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STERN PROFILED RECESS EFFICIENCY FOR REDUCING THE WATER RESISTANCE OF HIGH-SPEED VESSELS

ЕФЕКТИВНІСТЬ КОРМОВОЇ ПРОФІЛЬОВАНОЇ ВИЇМКИ ДЛЯ ЗНИЖЕННЯ ОПОРУ ВОДИ РУХУ ШВИДКІСНИХ СУДЕН

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Abstract. It is proposed to install a stern profiled recess on the wetted surface of a high-speed vessel, the shape and location of which depends on the size of the body and the speeds used by it. This device changes the pressure distribution on the surface of the selected hull. In the middle recess, a vortex motion is created, in the middle of which the pressure is lowered, which makes it possible to reduce the thickness of the boundary layer. With the proper development of the parameters, the profiled recess can be used to reduce the ship's full resistance. This research was carried out in the software package Flow Vision for obtaining the visualization and the calculations, which confirm that using the proposed device allows to reduce the resistance of the body when moving it in a liquid.

Keywords: recess; surfaces; resistance; pressure.

Анотація. Досліджено питання про ступінь ефективності використання профільованої виїмки на поверхнях швидкісних суден спрямованої на зниження опору тіл при їх русі в рідині.

Ключові слова: виїмки; поверхня; опір; тиск.

Аннотация. Исследованы вопросы о степени эффективности использования профилированной выемки на поверхностях скоростных судов, направленной на снижение сопротивления тел при их движении в жидкости.

Ключевые слова: выемки; поверхность; сопротивление; давление.

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Problem statement. The most modern cutters move at speeds corresponding to the transition or the planning regime. The planning motion mode uses the most of the small size vessels (boats, cutters, hydro cycles), small passenger speed boats, torpedo and anti-submarine boats, fire and rescue boats. Due to the widespread use of this type of vessels, the reduction of the resistance of the movement in the fluid is one of the main directions of their development. The installation of the fodder profiled slots will affect the resistance of the vessels. With the right choice of dimensions and their location, they will affect the thickness of the boundary layer, as well as contribute to the redistribution of the pressure on the surface of the ship's hull.

Latest researches and publications analysis. An analysis of the existing publications on the main trends in the high-speed fleet development showed that the "deep V" type due to the successful combination of the operational qualities, combined with the simplicity of the hull structure will dominate in the coming years. Today, the active research is being carried out and the fluids are used which allow to improve the stability of the vessel during her movement , to damp rolling and pitching, to lower the wetted surface of the hull, and, consequently, the resistance to the vessel movement. The active introduction of the cutter mechanization systems can also be observed as a consequence of the widespread expansion of the compact systems of the electronic control. All these described above trends require the significant complication of the vessel construction technology or the significant energy and the financial costs.

THE ARTICLE AIM. The purpose of this paper is to study the efficiency of the recess that changes pressure distribution on the bottom surface of a high-speed vessel.

Basic material. While planning the ship is situated above the surface of the water touching it with a small bottom area only. It is maintained in this position due to the hydrodynamic pressure that occurs as the reaction is thrown down the masses of the water and the current on the wetted area of the bottom. The main forces scheme on the bottom of the gliding boat is shown on Fig.1.

When a profiled slot is installed on the surface of the planning vessel, a macro vortex is formed, in the middle of which the velocity decreases, due to which the pressure in the centre decreases. The distribution of the viscous strength along the surface of the planning vessel is shown on Fig. 2–3.

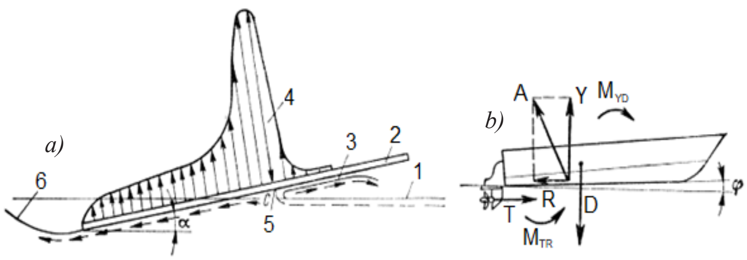

Fig. 1. Scheme of the hydrodynamic pressure effect on the planning plate (*a*) and the force on the bottom of the planning cutter (*b*) [1].

