Study the Hull Form and Propeller-Rudder System of the Fishing Vessel for Vietnam

Victor G. Bugaev, Dam Van Tung and Yana R. Domashevskaya

Abstract Currently, the construction of steel fishing vessels in Vietnam is extremely important. For the traditional fishing vessels were built in Vietnam, the characteristic form of the contours corresponding to low-speed running and block coefficient is increased. The transition to a new level of construction and operation of fishing vessels requires a thorough and detailed analysis of the hull form and the characteristics of propeller-rudder system, as well as their interaction in the process of fishing operations. In this paper we discuss the characteristics of the hull form and propeller-rudder system (propeller inside the nozzle) of the fishing vessel (project 70133), intended for the manufacture and operation in Vietnam by using Computational Fluid Dynamics.

Keywords Fishing vessel · Propeller-rudder system · Resistance of ship

1 Introduction

Today, computational fluid dynamics (CFD—Computational Fluid Dynamics) is widely used both in its traditional fields: shipbuilding, aviation, design vehicles, and at the creation of home appliances, printing equipment, etc. Modern software products of hydrodynamic simulation combine high level of functionality, accuracy, and ease of use.

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Features of designing and operation of fishing vessels are [1, 2]:

Search of fishing objects and fishing practices by various fishing gear;
Storage and transportation of whole cooled fish and seafood in refrigerated tanks with water from 6 to −1 °C;
Changing load during fishing and during the voyage;
Long-term stay in the sea under various meteorological conditions;
Conducting fishing in conditions of the agitated sea and in various modes of movement.

The organization of fishing is autonomous, in which the fishing vessel will deliver the catch or the cooled products ashore, receiving from the shore bases all types of supplies.

Errors in the selection of fishing speed, maneuverability, and seaworthiness can lead to a significant decrease in the efficiency of the vessel.

Currently, the construction of steel fishing vessels in Vietnam is extremely important. For the traditional fishing vessels had been built in Vietnam, the characteristic form of the contours corresponding to low-speed running and block coefficient is increased. The transition to a new level of construction and operation of fishing vessels requires a thorough and detailed analysis of the hull form and the characteristics of propeller-rudder system, as well as their interaction in the process of fishing operations.

The purpose of research is studying the characteristics of the hull form and propeller-rudder system (propeller in the nozzle) of the fishing vessel project 70133, intended for the manufacture and operation in Vietnam.

In this study, the following problems have been solved:

1. Created 3D models: of the hull vessel surface and propeller-rudder system, which allows carrying out parametric study and optimization.
2. Determined dependence of the resistance water from the vessel's speed and hull form.
3. Determined the hydrodynamic characteristics of the propeller-rudder system in the free water.
4. Determined the features of interaction of the propeller-rudder system with the vessel's hull.
5. Developed recommendations for improving the hull form and propeller-rudder system.

The vessel project 70133 is intended for seafood catching in the coastal areas of the exclusive economic zone of Vietnam and their transportation in the cooled condition (Fig. 1).

The vessel has been designed taking into account the requirements of the rules of the Russian Maritime Register of Shipping for compliance with foreign rules and regulations. The vessel has a diesel engine, single-screw, with transom stern, continuous upper deck and with two-tier forward deckhouse. The speed is 11.0 knots.

