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DESIGN OF A FLOATING CRANE: SELECTION OF STRUCTURAL ELEMENTS COMPARING S235 AND S355 STEEL GRADES

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Abstract. This study presents an analysis of floating cranes and the design of one such crane. During the analysis phase, various types of floating cranes and their structural designs were examined. Based on this analysis, the necessary calculations were performed to select a suitable crane and pontoon.

The study also investigates how different steel grades (S235 and S355) influence the selection of structural components. The emphasis is on ensuring the pontoon's structural integrity, assuming that the calculated plate thicknesses and profile dimensions will be implemented. Two software tools were utilised for the analysis: Mars Inland and Ansys. Furthermore, calculations adhered to the standards of Bureau Veritas, the French classification society, particularly Rule Note No. 217.

Keywords: floating crane, pontoon, structural analysis

Introduction

Floating cranes are essential in maritime construction, cargo handling, and heavy lifting operations in seaports and inland waterways. Their design necessitates a careful balance of structural integrity, hydrodynamic stability, operational mobility, and regulatory compliance. Given the increasing demand for efficient and cost-effective lifting solutions in inland water regions, there is a need to optimise pontoon-based crane platforms using advanced computational tools.

1. Background

Floating cranes and types

Floating crane – a marine vessel designed for lifting or transporting heavy loads. It is typically a barge or a pontoon structure equipped with high-capacity cranes. (Lietuvos Respublikos susisiekimo ministerija, 2025).

Floating crane types according to crane's mechanism:

- **Stiff boom crane**. A stiff boom crane features a fixed, non-articulating boom that can lift loads vertically, but has limited reach and flexibility. Due to its rigid structure, it is reliable and low-maintenance, but not ideal for complex lifting operations.
- **Slewing crane**. A slewing crane is equipped with a rotating base that allows the crane boom to spin horizontally 360 degrees. This allows excellent maneuverability and makes it suitable for various lifting operations.
- **Crawler crane**. A crawler crane is a land-based crane mounted on a pontoon. It is especially suitable for inland waterway operations due to its mobility and stability. This type of floating crane is a cost-effective and flexible solution.

Crane and pontoon selection

Given the task of lifting a 15 x 15 x 5 m cargo weighing 50 tons onto a vessel docked in a shipyard, it was determined to design a floating crane with a higher lifting capacity than the existing 30-ton dockside cranes. After assessing the current conditions and performing the necessary calculations, the Manitowoc MLC650 crawler crane was chosen, offering a maximum lifting capacity of 650 tons. (Manitowoc Cranes, 2022). The dimensions of the supporting pontoon were also established: length – 56 m, breadth – 20 m, height – 6,5 m, draught – 4 m.

The chosen crane can lift around 90 tons at a distance of 39 metres from the load, and at a height of 18 metres above the dock's staple deck.

Table 1. Manitowoc MLC650 crawler crane specification

Manufacturer	*Manitowoc*
Model	*MLC650*
Maximum lifting capacity	650 t
Weight	662,10 t
Boom length	68 m
Boom angle	30 – 85 degrees
Price	2,8 – 5 mln. Eur.*

* Price varies according to the condition of the crane (new or used).

Table 2. Pontoon dimensions

Length	56 m
Breadth	20 m
Height	6,5 m
Draft	4 m
Spacing	0.7 m

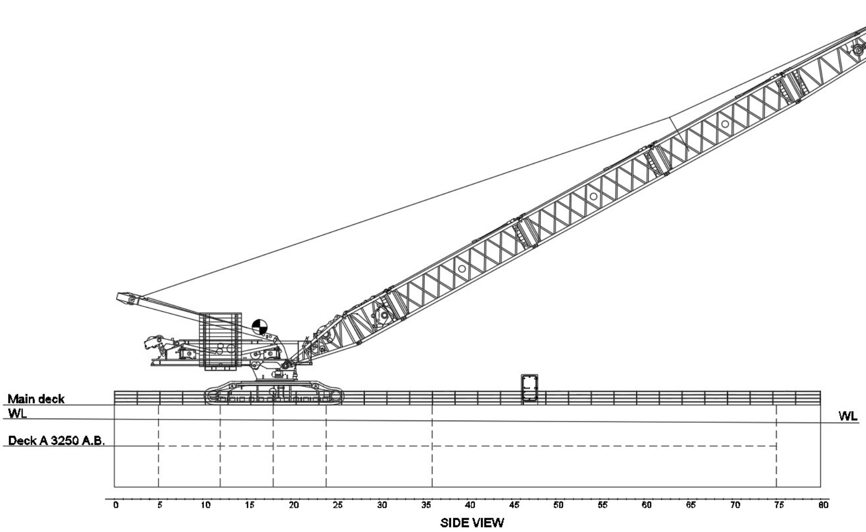

Figure 1. Designed floating crane

2. Mars Inland

Mars Inland is a 2D structural assessment tool developed by Bureau Veritas (BV) that conforms to BV Rules No. 217: Rules for the Classification of Inland Navigation Vessels. It calculates the minimum structural thickness based on applied loads and rule-based formulas.

