Designing a NAABSA Class Tanker Ship with Bottom Protection from Ground

Victor A. Kulesh, Mathias B. Prasetio*, Fam Chung Hiep

Department of Marine Technology and Transport, Polytechnic Institute, Far Eastern Federal University. Address: 10, Ajax Bay, Russky Island, Vladivostok, 690922, Russian Federation.
**Corresponding author: mathiasbimop@gmail.com*

Article history:
Received: 9 April 2023 / Received in revised form: 11 May 2023 / Accepted: 15 May 2023
Available online 9 June 2023

ABSTRACT

Indonesia is the world's largest archipelago country with a high potential for economic development and top producer and exporter of palm oil. As an archipelago country, the most efficient cargo transportation routes are through rivers and seas. Designing and building tankers, taking into account the specifics of the operation, are relevant. The paper considers the issues of designing a tanker for the transportation of crude palm oil with a defined operation area and route. The general concept of the vessel is proposed, taking into account the restrictions on the navigation area and draft for operation in the river. Particular attention is given to the issues of strengthening the hull in terms of overall longitudinal strength, as well as the bottom and the propeller-steering complex in terms of interaction with the ground. An external structural protection (ESP) from the ground was developed, and comparative calculations of the stress-strain state of the compartment and ESP structures were performed. The effectiveness of the solution for protecting the hull from direct contact with the ground is shown, and outlined ways for the possible development of tanker projects for the conditions.

Keywords: *External structural protection, FEM analysis, grounding resistance, NAABSA, Tanker*

I. Introduction

The Republic of Indonesia is the largest archipelago country in the world. It is located between The Indian and Pacific oceans. Indonesia is ranked 4th in the world by population (after China, India, and the USA), with a population of 280 million people. Indonesia has a rich shelf zone with biological and other resources (Figure 1a), with a total area of 1.92 million km^2 and 13.6 thousand islands.

The share of the oil industry in Indonesia is $292 billion, and it is an important part of the country's economy (29%) – 16th in the world and 1st in Southeast Asia. Oil and gas exports bring 20% of the country's income, ranking 3rd in the list of major exported goods after coal and palm oil [1]. Indonesia is the world leader in palm oil production, with 46 million tons worth $18 billion annually. Other major export commodities are rubber ($4 billion), coffee ($1.4 billion), seafood, etc. [1].

The planned route of the tanker is the port of Palembang (departure) and the port of Priok (Jakarta) (Figure 1b). The navigation range is 500 nautical miles, including the river section – 54 miles, then narrow Bangka Strait – 100 miles, and then in the open Java Sea – 346 miles.

DOI: 10.17977/um016v7i12023p059

Vol. 7, No. 1, July 2023, pp. 59-65

a) b)

Fig. 1. Map of Indonesia (a) and the planned navigation area of the tanker (b)

The minimum depth of the Musi River is 4.5 meters [2], with tide up and downs that can reach up to 2 m. This determines the probability of contact with the ground and partial drainage. The draft of the tanker was adopted 4 m, taking into account the margin for structural protection from the ground. There are no bridges on the considered section of the river, and no height restrictions are required.

The narrow Bangka Strait separates the islands of Sumatra, and Bangka has the lowest depth of 7.5 m. The Java Sea is relatively shallow, and its average depth is 40 m [3]. The Java Sea is characterized by great thermal stability with an annual average temperature of 28 °C and deviations up to 3 °C. [3].

II. Material and Methods

1. General Conception of the Tanker

Taking into account the conditions of the operating area, the dimensions of the tanker are length 90 m, width 15 m, side height 5 m, and draft 4 m, displacement 5037 t. The main cargo is palm oil. The possibility of modifying the tanker for crude oil transportation is also taken into account. Additionally, the issues of restrictions on the navigation area and the class of the vessel NAABSA1 were considered according to the Rules of the Russian Maritime Register of Shipping (RS) [4, 5].

The vessel is a 2-screw, with a tank and a 3-tier superstructure in the stern. In the area of the cargo area, there is an elevated main deck (height of 1 m), double bottom (height of 1 m), and double sides (width of 0.9 m) equipped. The transverse spacing is 700 mm in the cargo area. The longitudinal spacing is 600 mm. Floors and frames through 3-4 spacings. The hull has 9 transverse bulkheads and 1 longitudinal one. The side view of the vessel and the cross-section diagram are shown in Figure 2.