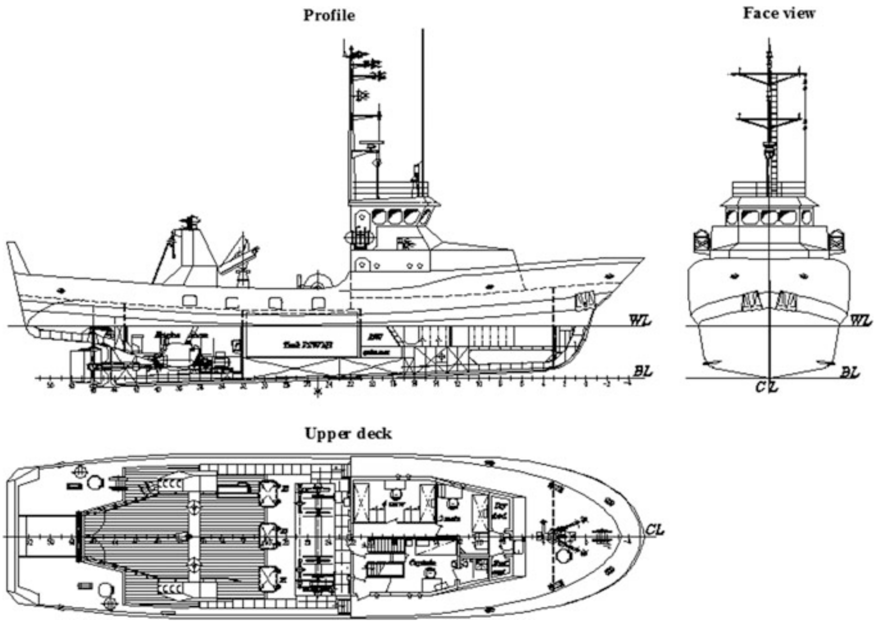

Fig. 1 General arrangement of ship

Table 1 Main characteristics of fishing vessel project 70133

Characteristics	Value
Lpp-length between perpendiculars, м	27.31
B-breadth by construction waterline, м	7.08
T-draft by load line, м	2.4
H-depth molded, м	3.42
β-mid-ship area coefficient	0.823
δ-block coefficient	0.534
φ-vertical prismatic coefficient	0.662

On modern fishing vessels, operating in various driving modes (on crossing, trawling, etc.), the use of controllable pitch propeller in the guide nozzle [3] is typical. Experience in the design and operation of these vessels has shown that they have large values of the coefficient of thrust and efficiency at low speeds as compared with vessels having a conventional propeller-rudder system.

The vessel has a controllable pitch propeller, with a diameter of 1.5 m and four blades of Ni-AL-BZ in the rotating guide nozzle (Table 1) [4].

The 3D model of the hull surface. The ship's surface has been made of ruled surfaces, interconnected by knuckles. The only exceptions are the bilge lines with rounded radius of 500 mm and part of the extreme end in the forepeak region. All knuckles are located higher the construction waterline. Thus, an increase in the process ability of the hull construction is achieved without a significant increase in

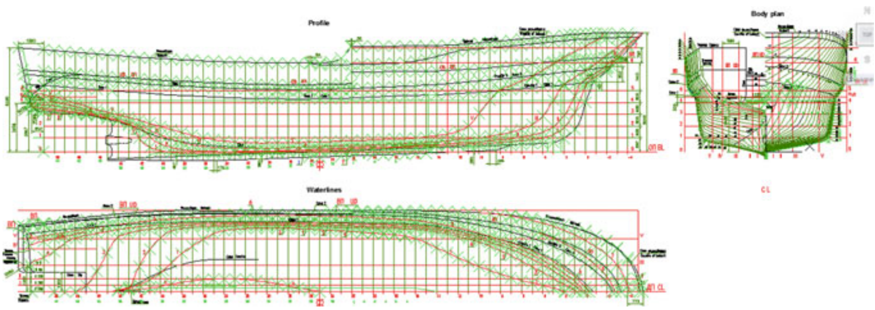

Fig. 2 Lines plan of ship

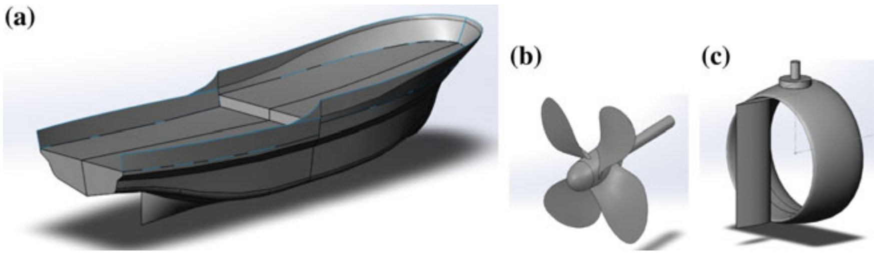

Fig. 3 3D models: **a** ship's surface; **b** propeller; and **c** nozzle with rudder

water resistance [5]. The line drawing is shown in Fig. 2, and a 3D model of the surface of the hull without a lito-welded stern frame, propeller, and nozzle with rudder in Fig. 3a

To study the hydrodynamic characteristics of the propeller-rudder system, a parametric model of four-blade propeller was created, which allows modeling the work of the vessel in various modes of field operations and transitions. The base screw has been chosen with a diameter of 1.5 m, with constructive pitch 1.24 m, pitch ratio 0.653, and the disk-area ratio 0.63 (Fig. 3b).