1 — a water surface; *2* — a plate; *3* — a bird stream that is thrown away; *4* — a diagram of the hydrodynamic pressure; *5* — a point *C*, in which the flow rate equals to 0, and the pressure has the maximum value; *6* — a wave cavity.

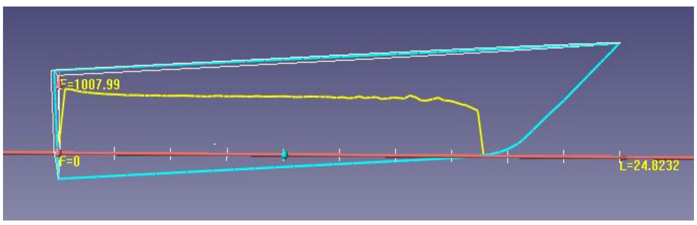

Fig. 2. Distribution of viscous strength along the surface of the planning vessel

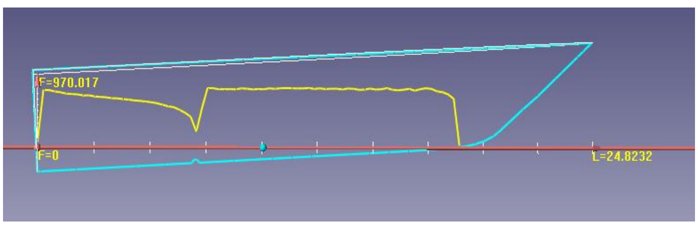

Fig. 3. Distribution of viscous strength along the surface of the planning vessel with a recess

Considering the picture of the distribution of the viscous strength along these hulls, we can conclude that the recess on the hull of the vessel changes the nature of pressure on the surface of this hull.

In order for the recess to affect the resistance of the vessels, their size must exceed the permissible roughness in the equation:

$$h_{sa} = (100 \cdot v)/\vartheta,$$

where v — is the kinetic coefficient of viscosity of the liquid [m²/s], ϑ – the speed of the ship [m/s], in this case, the recess will affect the redistribution of the pressure [2].

To study the effectiveness of the profiled recessed surfaces on the high-speed vessels, two variants of boats with slots were examined (see Fig. 4). In both cases, the diameter of the recess was taken 7.8 % of the board height. The location in the first case is $\bar{l}_v$ = 0,73 of the length of the vessel starting with the bow perpendicular ($\bar{l}_v = l_v / L_{nb}$), in the second by $\bar{l}_v$ = 0,65.

The main characteristics of the enclosure surface are the following:

length of the ship — L_{nb} = 25 m;
width of the ship — B = 6 m;
the ship's height — H = 4 m;
draft ship — d = 1 m.

The calculation was carried out in the CFD package "FlowVision". Boxing and solid-state models of the planning vessels were created in the SolidWorks CAD system and were stored in STL format. The planning hull model was loaded into FlowVision through a moving hull filter. A mathematical "free surface" model was chosen, in which the Reynolds equation will be supplemented by equations of the k-ε model of the turbulence and the equation for the function VOF, which simulates the free surface. The initial mesh had 152181 cells and the 2nd level of the adaptation of the grid near the solid surface of the hull was given. In the case of calculations of the planning vessel with a recess, the local grinding of the grid in the vicinity of the hole was performed.

At first, all hulls were examined under the same conditions, without taking into account the effect of free surface. This calculation is made as a preliminary analysis of the effect of a recess on a planning vessel, due to the suitable long time required to calculate the model with a free surface. Below is a table of coefficient dependence of motion resistance of planning vessel from the number of Reynolds (Tab. 1).

Then all the hulls were examined under the same conditions, taking into account the free surface effect. Below is a graph of the vessel's resistance coefficient dependence from the Reynolds number (Fig. 5).

During the graph analysis, we can conclude that at increased speed the effect of the recess shows a better result than at low speeds. The pressure distribution along the surface of the planning vessel is shown on Fig. 6–7.

