Offshore Stabilization Pontoon for a heavy lift vessel Concept design & workability

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Challenge the future

OFFSHORE STABILIZATION PONTOON FOR A HEAVY LIFT VESSEL

CONCEPT DESIGN & WORKABILITY

by

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Offshore & Dredging Engineering



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Introduction

The offshore heavy lift market is a continuously growing market. In order to keep up with the changes in the market, demands of the clients and grow its market segment, innovations and continuous improvement of heavy lift vessels is required. Being able to lift heavier loads offshore will give an advantage over the competition.

Hydrostatic stability has always been one of the most important parameters in the design of heavy lift vessels and over the years countless interesting and innovative concepts have been designed and tested to optimize the stability of these vessels. One way of obtaining this stability is by using a stabilization pontoon. Next to the stability the workability of a vessel is also very important.

This report is a summary of the thesis report of Mark ten Klooster which is done at Jumbo Maritime in order to complete the Master Offshore and Dredging Engineering at the Technical University of Delft. In the following eight pages the concept design and workability study for a stabilization pontoon will be explained briefly.

Company introduction

First a short introduction of Jumbo Maritime. Jumbo is a heavy lift shipping and offshore transportation and installation contractor. For more than 45 years Jumbo has been developing pioneering solutions for ocean transportation. Jumbo especially differentiates itself from its competition by combining the heavy lifting capacity of its vessels with high cruising speeds up to 17 knots.

The first vessel of Jumbo, the A-Class Stellaprima, was introduced in 1968. She had four 12-tonnes derricks and was a remarkable innovation for the time. Every few years a new class of better, stronger, safer and more efficient vessels was added to Jumbo's fleet.

In 2003 Jumbo stepped, in addition to the shipping sector, also into the offshore installation sector. With two J-Class vessels equipped with a DP2 system, they now provide offshore transportation and installation.

At the moment Jumbo has a fleet of 11 heavy lift vessels. The lifting capacity ranges from 500 tonnes up to the current flagships with a lifting capacity of 1,800 tonnes. To coop with the increasing demands, Jumbo is currently in the final stages of building a K-Class vessel with a lifting capacity of 3,000 tonnes and 1A ice class certification.

To keep innovating the first designs of the newest L-Class vessels have already been made. These vessels will also have two 1,500



tonnes cranes with a total lifting capacity of 3,000 tonnes. The focus of this thesis will be on this vessel. The major changes in the design of the L-Class is the increased size and the fly deck on port side.

Problem definition

Next to the standard stability criteria for vessels, the stability for a heavy lift vessel must also take into account the scenario when there is a heavy piece of cargo hanging in the cranes. This drastically reduces the stability of the vessel and if it is not sufficiently stable the ship will capsize. To increase the stability of a vessel of Jumbo, a stabilization pontoon can be connected to the vessel during on- and offloading. This makes the vessel able to lift heavier loads or increase the outreach of the cranes.

Currently stabilization pontoons are already used within Jumbo, but is has not been used offshore yet. Nor is any information found confirms the use of offshore stabilization pontoons in other companies.

Objective

The objective of this thesis is to design a concept and analyse the workability for this offshore stabilization pontoon for a heave lift vessel. This will be done specifically for the new generation L-Class vessels of Jumbo. The focus of this thesis will lie on the workability of these pontoons.

This thesis includes:

- Concept design of stabilization pontoons
- Connection system of the pontoon to the vessel
- Installation method of the pontoon to the vessel
- Calculation of the hydrostatics
- Calculation of the RAOs and the motions
- Determine the workability of the vessel

Research questions

The project can roughly be divided into two sections. Each with its own research questions. The first is the concept design of the new pontoons and the second is the modelling of the stability of the pontoons from which the forces on the hull can be obtained.

Concept design

- What are the optimal dimensions of the stabilization pontoons?
- How can the pontoons be connected to the ship?

Modelling the stability

- What is the influence of waves on the stability of the vessel with stabilization pontoons?
- What impact do the stabilization pontoons on the motion behaviour?
- What is the workability of the vessel in offshore conditions using stabilization pontoons?

Scope

The forces, moments, stresses and strains in the vessel are outside the scope of this thesis. For the calculation of the workability of the vessel only the influence of waves is taken into account. Other environmental loads will not be looked at. This can later be examined after the workability and potential gain of the offshore pontoon is known.

This thesis comprise out of just the frequency domain analysis. The time domain analysis is outside the scope of this research.

Only the use of a stabilization pontoon will be looked at, other measures of increasing the stability will not be taken into account.