In the first stage, loads and general requirements for the size of connections are determined according to the Rules [5]. The lining of the bottom and cheekbones is 10 mm thick. The flooring of the second bottom is 9 mm thick. Floors and zygomatic brackets with a thickness of 10 mm. Checking the overall strength of the hull showed that there is a shortage for the I limited navigation area (200 miles away), and it was decided to use steel with 235 yield strength for bottom and sideboard construction and high-strength steel with 315 MPa for the elevated main deck and its longitudinal beams [15]. Then the total longitudinal strength is provided with a margin of 12.1%.

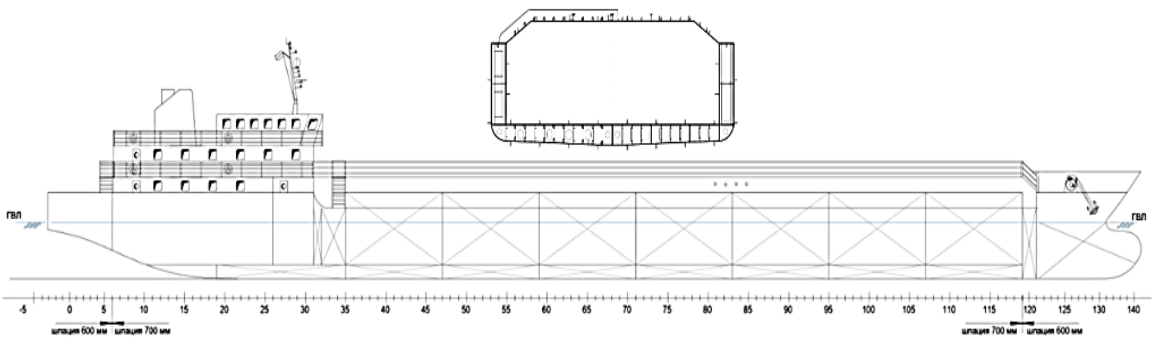


Fig. 2. Side view and midship section concept of the tanker hull

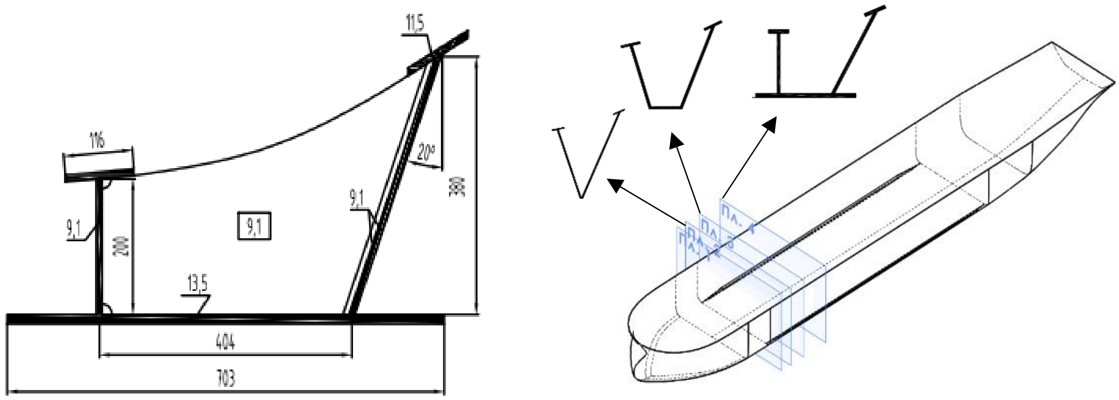
2. Hull Reinforcements for NAABSA1 Class and Ground Landing

In the second stage, the task of strengthening the hull for safe contact with the ground and compliance with the NAABSA1 class was solved [5]. Additionally, the issues of the influence of the external structural protection of the hull were considered. Based on the results of calculations and in the absence of an ESP, it was obtained:

- increase the thickness of the lining of the bottom and cheekbones to 11 mm, the flooring of 2 bottoms - up to 10 mm;
- increase the longitudinal bottom beams No 2-8 from Diametrical Plane (DP) from the half-column 18a to 20b [9].

