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POLYMER COMPOSITE MATERIALS FOR SHIP SUPERSTRUCTURES

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Abstract. Throughout the history of shipbuilding the problem of increasing the economic efficiency (EE) of the ship both at the initial stage of design and construction, and during operation is relevant. This paper discusses some issues related to the prospect of using polymer composite materials (PCM) in the construction of superstructures of dry cargo ships with a metal hull in order to achieve higher economic indicators during the service life of ship.

Keywords: *polymer composite materials, superstructure, dry cargo ship, economic efficiency.*

1. Introduction

The technical level of shipbuilding is largely determined by the compliance of the used materials, the growing operational and design requirements. Currently, the use of polymer composite materials is expanding quickly and efficiently in both surface and underwater shipbuilding [1], [2]. This fact is explained by the special advantages of these materials compared to the traditionally used (steel, aluminum, wood). Polymer composite materials have good strength with a low specific weight, which will allow reducing the weight of the product, as well as these materials have a high corrosion resistance and durability in aggressive surroundings. The main feature of polymer composite materials lies in the fact that they do not exist separately from the structures and technology of their manufacture, which allows to control the final characteristics of products at the design stage by changing components.

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2. Materials for Ships Superstructure

The rules of the Russian Maritime Register of Shipping (RS) until 2017 allowed using only steel or aluminum alloys as a material for superstructures and deckhouse of transport ships. In 2018, in the new edition, the rules of the RS began to apply polymer composite materials for superstructures and deckhouses on ships with metal hulls [3]. Rules of (RS) give special attention to fiberglass, because it is the cheapest and most common type of composite materials, which does not require special maintenance, which significantly reduces its life cycle cost. According to the static data of a German shipbuilding company Howaldtswerke-Deutsche Werft (HDW), and a Swedish shipyard in Kockums, the cost of maintenance of structures made of fiberglass is 6-10 times lower than the maintenance cost of the same structures, which are made from steel. Table 1 shows the characteristics of the materials used for transport ship superstructures [4].

Table 1 - characteristics of the materials used for the fabrication of the ship superstructures

characteristic	fiberglass	Steel	aluminum
Density ton/m^3	1,6 - 2,0	7,8	2,7
Flexural Modulus of elasticity, GPa	27	210	70
Ultimate flexural strength, MPa	690 - 1240	400	275
Ultimate tensile (compression) strength, MPa	410 - 1180	410 - 480	80 - 430
Tensile modulus, GPa	21 - 41	210	70
The coefficient of thermal conductivity W/(m·^{0}C)	0,3 - 0,33	46	140 - 190
coefficient of linear expansion 10^{-6}·1/ ^{0}C	5 -14	11 - 14	22 - 23

3. Economic efficiency of ship superstructures made of polymer composite materials

The use of new materials in the construction of superstructures in particular on dry cargo ships is aimed at improving economic efficiency (EE) during operation. The assessment of economic efficiency is determined by the following parameters:

1. Payload capacity ratio η:

$$\eta = \frac{W_P}{\Delta} \quad (1)$$

where:

W_P is payload capacity (tonnes);

Δ is ship's displacement (tonnes);

2. Fuel, oil and water reserves $W_{reserves}$

$$W_{reserves} = DWT - (W_P - W_1 - W_2 - W_3) \quad (2)$$

$$W_{reserves} = \Delta - LWT - (W_P - W_1 - W_2 - W_3) \quad (3)$$

Where:

DWT is deadweight Tonnage (tonnes);

LWT is Light Weight Tonnage (tonnes);

W_1 is total weight of crew, provisions, water, consumables (tonnes);

W_2 is consumable weight of liquid loads (tonnes);

W_3 is liquid ballast weight (tonnes);

3. Required shaft power of the main engine of the ship P (kW):

$$P = \frac{\Delta^{2/3}.V^3}{C_a} \quad (4)$$

Where:

V is ship's speed (knots);

$C_a$is Admiralty coefficient;

4. Cruising range r (miles):

$$r = V.t \quad (5)$$

Where:

t is sea days (hour).

Analysis of equations (1), (2), (3), (4), (5) shows that reducing the weight of superstructures of dry cargo ships due to their manufacture from polymer composite materials leads to a decrease in the light displacement and therefore the ship's displacement decreases on ΔD. The reduction in ship's displacement ΔD makes possible to increase the EE of by implementing one of the following approaches:

a) increasing in paying load capacity of ship;

b) increasing in endurance fuel capacity, oil reserve and fresh water capacity, which leads to an increase in the endurance and cruising range of the ship;

c) reducing the power of the propulsion power plant while maintaining the ship's speed, which leads to saves fuel consumption;

d) increasing the ship's speed and, as a result, reducing the time required for one voyage.

There are some results of practical studies, witch argue that the use of PCM for the construction of superstructures mainly affects the EE of the vessel. As examples, the following could be listed:

1. Modernization of the project of a hydrofoil № 17091 "Polesye" with a superstructure of polymer composites; the passenger capacity of this project increased from 51 people to 60 people. Also, with the same power of the main engines, this project is by 33% more efficient than the passenger hydrofoil project "Valdai-45R", which has a passenger capacity of 45 people [8].
2. As a result of the use of the composite superstructure of the RoPax ferry "PRINSESSE BENEDIKTE", the vessel's lightweight has decreased by

4.8% compared to the steel superstructure [9], therefore, the fuel consumption is reduced by 1.5% (84 tons per year) [10].

4. Conclusions

Evaluating the effects that the implementation of composite materials has had on the ship the following conclusions can be drawn. The use of polymer composite materials as a material for superstructures on transport ships, in particular dry cargo ships, significantly increases the economic efficiency of the vessel according to a number of key indicators such as paying load, endurance and ship propulsion.

5. References

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