UDC 629.5
DOI 10.47049/2226-1915-2025-3-7-24

ANALYSIS OF HYDROSTATIC CHARACTERISTICS AND JUSTIFICATION OF THE SELECT SUPERFULL HULL FORM OF THE SUBSEA CONSTRUCTION VESSELS

O.G. Egorov
PhD, Director general
ORCID 0000-0002-2050-8640

CJSC «Marine Engineering Bureau», Odesa, Ukraine

Oyrad Abdullayev
Master degree
ORCID 0009-0003-3593-5375

ASCO Engineering ltd, Baku, Azerbaijan

Abstract. *Within the research the analysis of hydrostatic characteristics such as volumetric and weight displacement, buoyancy center abscissa, buoyancy center appliqué, waterline area, waterline area center of gravity abscissa, waterline area transverse moment of inertia, waterline area longitudinal moment of inertia, transverse metacentric radius, block coefficient, waterline area coefficient, midshipsection coefficient, and justification of the choice of a superfull hull form of the subsea construction vessel was made.*

At the same time, the system analysis and mathematical model of justification of the select of a superfull shell was developed considering influence on the main dimension of the vessel of load-lifting devices, a diving complex, a mobile drilling complex, a pipelaying complex, the cablelaying equipment and hydrostatic characteristics. The block diagram reflecting an algorithm of a research and justification of a superfull shell is made. The mathematical model describing researches of justification of a superfull shell of the subsea construction vessels is made. Dependences of hydrostatic characteristics of the studied shell of the subsea construction vessel were developed for justification of the select of a shell of a superfull form and comparison with a superfull shell is executed.

At the same time, a systematic analysis and mathematical model were developed to justify the choice of ansuperfull hull form, taking into account the impact on the main dimensions of the vessel of lifting devices, diving complex, mobile drilling complex, pipe-laying complex, cable-laying equipment, and hydrostatic characteristics. A structural diagram was drawn up reflecting the algorithm for researching and justifying the super-full hull form. A mathematical model was developed describing the research to justify the superfull hull form of a vessel for underwater construction work. The dependencies of the hydrostatic characteristics of the vessel's hull were developed to justify the contours of the superfull hull form.

© Єгоров О.Г., Абдуллаєв О.М., 2025

Analysis of the hydrostatic characteristics of the studied superfull hulls allowed us to make an informed choice of hull shape for a vessel for underwater construction work. A calculation method was developed, the main characteristics were determined, and preliminary estimates of the required power of the main engines of a vessel with a superfull hull for underwater construction work were made.

To confirm the reliability of the calculation model, a comparative diagram of calculations was developed using the CFD model of an existing vessel with an overfilled hull shape that is in operation, and a calculation of the superfull hull shape of a vessel for underwater construction work. As a result of the study, the superfull hull shape of the vessel for underwater construction work was confirmed.

Keywords: *system analysis, superfull hull form, subsea construction vessel.*

УДК 629.5
DOI 10.47049/2226-1915-2025-3-7-24

АНАЛІЗ ГІДРОСТАТИЧНИХ ХАРАКТЕРИСТИК ТА ОБГРУНТУВАННЯ ВИБОРУ НАДПОВНОЇ ФОРМИ КОРПУСУ СУДНА ДЛЯ ПІДВОДНИХ БУДІВЕЛЬНИХ РОБІТ

О.Г. Єгоров
к.т.н., генеральний директор
ORCID 0000-0002-2050-8640

ТОВ «Морське Інженерне Бюро», Одеса, Україна

О.М. Абдуллаєв
магістр, директор
ORCID 0009-0003-3593-5375

ASCO Engineering LTD, Баку, Азербайджан

Анотація. *У рамках дослідження проводився аналіз гідростатичних характеристик, таких як об'ємна та вагова водотоннажність, абсциса центру плавучості, апліката центру плавучості, площа ватерлінії, абсциса центру ваги площі ватерлінії, поперечний момент інерції площі ватерлінії, поздовжній момент інерції площі ватерлінії, поперечний метацентричний радіус, поздовжній метацентричний радіус, апліката поперечного метацентру, коефіцієнт загальної повноти, коефіцієнт площі ватерлінії, коефіцієнт повноти мідель-шпангоуту та зроблено обґрунтування вибору надповної форми корпусу судна для підводних будівельних робіт.*

Одночасно розроблено системний аналіз і математичну модель обґрунтування вибору надповної форми корпусу з урахуванням впливу на основні габарити судна вантажопідйомних пристроїв, водолазного комплексу, мобільного бурового комплексу, трубоукладального комплексу, кабелеукладального обладнання та гідростатичних характеристик.

Складено структурну схему, що відображає алгоритм дослідження та обґрунтування надповної форми корпусу.

Складено математичну модель, що описує дослідження обґрунтування надповної форми корпусу судна для підводних будівельних робіт.

Розроблено залежності гідростатичних характеристик корпусу судна для обґрунтування обводів корпусу надповної форми.

Аналіз гідростатичних характеристик досліджуваних корпусів надповної форми дозволив зробити обґрунтований вибір форми корпусу судна для підводних будівельних робіт.

Розроблено метод розрахунку, визначені основні характеристики та виконані попередні оцінки необхідної потужності головних двигунів судна надповної форми для підводних будівельних робіт.

Для підтвердження достовірності розрахункової моделі розроблено порівняльну діаграму розрахунків із застосуванням CFD-моделі існуючого судна надповної форми корпусу, що є в експлуатації, і розрахунок надповної форми корпусу судна для підводних будівельних робіт.

У результаті дослідження надповна форма судна для підводних будівельних робіт була підтверджена.

Ключові слова: *системний аналіз, надповна форма, судно для підводних будівельних робіт.*

The system analysis and mathematical model of justification of the select superfull shell on the basis of hydrostatic characteristics. For ensuring safe operation of the subsea construction vessel (SCV), within the research the analysis of surfaces of various forms developed on received to optimum main dimension was made.

For the studied perspective SCV, the most suitable was select under the terms of boundary factors a superfull shell. Having select a superfull shell, it is supposed to make justification of the select taking into account boundary factors.

For providing the correct solution of a problem of justification of the select of a superfull shell of SCV, within the research the system analysis [1] is made and the mathematical model [2; 3] of justification of the select of a superfull shell of SCV.

Below in the block diagram is developed (see fig. 1.) the algorithm of justification of the select superfull shell for ensuring the subsea operations [4] provided by conditions, by influence of technology equipment [5; 6] on the select of a surface with comparison of hydrostatic characteristics of the considered surfaces and justification of the select of a superfull surface with the subsequent research of speed of SCV is reflected.

