Stability Issues in the Upgrade of Drilling Rigs for Increased Water Depths

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ABSTRACT

With the increased demand of exploration in each time deeper waters and the reduced availability of drill rigs, existing rigs are being upgraded for operating in water depths greater that their original design limits. When an upgrade of this type is performed, the stability issue is a critical one. The loading demand increases and usually extra flotation is required. There is an increase in mooring loads, riser tension, mud and bulk capacity, steel weight of derrick and cranes of greater capacity.

We can divide the rig's loading in mooring and drilling loads, payload and lightweight. The first two vary mainly with the environmental conditions and the water depth. These can be optimized by using the correct conditions for the site location and by choosing adequate materials and solutions. The second comes from the augmented storage capacity of drilling necessities, and this is the main demand for an upgrade in the rig. The optimization in this case can only come from reduced vcg obtained with an optimized arrangement of weight distribution. The third is a consequence that comes from the increase in equipment capacities, additional reinforcements, etc. This can also be optimized in the concept design of the upgrade, such as choice of environmental conditions, materials and equipment, dismantling of existing unnecessary items and optimization in the structural reinforcements.

A statistical analysis of many upgrades performed presents the impact of each of these items. We can analyze how each item like the choice for dynamic positioning, vertical riser storage, and the dimensioning for adequate environmental conditions can affect the viability of the project. Many of these upgrades have been developed at PROJEMAR and the impact on stability of each of the increased demands has been verified and compensated.

With the use of data obtained from previous upgrade projects, a more precise estimate can be performed in order to study the viability of a new project.

Keywords: *drill rig, variable deck load, upgrade, water depth.*

1. INTRODUCTION

The upgrade of a drilling rig to operate in a water depth that is deeper than the original design may imply in the necessity of additional stability and/or additional buoyancy in order to sustain the new loads that will be required.

Additional stability is often required if the unit is operating already close to the limiting parameters, what are most of the cases found in the market. This stability can be achieved by the inclusion of blisters or additional stability columns that will increase the inertia by the increase of the waterplane area. If the upgrade represents a great amount of additional load above the main deck, it may become necessary to increase not only the waterplane area, but also the hull displacement. In this case, the volume can be increased by the use of sponsons, buoyancy boxes, closure of existing open bracings, etc.

Generally, for any upgrade of existing drilling rigs, the weight and the height of the vertical center of gravity shall be minimised in order to reduce the amount of modifications needed on the hull. The lightweight and the center of gravity can be optimised by the use of state of the art equipment and reinforcements shall have their scantling optimised.

The most important point is that there are no general rules to be followed. Drilling rigs upgrades shall be treated in a case by case basis, but there are very important points to be noted since the early beginning of the upgrade design which can make a considerable difference in terms of cost and schedule if are considered on the correct time.

2. LIGHTWEIGHT

Usually, when an upgrade of water depth is undertaken, a direct consequence is the increase in the lightweight of the rig. The derrick needs extra hook loads, the set-back area requires a greater capacity, the tensioning system must support greater tensions, etc.

Additional loads can be precisely predicted, but additional weight due to reinforcements and refurbishment of existing areas are often uncertain and is very important to consider reasonable margins in the earlier stages of the design to assure that the upgraded rig will perform as intended.

Table 1 exemplifies the main lightweight items of a drilling rig with their participation on the total lightweight of a typical 2000 m water depth drilling rig. Column 3 shows the main modifications that would be involved on an upgrade.

Table 1 Items composing the lightweight

Item	% Total Weight	Modifications for an upgrade
Steel	57%	- structural reinforcements - deck extensions - blisters - tanks
Outfitting	10%	- new equipment - new deck areas
Equipment	27%	- mud pump - derrick - riser tensioners - crane
Piping	5%	- new tanks - increased accommodation
Electrical	1%	- new drilling equipment - positioning system (DP rigs)

During the design stage, the necessity of minimizing the increase in weight must be always kept in mind and for this it is of fundamental importance to keep an effective weight control procedure during all phases of the design and during the construction work.

To have a consistent weight control procedure implemented, it is necessary to obtain consistent lightweight data of the existing rig. In some cases, due to the age of the rig and the lack of actualisation of the lightweight characteristic during its life, it is strongly recommended to conduct an inclining experiment or at least a deadweight survey prior to the beginning of the shipyard work. This initial inclining experiment shall be used as the starting point of the weight control.

