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The Effect of the Change in the Position of Load on the Inclination Angle of Floating Crane

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Abstract: Floating cranes are equipment used for the transport of goods in the ports of Viet Nam. Some of the floating cranes such as the equipment to renovate river cages are also widely used in Vietnam. During operation, the balance of the floating cranes differs from that of the land cranes because of changes in the volume displacement. Besides, the center of the entire structure will vary depending on the location of the goods. For floating cranes the research document is often interested in statically and dynamically stabilizing. Static stability in idle or under load condition is no longer considered by checking whether the stabilization moment is greater than the overturning moment. The dynamic stability was the static balance of the crane is disturbed and behave like certain periodic or unexpected movements on the way to a different balancing position. However, this article refers to the effect of the lifting process on the static equilibrium of floating cranes. The stability of the floating crane is differ from normal ship especially when it is lifting cargo or goods, when the hangging cargo changes its position that will effect to the position of the gavity center of the total weight. In this paper we would like to show the way to calculate hydrostatic and stability of floating crane, especially the changing of inclination angle (heeling and pitching angle) as the hangging goods change its position.

Keywords: Floating Crane Operation, Crane Hydrostatic Stability, Floating Crane Stability, Floating Crane Dynamics

1. Introduction

The demand for marine and island environment, resources is increasing to meet the needs of the country's economic development. Offshore works are constructed such as oil and gas fields, pontoon bridge… So the attention to safety and performance of these works at operation is necessary. Unlike on land, with marine buildings the main threat is the influence of the surrounding environment such as wind, waves, corrosion, changes of the sea.

Floating cranes are equipped which carries goods from one place to another, often used in the construction or repair of offshore installations. A load suspended on a crane fastened to the hull can be easily affected by waves, wind, ocean currents [1, 2]. This will create complex, uncontrollable non-linear motions that cause accidents. In fact, many cranes-related jobs were postponed due to bad sea conditions, which prolonged the time and increased the cost of the project. Therefore, studies on floating cranes aim to carry out offshore activities more efficiently, safely and reduce costs.

Source: https://www.marinetraffic.com

Figure 1. *Floating crane (Hoang Sa).*

Kind of floating crane often used in Vietnam is the same to figure 1. We would like to use this crane to calculate in this paper. During operation, changing the position of goods will easily change the position of the whole system of floating cranes (figure 2). This change affects the balance of floating cranes. Static stability and dynamic stability are two states that are often considered, when a system is imbalanced on the water surface. Static stabilization is considering the recovery torque value that appears when tilting the vessel. The torque recovers against the tilted torque, and when the inclined torque no longer acts, the restored torque returns the ship to a balanced position. Dynamic balance appears when the static balance is affected by external forces that lead the system to a new balanced position.

Source: https://www.marinetraffic.com

Figure 2. *Floating crane operation.*

This paper focuses research on the static balance of floating cranes. During operation, the position of goods changes the center of the system. The change of the center will affect the tilt angle of the floating crane. The paper will make assumptions about changing the position of goods affecting the angle of inclination of floating cranes and find out the connection between them.

2. Hydrostatic and Stability of Floating Crane

In this paper, the floating crane is modelling as is a system consisting of a pontoon carring a crane, figure 3.

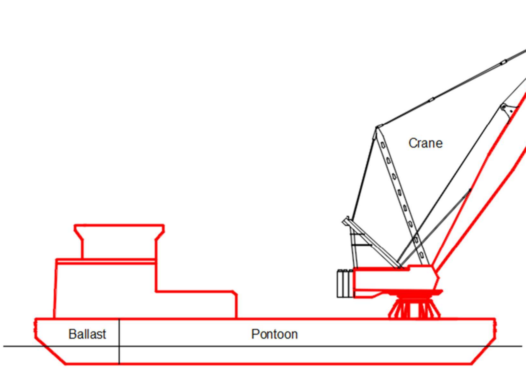


Figure 3. *Floating crane modeling.*

During the process of lifting, load is lifting from curent position (x_1, z_1) to the next position (x_2, z_2) (Figure 4). When the load reach to new position, the center G of the whole floating crane will changes. This lead to the changing of metacentric height GM, and make incline angle. In oder to keep the stability, the floating crane have to make a force or momentum which belong to value of stability lever L_k.

In this paper, we want to study about the changing of incline angle when the load is lifting and hope this result can be used in the study of dynamic in future.