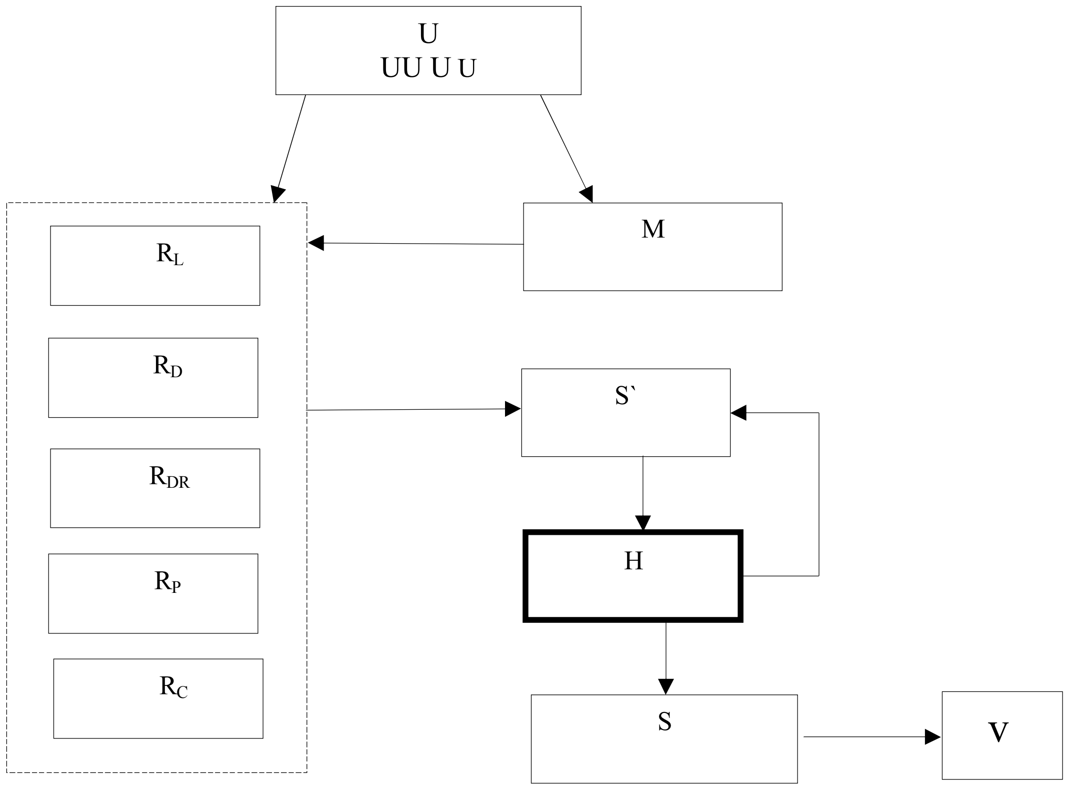

Fig. 1. Block diagram of justification of the select of a superfull surface of SCV

here: U – subsea operation;
RL – influence of lifting gear on the main dimensions of SCV;
RD – influence of diving complex on the main dimensions of SCV;
RDR – influence of mobile drilling complex on the main dimensions of SCV;
RP – influence of pipelaying complex on the main dimensions of SCV;
RC – influence cablelaying complex on the main dimensions of SCV;
M – preliminary select of the main dimension of SCV;
S` – preliminary shell of SCV;
H – hydrostatic characteristic of SCV;
S – shell of SCV;
v – speed of SCV.

The shown in figure 1., block diagram of justification of the select of a superfull shell of SCV, is described by mathematical model, formula (1). At the same time, considering that process of justification of a surface is iterative, the factor of a preliminary surface, reflected in a formula (2) which is essentially select surface in the first iteration and serves for further adjustment on the basis of the made researches is reflected in a formula (1)

$$S=\left\{\left(U\left(R_L,R_D,R_{DR},R_P,R_C\right)\cap U(M)\right)\subset S^{\backprime}(H)\right\}\to v \tag{1}$$

$$S^{\backprime}(H)=\frac{1}{K}\sum h_{ji} \tag{2}$$

here K – quantity of steps of increment of hydrostatic parameters;

$$h_{ij}=\left(D,V,XC,ZC,S,XF,IX,IYF,RB,RL,ZMB,C_b,\alpha,\beta\right)$$

D – displacement;
V – volume displacement;
XC – abscissa of the center of size;
ZC – z-coordinate of the center of size;
S – area of a waterline;
XF – abscissa of the center of gravity of the area of a waterline;
IX – cross moment of inertia of the area of a waterline;
IYF – longitudinal moment of inertia of the area of a waterline;
RB – cross metacentric radius;
RL – longitudinal metacentric radius;
ZMB – z-coordinate of the cross metacenter;
Cb – block coefficient;
α – coefficient of the area of a waterline;
β – coefficient of the fullest frame.

Justification of a superfull shell, is made comparing dependences of hydrostatic parameters of the researched surfaces.

Analysis of dependence of hydrostatic characteristic of a superfull shell

For comparison dependences on set depth of displacement of fig. 2, volume displacement of fig. 3, an abscissa of the center of size of fig. 4, z-coordinate of cent of size of fig. 5, the area of waterlines of fig. 6, an abscissa of the center of gravity of the area of waterlines of fig. 7, the cross moment of inertia of the area of a waterline of fig. 8, the longitudinal moment of inertia of the area of waterlines of fig. 9, cross metacentric radius of fig. 10, longitudinal metacentric radius of fig. 11, z-coordinate of the cross metacenter of fig. 12, block coefficient of fig. 13, coefficient of the area of a waterline of fig. 14 and coefficient of the fullest frame of fig. 15 were.

The dependence reflected in fig. 2; 3; 6; 8; 9; 13-15 shows that in comparison with other shells, the superfull surface has the greatest value at the set draft that for SCV has clear advantage.

The dependence reflected in fig. 4; 7 shows that in comparison with other surfaces, the superfull shell has negative value at the set draft that for SCV has clear advantage.

The dependence reflected in fig. 5; 10; 12 shows that in comparison with other surfaces, the superfull shell has approximately identical value at the set draft that for SCV does not matter.