3. VARIABLE DECK LOAD

The variable deck load (VDL) is normally defined as the rig's weight excluded the lightweight, ballast and consumables. This figure indicates the rig's operational capacity, that means, the greater de VDL, the greater the water depth the rig can achieve without mayor alterations.

The following items compose the Variable Deck Load of a drilling rig:

- mud;
- BOP and accessories;
- tubulars and drilling tools;
- stores and supplies;
- equipment on drill floor;
- sack material;
- hook and tensioners;
- mooring material and tension;
- brine;
- bulk (cement, betonite and baritine);
- ROV and containers on main deck.

The remaining items that compose the total weight of the rig are:

- ballast;
- consumables;
- lightweight.

Figure 1 presents the variable deck load of drilling rigs operating in three different water depths. It shows the increase of the mooring loads from the 600m to the 1200m and the participation of these loads on the VDL, reaching almost 30% of the VDL for 1200m.of water depth. The rig operating in 2400m is dynamic positioned, what eliminates the mooring lines, reducing to zero the line tension loads.

Figure 2 presents the increase on the VDL due to the upgrade of a 3rd generation drilling rig originally designed to operate in 360 m of water depth that was planed to operate in 2400m of water depth as a dynamic position drilling rig. For a so drastic upgrade, special considerations like the use of a non-conventional open tower and the use of vertical storage of drilling risers were considered in order to make the upgrade feasible.

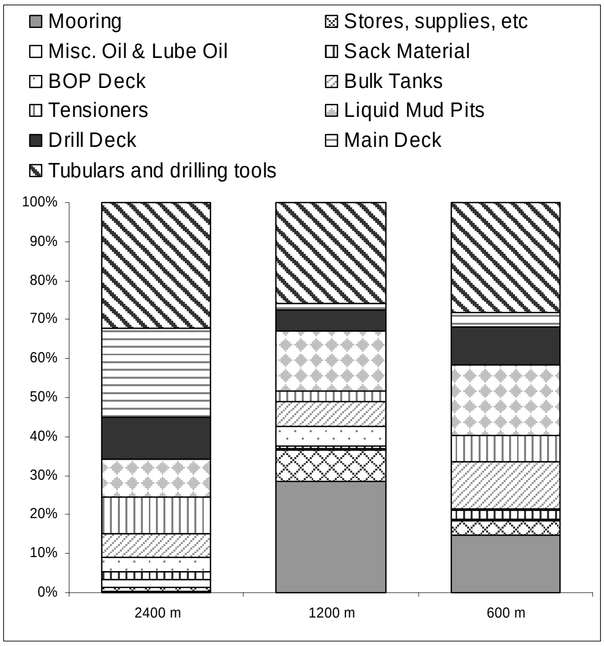

Figure 1 Composition of the Variable Deck Load

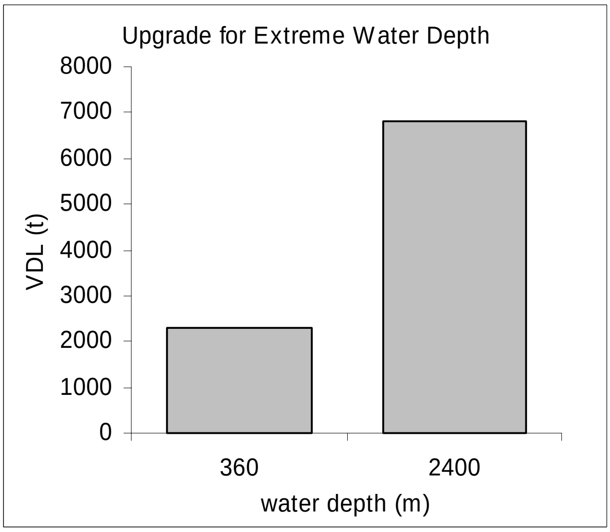

Figure 2 Upgrade for ultra-deep waters

Figure 3 shows the increase on the VDL due to the upgrade of a drilling rig from 365m of water depth to 600m, what was a much reasonable alteration and only small modification on the hull were needed

