must use the new hull shape, which was proposed for such speed regimes, [9].

Significantly increased compared to previous versions speed means increased demands for main engine power, and therefore leads to increase of displacement. However, the estimated full speed mode, the ship will float up to the waterline at the upper edge of the gondolas, so here are a few bigger water-plane area at full speed [10].

The approximate scheme of this variant of fast SWA ship is shown in Figure 5.

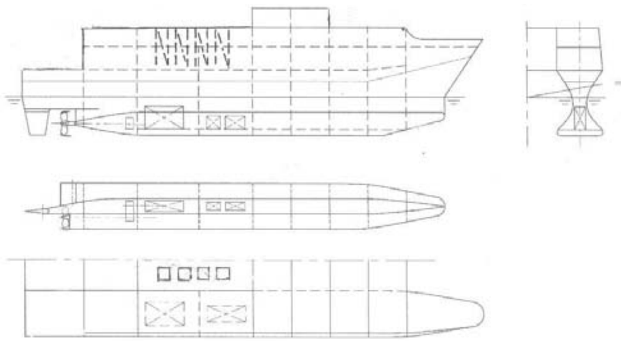

Figure 5. *General arrangement draft of 50-knot small-sized missile ship.*

5. The Main Results

Comparative data on the principal dimensions and main characteristics of the two options, draft which is not limited, are given in table 1.

Table 1. *Rough estimation of the main dimensions and general characteristics options of small-sized missile ships with not restricted draft.*

Type of vessel	SWA hull with 2 outriggers, single shaft	The same double-shaft	Twin-Hulled SWA ship
Internal decks in connecting hull superstructure, sq. m	1300		
Armament and ammunition, t	150		
Overall dimensions, m	65 x 25 x 12		55x20x15
Draft at full displacement, m	4.5		6.0
Full displacement, t	abt. 800	abt. 850	abt. 1300
Main engine power, MW	7.55	2 x 6.0	2 x 25
Full speed at full displacement, knots	abt. 21	abt. 25	abt. 50
The cruising range at a speed of 15 knots, n. miles	2500		2500
Sea State, in which there are no speed and heading angle restriction	5		
Sea State, in which heading angle must be corrected	6		

6. Conclusions, Recommendations

The previously examined options of multi-hulls are better, than the built mono-hull, from seaworthiness point of view, including speed in waves, and can fulfill all the other demands to such ships. Option selection depends strongly from the initial conditions and pre-design solutions.

The described options can be a good base of more detail designs of developed small-sized missile ships.

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