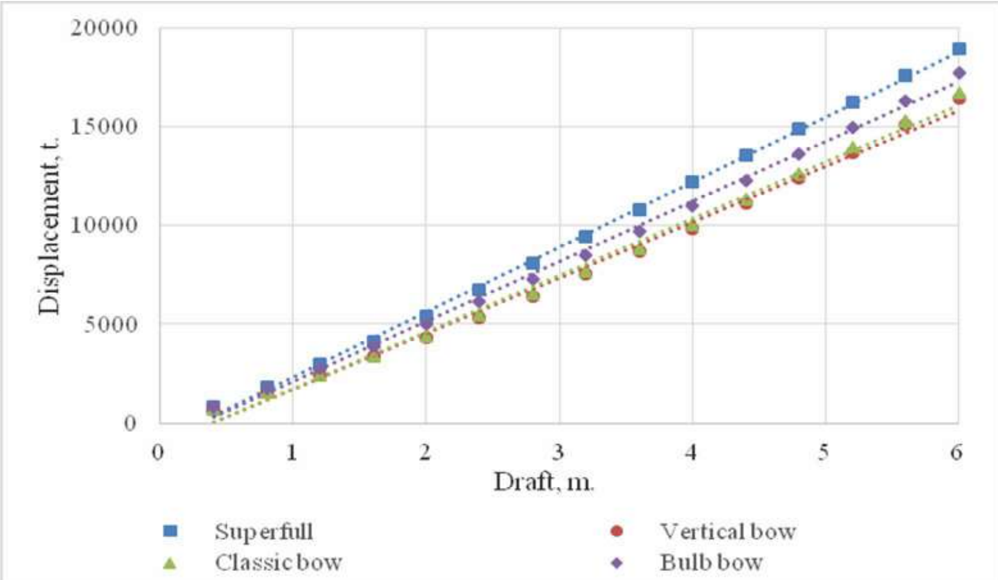

Fig. 2. Dependence of draft and displacement of the offered SCV surfaces

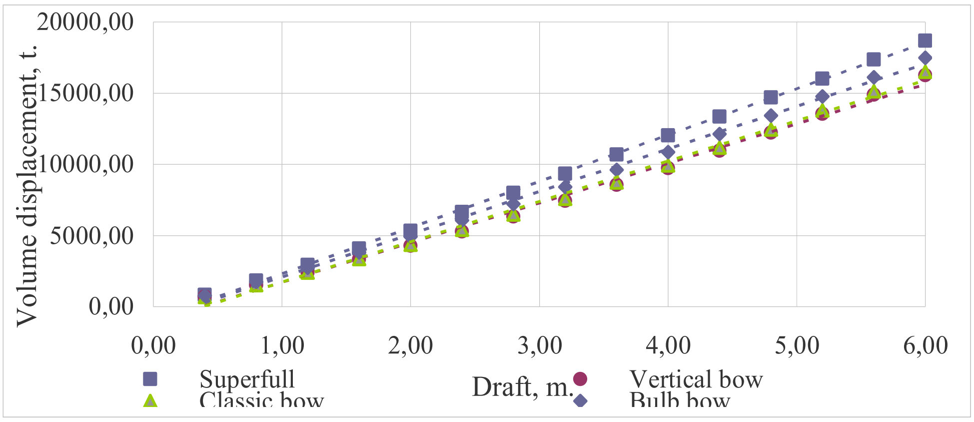

Fig. 3. Dependence of draft and volume displacement of the offered SCV surface

Shown in fig. 2 – the 15th dependences of hydrostatic parameters, reflect that in most cases the superfull surface has the greatest advantage before other surfaces to SCV.

Justification of the select of a superfull shell for SCV

For justification of the select of a surface in the hydrostatic parameters reflected in dependences in fig. 2-15, is lower in diagrams 16-29, the analysis of comparison of hydrostatic parameters of a superfull surface is reflected.

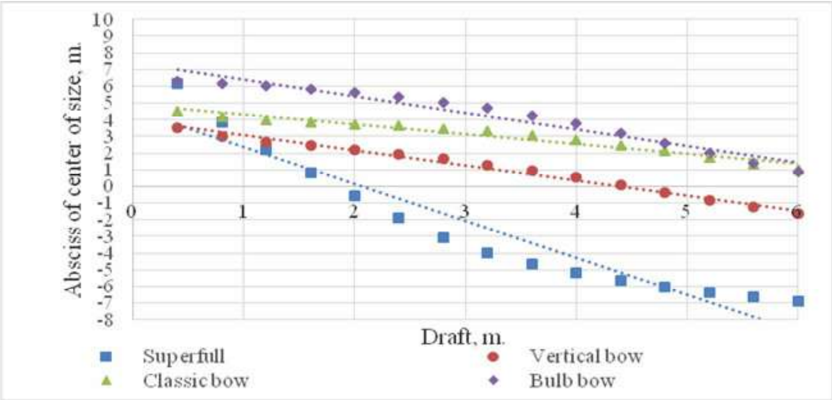

Fig. 4. Dependence of draft and absciss of center of size offered SCV surface

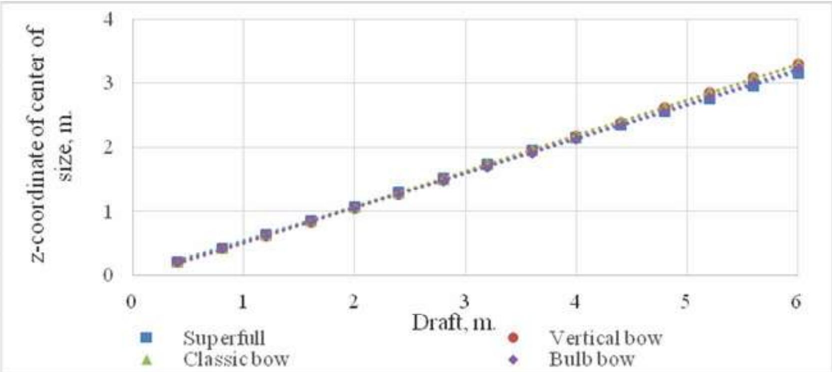

Fig. 5. Dependence of draft and z-coordinate offered SCV surface

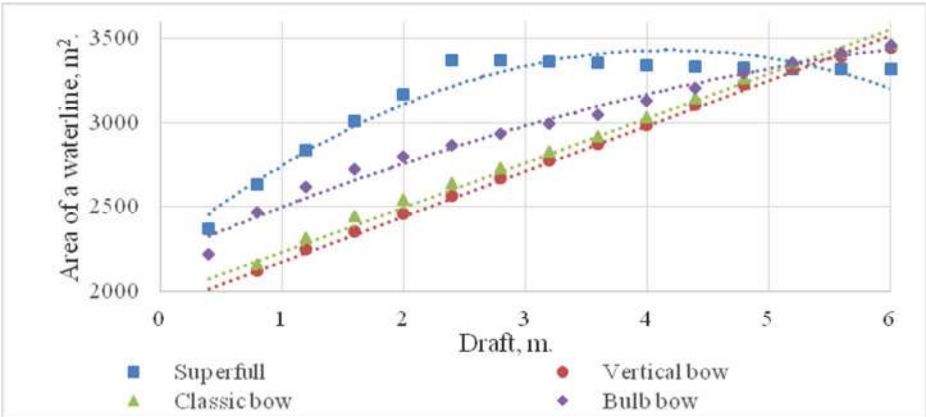

Fig. 6. Dependence of draft and area of a waterline offered SCV surface

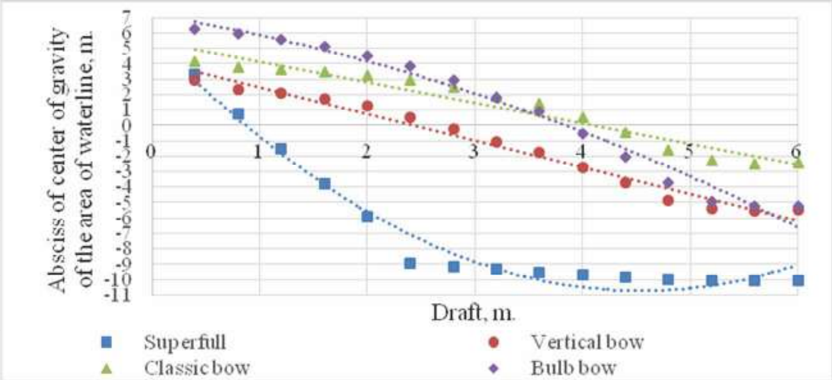

Fig. 7. Dependence of draft and abscis of center of gravity of the area of waterline offered SCV surface