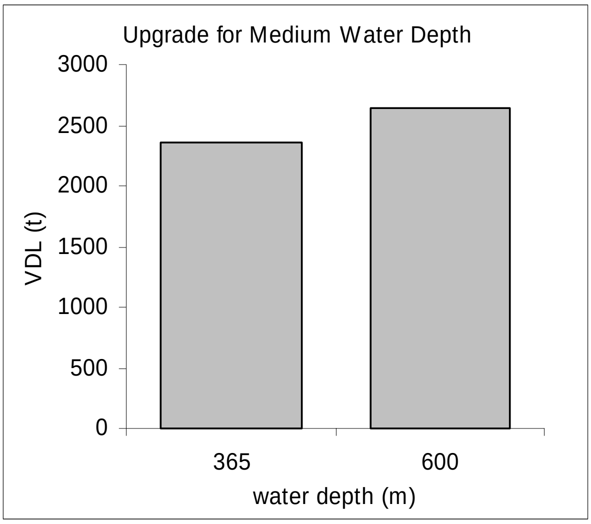

Figure 3 Upgrade for deep waters

Figure 4 presents some statistics for several drilling rigs showing the VDL as a function of the water depth. It can be noted that there is a quite strong linear relationship between them, with few units out of the average linear correlation.

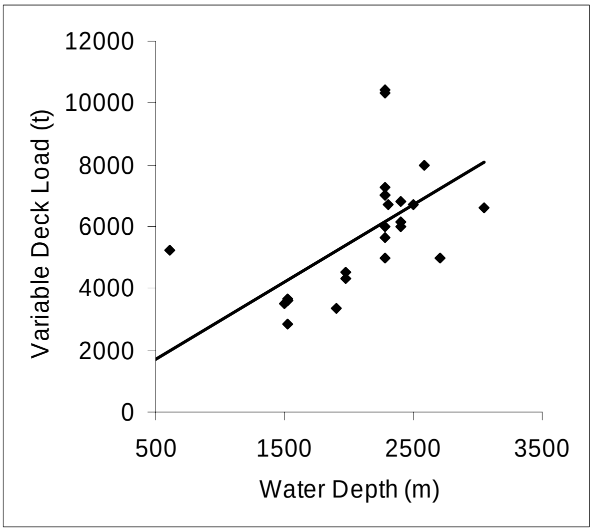

Figure 4 Statistics for variable deck loads with respect to maximum rated water depth

3.1 Riser Tensioning System

With the increased water depth, the weight and the hydrodynamic loads on the riser column increase and it becomes necessary to increase the traction in the riser tensioning system in order to avoid excessive angles in the riser joints.

Figure 5 presents the increase on the riser tension due to the upgrade of a drilling rig originally designed to operate in 360 m of water depth to 2400m of water depth. In this case the increase in tension is about 4 times. When this increase is divided by the increase in water depth, we obtain a relation of about 0.6.

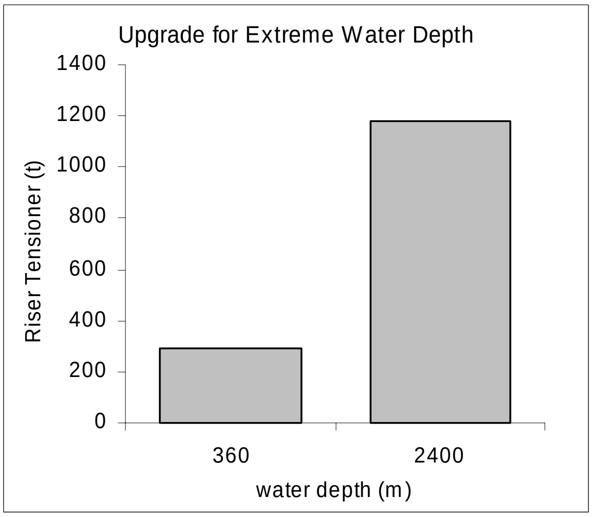

Figure 5 Upgrade for ultra-deep waters

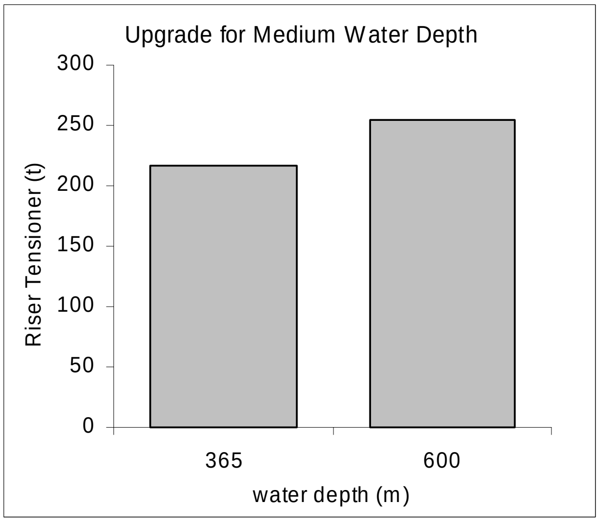

Figure 6 Upgrade for deep waters

Figure 6 presents the increase on the riser tension due to the upgrade of a drilling rig originally designed to operate in 365 m of water depth to 600m of water depth. In this case, the relation between the increase in tension and the increase in water depth is about 0.7. This indicates a great linearity in the relation of riser tension and water depth, as can be seen in the statistics shown in figure 7 for various drilling rigs.