In this study, a midship section of the pontoon – specifically the machine room area – was modelled in Mars Inland (see Figure 2). The focus was to compare two common shipbuilding steels, S235 and S355, in terms of structural efficiency and cost.

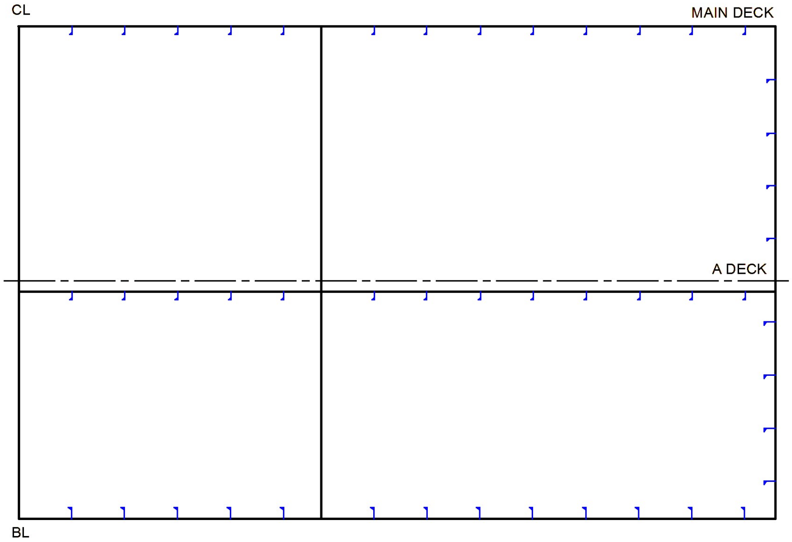

Figure 2 Midship section in Mars Inland

Mars Inland **results**

1. S355 Steel:
    1. Plate thickness (shell and bulkheads): 7 mm
    2. Bottom longitudinal bulb flat profiles (hereinafter referred to as HP): 140×7 mm;
    3. 2nd and main deck longitudinal HP profiles: 100×7 mm.
2. S235 Steel:
    1. Plate thickness: 7 mm;
    2. Bottom and side HP profiles to 2nd deck: 140×10 mm;
    3. Deck and upper side HP profiles: 100×7 mm.

Shell plate thickness was consistent between steels due to constant applies water pressure (41.12 kPa) (Figure 3).

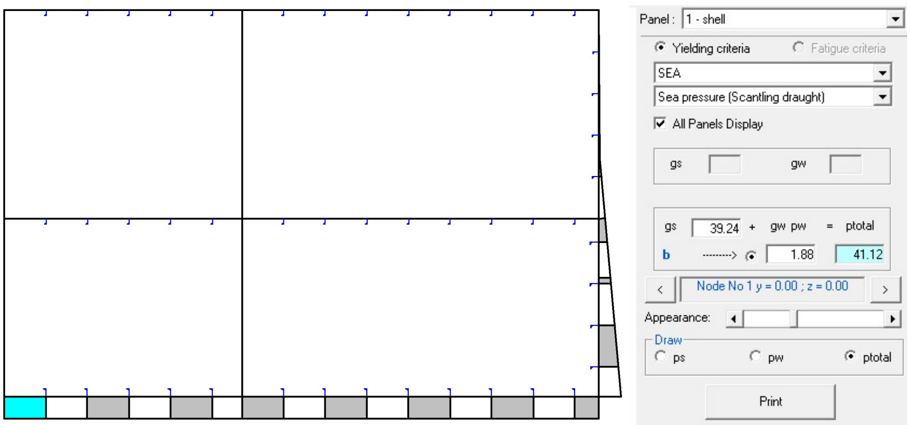

Figure 3. Calculated water pressure

However, S235 required thicker profiles (by 3 mm), increasing material weight and cost.