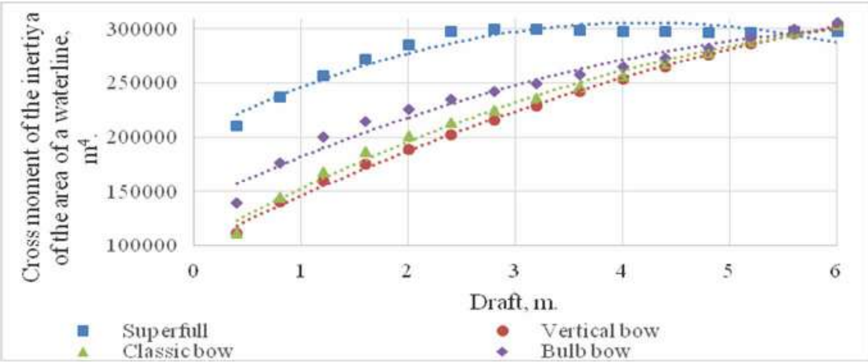

Fig. 8. Dependence of draft and cross moment of the inertia of the area of a waterline offered SCV surface

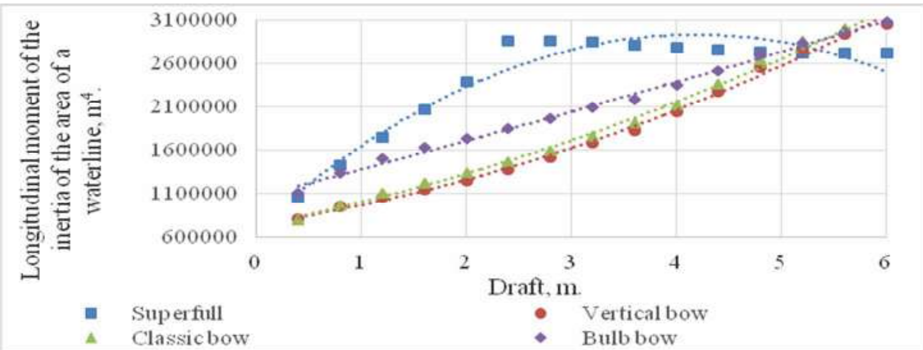

Fig. 9. Dependence of draft and longitudinal moment of the inertia of the area of a waterline offered SCV surface

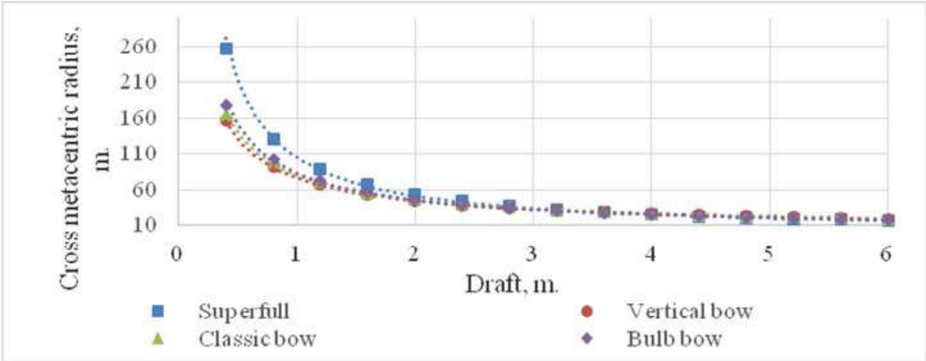

Fig. 10. Dependence of draft and cross metacentric radius offered SCV surface

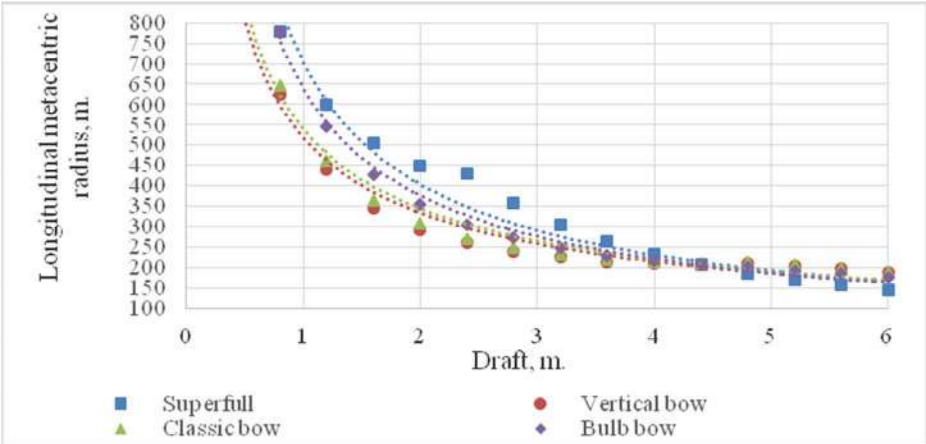

Fig. 11. Dependence of draft and longitudinal metacentric radius offered SCV surface

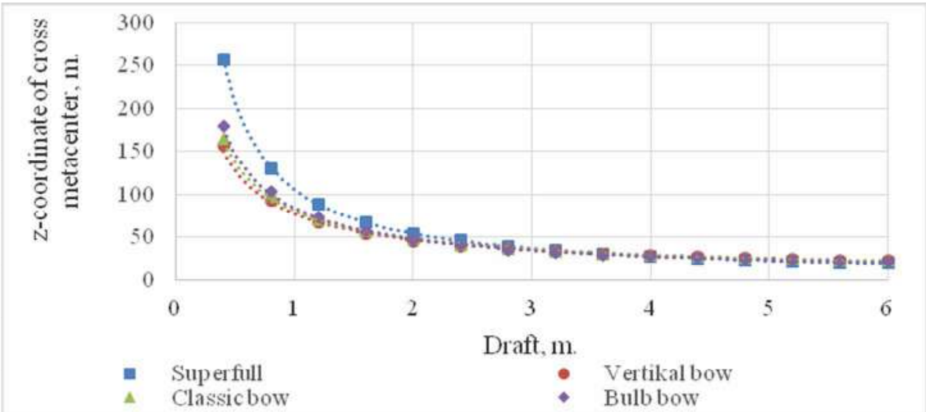

Fig. 12. Dependence of draft and z-coordinate of crass metacenter offered SCV surface

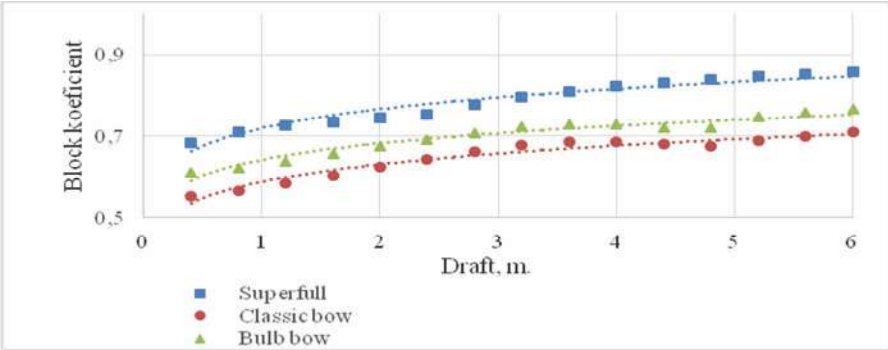

Fig. 13. Dependence of draft and block coefficient offered SCV surface

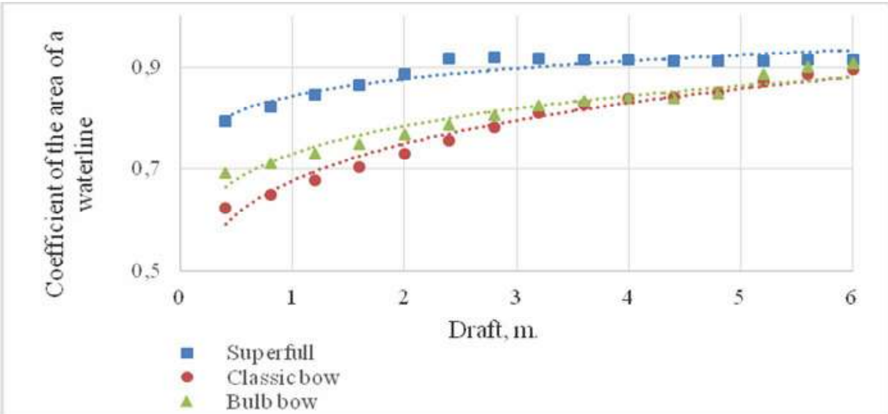

Fig. 14. Dependence of draft and coefficient of the area of a waterline offered SCV surface