The model of the basic version of the nozzle is shown in Fig. 3c.

1.1 Simulation and Results

Dependence of water resistance on ship's speed and the hull shape

Simulation of the vessel's motion is carried out in a mode of transition (without regard to agitation) with Froude numbers, which allow calculating the water resistance of the vessel by traditional methods and comparing it with the results of the present studies. The focus is on the movement of the vessel at speeds of 4.06 m/s. The flow is laminar and turbulent. The surface roughness of the hull is assumed to

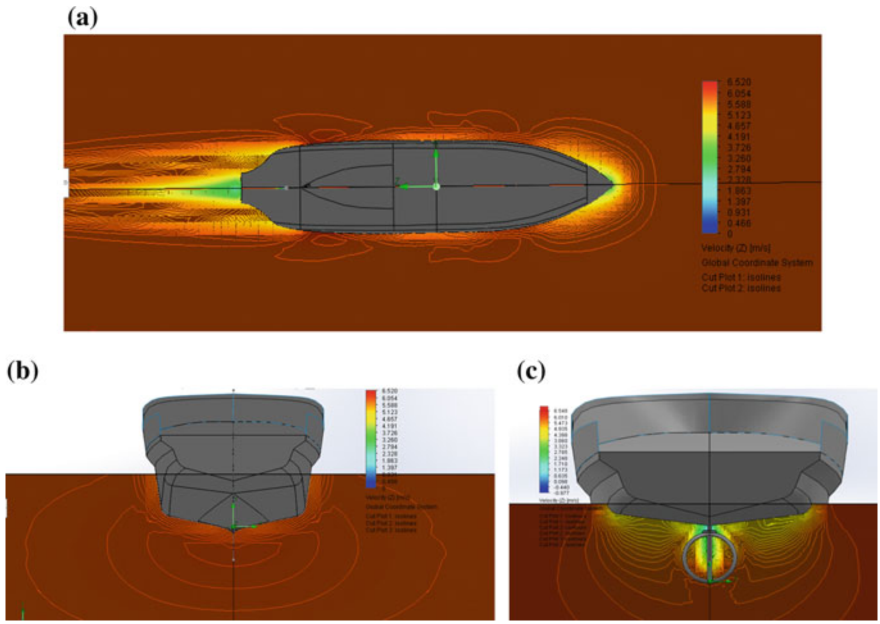

Fig. 4 Diagrams (field) of velocities: **a** in the plane of CWL; **b** in the plane of the mid-ship frame; and **c** in the plane of the disk propeller(in the system the hull—nozzle), the rear view

be 100 μm (micrometer). The dimensions of the computational domain have been chosen in such a way as to exclude the influence of the boundary conditions on the results of flow past the surface of the hull. As indicators determining the quality of the hull form, the following are accepted: complete resistance, pressure resistance, and frictional resistance, as well as flow velocities in the boundary layer and surface pressure [6]. In Fig. 4 is shown the diagrams of velocity distribution in various planes of the ship's hull, and in Fig. 6 curves of the resistance of the vessel, obtained in this study (R2) and calculated using the method Eroshin V.A. (R1).

Conclusion (Fig. 4):

In the area of the stern extremity, a significant decrease in pressure (flow velocity) is observed, which causes the formation of vortices and the separation of the flow in places of the sharp increase in pressure.

The velocity field in the plane of the propeller disk has a significant circumferential irregularity, which is associated with the V-shaped shape of the contours in the aft extremity.

Installing the wheel with the rudder (without screw) leads, on the one hand, to some leveling of the flow and, on the other, to increasing of the joint and frictional resistance, respectively, by 3 and 2%.

