UDC 629.5
DOI 10.52171/herald.333

System Analysis and Mathematical Model of Designing Remotely Operated Vehicle Support Vessels

A.G. Egorov[1], O.M. Abdullayev[2], R.O. Abdullayev[3]

[1] *Marine Engineering Bureau (Odessa, Ukraine)*
[2] *ASCO Engineering (Baku, Azerbaijan)*
[3] *Maritime University of Szszecin (Warshava, Poland)*

For correspondence:
Oyrad Abdullayev / e-mail: oyrad-abdullayev@asco.az

Abstract

A model for studying the scientifically based design of remotely operated vehicle support vessels (ROV support vessel) has been developed, taking the vessel as a functional system with a subsystem of installed hardware. The work proposes theoretical foundations for forming the main dimensions of the vessel. A structural and mathematical model has been formed that describes the formation of the main dimensions of the remotely operated vehicle support vessels (ROV support vessel). A structural and mathematical model for optimizing the main dimensions of the vessel is proposed, taking into account the optimization criteria. A structural and mathematical model has been developed that describes the formation of the surface of the ROV support vessel. Based on the developed structural and mathematical models for forming the main dimensions, the surface of the vessel, a structural and mathematical model has been proposed that describes the functional parameters of the ROV support vessel. As a result of theoretical research, directions for studying the design method described by the structural and mathematical model of the ROV support vessel, reflecting its functional qualities, have been proposed.

Keywords: subsea operation, ship design, ROV support vessel, the system analysis, mathematical models, the vessel main dimension.

Submitted *30 July 2024*
Published *17 December 2025*

For citation:
A.G. Egorov, O.M. Abdullayev, R.O. Abdullayev
[System Analysis and Mathematical Model of Designing Remotely Operated Vehicle Support Vessels]
Herald of the Azerbaijan Engineering Academy, 2025, vol.17 (4), pp. 94-99

Heyətsiz sualtı aparatların daşıyıcı gəmilərinin layihələndirilməsinin sistem analizi və riyazi modeli

A.G. Eqorov[1], O.M. Abdullayev[2], R.O. Abdullayev[3]
[1] *Dəniz Mühəndisliyi Bürosu (Odessa, Ukrayna)*
[2] *ASCO Mühəndislik MMC (Bakı, Azərbaycan)*
[3] *Szszecin Dəniz Universiteti (Varşava, Polşa)*

Xülasə

Sualtı heyətsiz aparatların daşıyıcı gəmisinin elmi əsaslarla layhəsinin tədqiqi üçün model işlənib hazırlamışdır. Gəmi, göyərtəsində quraşdırılmış aparatları alt sistem kimi nəzərə almaqla, funksional vahid kimi qəbul edilir. Bu təhlil gəminin əsas ölçülərinin formalaşması üçün nəzəri əsas kimi təklif edilir. Sualtı heyətsiz aparatların daşıyıcı gəmisinin əsas ölçülərinin formalaşmasını təsvir edən struktur və riyazi model hazırlanıb. Bütün meyarlar nəzərə alınmaqla gəminin əsas ölçülərinin optimallaşdırılması üçün struktur və riyazi model təklif edilir. Sualtı heyyətsiz aparatların daşıyıcısı, gəminin səthinin formalaşmasını təsvir edən struktur-riyazi model işlənib hazırlanmışdır. Gəminin səthinin əsas ölçülərinin formalaşmasını işlənmiş struktur və riyazi modelləri əsasında sualtı heyyətsiz aparatların daşıyıcı gəminin funksional parametrlərini təsvir edən struktur-riyazi model təklif olunur. Nəzəri tədqiqatlar nəticəsində onun funksional keyfiyyətlərini əks etdirən, sualtı heyətsiz aparatların daşıyıcı gəminin struktur-riyazi modeli ilə təsvir edilən konstruksiya metodunun tədqiqi istiqamətləri təklif edilmişdir.

Açar sözlər: sualtı texniki işlər, gəmilərin layihələndirilməsi, sualtı heyyətsiz aparatların daşıyıcı gəmiləri, sistem analizi, riyazi model, gəminin əsas ölçüləri.

Системный анализ и математическая модель проектирования судов носителей телеуправляемых необитаемых подводных аппаратов

А.Г. Егоров[1], О.М. Абдуллаев[2], Р.О. Абдуллаев[3]
[1] *Морское Инженерное Бюро (Одесса, Украина)*
[2] *ASCO Engineering (Баку, Азербайджан)*
[3] *Морская академия в Щецине (Варшава, Польша)*

Аннотация

Разработана исследовательская модель научно обоснованного проектирования судна-носителя телеуправляемых необитаемых подводных аппаратов, рассматриваемого как функциональная система с подсистемой установленных аппаратных средств. В работе изложены теоретические основы формирования главных размерений судна. Созданы структурная и математическая модели, описывающие процесс формирования главных размерений судна-носителя. Предложена модель оптимизации главных размерений с учетом заданного критерия эффективности. В результате теоретических исследований определены направления дальнейшего развития метода проектирования, основанного на данных моделях, отражающих функциональные характеристики судна-носителя телеуправляемых необитаемых подводных аппаратов.

