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Conceptual design of multifunctional hydrofoil vessel “Afalina”

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Abstract. The article is concerned with the conceptual modeling of multifunctional hydrofoil vessel “Afalina”. The review of analogs is represented and the basic characteristics of this type of vessels as well as their multitasking functionality are described. The search of lines is carried out on the basis of biological prototypes and the searching process is illustrated by the variants of rough drawings. The vessel drawings are designed on the basis of chosen rough drawing; the constructional features and ergonomics of different modifications are described. The methods and tools of three-dimensional computer modeling are selected; shading and rendering stages are represented. The settings of multifunctional hydrofoil vessel rendering are obtained in the course of engineering.

1. Introduction

The task of passengers and cargo delivery over a short period of time and for long distances continues to be relevant for many coastal countries and island states. The process of development of concept design of multifunctional hydrofoil vessel is represented in this work. The main goal of this project consists in the development of general-purpose multifunctional platform on the basis of which it is possible to promptly apply different configurations with regard to the dedication of transport vessel. The engineering research will be based on the ingenious method of design with consideration to the biological prototypes; the high-technology computer modeling will be brought from the idea to real-world model. In the middle of the past century the dynamically supported crafts were designed. The effect of lift airfoil was used to move above the water; such vessels were called the hydrofoil vessels and airfoil boats. These vessels use the general principle of motion; the hull is lifted above the water by means of foils that enables reduction of hydraulic resistance of moving vessel thus considerably increasing the moving speed.

The hydrofoil vessel is a type of high-speed ship using the effect of shallowly submerged hydrofoil that consists of two main horizontal airfoils – one at the front and one from backside [1], [2]. The ‘airfoils’ are submerged into the water in such a way that vessel hull is above the water when moving thus allowing the vessel to move much faster as the water is thousand times denser than the air [3]. Initially, the hydrofoil vessels were attached to the small hulls and mainly held the experimental interest. Nowadays several large hydrofoil passenger ferries which are ergonomic and basically used in the coastal countries of Europe, Canada and Russia serve out all over the world. These modern vessels are effective enough as they feature good sea going characteristics and thus are used for the commercial cargo carriage.



2. Studies overview

Let's consider some current publications in this field and the conceptual models of hydrofoil vessels. The mathematical models of movement and stability of air-cushion and hydrofoil vessels are analyzed in this work [4]. The mathematical model for improving the stability coefficients of the vessel to prevent the girding and increase the maneuvering ability of the hydrofoil vessel at high speeds was developed in the work [5]. The offered model suggests the use of versatile lift airfoil technology.

The work [6] is focused on the optimization of main elements of speed hydrofoil twin-hull vessels at the stage of designing and analysis of their advantages and disadvantages. The aim of work [7] consists in the improving of the performance characteristics of the displacement hydrofoil twin-hull vessel equipped with the wind turbine generator. The hydrodynamic model is based on Reynolds Averaged Navier-Stokes (RANS) equations; the calculation data demonstrated the energy savings when using the hydrofoil technology.

The hydrodynamic characteristics of hydrofoil vessels are studied by means of discrete vortex method in the work [8]. The method of mathematical modeling of dynamic motion of hydrofoil vessel is offered to calculate the resistance, trim, stability, maneuverability and durability. The turbulent flow around the body of hydrofoil vessels is studied in the work [9]; the averaged Navier-Stokes method is used for modeling. The calculation data are compared with the experimental data. The analytical review of historical experience of use of hydrofoil sea vessels is represented in the article [10], the current state and further development of winged vessels fleet are described. The genuine drawings and models of hydrofoil vessels made by R.Ye. Alekseyev are presented in the article [11].

Let's consider the current models of these vessels designed by Alekseyev Central Hydrofoil Design Bureau of Nizhny Novgorod. The sea passenger hydrofoil vessel "Kometa 120M" designed in 2017 [12] (figure 1, from the left) belongs to these vessels. It is meant for the rapid transit of passengers in the state rooms with the chairs of airfoil type during the day. This single-deck geared diesel vessel has the overall length of 35.2 m being designed for 120 passengers. The vessel motion in the foilborne mode is ensured at the wave height of up to 2.0 m and wind capacity of up to 4 scores due to Beaufort wind force. Moreover, it is possible to mention the river shallow-draft passenger hydrofoil vessel "Valdai 45P" that was designed in 2017 [12] (figure 1, from the right); its overall length is 21.3 m, number of passengers – 45 people. The vessel motion in the foilborne mode is ensured at the wave height of up to 0.7 m and wind capacity of up to 4 scores (if its speed is 45 km/h).