Concept design

Boundary conditions and design considerations

The goal of the stabilizers is to increase the intact stability of the vessel to be able to have sufficient stability for the required lifting operations. This can be done by either increasing the waterplane area of the stabilizer or increasing the distance between the stabilizer and the ship. The boundary conditions and considerations for the design of the are given in this section. The boundary conditions are required for the design and the considerations are optional to incorporate.

Boundary conditions

The minimal requirements for the stabilizing pontoons are:

- The pontoons must provide sufficient intact stability for a lift of 3000 tons in harbor conditions and a 2000t offshore.
- The corners of the pontoons can never emerge or submerge completely.
- The connection must be strong enough to withstand the reaction forces.
- The design must be done according the relevant classifications and certifications.

Design considerations

Some considerations for the design of stabilizing pontoons are:

- Safety and reliability
- Offshore lifting capacity
- Bending moments and shear forces
- Torsion moments
- Openings
- Grounding
- Different loading conditions
- Operating conditions
- Bunkering, mooring and piloting operations along the (both) the sides of the vessel
- Weight and dimensions
- Resistance/ drag of the construction during normal transit conditions
- Storage position
- Influence on available deck space
- Positioning the pontoon
- Installation/ connection method
- Motions and accelerations of the vessel
- Parametric resonance of the vessel.
- Mooring and transit through the Panama Canal
- Materials used for the construction
- Corrosion and maintenance
- Costs

Classification and guidelines

All certifications within Jumbo are done according to the *Lloyd's register* group. This is a global engineering,

technical and maritime classification society. The Lloyd's register is best known for the classification and of ships, but also provide quality assurance and certification for offshore structures and shore-based installations.

Since there are no IMO rules set for offshore lifting operations, Jumbo uses an in-house additional criterion for lifting operations offshore. This rule is that the ship must have a sufficient GM so that the list of the ship doesn't increase more than 1 degree when the load is slewed inward 1 meter.

$$G'M_{min} = \frac{w}{\Delta \sin(1)}$$

Load cases

For a typical offshore lifting operation a number of different load cases can be identified. I general the project can be divided in two phases. All the stability criteria must be satisfied during both the phases.

- The transportation phase
- The offshore phase

In the offshore phase the G'M is usually lowered by filling the Topwing (TW) and Upperwing (UW) tanks to decrease the vessel's motions. The stability is to be checked for the following situations for the first lift, the last lift and the heaviest lift:

- before lift-off
- lift-off
- max-out
- upended (for piles only)

Morphological analysis

This section describes the *morphological analysis* used to find different concepts for the stability problem. The design of the stabilization pontoon is divided in multiple sub-divisions. The concepts have to comply with all the boundary conditions and the design considerations are taken into account but are not required.

The used sub-divisions are:

- Pontoons
- Connection
- Ship

Several solutions are generated, with the goal to find solutions that are innovative, safe, reliable and provide sufficient stability.

hological Cha	rt	Ortina	- Increase GM					
	-	Options				→		
Pontoons	Stability	Multiple poptoops	Distance to bull	Long area	Wide area			i i
	Shane	Circular- horizontal	Circular-vertical	Box	Hull - hydrodynamic	Beam		
	Shane 2	Fixed	Inflatable	Unfold		beam		
	Amount	Multiple	Single	onnord				
	Greenwater protection	Skirts	Sufficient height	Sloping	Balloons			
	Material	Steel	Rubber	Synthetics	Foam			
	Material	oteen	NGD DCI N	officies				
Connection	Positioning X-direction	Fixed	Floating	Extending/ sliding	Hinging	Crane	Unfolding	Cables
	Positioning Y-direction	Fixed	Floating	Extending/ sliding	Hinging	Crane	Unfolding	Cables
	Positioning Z-direction	Fixed	Floating	Extending/ sliding	Hinging	Crane	Unfolding	Cables
	Locking X-direction	Rails	Rigid beam	Hinges	Hooks	Clamps	Pins	Wedge
	Locking Y-direction	Rails	Rigid beam	Hinges	Hooks	Clamps	Pins	Wedge
	Locking Z-direction	Rails	Rigid beam	Hinges	Hooks	Clamps	Pins	Wedge
	Locking Z-direction 2	Rigid	Damped					
	Locking moment	Only on along the side of the pontoon	On the fly deck	Multiple connection points	Rigid beam			
	System	Fixed to pontoon	Fixed to ship					
Ship	Storage	On deck - aft	On deck - bow	On deck - Flexible	In cargo hold	In fly-deck	in hull	
	Position	Full length	Half length	Deck length	Locally - next to cranes	Locally - other	Locally - flexible	
	Position 2	Against hull	Away from hull	Adjustable				
	Position 3	Starboard	Portside	Both	Both possible			
	Deck space	Increased	Decreased					
,	Pilot/Mooring	Beams	On pontoons					
Missollanoous	C	In the set of Base and		R000000				
wiscellaneous	current system	Hull and Pontoon	null	Pontoon	New design			