Ключевые слова: подводно-технические работы, проектирование судов, суда-носители телеуправляемых необитаемых подводных аппаратов, системный анализ, математическая модель, главные размерения судна.

Introduction

In this research a model of formation of a system of the vessel [1 - 6] taking into account installation of Remotely Operated Vehicle [7] reflecting model of a research of a design method of the perspective vessel has been developed. The model of formation of the main dimension [8, 9] of the vessel as a system has been proposed. The developed mathematical model, in the system of design of the vessel, describes formations of a subsystem the main dimension [10], being based on parameters of the installed apparatus, capacities of the propulsion plant, volumes of accommodations and seagoing qualities of the vessel. When forming of the received sets of the main dimension by a database method, it is supposed to form the main dimensions of the vessel taking into consider criteria of optimization. On the received sets, optimization of the main dimension and functional parameters of the remotely operation vehicle support vessels (ROV support vessel) developed by model is offered.

On the received optimum main dimension, the theoretical model of formation of a shell of the ROV support vessel is offered. When forming a theoretical shell of the ROV support vessel, it is supposed to carry out researches of seagoing qualities, hydrostatic characteristics, vessel speeds, capacities of the propulsion plant and volumes of accommodation. Using researches of the system and mathematical models reflected in the real article the functional model of the vessel of the carrier of the remotely piloted uninhabited submersibles reflecting functional qualities of the vessel is proposed. The developed block diagrams and mathematical models, reflect the offered directions of researches on evidence-based design of ROV support vessels.

Research objective

Using methods of the system analysis and mathematical modeling to develop structural and mathematical model of a research of theoretical design of the ROV support vessels.

Problem definition

To reflect the direction of researches on definition of influence of the parameters set apparatus to formation of the main dimension and functional parameters of the perspective ROV support vessel.

Model of formation of a system of the vessel taking into account installation of Remotely Operation Vehicle (ROV)

Let, the ROV support vessel, is accepted as the system [1 - 3] having a large number of the subsystems participating in formation of a system. In the article the structural model is developed (see fig. 1.) concentrating on formation of a system of the vessel in parameters of the applied ROV.

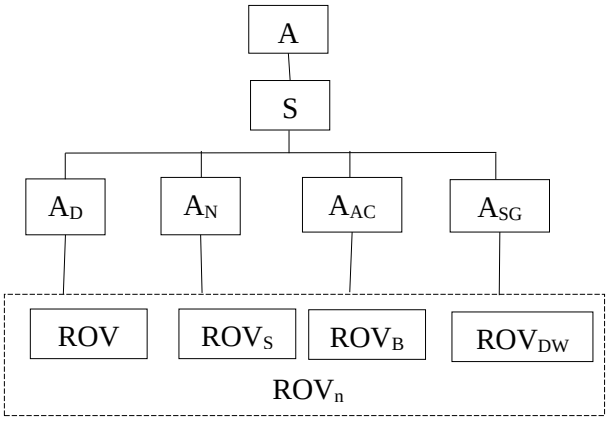

Figure 1 – Structural model formation of a system of the vessel

Thus, in further researches will be considered, influences of the types established on the perspective ROV support vessel on the main dimension, type of the propulsion plant, volumes of accommodations and seagoing qualities of the vessel reflected by mathematical model (1).

$$A = A_f \left\{ \left(\sum_{n=1}^{n} ROV_n \left(A_D, S \right) \right) \bigcup \left(\sum_{n=1}^{n} ROV_n \left(A_n \right) \right) \right\} \quad (1)$$

Where A – Vessel's system; A_f – ROV support vessel functions; S – the vessel shell; A_D – main dimensions; A_N – propulsion system; A_{AC} – accommodation; A_{SG} – seagoing qualities; ROV_M – "Mikro" & "Mini" type of ROV apparatus; ROV_S – "Small" type of ROV apparatus; ROV_B – "Big" type of ROV apparatus; ROV_{DW} – "Deep Water" type of ROV apparatus; ROV_n – the installation on the vessel ROV apparatus types.

Mathematical model (1) and the block diagram (see fig. 1.), reflects further model of a research of a system design method of the ROV support vessel.