Figure 1. Hydrofoil vessels "Kometa" and "Valdai 45P".

The project of the large sea passenger hydrofoil vessel "Tsiklon 250M" is developed by Alekseyev Central Hydrofoil Design Bureau [12]. The length of the vessel will be 42 m; it will be able to transit up to 320 people aboard. The power station consisting of two engines will ensure the speed of up to 55 knots (101 km/h) as well as range of 700 miles (1300 km). The favourable areas of operation of "Tsiklon 250M" embrace the following ones: south-eastern Asia, Russia's Far East, the Baltic and Black Sea as well as the Caspian Sea. The hull-borne vessel travel is to be safe if the wind force is up to 4 scores and wave height is up to 3.5 m.

The interdisciplinary method of designing of the conceptual model of large-sized speed hydrofoil vessel is presented in the article [13]. This method is used to determine the maximal lift force in case of

high speed of motion. The cost-effective river speed vessels of new generation “Strela M1” which are designed by Krylov Research Center are described in the work [14] (number of passengers – 60 people, speed – up to 50 km/h; for use in the sparsely populated regions). The results of full-scale testing of hydrofoil vessel model are presented in the work [15]. The model was equipped with two lift foils and stabilizing front foil. The aim of work [16] consisted in the development and creation of prototype of hydrofoil vessel that is consistent with the usual sail-boat. The vessel design was completed and prototype model was built with the help of mathematical modeling.

The work [17] is dedicated to the building of hydrofoil vessel that combines the simplicity of classic structures and modern innovative solutions. The vessel is equipped with the front aluminium V-shaped foils as well as T-shaped tail foils. The single-engine hydrofoil motorboat operating from the electrical accumulators is shown in the work [18]. The absence of emissions enables its using in the places where the water transport driven by gas is prohibited. The ship body is made of the composite materials, and C-shaped foil legs – from the aluminium alloy. The vessel has the high-class and driver-friendly cockpit with all main functions inside; the rudder designed in the style of Formula-1 is equipped with the color sensor display; the passenger seats are optimized to ensure the comfort and panorama during the voyage.

3. Concept development

Let's move to the development of vessel design concept. Generally, the rough drawings of hull lines and form were prepared on the basis of associative series. It is necessary to follow the requirements of ergonomics and concept functionality in the course of work [19], [20], [21]. Some visual solutions for different vessel configurations were found in view of these requirements. The results of work on the search of massing are presented in the rough drawings (figure 2).

After analyzing the environment of vessel use, the dolphin was selected as the biological prototype. Therefore, the project was called “Afalina”. The afalina is a large bottle-nosed dolphin that is a kind of Cetacea dolphin belonging to the marine mammals [22]. The length of this bottle-nosed dolphin is usually not more than 3 m and weight – 300 kg. They have the moderately advanced ‘beak’ that is sharply insulated from the arched frontonasal cushion; the body coloration is dark-brown at the top and light from below.

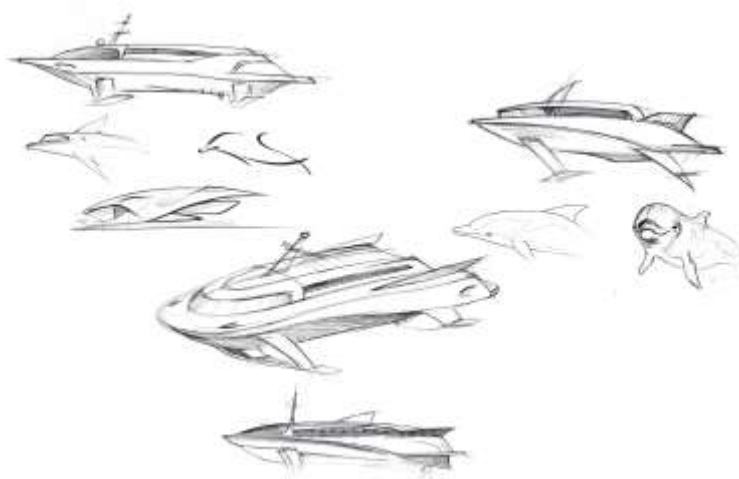


Figure 2. Sketching the prototype of the vessel.