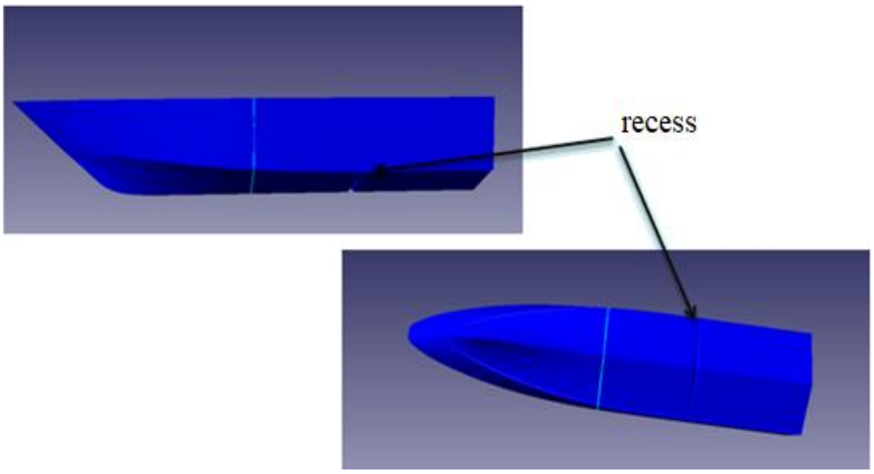

Fig. 4. The hull of the gliding vessel with the installed recess

Table 1. A graph of the dependence of the planning vessel motion resistance coefficient from the number of Reynolds

Re · 10⁻⁶ [кН]	C_r (a smooth hull)	The location recess	
		C_r when $\bar{l}_v$ = 0,73	C_r when $\bar{l}_v$ = 0,65
111,47	0,0125	0,0089	0,0088
143,3	0,0124	0,0090	0,0089
238,85	0,0124	0,0100	0,0097
318,47	0,0137	0,0109	0,0106
398,089	0,0123	0,0100	0,0094
477,71	0,0122	0,0098	0,0091
557,33	0,0122	0,0097	0,0088

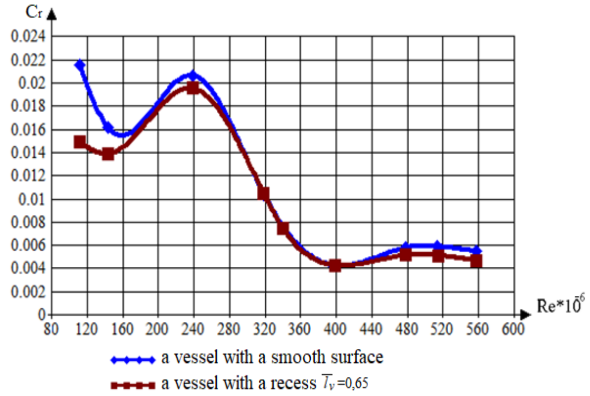

Fig. 5. A graph of the motion resistance dependence of planning vessel on the Reynolds number, taking into account the effect of free surface

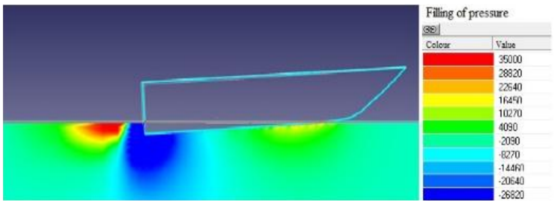

Fig. 6. Pressure distribution along the planning vessel surface

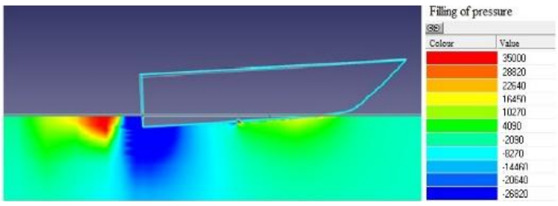

Fig. 7. Pressure distribution along the planning vessel surface with a recess

CONCLUSIONS. In this paper one of the ways of controlling the boundary layer was considered in order to reduce the high-speed vessels resistance on the surface. The task was to create projects in the Flow Vision software system and perform the calculations for a smooth surface and a surface with the fitted recess. A large number of verifications of the size, number and location of the profile recess on the surface of a high-speed vessel was carried out to achieve their optimum size. In the future, it is planned to study the effectiveness of using the recess, in conjunction with other methods of reducing resistance.

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