Model of formation of the main dimension of the ROV support vessel

Important factor of formation of a system, the ROV support vessel, the method of definition of the main dimension of the vessel is. Fig. 2. shows the structural model of formation of the main dimension of the ROV support vessel is reflected. The structural model is described by mathematical model (2) and serves as method of further researches of formation of the main dimension of the ROV support vessel as a database method, using the parameters connected with functioning of ROV.

So the necessary sizes of hangars for storage of ROV, control stations, workshops and storerooms belong to the corresponding parameters.

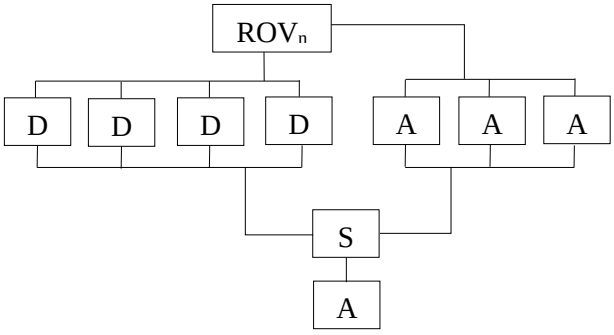

Figure 2 – Structural model formation of the main dimension of the ROV support vessel

$$A_D = S_D \left(\left(\sum_{n=1}^{n} ROV_n \left(D_H, D_{CR}, D_{WS}, D_S \right) \right) \bigcap \bigcap \left(\sum_{n=1}^{n} ROV_n \left(A_N, A_{AC}, A_{SG} \right) \right) \right) \quad (2)$$

Where D_H – dimension of ROV hangar; D_{CR} – dimension of ROV remote control post; D_{WS} – dimension of ROV workshop; D_S – dimension of ROV store; S_D – criteria of optimization.

The mathematical model (2), describes at research design of a system the vessel, formation of the subsystem of the main dimensions, being based on parameters of ROV and values like the propulsion plant, necessary volumes of accommodations and seagoing qualities of the vessel. On the considered sets, it is supposed to form the main dimensions taking into considered criteria of the optimization reflected in mathematical model (2).

Model of optimization of the main dimension and functional parameters of the ROV support vessels

The solution of a problem of optimization, is supposed formation of the main dimension of the ROV support vessel on

the basis of sets of sizes of the main dimension, with use of boundary factors criterion of optimization. Thereby optimum main dimension of the ROV support vessel, are reflected in structural model of optimization of the main dimension of the ROV support vessel (see fig. 3) and is described by mathematical model (3).

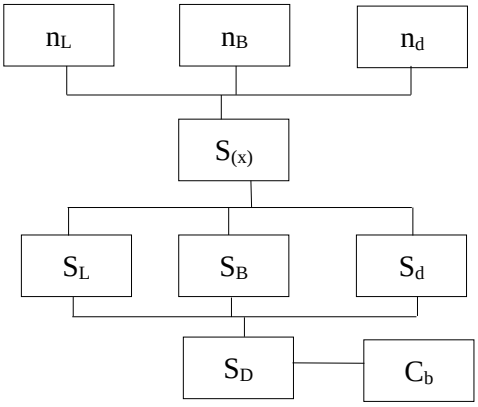

Figure 3 – Structural model of optimization of the main dimension of the ROV support vessel

$$S_D = C_b\left(n_L, n_B, n_d\right) \rightarrow S_{(x)}\left(S_L, S_B, S_d\right) \quad (3)$$

Where n_L – set of length from the database; n_B – set of width from the database; n_d – set of draft from the database; $S_{(x)}$ – boundary factors of optimization; S_L – optimum length; S_B – optimum width; S_d – optimum draft; C_b – block coefficient.

The formation of the optimum main dimensions as shown in Fig. 3. and mathematical (3) models opens a way to formation of a theoretical surface of the hull of the perspective vessel.

Model of formation of a surface of the ROV support vessel

It is well-known that formation of a surface, being the central task at research design and affects constructive and operational characteristics of the perspective vessel. The offered structural model (Fig. 4.), reflects influence by the described mathematical model (4), the parameters established on the vessel ROV and the factors influencing a theoretical surface, ROV support vessel.

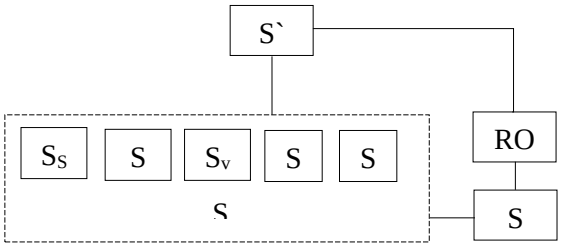

Figure 4 – Structural model formation of a surface of the ROV support vessel

$$S = S`\left(\sum_{n=1}^{n} ROV_n\right) \bigcap S`\left(\sum_{n=1}^{n} S_n\right) \quad (4)$$

Where S` - the initial surface; S_{SG} – seagoing factors; S_H – hydrostatic factors; S_v – vessel speed factors; S_N – power plant factors; S_{AC} – accommodation factors; S_n – surface influence factors.