The concept design is planned for the seashore journeys, that's why the rated length of the suggested vessel will be 44.3 m and width – 13.7 m. The vessel is designed for transportation of 100-150 passengers depending on the configuration of the state room; the cruising speed is up to 100 km/h. Figure 3 demonstrates the projections of vessel of overall size that features the entrances on each side and abaft. Such entrances are equipped with the sealed doors and life-saving floats. Due to the concept the body is

represented by the single housing with gloves abaft [23], [24].

The gloves form the compartments for the power unit; the containers for fuel are assumed to be portside and starboard. The power unit is presented by three engines – right, left and central. Speaking about the cargo-handling configuration, so the body will be represented by the cock pit and hold compartment that is rectangular in shape. In this case the upper passengers' module is removed.

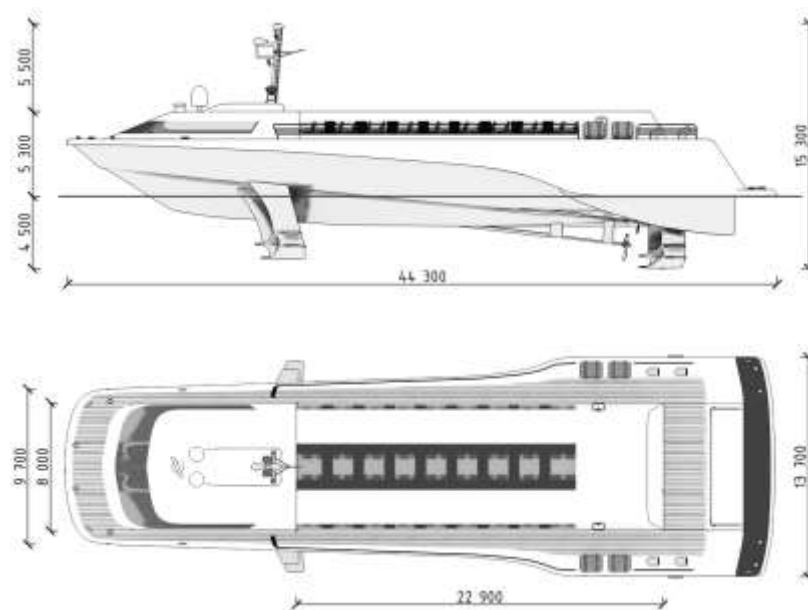


Figure 3. Projections of vessel of overall size.

4. Vessel modeling

The current designing computer technologies allow to create the model as well as print it with the help of 3D printer before actualization. The three-dimensional system of computer modeling known as 3D Studio Max [25], [26] will be used in this work. This graphical system is multipurpose enough and provides the opportunity to design both simple projects and complex scenes. In order to create three-dimensional model, it is possible to use several methods which consist in the building of projections of model object with the help of three perpendicular surfaces [27].

The set of fuselage sections which are located along the centerline is created subsequently. Three-dimensional grid is extruded along the polygons due to these sections, and the model surface is formed according to this grid. The ready-built grid is slightly drafted in the course of model debugging. All other vessel constituents are worked out in the same way with the subsequent adapting to projections. The final three-dimensional model is shown in figure 4.

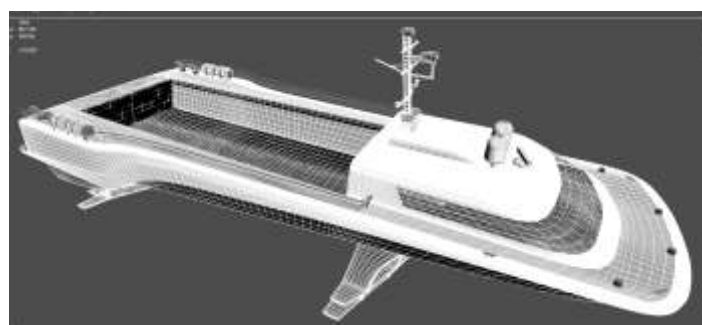


Figure 4. Result of development of three-dimensional vessel model.