3. External Structural Protection Design

The operation of vessels in rivers increases the possibility of interaction with the ground. To avoid accidents and damage to the hulls, the bottom is most often damaged. Therefore, protecting the bottom from direct contact with the ground is important [6]. The works [11,12] show the advantages of a trapezoidal ESP with overhangs. The parameter of the ESP was achieved by following methods by Kulesh V.A. and Pham Trung Hiep [8-10], and for such a form, the decision was made in Figure 3a.



a) b)

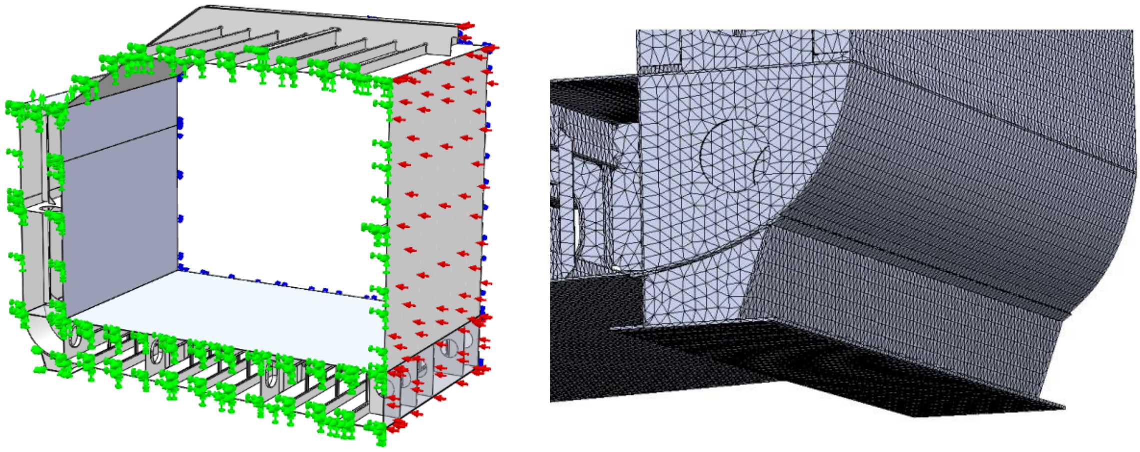
Fig. 3. Cross section of ESP (a) and Closing sections of the ESP (b)

The ESP includes 4 elements: a horizontal support strip, a vertical sheet, an inclined sheet, and internal brackets (through 2 spacers) with a length of 49 m on the parallel midbody of the ship (Figure 3b). Vertical and inclined strips are connected to the bottom lining through lining strips.

4. FEM Analysis

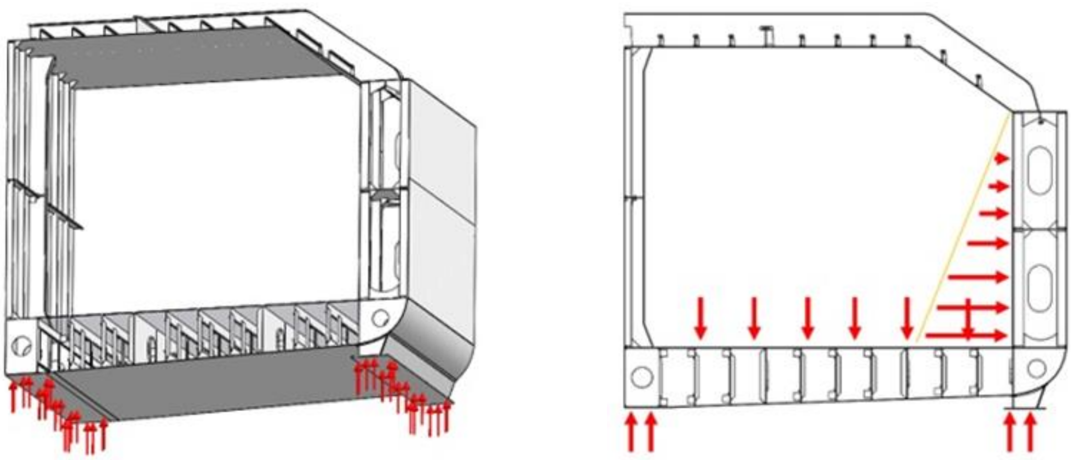
The ship's hull compartment was modeled using the SolidWorks program [13]. The model was created as a fragment of ¼ compartment. The design of the compartment and its loading conditions were assumed to be symmetrical with respect to the diametral plane. The set of the compartment included different types of bracing sections: tees (keel, bottom stringers, carlings, beams, and bulkhead frame racks), bulb strips (frames, bottom longitudinal beams, above-deck longitudinal beams, idle racks, and horizontal bulkhead shelf).