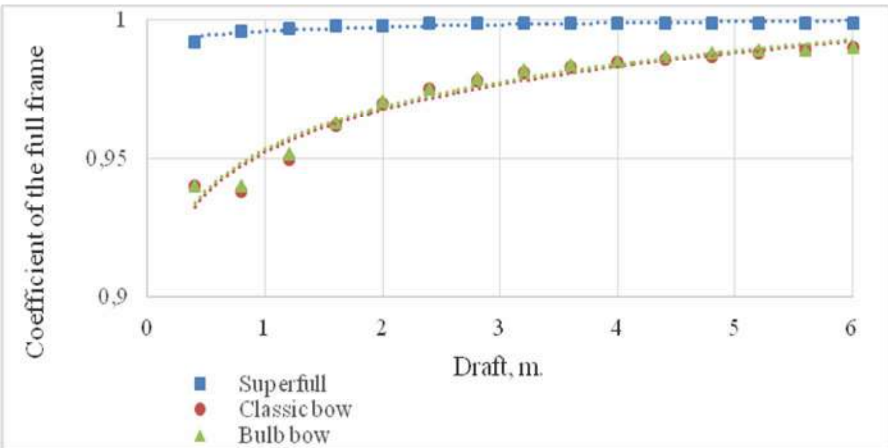

Fig. 15. Dependence of draft and coefficient of the full frame offered SCV surface

The analysis of hydrostatic these surfaces, in dependences, fig. 2; 3; 6; 8; 9; 13-15, are reflected in diagrams of fig. 16; 17; 20; 22; 23; 27-29 and confirm that it for SCV has the greatest value at the set draft and clear advantage.

The analysis of hydrostatic these surfaces, in dependences, fig. 4; 7, are reflected in diagrams of fig. 18; 21 and confirm that it for SCV has negative value at the set draft and clear advantage.

The analysis of hydrostatic these surfaces, in dependences, fig. 5; 10; 12 are reflected in diagrams of fig. 19; 24; 26 and confirm that it for SCV has approximately identical value at the set draft and does not matter.

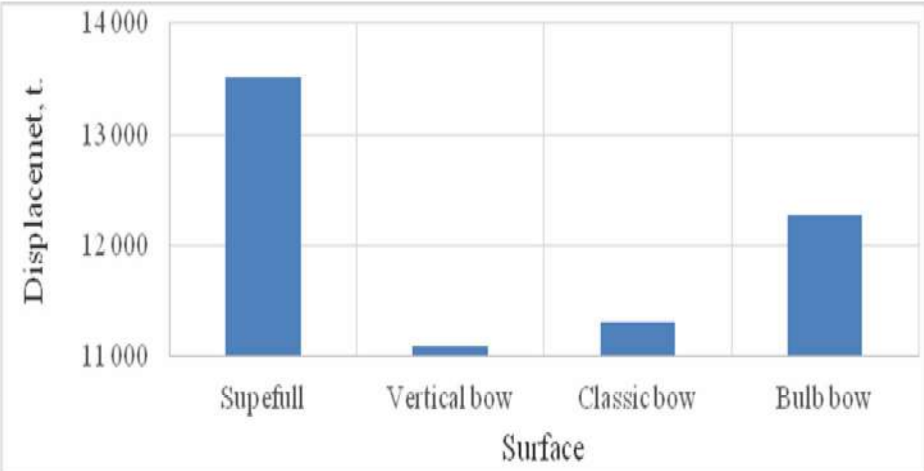

Fig. 16. Dependence displacement offered SCV surface at draft (d = 4,5 m)

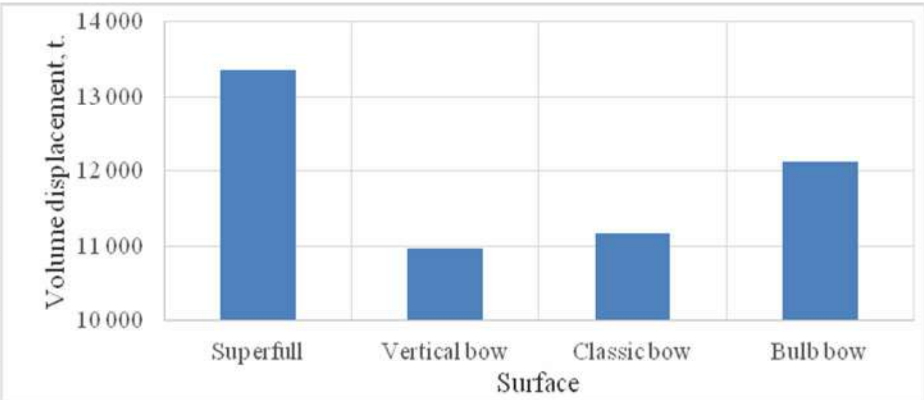

Fig. 17. Dependence of a volume displacement of the offered SCV surface at draft (d = 4,5 m)

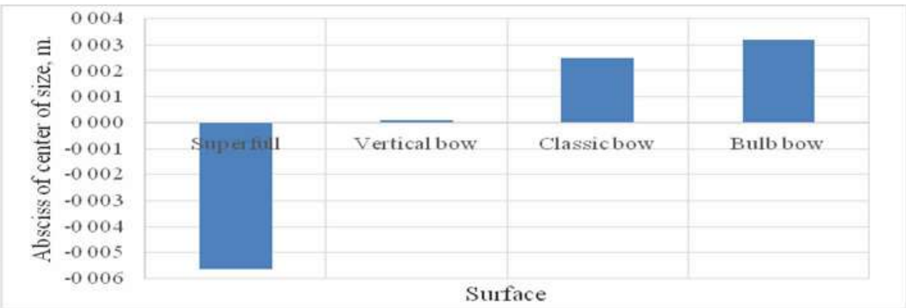

Fig. 18. Dependence of an absciss of the center of size of the offered SCV surface at draft (d = 4,5 m)