The unification of modules provides an opportunity to change the nomination of the vessel. The cargo and passenger version is represented by the vessel under the principle of sea-going ferry on which the lower deck is used for motor-vehicle transport or other cargo and the upper deck is meant for the passengers (figure 5). If consider the intended purpose the vessel may be used as the floating medical center needed by the life saving service. Moreover, it may be used by the armed forces for operational deployment of the armed personnel and military equipment. Considering the life saving configuration, the passenger module is replaced by the module of mobile medical unit; the logistics module is used for the cargo-handling version (figure 5, bottom). The power structure is represented by U-shaped diagram that is closed on the aft by the lifting ramp to load the transport aboard.

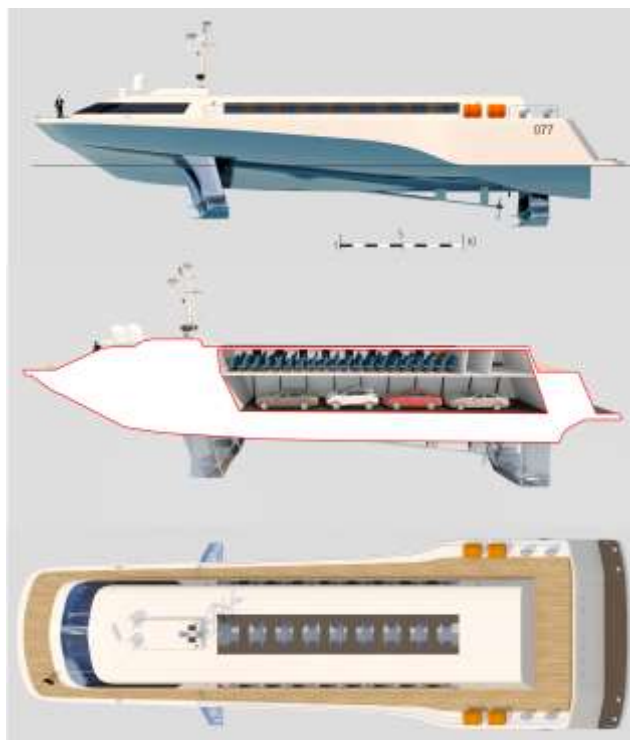


Figure 5. Passenger and cargo configuration of the vessel.

It is necessary to admit that the peculiarity of this project consists in the combination of classic single-hull layout of the central body with the elements of trimaran. This enables the increasing of ship's stability in case of slow speeds. Moreover, the three-point configuration is based on the tunnel effect that is created by the forward body with two floats. The application of modular configuration allows to increase the universality of the transportation facility making it cost-efficient in the course of operation.

5. Shading and rendering of model

It is necessary to proceed to the adjustment and allocation of material, as well as install the lights if the model constructional parts are modeled. The exterior rendering module V-Ray is used to create the photorealistic rendering in 3D Studio Max. Using this visualizer, it is necessary to customize the own library of V-RayMtl materials which differ from the standard ones. Several materials with the characteristic parameters were used in the course of modeling. Figure 6 shows the process of making the lacquered coating for the material of upper deck.

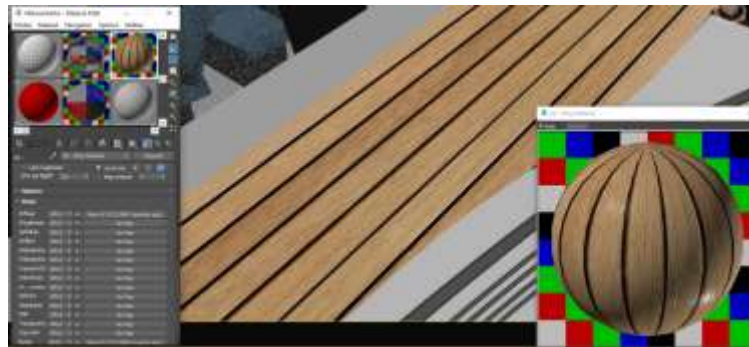


Figure 6. Generation of VRayMtl material in the materials editor.

The renderer V-Ray has a lot of options for setting oversight and realistic rendering. This process is variable. The different materials, diverse models geometry and scenery settings influence the time of countdown and rendering quality. The three-dimensional view of model demonstrating the peculiarities of hydrofoil vessel construction is shown at the bottom of the figure 7. The result of final rendering of vessel model under the operation environment is shown in figure 8.



Figure 7. Three-dimensional model of hydrofoil vessel “Afalina”.



Figure 8. Photorealistic rendering of the model of hydrofoil vessel “Afalina” under the operation environment during the sea voyage.