The compartment boundary conditions shown in Figure 4a are fixed along the section in the diametral plane (no displacements and no rotations), fixed on the transverse bulkhead (no shifts or turns), reference geometry along the cross-section of the middle of the compartment (no rotations around the y axis). The mesh used is standard and solid, with a global size of 200 mm and a tolerance of 3.8 mm [14], shown in Figure 4b.



a) b)

Fig. 4. Fixtures (a) and mesh (b)



a) b)

Fig. 5. Case 1 tank without cargo (a) and case 2 tank with cargo (b)

The analysis of the stress-strain state of the compartment under the action of soil was performed, and 2 cases are considered: 1. Tank without cargo (Figure 5a.); 2. Tank with cargo (Figure 5b.). The soil is different and has many properties, but for this study, we take the calculated nominal resistance of the soil; 300 kPa is assumed (we take an average of 100-600 kPa). The load on the compartment from the ground side was 8357 kN.

III. Results and Discussions

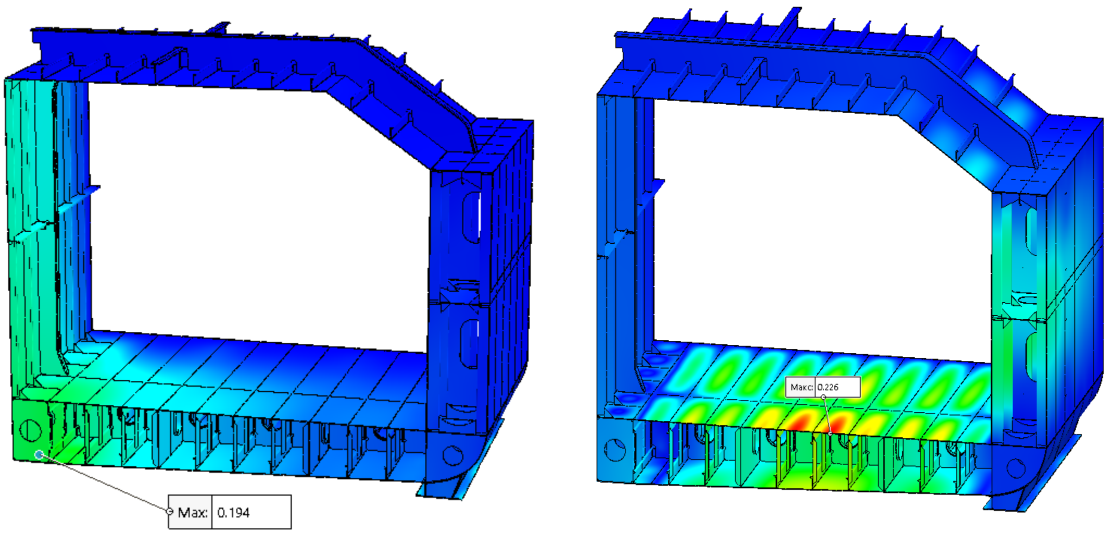
The calculation is presented in Table 1. The highest stresses in the floor are 192 MPa when the tank is filled. Stresses in double bottom longitudinal, stringer and stiffner connection also increased significantly caused by the pressure of the filled cargo tank. The maximum deflections along the horizontal keel are 0.19 mm (Figure 6a) and along the decking of the second bottom 0.23 mm (Figure 6b) for case 1 and case 2, respectively.

Table 1. Maximum stresses (MPa) in structural elements

No		Element	Case 1	Case 2
1	Compartment	Vertical Keel	79	80
2		Bottom longitudinal beams	95	99
3		Stringer	24	59
4		Floor	136	192
5		Double bottom longitudinal beams	52	101
6		Stiffener	40	103
7		Bracket bilge keel	25	25
8		Keel bracket	131	144
9		Horizontal keel	114	113
10		Bottom skin	43	66
11	ESP	Lining plate 1	104	101
12		Vertical plate	82	72
13		Horizontal support strip	64	64
14		Lining plate 2	100	100
15		Inclined sheet	42	43
16		Internal brackets	94	100
17		Maximum deflection, mm / location	0.19 / Horizontal Keel	0.23 / Double bottom

The stresses differences in ESP (external structural protection) of case 1 and case 2 are identical. All of the maximum stresses are below the maximum yield strength of the material of 235 MPa.