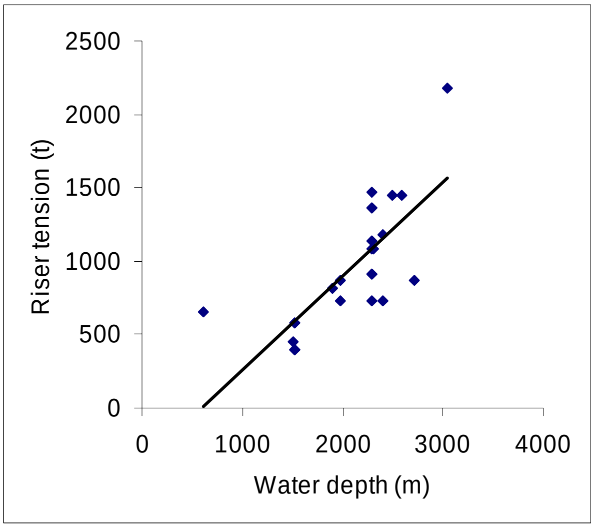

Figure 7 Statistics relating riser tension with water depth

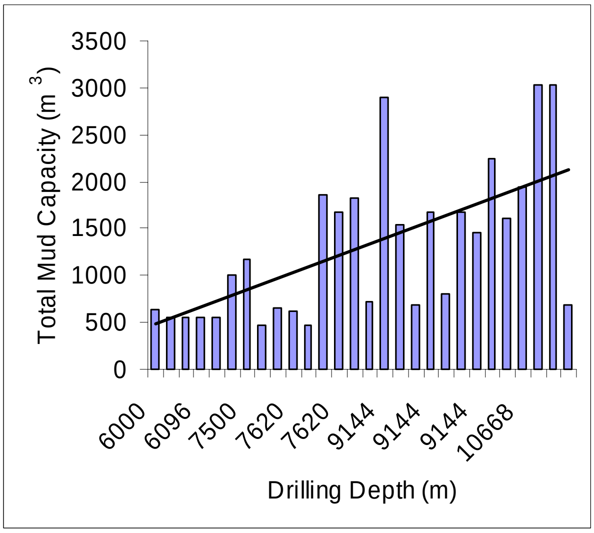

Figure 8 Statistics relating drilling depth with mud capacity

3.2 Mud Capacity

As the water depth and the drilling length increase, the necessity of mud increases. This increase depends on the annular and pipe volumes. The annular volume can be calculated by the sectional area between the hole and the outer wall of the pipe multiplied by the maximum drill length. The drill pipe capacity can be calculated by the inner sectional area of the drill pipe times the drill length.

Regarding the mud capacity what was seen on some drilling rigs upgrades intended to operate in deep water is the necessity to use heavier mud, what can affect not only the riser column, but also the mud system.

Figure 8 presents the total mud storage capacity of several drilling rigs comparing to their total drilling depth.

3.3 Bulk Storage Capacity

Not only the weight of stored bulk increases but also there is a necessity for greater storage area. As a result, there is a greater steel weight at the deck level.

3.4 Mooring Loads

As the water depth increases, the mooring lines become longer and their diameter increases. They also become more elastic and the pre-tension to be imposed on the lines increases. After a certain depth, the VDL becomes greatly compromised by the mooring loads.

In order to reduce the vertical load caused by the mooring lines synthetic lines (polyester or others) can be used or positioning thrusters installed providing a dynamic position station keeping system.

For a dynamic positioned system, the increase in the fuel consumption shall be considered. This will demand greater tank capacities and consequently consumable weight and also a greater operational cost.

3.5 Risers and Drill Pipes Storage

Riser storage is the typical item that relates directly to water depth. Figure 9 presents the riser storage capacity for various drilling rigs with relation to the maximum rated water depth.