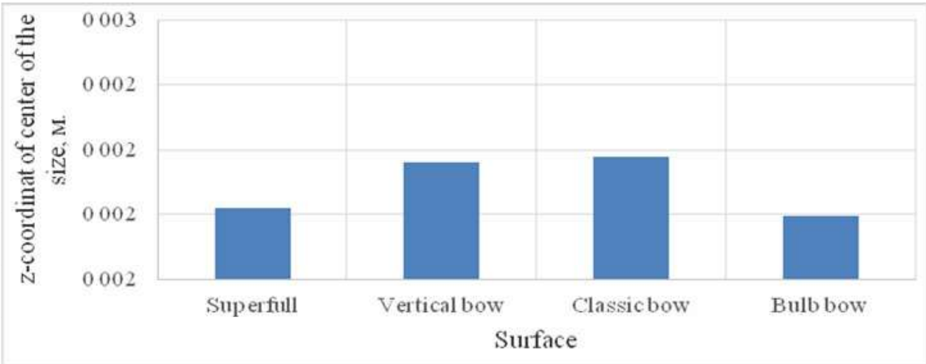

Fig. 19. Dependence of an z-coordinate of center of the size of the offered SCV surface at draft (d = 4,5 m)

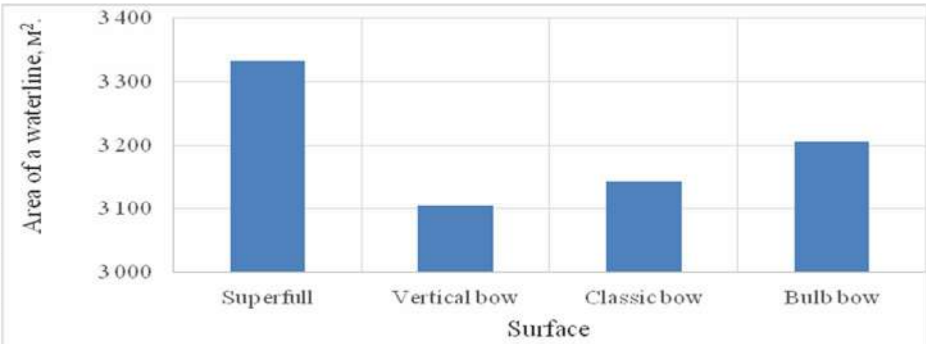

Fig. 20. Dependence of an area of a waterline of the offered SCV surface at draft (d = 4,5 m)

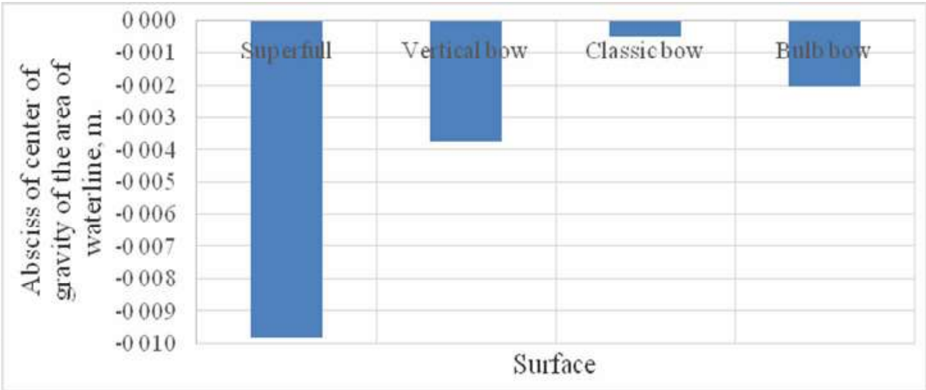

Fig. 21. Dependence of an absciss of center of gravity of the area of waterline offered SCV surface at draft (d = 4,5 m)

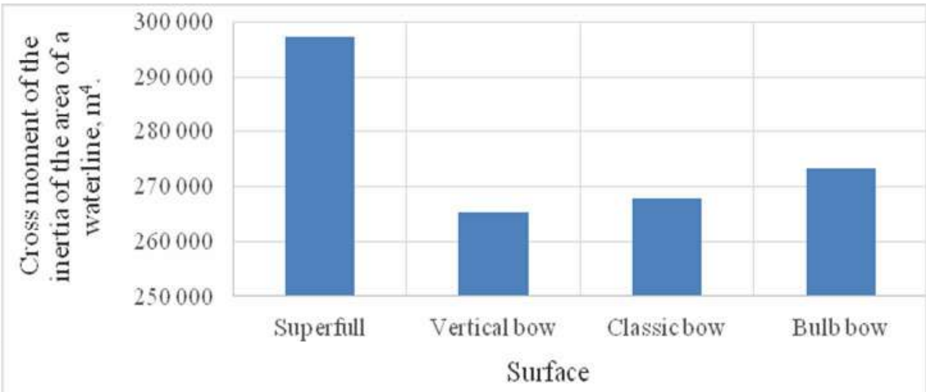

Fig. 22. Dependence of a cross moment of the inertia of the area of a waterline offered SCV surface at draft (d = 4,5 m)

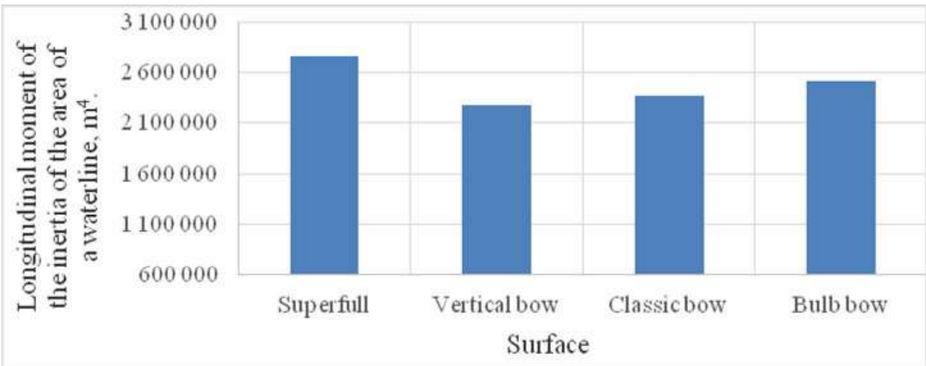

Fig. 23. Dependence of a longitudinal moment of the inertia of the area of a waterline offered SCV surface at draft (d = 4,5 m)

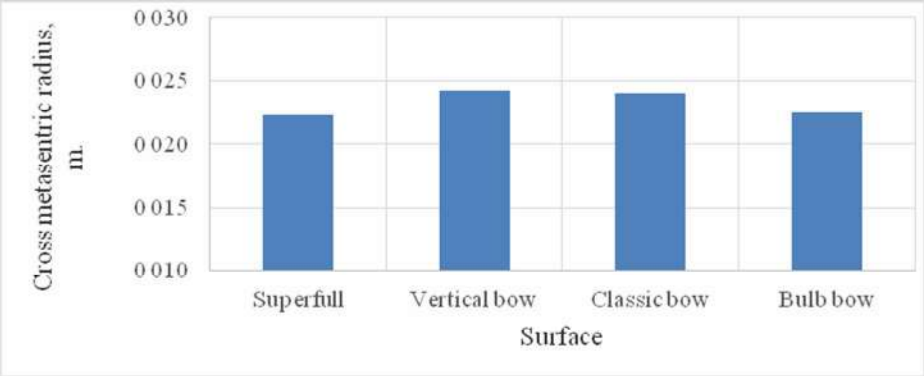

Fig. 24. Dependence of a cross metacentric radius offered SCV surface at draft (d = 4,5 m)