The thickness of the boundary layer in the middle part of the ship is changed significantly around the perimeter of the frame, and the greatest value is in the bilge area, which is explained by the presence of bilge vortices in this region.

A significant perturbation of the boundary layer is observed in the region of 06fr. and 40fr., which makes us pay attention to the shape of the surface of the hull in these areas.

The curvature of the flow lines in the boundary layer leads to the appearance of vortices and flow separation in the form of discrete vortices, which affects the resistance and associated flow.

The character of the distribution of velocities and flow lines in the location of the propeller in many (but not only) depends on the shape of the aft extremity and protruding parts.

Hydrodynamic characteristics of propeller-rudder systems in free water

In the simulation, the following initial conditions are assumed:

The propeller rotational speed is 350, 400, 450 rpm;

Speed motion 8 m/s with lead 2 m/s;

The dimensions of the computational domain exclude the influence of the walls on the hydrodynamic characteristics of the propeller in addition to the previous ones, and the following quality indicators have been introduced: Kt—coefficient of thrust; Kq—coefficient of moment; CE—Coefficient of efficiency sizes of mesh allow to obtain results with sufficient accuracy.

Fig. 5 shows the calculation results: (a) Diagram of velocity in the DP; (b) Line flow through the nozzle and rudder, and in Fig. 6—curves of the action of the propeller Kt, Kq, and CE.

The results of the calculations are in good agreement with the values obtained from the diagrams of the propeller in the guide nozzles, given in the references (so the difference in the coefficients of thrust is 5–10%) [7]. The calculated value of the efficiency of the propeller installed on the ship is slightly smaller (by 5%) than for the B-series propeller. However, the advantage of the controllable pitch propeller in the nozzle is its versatility and possibility of thrust control.

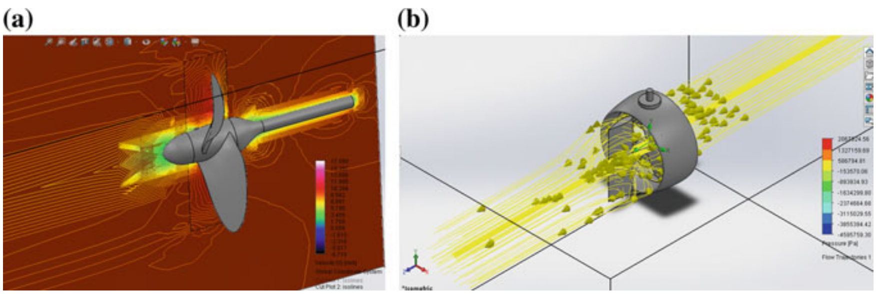

Fig. 5 Visualization of calculation results: **a** diagram of velocity in the DP; **b** line flow through the nozzle and rudder

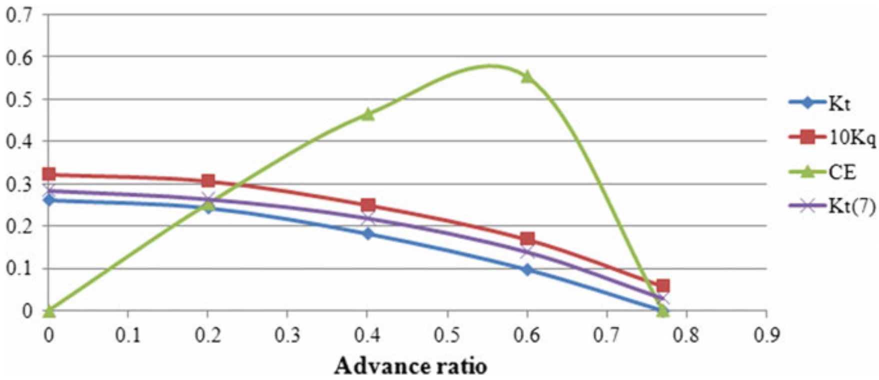

Fig. 6 Curves of the action of the propeller Kt, Kq, and CE

A drawback of some propellers in the nozzle is the screw twisting of the water flows inside the nozzle which, under the action of the centrifugal force, move radially and create an increased pressure between the end of the blade and the nozzle, which leads to the appearance of an additional component of the torque and a decrease in the efficiency.