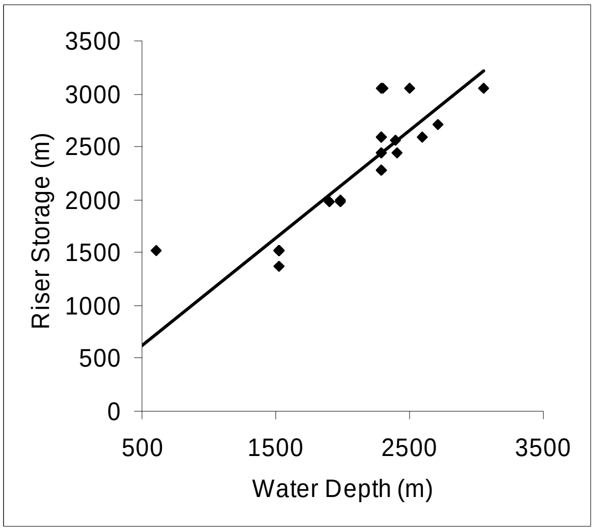

Figure 9 Riser storage x water depth

In deeper waters, the need for riser rack area increases significantly. As a consequence, the deck area must be increase, resulting in more steel, what increases the lightweight. The height of the center of gravity also increases. This means the rig shall have an increased buoyancy and waterplane area, generating a bigger rig and also bigger expenses.

The option for vertical riser storage may be convenient in this case. The risers can be stored vertically on the main deck. In this case the sail area will increase due to the side wall created by the riser racks. In a more optimized solution, the risers can be fitted in the void space of a column. This solution reduces the sail area, the height of the center of gravity and also the amount of steel for the rack.

4. BUOYANCY

In case the alterations to the rig surpass it's capacity, some hull alterations will become necessary:

- For an increased displacement in the ocean tow conditions an enlargement of the pontoons or conversion from a catamaran configuration to a ring pontoon.
- To increase metacentric height it is necessary to include additional columns or construct blisters in the existing ones.

5. RULES AND REGULATIONS

The limitation of the height of the vertical center of gravity is obtained from the stability analysis which shall be performed in accordance with the IMO Mobile Offshore Drilling Units Code and the Classification Society Rules for offshore drilling units.

The analysis shall be conducted for all anticipated normal operating drafts such as drilling, survival and transit. Other drafts shall be subjected to less strict limitations as they are only temporary conditions. For the operational drafts the stability of the rig shall be verified for compliance with intact and damaged stability criteria.

When the rig is only subjected to minor alterations, usually there is no need to update the limiting maximum VCG. If it is necessary to perform alterations in the underwater parts, not only the maximum VCG shall be redefined but, in case of major alterations, the updated regulations shall be applied.

It is not unusual to convert a 1979 MODU CODE rig to a 1989 one. Table 2 indicates the main differences between both.

If the rig was originally designed very close to the limiting criteria, these modifications may need structural alterations so the requirements can be complied with. This should be noted before any upgrade is performed and the adequacy to the updated criteria shall be verified.

Table 2 Stability Criteria

	1979	1989
Wind heeling moment	No alterations.	
Intact Stability	No alterations.	
Damage Stability	No flooded compartments.	Flooding of compartments shall be analysed.
	Extent of damage 1.5 m above and bellow the specified draught.	Extent of damage 5.0 m above and 3.0 m bellow the specified draught.
	No range required	Restrictions in the 7o range

6. CONCLUSIONS

The two main questions that occur when planning for an upgrade are:

- Is it possible to perform the upgrade as intended?
- Is it economically viable to perform the upgrade?

As a conclusion of the many aspects related to the stability of the drilling rigs, we can perform an initial evaluation of these decisive parameters.

In terms of the first question, the main point to be observed is the stability. It shall be necessary to achieve a hull configuration that will supply the necessary capacity of VDL to operate in the desired water depth. In case there is the necessity of updating the applicable regulations, it shall also be observed if the rig is capable of attaining all new requirements, not only in the stability aspects but also in all other matters.

Other points that may be observed are the available spaces and tank capacities. In most cases, it is possible to perform the upgrade.

The economical viability will normally be the main aspect in deciding the upgrade. If it can be kept in a small scale, with no need to change the underwater configuration, it is very likely that the upgrade will be very economical. If a major alteration is necessary, the extent of this alteration shall be evaluated. If all the equipment must be changed and a great amount of steelwork shall be done, it is very likely that a newbuilt rig will be more viable.

7. REFERENCES

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