Multi criteria analysis

From the all of the constructed concepts one final concept has been chosen. This is done by means of a *Multi Criteria Analysis* (MCA). This evaluation method makes it possible to rationally analyze multiple discrete alternatives on the basis of more than one criterion with a certain weight factor. The result of the MCA is:

Multi Criteria Analys	sis									
	Weight factor				Concept					
	_	А	В	С	D	E	F	G	Н	I
Safety	7	++	+	0	0	0	+	++		+
Operability	6	++	0			+	0	++	+	+
Installation/ connection	5	++	+	+	+	+	+	++	0	+
Storage	4	+	0	0	0	+	-	+	+	0
Maintenance	1	++	+	0	-	0	0	++		+
Mooring possibilities	2	++			+	+		++	+	-
Resistance	3		++	++	+	0	++		0	++
	Total:	40	15	-5	-3	17	10	40	-4	23

Costs

The costs are also an important for the selection of a concept. These costs are divided in the CAPEX (capital expenditure) and the OPEX (Operational expenditure). The numbers are not quantified, this is outside the scope of this report but are estimated on an ordinal scale from -- up to ++.

Cost est	imation	n							
				Concept					
	А	В	С	D	E	F	G	Н	Ι
CAPEX		0	-		0	-			0
OPEX		+			+	+			+
Total:	-4	1	-3	-4	1	0	-4	-4	1

Concept selection

Based on the MCA and cost analysis concept I is chosen as the best fitting solution. Especially for the offshore use since the pontoon can be adjusted according to the seastate, changing the natural frequencies of the ship.





Pros:

- No deck space used
- Rigid construction
- Easily deployed
- Very suitable for offshore use

Cons:

- Limited volume in engine room
- Relatively small additional waterplane area
- No mooring over starboard

The exact construction still needs to be determined, to be able to coop with all forces and moments in the pontoon and vessel. Instead of just one pontoon it could for example also be built up out of two or three pontoons. This way the forces inside the vessel could be better transferred with reinforcing beams and the overall effect is not that significant. From here the effect of the pontoon will be analyzed for different sizes and the workability will be calculated.

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Model

PIAS

Based on hand calculations for the minimal stability and the available space for the pontoon an estimation of the dimensions of the pontoon is been selected.

The dimensioning of the pontoon starts with determining the minimal G'M value. This is calculated with in-house guidelines, a lift of 3000t results in a minimal G'M of 4.55m and a lift of 2000t results in a G'M of 3.57m. With hand calculations and PIAS the minimal dimensions for a 3000t lift are determined to be 26m x 6m x 10m.

For the 2000t offshore lift on which this thesis research is based the following relevant load cases are identified with respective hydrostatic variables:

Before	e lift-off		Maximur	n outrea	ch
G'M _{liquid}	6.473	m	G'M _{liquid}	3.859	m
T _{roll}	9.22	s	T _{roll}	11.93	s

The influence of the amount of consumables on board appears to be insignificant and the difference in hydrostatic variables between the moment just after lift-off and at maximum outreach is minimal.

Ansys Aqwa

After the hydrostatic variables are calculated in PIAS, they are inserted in Ansys Aqwa to calculate the response amplitude operators (RAOs). The vessel's properties can be seen in the following tables:

Before	e lift-of	f	Ma	aximum out	reach
GM _{solid}	6.83	m	GN	M _{solid} 4.09	m
T _{roll}	8.2	s	Tre	oll 14.5	S
Tpitch	8.7	s	Tp	itch 8.7	s

RAO roll before lif-off



RAO roll at maximum outreach



RAO pitch before lif-off



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RAO pitch at maximum outreach



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Here can be seen that although the GM value is in order, the natural roll and pitch periods are in the middle of the wave spectrum where most periods lie between 9 and 15 seconds. This is unfavorable. Preferably the natural roll period of the vessel must be above the wave spectrum, this can be done by decreasing the GM. However, this is not possible within the stability requirements of Jumbo.

Another option would be to have the natural roll period of the vessel below the wave spectrum, this can be done by increasing the GM value and thereby reducing the natural roll period. However, this is creates unwanted rapid motions and accelerations which leads to unpleasant working conditions and high forces in sea fastening and rigging.