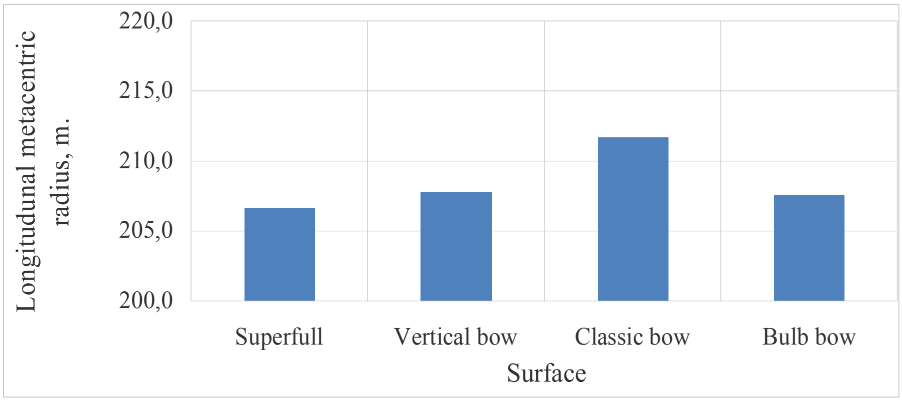

Fig. 25. Dependence of a longitudinal metacentric radius offered SCV surface at draft (d = 4,5 m)

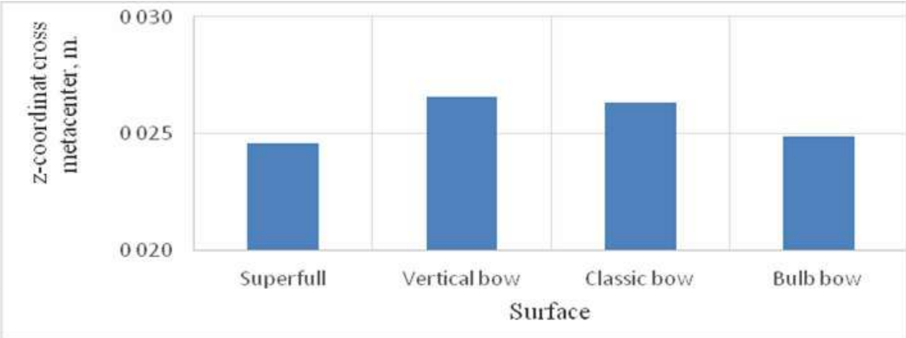

Fig. 26. Dependence of a z-coordinate cross metacenter offered SCV surface at draft (d = 4,5 m)

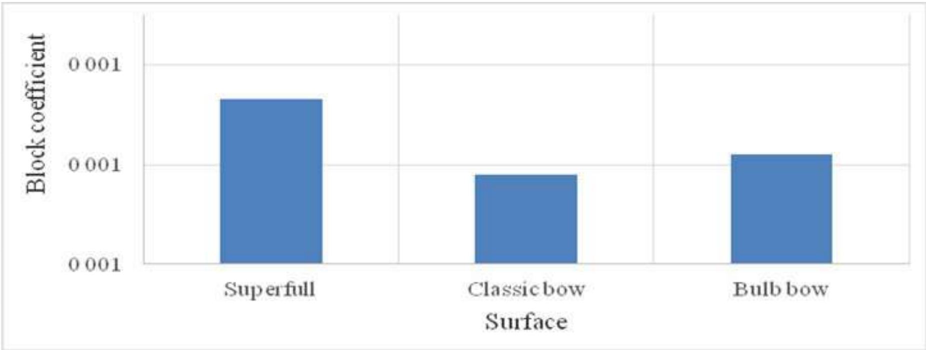

Fig. 27. Dependence of a block coefficient offered SCV surface at draft (d = 4,5 m)

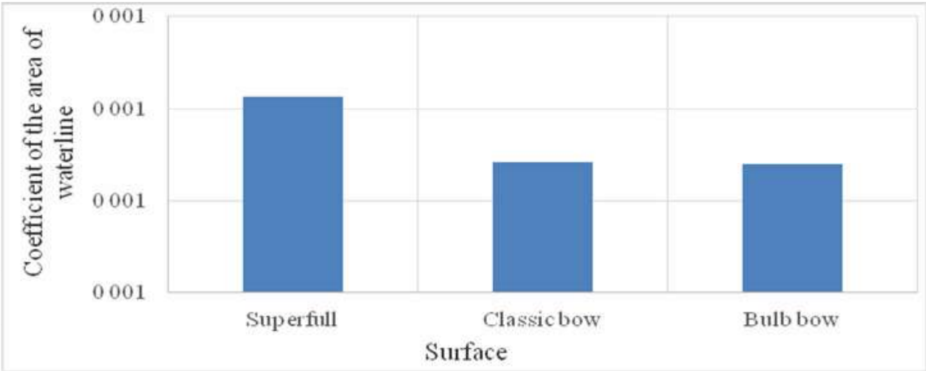

Fig. 28. Dependence of a coefficient of the area of waterline offered SCV surface at draft (d = 4,5 m)

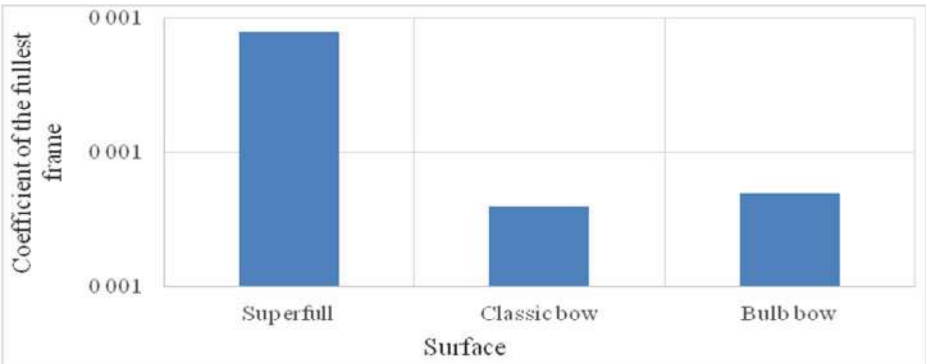

Fig. 29. Dependence of a coefficient of the fullest frame offered SCV surface at draft (d = 4,5 m)

Thus, the analysis of diagrams of fig. 16-29, made on dependences fig. 2-15, shows that in most cases the superfull surface has the greatest advantage before other surfaces to SCV.

Research of propulsion quality of a superfull surface of SCV

One of the important factors affecting seaworthy qualities of any vessel is vessel speed. Considering that, investigating the analysis of hydrostatic parameters of a superfull surface of SCV, it was received, advantage before other forms, the diagram of comparative dependence of required power of the main engines of the researched surfaces, fig. 30, showed need of bigger required power of the main engines for a superfull surface. Considering feature of operation of SCV at which subsea operations are generally made at the parking mode and demand high installed power per employee and a relative small shoulder of transitions, grants the right to consider vessel speed a minor factor before advantage of hydrostatic parameters of fig. 2-15.