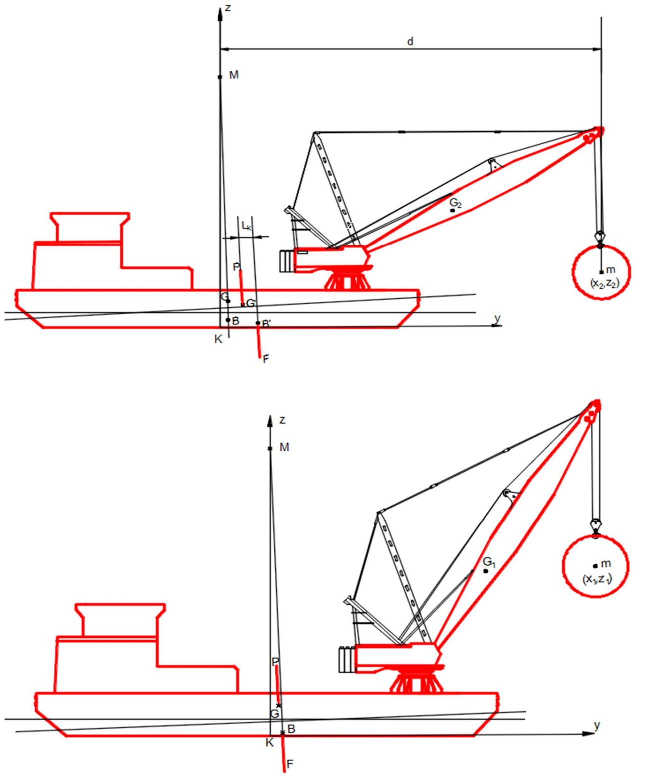


Figure 4. *Cargo lifting process.*

In figure 5, we assume that gravity force P (or total weight of the floating crane) and buoyancy force F are putting at the center G and B.

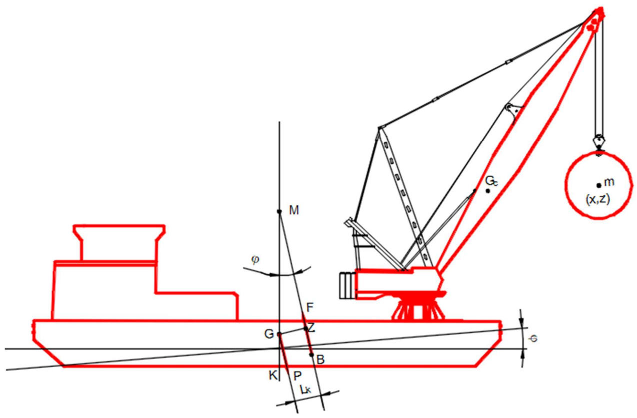


Figure 5. *Cargo lifting process.*

When the total weight P is greater than F, the vessel will be pulled down. As the sinking deeper in the water the volume of the sinking part of the ship increased, according to Archimedes law the force F grew. When crossing the balance limit, F > P the situation will look back. The ship is balanced only when located in a position of 2 equal forces.

$$F = P \quad (1)$$

However, when the condition (1) have not ensured that the ship is stable. In case the vessel is tilted, the position of the center of buoyancy changes, the floating force line through the center B' does not coincide with the gravity effect line through G' (figure 5). In this tilted state caused by heeling moment M_h, besides the distance between the two forces-acting lines carries a certain value of Lk, righting moment appears $M_r = F \times GZ$. As the ship continued to tilt, the angle of inclination φ changed, increasing. The state of balance is determined when [3]:

$$M_h = M_r \quad (2)$$

Which we have: $F = P$, so:

$$GZ = \frac{M_h}{P} \quad (3)$$

And incline angle can be [4]:

$$sin\varphi = \frac{GZ}{GM} \quad (4)$$

In some case, to calculate longitudinal metacentric height:

$$GM_L = \frac{I_L}{V} \quad (5)$$

We have longitudinal moment of inertia of waterplane [5]:

$$I_L = \int_L x^2 y\, dx \quad (6)$$

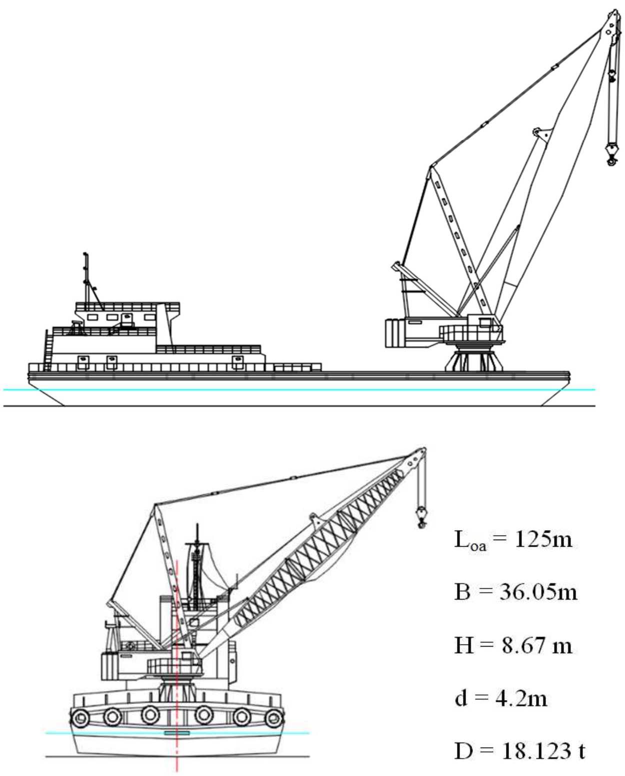


Figure 6. *Hoang Sa Floating crane.*

3. Case Study

3.1. Basic Parameter of the Model – Floating Crane

Crane Barge Hoang Sa [6, 7] is currently located at SEASIA South-East Asia at position 10° 23' 18.384" N, 107° 5' 28.32" E as reported by Marine Traffic Terrestrial Automatic Identification System on 2020-11-16 05: 34 UTC. The wind in this area at that time blows from Northeast direction at force 4 Beaufort. Hoang Sa (IMO: 8757233) is a Crane Barge that is sailing under the flag of Vietnam. It's carrying capacity is 12993 DWT and her current draught is reported to be 4.2 meters. Her length overall (LOA) is 125 meters and her width is 36.05 meters (figure 6).

3.2. Result of Hydrotasic and Stability of Floating Crane [8-10]

Displacement volume:

$$V = L \times B \times D \times C_b = 18927\, m^3$$

According to the ship's image, we have longitudinal moment of inertia of waterplane:

$$I_L = \int_L x^2 y\, dx = 5870000\, m^4$$

We have longitudinal metacentric height:

$$GM_L = \frac{I_L}{V} = 310\, m$$

And: $Lk = GZ = \frac{M_h}{P} = \frac{m \times d}{\gamma \times V} = \frac{m \times d}{19400}$

With $sin\varphi = \frac{GZ}{GM}$, we have a formula according to parameters m and d:

$$sin\varphi = \frac{m \times d}{19400 * 310} = \frac{m \times d}{6014000}$$

Buoyancy center above moulded base:

$$KB = \frac{\int_0^z Aw(z) \times zdz}{V} = \frac{39745}{18926} = 2.1\, m$$

Metacenter above center of buoyancy:

$$BM = \frac{I_T}{V} = \frac{488030}{18926} = 25.8\, m$$

Center of gravity above moulded base:

$$KG = \frac{\sum w_i z_i}{\sum w_i} = 3.9\, m$$

Metacentric height:

$$GM = KB + BM - KG = 24\, m$$

With $sin\varphi = \frac{GZ}{GM}$, we have a formula according to parameters m and d:

$$sin\varphi = \frac{m \times d}{19400 * 24} = \frac{m \times d}{465600}$$

The result in table 1 and table 2 show the calculating of heeling and pitching angle when load change its position.

Base on the the result in tables 1 and 2, figures 7 and 8 show that when the load change position heeling and pitching angle change linearly. This is normal because the floating (pontoon) has box shape.

Table 1. *Pitching angle when changing the position of load.*

m	d	φ
1300	130	1.6
1300	120	1.49
1300	110	1.36
1300	100	1.24
1300	90	1.11
1300	80	0.99

Table 2. *Heeling angle when changing the position of load.*

m	d	φ
1300	42	6.73
1300	35	5.61
1300	28	4.48
1300	21	3.36
1300	14	2.24
1300	7	1.12