Rule – based validation

According to BV rules Part B, Chapter 5, Section 2 *Bottom scantlings* (Bureau Veritas, 2021), two approaches for minimum plate thickness were used:

1. Geometrical rule:

$$t_1 = 1{,}1 + 0{,}03 \cdot L \cdot (k_0 k)^{0{,}5} + 3{,}6 \cdot s, \tag{1}$$

where L is ship length, k_0 and k – coefficients, s – spacing.

4. S235 steel: $t_{1_{S235}} = 5.30$ mm
5. S355 steel: $t_{1_{S355}} = 5.05$ mm

2. Pressure rule:

$$t_2 = 14{,}9 \cdot C_a \cdot C_r \cdot s \cdot \sqrt{\frac{\gamma_R \cdot \gamma_m \cdot P}{\lambda_L \cdot R_y}}, \tag{2}$$

where C_a, C_r and λ_L are coefficients, s – spacing, γ_R and γ_m – safety factors, P – pressure, R_y – minimum yield stress.

Both steel types yielded a pressure – based thickness of 5.50 mm.

With a corrosion allowance of 1 mm, the final thickness becomes 6.5 mm, closely matching the Mars Inland results and validating the software under constant pressure.

The study also investigated variations in thickness under increased pressure (see Table 3 and Figure 4).

Table 3. Results

	t_2, mm	C_a	C_r	s, m	γ_R	γ_m	P, kN/m²	λ_L	R_y, N/mm²	l, m
1	**0**	1,05	1	0,7	1,2	1,2	**0**	1	235	2,8
2	**2,71**	1,05	1	0,7	1,2	1,2	**10**	1	235	2,8
3	**3,83**	1,05	1	0,7	1,2	1,2	**20**	1	235	2,8
4	**4,70**	1,05	1	0,7	1,2	1,2	**30**	1	235	2,8
5	**5,42**	1,05	1	0,7	1,2	1,2	**40**	1	235	2,8
6	**6,06**	1,05	1	0,7	1,2	1,2	**50**	1	235	2,8
7	**6,64**	1,05	1	0,7	1,2	1,2	**60**	1	235	2,8
8	**7,17**	1,05	1	0,7	1,2	1,2	**70**	1	235	2,8
9	**7,67**	1,05	1	0,7	1,2	1,2	**80**	1	235	2,8
10	**8,13**	1,05	1	0,7	1,2	1,2	**90**	1	235	2,8
11	**8,57**	1,05	1	0,7	1,2	1,2	**100**	1	235	2,8

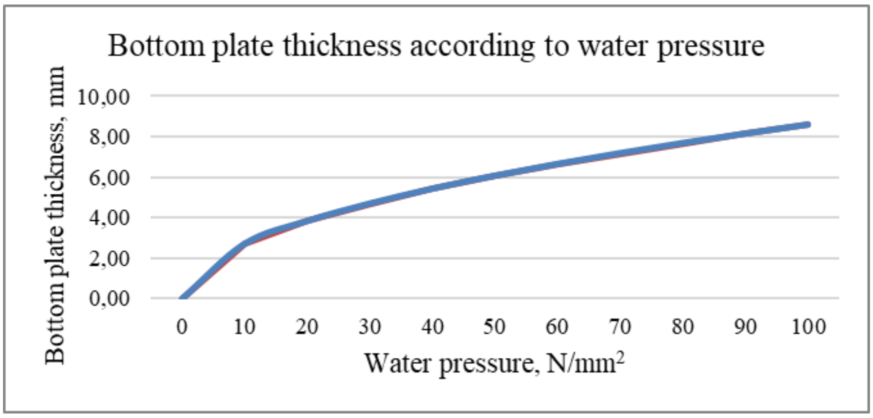

Figure 4. Bottom plate thickness according to water pressure

From the graph, as the pressure increases—up to 20 N/mm²—the plate thickness rises more rapidly; however, beyond this point, the increase becomes more uniform. This indicates that the higher the pressure, the thicker the minimum required bottom plate must be. However, these results are valid only at midship; further analysis using finite elements is necessary to assess localized structural effects, particularly under crane loads.

3. Finite element analysis (FEA) in *Ansys*

Mars Inland does not consider local reinforcements beneath crane tracks. Therefore, *Ansys* was utilised for detailed FEA.