6. Conclusion

The results of hydrofoil vessel prototyping are mainly of the theoretical nature. To design the prototype model it is possible to finish the working of concept proceeding from the requirements of fluid-dynamic theory. The process of development of hydrofoil vessel “Afalina” beginning from the concept design and ending by the final rendering of finished model is represented in this work. The peculiarity of this concept consists in its multitasking functionality. It may be applied for the high-speed delivery of passengers or other cargo within offshore strips.

References

- [1] Yablonsky P P 1997 *Cruise ships of the fatherland* (Moscow: WIG of the world) p 98
- [2] Alekseev R E 2001 *Big Encyclopedic Dictionary* Ed A M Prokhorova (Moscow) p 34
- [3] Ivanov A V 2010 *He was ahead of time: Rostislav Alekseev* (N. Novgorod: Quartz) p 168
- [4] Lukomsky Yu A and Starichenkov A L 2004 *Proceeding of St. Petersburg State Electrotechnical University LETI* **16** 13-7
- [5] Shamim M 2015 *Journal of Marine Science and Application* **14** 1-6
- [6] Liakhovitsky A G, Sakhnovsky E B and Sakhnovsky B M 2005 *Shipbuilding* **2** 9-15
- [7] Aktas B, Turkmen S, Sasaki N, Atlar M, Turnbull M and Knos M 2016 *Conference: 10th Symposium on High-Performance Marine Vehicles* p 20
- [8] Bolotin A A 2015 *Transactions of NGTU* **3(110)** 209-13
- [9] Bin Ji, Xianwu Luo, Yulin Wu, Xiaoxing Peng and Yunling Duan 2013 *International Journal of Multiphase Flow* **51** 33-43
- [10] Gribov K V and Fedoreev G A 2017 *Bulletin of the Engineering School of the Far Eastern Federal University* **30** 98-115
- [11] Korzinov N 2007 *Popular mechanics* **12**
- [12] Central Design Bureau for hydrofoil ships named after R.E. Alekseev [www /URL:http://www.ckbspk.ru/](http://www.ckbspk.ru/)
- [13] Besnard E, Schmitz A, Kaups K, Tzong G, Hefazi H, Kural O, Chen H and Cebeci T 1998 *American Society of Mechanical Engineers, Aerospace Division* **56** 61
- [14] Sokolov V P 2015 *Transport of the Russian Federation* **1(56)** 64-6
- [15] Maciej R and Bednarek A 2007 *Archives of Civil and Mechanical Engineering* **7(3)** 167–75 [http://dx.doi.org/10.1016/S1644-9665\(12\)60024-7](http://dx.doi.org/10.1016/S1644-9665(12)60024-7)
- [16] Karlsson S and Urde J 2018 Hydrofoiling Europe-Dinghy Development of separate hydrofoils as complement to Europe-dinghies *Lund University* p 120
- [17] Electric hydrofoil finally ready to skim the waves MARINE Stu Robarts December 15th, 2016 <https://newatlas.com/quadrofoil-q2-electric-hydrofoil/46973/>
- [18] Eickmeier J, Dalanaj M, Gray J and Kotecki M 2006 Hydrofoil Development Team *Spring/Summer: Florida Institute of Technology* p 85
- [19] Howe D 2000 *Aircraft Conceptual Design Synthesis* (London: Professional Engineering Pub. Ltd) p 474
- [20] Runge V F and Manusevich Y P 2005 *Ergonomics in environmental design* (Moscow: Architecture) p 328
- [21] Abbasov I B 2019 Computer modeling in industrial design *Amazon Digital Services LLC* p 60
- [22] Caldwell D and Caldwell M 1980 *The World of the Bottlenosed Dolphin* Ed A S Sokolov (Moscow: Gidrometeoizdat) p 136
- [23] Yeager S M, Matvienko A M and Shatalov I A 2003 *Basics of aircraft* (Moscow: Mashinostroenie) p 720
- [24] Raymer D P 2009 *Living in the Future* (Design Dimension Press, Los Angeles) p 360
- [25] Mooney T 2012 *3ds Max speed modeling for 3D artists* (Packt Publishing) p 422
- [26] Abbasov I B 2017 *A Fascinating Journey into the World of 3D Graphics with 3ds* (Max Amazon Digital Services LLC) p 239
- [27] Abbasov I B and Orekhov V V 2017 *Adv. in Eng. Software* **114** 227–34