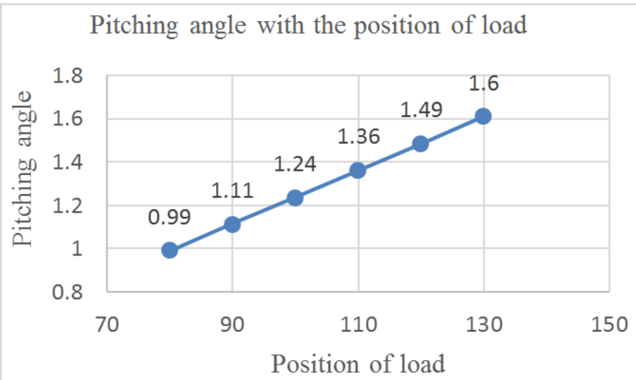


Figure 7. *Diagram of Pitching angle when changing the position of load.*

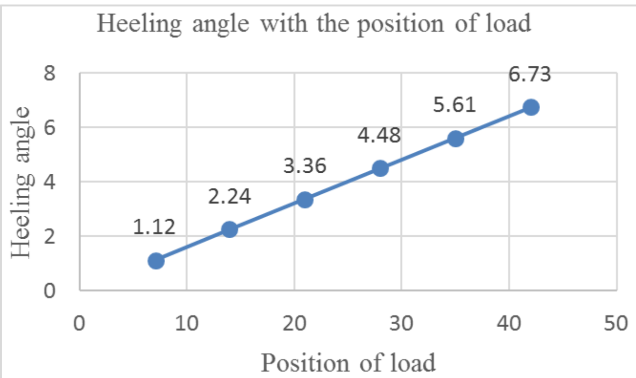
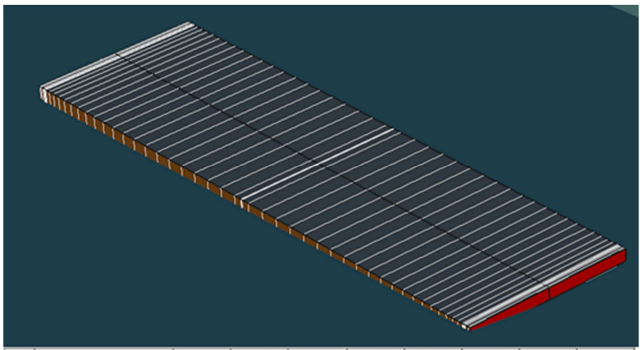


Figure 8. *Diagram of Heeling angle when changing the position of load.*

3.3. Result in Modelling Software

In order to describe the result clearly, we would like to show some data in software modelling (figure 9).



	Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
1	Lightship	1	16823.000	16823.000	0.000	0.000	0.000	0.000	User Specifi
2	item	1	1300.000	1300.000	72.000	41.000	40.000	0.000	User Specifi
3	Total Loadcase			18123.000	5.165	2.941	2.869	0.000	
4	FS correction						0.000		
5	VCG fluid						2.869		

Figure 9. *Full load and incline angle with Load case table.*

We use full load as the load case for calculating when the crane reach maximum distance. Pitching and heeling angle are shown in figures 10 and 11. We can see that the pitching angle is bigger than the heeling angle. In the next paper, we want to study about the pitching vibration of floating crane [11].

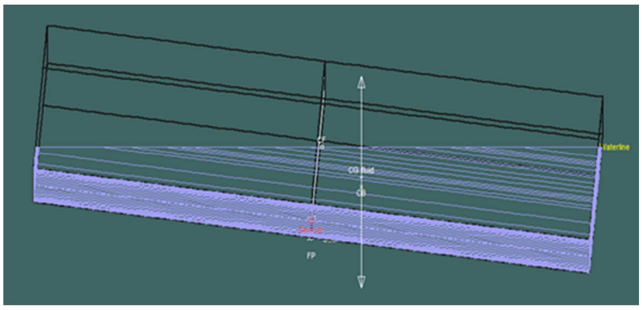


Figure 10. *Pitching angle of floating crane.*

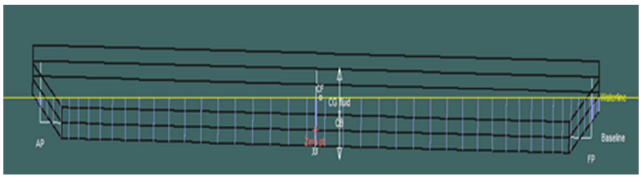


Figure 11. *Heeling angle of floating crane.*

4. Summary

In short, study of hydrotatic and stability of floating crane is the same boat or ship. However, floating crane often lifting heavy load in large distance that makes floating incline.

The result of this paper have showed the changing of heeling and pitching angle with full load condition.

The result can be used to analysis the stability of floating crane in wave condition or windy condition. Beside that's, we also want to use this result for studying the dynamic of floating crane in the future [12, 13].

In the next stage of dynamic study we will assume the load is hangging [14] and find out the vibration of floating crane in wave [15].

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Biography

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