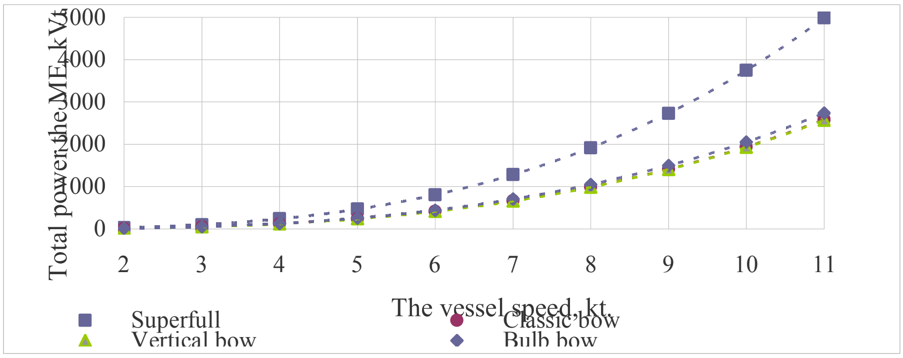

Fig. 30. Comparative dependence of required power of the main engines of the researched surfaces

Calculations were made by a formula (3), at a ratio of length and width L/B = 3,17. For confirmation of reliability of calculations, calculation of total power of the main engines of a superfull surface of the vessel which already had in operation with a ratio of length and width L/B = 8,1 was made. Lower in comparative dependence of towing power of superfull surfaces, fig. 31, estimated dependences of a superfull surface of L/B = 3,17 and 8,1, also results of «CFD» of tests of a superfull surface L/B = 8,1 are reflected. Character settlement and «CFD» of dependences of superfull surfaces L/B = 8,1, confirm reliability of calculations.

$$N = b * N - {}^{v}\!/_{N} \qquad (3)$$

here N – main engine power;

v – vessel speed;

b – correlation coefficient the considering regularity of the considered ratios determined by formula (5);

${}^{v}\!/_{N}$ – ratios of speed and draft of the vessel, determined by formula (4).

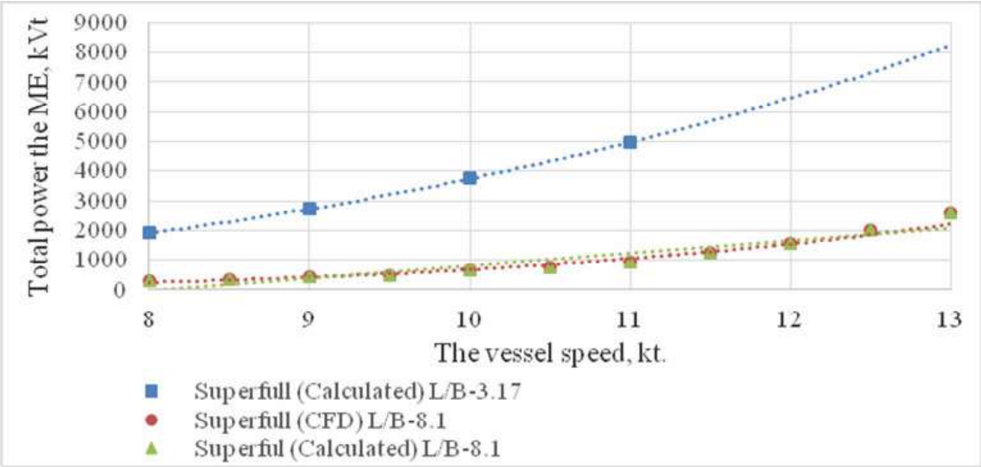

Fig. 31. Comparative dependence of towing power of superfull surfaces L/B-8.1 & 3.17

$$v/N = \sum_{i=1}^{n} \bar{N} - b * \sum_{i=1}^{n} v \qquad (4)$$

$$b = \frac{\sum_{i=1}^{n} \left(v - \bar{v}_i\right)\left(N - \bar{N}_i\right)}{\sqrt{\sum_{i=1}^{n} \left(v - \bar{v}_i\right)^2 \sum_{i=1}^{n} \left(N - \bar{n}_i\right)^2}} \qquad (5)$$

Thus, justification of the select of a superfull surface for SOPTR. is confirmed it is supposed to execute at further stages of a research «CFD» modeling and pool tests of a superfull surface.

Conclusion. The system analysis and mathematical model of justification of the select of a superfull surface on the basis of hydrostatic characteristics of SCV is developed;

The comparative analysis of dependences of hydrostatic characteristics of a superfull surface with other types of the considered surfaces is made;

Justification of the select of a superfull surface for SCV is executed;

The research of propulsion quality of a superfull surface of SCV is executed.

СПИСОК ЛІТЕРАТУРИ

1. Говард Гулд.: Системний аналіз і дизайн: / www.bookboon.com. (2016).
2. Тімоті Дж. Росс: Нечітка логіка з інженерними додатками. John Wiley & Sons, Ltd. (2017).
3. Кеннет Г. Розен.: Дискретна математика та її застосування. McGraw-Hill Education, Нью-Йорк. (2019).

4. Караєв Р.Н. Морські плавучі споруди для нафтогазової промисловості. Бакинський університет. Баку. (2002).
5. Баширов Р.Д., Абдуллаєв О.М. Класифікація суден підводного будівництва та оцінка ефективності дослідження. 2 міжнародна науково-практична конференція «Машинобудування та енергетика: нові концепції та технології». Т. 148. Р. 217-223. (2024).
6. Абдуллаєв О.М. Вибір основних розмірів судів забезпечення підводно-технічних робіт з використанням методу бази даних. Праці Азербайджанської державної морської академії. 2(40). 7-18 (2024).

REFERENCES

1. Howard Gould.: Systems analysis and Design: / www.bookboon.com. (2016).
2. Timothy J. Ross. Fuzzy logic with engineering applications. John Wiley & Sons, Ltd. (2017).
3. Kenneth H. Rosen. Discrete mathematics and its applications. McGraw-Hill Education. New York. (2019).
4. Karayev R.N. Offshore floating structures for oil and gas industry. Baku university. Baku. (2002).
5. Bashirov R.D., Abdullayev O.M. Classification of subsea construction vessels and evaluation of study effectiveness. 2nd international scientific-practical conference «Machine Building and Energy: New Concepts and Technologies». Vol. 148. P. 217-223. (2024).
6. Abdullayev O.M. Vibor qlavnikh razmereniy sudov obespecheniya podvodno-tekhnicheskih rabot s ispolzovaniyem metoda bazi dannikh. Proceedings of Azerbaijan State Marine Academy. 2(40). 7-18 (2024).

Стаття надійшла до редакції 03.06.2025

Посилання на статтю: Єгоров О.Г., Абдуллаєв О.М. Аналіз гідростатичних характеристик та обґрунтування вибору надповної форми корпусу судна для підводних будівельних робіт // *Вісник Одеського національного морського університету:* Зб. наук. праць, 2025. № 3 (77). С. 7-24. DOI 10.47049/2226-1893-2025-3-7-24.

Article received 03.06.2025

Reference a journal artic: Egorov O.G., Abdullayev O. Analysis of hydrostatic characteristics and justification of the select superfull hull form of the subsea construction vessels // *Herald of the Odesa National Maritime University*: Coll. scient. works, 2025. № 3 (77). P. 7-24. DOI 10.47049/2226-1893-2025-3-7-24.