Geometry and mesh

The model was created using shell (plate) elements. The thickness of the outer plating and bulkheads is 7 mm. Corrugated bulkheads were chosen to reinforce the structure beneath the crane tracks. The stringers and longitudinal HP profiles measure 140 mm × 7 mm. As the crane and cargo will be placed on the upper deck, HP 140 mm × 7 mm profiles were selected for reinforcement instead of the previously calculated HP 100 mm × 7 mm (based on the Mars Inland software). To enhance the overall structure, T-shaped transverse frame profiles of 200 mm × 10 mm and 100 mm × 12 mm were selected. For the sides between the second and upper decks, as well as on the second deck, HP 100 mm × 7 mm profiles were used, as calculated using the Mars Inland software. Calculations can only be performed when the model is properly meshed. A 100 mm × 100 mm mesh was chosen.

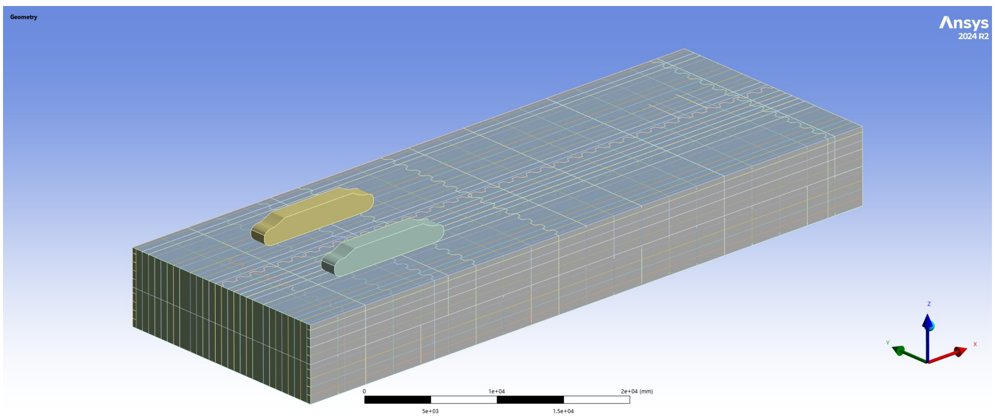

Figure 5. Model geometry

Load cases

Given that the floating crane will be used on water under varying conditions, different operational scenarios must be taken into account. Four loading scenarios were chosen for analysis:

1. The crane raises a load onto a ship that is docked in a floating dock.
2. The crane boom is in a "rest" position when the crane is not in operation.
3. The crane carries a load on the upper deck.
4. The crane lifts a load from the quay.

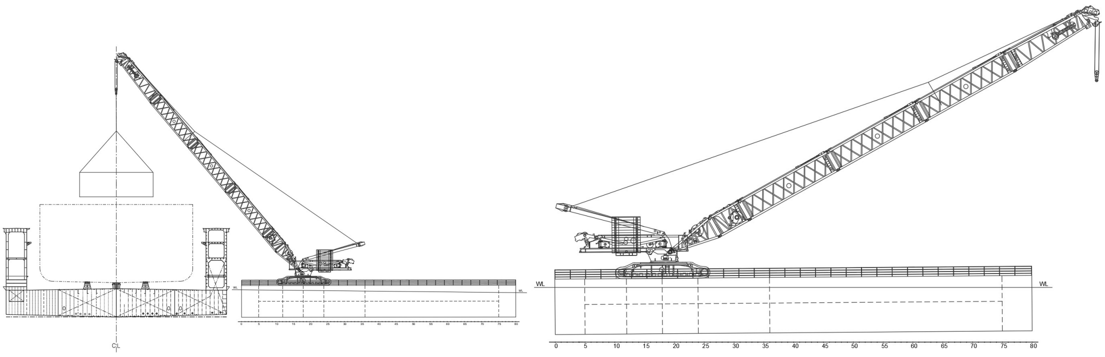

Figure 6. Load case 1 and 2

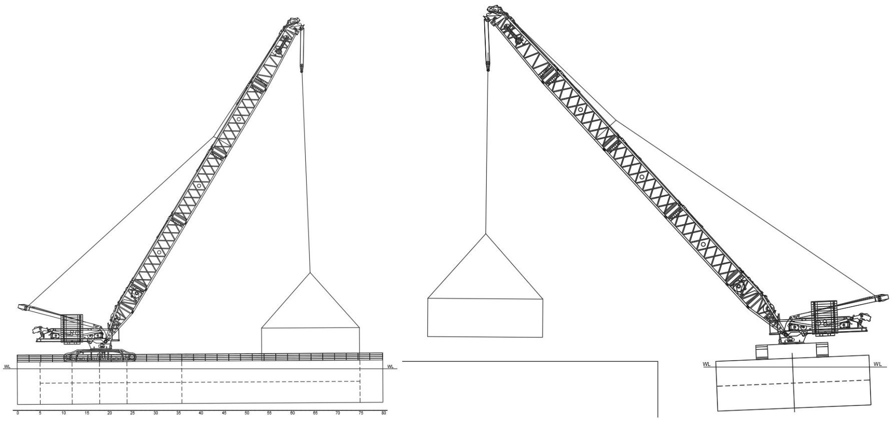

Figure 7. Load case 3 and 4

Load application

The weight of the crane and load was calculated using the formula:

$$m = m_{crane} + m_{cargo}, \tag{3}$$

where m_{crane} is the mass of the crane, m_{cargo} – mass of the cargo.

The weight of the crane and load is 712100 kg = 712.1 t.

When the combined weight of the crane and its load is known, the force exerted on the pontoon's upper deck can be calculated using the formula:

$$F = m \cdot g, \tag{4}$$

where m represents the combined weight of the crane and load, and g denotes the acceleration due to freefall.

The calculated force is 6958.701 kN. To ensure safety, a higher load of 7121 kN has been assumed.

In the finite element analysis (FEA) model, this load is applied at the crane's centre along with its load. To ensure stability during simulations, the bottom contour of the pontoon is fixed.

Results

After conducting the calculations, the resulting deformations and stresses can be observed. The summarised results are presented in Table 4.

Table 4. Overall results from Ansys

	Total deformations, mm	Equivalent stress, MPa	Allowable S235 stress, MPa	Allowable S355 stress, MPa	Check	Check
1	4,53	288,02	235	355	NO	OK
2	4,24	223,32	235	355	OK	OK
3	4,56	237,79	235	355	NO	OK
4	4,63	226,77	235	355	OK	OK

The maximum stresses are for load case 1.

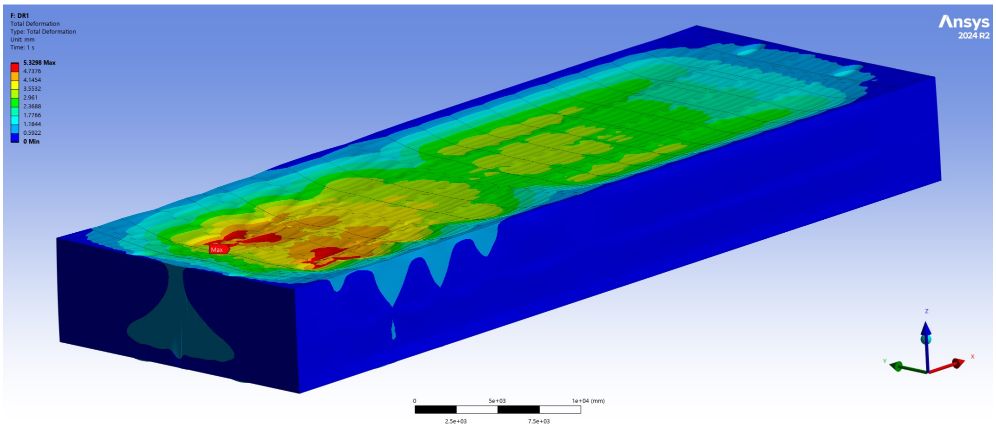

Figure 8. Load case 1 total deformations

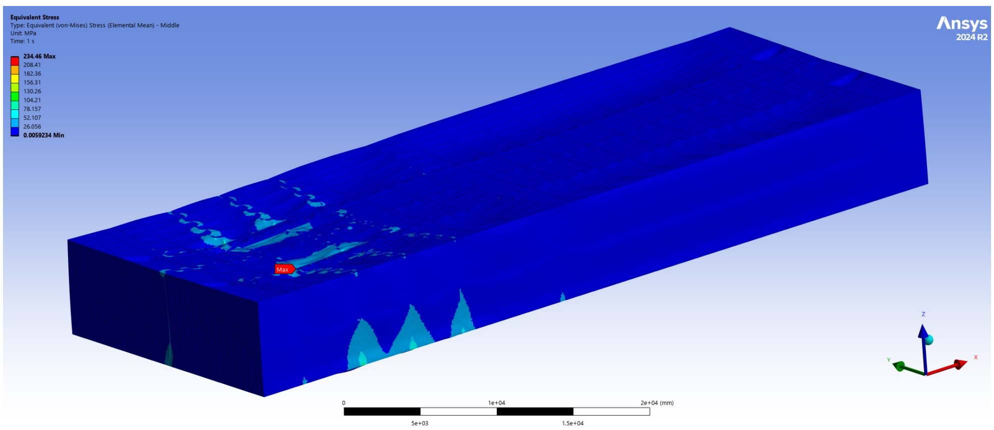

Figure 9. Load case 1 equivalent stress

The results indicate that deformations do not exceed 5 mm.