Workability

With the RAOs known, the vessel's motions can be determined. This is done for the Wheatstone field in the North-Eastern part of Australia. These motions are then compared against the workability criteria of 1° roll and 1.5° pitch and the wave scatter diagram of the location to result in the workability per month, season and year.

The two motion criteria are for the entire lifting process from positioning the crane to setting down the equipment. The different scenarios mentioned above give a completely different workability. The high GM value before lift-off gives a workability of around 1% in January, which is the month with the highest workability.



From the moment of lift-off the workability is around 14% in January for a wave heading of 180°. These values are determined with a probability of exceedance of the most probable maximum of 7%. An option is to change the workability criteria for the limiting moments before lift-off. With criteria for roll and pitch angles of 3° the workability increases to about 14% for the winter months and around 9% for the entire year.



The impact of the pontoons on the stability is significant. Without the pontoons a 2000t lift is not possible. The minimal GM value cannot be reached. The difference in GM between when the pontoon is connected and not connected is around 3m for all loading scenarios.

It can be concluded that is not recommended to use this specific stabilization pontoon for offshore heavy lifting with the current workability criteria.

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Discussion and recommendation

Workability criteria

This research shows that the use of an offshore stabilization pontoon designed in this research is not feasible with the current criteria. Since the limiting factor is only the duration from the moment of high GM due to ballasting until the moment that the cargo is lifted, an evaluation of the workability criteria for this duration is recommended. A roll and pitch angles of 30 would already result in an acceptable workability.

In this thesis the workability was limited by roll and pitch motions and a minimal stability. These motions can not only be influenced by the GM value, but also by active of passive anti-heeling system. The use of such a system will increase the workability. The feasibility of the stabilization could improve in combination with such a system.

Since the only workability criteria used are the roll and pitch motions, other limiting criteria have not been looked at. This is done because this is the way Jumbo works, but other criteria like accelerations in the vessel could also have been taken as a criteria.

Concept selection

This concept chosen in this thesis was based on the results of the multi criteria analysis and cost estimations. Further research in this is needed to verify if this was the best option. A different concept will most likely have a different workability. Perhaps there is a concept where the workability is higher and falls within an acceptable range.

Also in this thesis the forces and moments in the vessel and pontoon haven't been taken into account in the selection of the concept. When it is determined that the workability of an offshore pontoon is sufficient, research in this is needed.

The selection of the concept is in this report also based on the cost estimations of the concepts. These results were only an indication/ estimation. Although a sensitivity analysis has been done over this analysis the results need to be verified.

The location of the pontoon is now primarily based on the available space in the vessel and the method of which it is connected to the vessel. However, due to the coupling of motions, roll and pitch, unwanted motions might have been introduced. An analysis for the optimal location of the pontoon is recommended to do.

Combination offshore-heavy transport

The concept of the L-Class can be used for both offshore projects and the core business of heavy transport. The dimensions of the pontoon in this thesis were determined based on a 3000t lift in the harbor. However, the dimensions of the pontoon will most likely be different if they were not designed for this. This could have a positive influence on the RAOs of the vessel. It is recommended to specialize in one field in order to optimize the vessel. An offshore vessel is far too expensive to use for simply transporting cargo and a transport vessel is not equipped for an offshore task.

When this combination is still desired, a concession can be made by implementing two types of stabilization pontoons in the vessel. One for the offshore use and/ or relatively light lifts and an extra pontoon which can be connected to the vessel for the extremely heavy lifts. This has not been taken into account in this research, but is a very promising solution. The dimensions and characteristics of the vessel and pontoon can be optimized for both scenarios when this is done.

Stability alternatives

The additional stability was in this thesis created by a stabilization pontoon. There are other ways to obtain this stability. The L-Class already has a significant increase in width compared to the previous versions of Jumbo vessel. However this also creates a lot of drag, which is unfavorable for the operational costs.

A very interesting for an offshore vessel is the design of the 'Oleg Strashnov' of Seaway heavy lifting. Here a dualdraught hull design creates an optimal combination between a small waterline breadth during transit and a significantly larger waterline breadth with additional stability during heavy lift operations.

Environmental conditions

The only environmental loads in this thesis to cause motion responses are wave loads. Of course other environmental influences also have an impact on the workability. Especially wind loads can have an impact on the workability. These can be dangerous loads when handling cargo hanging in the crane. However, the wave loads and wind loads are not independent. Usually in conditions with high winds, there are also high waves.

The use of wave scatter diagrams was leading in the determination for the operability. Here however only a frequency domain analysis is done. A time domain analysis and the use of environmental data with characteristics of for instance a three hours' time interval over a period of multiple years is recommended.

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