As the result, within the researches of formation of a theoretical surface of the ROV support vessel, is supposed to investigate seagoing qualities, hydrostatic characteristics, vessel speed, capacities of the power plant and volumes of accommodation.

Model of functionality of the ROV support vessel

The main goal of the research of design of the ROV support vessel, providing and justifications of optimum functions of the perspective vessel is. Being guided by the block diagrams considered above (see fig. 1 - 4) and mathematical models (1 - 4), it has been proposed, structural (Fig. 5.) and mathematical (5) models, reflecting formation of functions of the ROV support vessel.

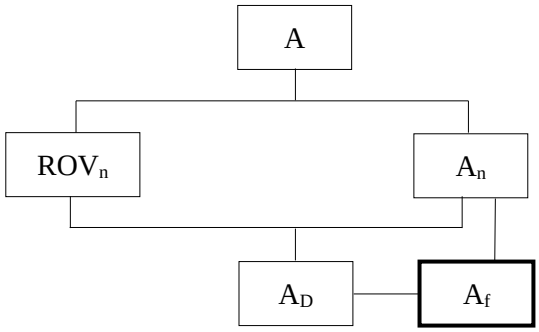

Figure 5 – Structural model of formation of functions of the ROV support vessel

$$A_f = A\left(A_D \left(\left(\sum_{n=1}^{n} ROV_b \right) \bigcup A_n \right) \right) \quad (5)$$

Where A_n – constant factors of the vessel systems.

The developed block diagrams (Fig. 1-5) and mathematical models (1-5), reflect the offered direction of researches at evidence-based and research design of ROV support vessel.

Conclusion

Structural and mathematical models of a system of the vessel with the ROV installations are offered; Structural and mathematical models of the main dimension of the ROV support vessel are offered; Structural and mathematical models of optimization of the main dimension and functional parameters of the ROV support vessel are offered; Structural and mathematical models formation of a surface of the ROV support vessel are offered; Structural and mathematical models of function of the ROV support vessel are developed.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

REFERENCES

1. **Gaykovich A.I.** Osnovi teorii proektirovaniya slojnikh technicheskikh sistem. – SPb.: MORINTEKh, 2001. – 432p.
2. **Gaykovich A.I.** Theoriya proyektirovaniya vodoizmeshayushikh korabley i sudov. T1. – SPb.: MORINTEKh, 2014. - 819p.
3. **Gaykovich A.I.** Theoriya proyektirovaniya vodoizmeshayushikh korabley i sudov. T2. – SPb.: MORINTEKh, 2014. - 872p.
4. Bashirov R.J. Sistemniy analiz i kriterii optimizacii technologicheskogo oborudovaniya mnogocelevoqo sudna s cranom qruzopodyomnostyu 300t / O.M. Abdullayev // Morskoy Vestnik, - SPb.: 2015. №2, p. 20.
5. **Nasirova E.A.** Architecture of Modeling Process of Flexible Manufacture System Actions // - Herald of the Azerbaijan Engineering Academy, Baku, 2022. Vol.14. №1, pp. 106-116. DOI: https://doi.org/10.52171/2076-0515_2022_14_01_106_116
6. **Ronnov E.P.** Proyektirovaniye sudov. – SPb.: Lan, 2022. – 296 s.
7. **Voytov D.V.** Teleupravlyaemiye neobitayemiye podvodniye aparati. - M.: «MORKNIGA», 2012. – 506 s.
8. **Abdullayev O.M.** Razrabotka nomoqrammi vibora qlavnikh razmereniy sudov obespecheniya podvodno-tekhnicheskih rabot // XIX International scientific-technical conference on “WATER TRANSPORT PROBLEMS”. Baku: 02 – 03 may, 2024, c. 15 – 17.
9. **Abdullayev O.M.** Vibor qlavnikh razmereniy sudov obespecheniya podvodno-tekhnicheskih rabot s ispolzovaniyem metoda bazi dannikh // Baku: Proceedings of Azerbaijan State Marine Academy, 2024. №2(40), c.7 – 18.
10. **Lebedeva M.P.** Algoritm proyektirovaniya sudov obespecheniya podvodno-tekhnicheskih rabot methodom bazi dannikh / O.M.Abdullayev // Nauchniye problem vodnoqo transporta. Voljskiy Gosudarstvenniy Universitet Vodnogo Transporta. - Nijniy Novqorod, 2023, №76(3). – C.32 – 49.