The dimensions and shape of the nozzle with the rudder and propeller have been chosen in such a way as to exclude the phenomenon described above.

Features of interaction of the propeller-rudder systems with the hull

After creating the assembly surface of the body—the screw in the nozzle, a new study has been made in order to determine the influence of the elements on the entire system

Figure 7 shows: (a) the assembly model; (b) the diagram of the speeds of assembling the vessel's ship's surface with propeller-rudder systems in the plane of the mid-ship frame and (c) in the plane DP.

In Fig. 8 along with the ship's resistance curves obtained in this study (R2) and calculated using the method Eroshin V.A. (R1), the dependence of the resistance of the vessel with the nozzle and the propeller (R3) is shown.

At the end of the study, passport diagram is constructed to analyze the interaction of the hydrodynamic complex and the propelling engine (Fig. 9).

On the profile of the nozzle installed behind the hull of the vessel, circulation of the velocity is created, so the speed of water flow through the propeller disk increases, which contributes to an additional increase in its efficiency, in comparison with the value in free water (see Fig. 6). As a result, the use of the power of the main engine in various modes is improved due to the fact that the speed of the flow in the propeller disk varies more slowly than the speed of the vessel. When the propeller rotation speed of 450 per/min, obtaining at power of propelling engine Ng = 350 kW, the ship has a top speed of 11.2 knots (see Fig. 9) which corresponds sufficiently to the speed of the project vessel 70133 in free water.

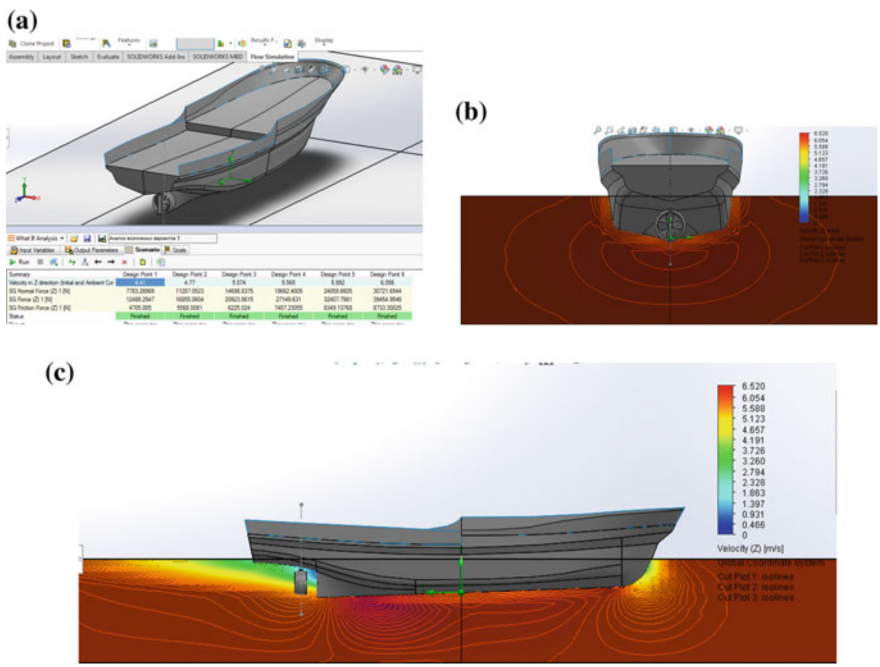

Fig. 7 Interaction of the propeller-rudder system with the hull: **a** assembly model; **b** diagram of velocity in the plane of the mid-ship frame; and **c** in the DP