Analysis of the results of FEM calculations showed: 1. Tanker with ESP under the most severe conditions (full draining at the highest weight) receives a relatively high level of stress in the bottom floors - up to 82% of the yield stress in the filled tank scenario; 2. The stresses in the ESP elements are less significant - up to 6% of the yield stresses in the vertical plate and in the internal bracket- 3%; 3. For relatively large vessels, the conditions with a partial transfer of the reaction of the soil simultaneously to the hull and to the ESP are especially important and provide opportunities for obtaining acceptable design solutions in terms of dimensions, weight, and stresses. This design solution was also developed from previously researched by Prasetio et al. [9].



a) b)

Fig. 6. Diagram of deflection of case 1 (a) and case 2 (b)

IV. Conclusion

As a result of the work, a tanker concept is proposed for the considered operating conditions. The necessity of increasing the overall longitudinal strength of the hull and the local strength of the bottom is shown. The directions and objectives of the development of this project are related to the technical and economic performance indicators, taking into account loading options and clarifying design concepts for protection from the soil.

References

[1] A.V. Popov, *Economy of Indonesia: special state and development prospects*. Institute of Oriental Countries, 2019. 372 p (original document in Russian).

[2] S. Sunarso, Impact of sailing route in Musi River Flow. *Gema Teknologi*, vol. 16, no. 1, Diponegoro University, Indonesia. 2010. 8 p (original document in Indonesian).

[3] J.R. Durand, D. Petit. The Java Sea environment, M. Potier, and S. Nurhakim (Eds.), in *BIODYNEX. Biology, Dynamics, Exploitation of the Small Pelagic Fishes in the Java Sea*, Agency for Agricultural Research and Development-ORSTOM-EU. 1995, pp. 14-38

[4] V.A. Kulesh, Fundamentals of the design of marine hulls. Guidelines for the implementation of the course project in the discipline "*The design of the hull of sea vessels*." DVGTU, Vladivostok, 2007. 70 p (original document in Russian).

[5] *Rules for the classification and construction of sea vessels*. Russian Maritime Register of Shipping. RMRS, Saint Petersburg, 2022. 337 p.

[6] O.E. Surov, H.C. Fam, and A.S. Vorobyova, *External constructive protection of ships from soil*. Modern technologies in shipbuilding and aviation education, science and production: a collection of reports of the All-Russian scientific and practical conference, Nizhegorsk state technology University named R. E. Alekseev. Nizhny Novgorod. 2021. pp 46-51 (original document in Russian).

[7] V.A. Kulesh and H.C. Fam. Structural protection of ship from soil. *Proceedings of the Krylovsky State Scientific Center*. Issue No. 1. Saint Petersburg. 2022, pp. 113 – 119

(original document in Russian)

[8] V.A. Kulesh and H.C. Fam. *Interaction of ships with ground: teaching aid*. Politechnic Institute FEFU. Vladivostok, 2021. 33p (original document in Russian).

[9] M.B. Prasetio, H.C. Fam, K.V. Elkina, V.A. Kulesh. *Research design of a tanker for the seas and rivers of Indonesia, taking into account interactions with the ground*. Regional Scientific and Practical Conference “Youth and Scientific and Technical Progress” ISTP. Vladivostok, 2022, pp. 1022-1026.

[10] M.B. Prasetio, H.C. Fam, and V.A. Kulesh. *Analysis of the resistance to movement of a large tanker with regard to external structural protection from ground*. Regional Scientific and Practical Conference “Youth and Scientific and Technical Progress” ISTP. Vladivostok, pp.1017-1021.

[11] V.A. Kulesh, O.E. Surov, and H.C. Fam. Patent No. 215629 Russian Federation. *Bottom protection device with a longitudinal system when landing on the ground*. FEFU applicant, 2s.

[12] V.A. Kulesh, O.E. Surov, and H.C. Fam. Patent No. 216642 Russian Federation. *Bottom protection device with a transverse framing system when landing on the ground*. FEFU applicant, 11s.

[13] V.G. Bugaev and D.V. Tung. *Information technologies in the life-cycle of marine engineering: teaching aid*. Politechnic Institute FEFU. Vladivostok, 2021. 145p (original document in Russian).

[14] *Class guideline for Finite Element Analysis*. DNV GL. DNV GL AS, Berum, Norway 2015. 93 p.

[15] *Technical specification 5.961-11605-95. Rolled steel shaped for shipbuilding. Bulbs profile*. Central Research Institute of KM "Prometheus". Moscow, 2017.