For S235 steel, in operating modes 1 and 3, the stresses in the bulkheads supporting the crane tracks exceed the allowable limits. Consequently, when selecting S235 steel, the bulkheads between frames 10 and 25 were reinforced to a thickness of 10 mm.

Following the recalculations, the revised results are shown in Table 5.

Table 5. Recalculated results

	Equivalent stress, MPa	Allowable S235 stress, MPa	Allowable S355 stress, MPa	S235	S355
1	232.46	235	355	OK	OK
2	183.67	235	355	OK	OK
3	193.95	235	355	OK	OK
4	186.47	235	355	OK	OK

Following these modifications, it can be concluded that the structural integrity of the pontoon is assured for both steel grades. The maximum stresses in the steel structures do not exceed the permissible limits for either S235 or S355 steel.

Cost evaluation

Material costs were estimated based on the average prices for 2024–2025 sourced from the websites of metal suppliers and publicly available catalogues (e.g., Thyssenkrupp Materials, Metalo Prekyba, SteelTrade, etc.). (Thyssenkrupp Materials, 2024.; Metalo Prekyba, 2024; SteelTrade, 2024).

Table 6. Estimated prices

	S235	S355
Steel plate 7 mm	45 – 55 Eur/m²	50 – 60 Eur/m²
Steel plate 10 mm	64 – 72 Eur/m²	-
HP 140 x 7 mm	-	19 – 24 Eur/m
HP 140 x 10 mm	18 – 22 Eur/m	-
HP 100 x 7 mm	12 – 15 Eur/m	13 – 17 Eur/m

Assuming the crane is newly purchased at a cost of 5 million EUR, the total project cost is presented in Table 7. This includes only the costs for materials and the crane itself; labour, transportation, and potential errors are not accounted for.

Table 7. Project price

Steel grade	S235	S355
Price for materials	155599,37 Eur	167950,64 Eur
Crane price	5 mln. Eur	5 mln. Eur
Whole price	5155599,37 Eur	5167950,64 Eur

Calculations indicate that constructing the pontoon using S235 steel results in material costs that are €12351,27 lower. However, when considering long-term durability and strength, a pontoon made from S355 steel would be more robust and longer-lasting. Therefore, it is advisable to select S355 steel.

Conclusion

This study demonstrates that combining Mars Inland and Ansys provides an effective approach for designing and verifying a floating crane for inland waterways. While both S235 and S355 steel grades met strength requirements, S235 required thicker profiles, which increased material weight and cost. With reinforcements, S235 was adequate, but S355 offered superior long-term durability. Despite a small cost difference (12351,27 Eur), S355 is the more robust choice.

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Aura Malakauskaitė is a marine transport engineering student at Klaipėda University, preparing a bachelor's thesis on the design of a floating crane for inland waters. Her academic focus encompasses ship construction, maritime regulations, and innovative engineering solutions within the marine industry.

PLAUKIOJANČIO KRANO PROJEKTAVIMAS: KONSTRUKCIJOS ELEMENTŲ PARINKIMAS, LYGINANT S235 IR S355 PLIENO MARKES

Aura Malakauskaitė

Santrauka

Šiame tyrime atlikta plaukiojančių kranų analizė ir vieno krano projektavimas. Analizės metu susipažinta su skirtingais plaukiojančių kranų tipais bei konstrukcija. Po analizės, atlikti reikalingi skaičiavimai tinkamo krano bei pontono parinkimui.

Atliktas tyrimas, kaip skirtingos plieno markės (S235 ir S355) daro įtaką konstrukcijos elementų parinkimui. Tyrimas orientuotas į pontono konstrukcijos stiprumo užtikrinimą, su prielaida, kad bus taikomi paskaičiuoti lakštų storiai ir profilių dydžiai. Tyrimui atlikti buvo naudojamos dvi programinės įrangos: „Mars Inland" ir „Ansys". Be to, atliekami skaičiavimai pagal Prancūzijos klasifikacinės bendrovės Bureau Veritas taisykles Nr. 217.

Pagrindiniai žodžiai: plūduriuojantis kranas, pontonas, statinio konstrukcijos analizė