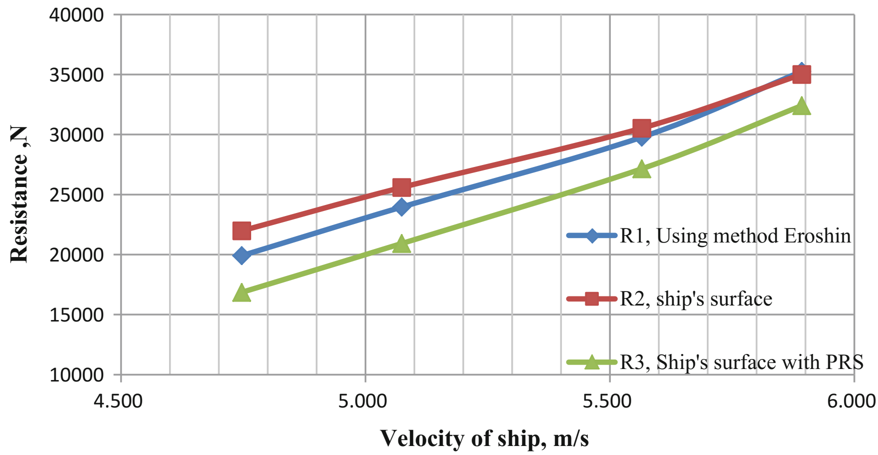

Fig. 8 Dependence of ship's resistance on speed

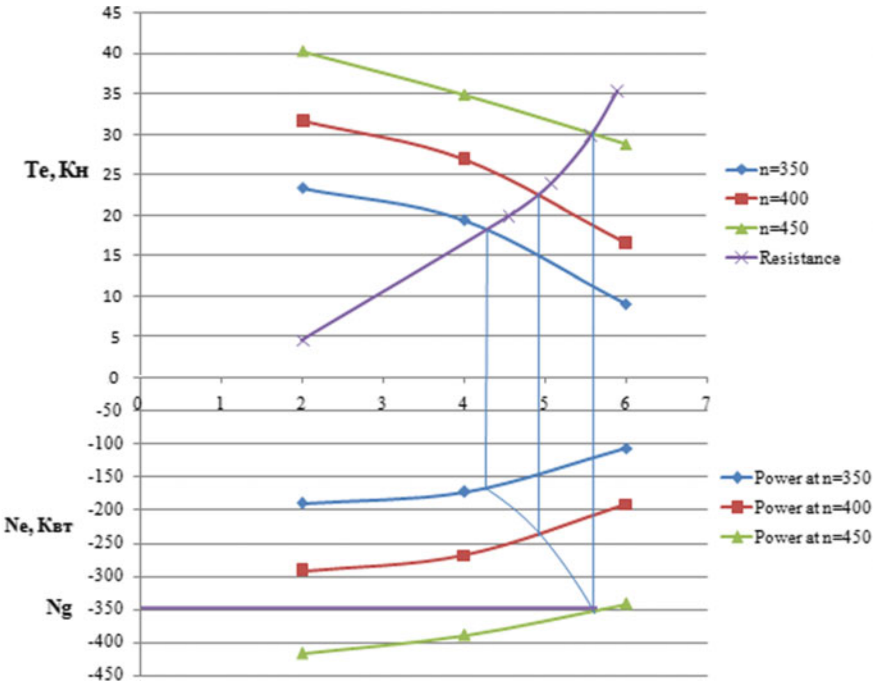

Fig. 9 Passport diagram

2 Conclusion

(1) In the area of the stern extremity, a significant decrease in pressure (flow velocity) is observed, which causes the formation of vortices and the separation of the flow in places of the sharp increase in pressure.

(2) The velocity field in the plane of the propeller disk has a significant circumferential irregularity and the installation of a nozzle with rudder somewhat smooth out this irregularity.

(3) The results of calculations of the resistance to movement of the vessel (R2) are in good agreement with calculations using the method Eroshin V.A. (R1), at a speed of 4.75 m/s the difference is 10%, and at a speed of 5.9 m/s decreases to a value of 0.6%.

(4) Estimation the nozzle with rudder behind the ship's hull leads to decrease of joint resistance (ship surface and propeller-rudder system) (R3) of the system, 20% (at medium speeds) and 8% (at high speeds) respectively. The positive effect of the propeller-rudder system has an impact on formation of streams of flow around the elements of the whole system.

(5) The picture of fishing vessel simulation and also numerical values of the parameters (speed and resistance) shows the suitability of SolidWorks Flow Simulation for using it at the stage of design and engineering analysis before carrying out experimental research.

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