Design Optimization & Application of Cofferdam for Jack-Up Rig Refurbishment

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Abstract
Drilling Rig availability is a major bottleneck for Oil & Gas exploration. Hurricanes in GOM have damaged many Jack-Up rigs. Jack-Up rig refurbishment is generally carried out on Land or in Dry Docks. However due to lack of availability of facilities & resources refurbishment in afloat mode was necessitated, leading to use of unconventional methods like cofferdam for refurbishment. This method was adopted for FD-VII Jack-Up rig refurbishment

Cofferdams provide dry environment / work area for submerged hull portions. Generic concept was developed so that the cofferdam can be used for different models of Jack-Up rig. The final size of cofferdam was 18m dia. This comes under large size cofferdam

The detail design engineering of cofferdam from the vendor indicated the weight to be 127MT compared to the estimated 75MT. Hence in-house optimization exercise was undertaken using Finite Element Method which helped in reducing the weight to 105MT

The sizes of the plate girder stiffeners were not fabrication friendly & would have led to extensive material wastage & more welding effort. Hence further optimization exercise was carried out which saved substantial material & fabrication effort. Sealed & Adjustable buoyancy tanks of the cofferdam were checked from operability point of view.

Cofferdam attachment to the Rig generates huge amount of buoyancy forces (700MT). This needs to be balanced by ballasting the appropriate tanks in the hull. Some of the tanks in damaged condition imposed unavoidable constraints.

Real time support for the hydrostatic stability of the rig was provided to the yard which helped in successful application of cofferdam for refurbishment of Jack-Up Rig.

This paper discusses the above aspects.

Introduction
Harsh environmental conditions have been a major cause of damage to Drilling Rigs around the world. Demand of Drilling Rigs being high, drilling operators don’t want any of there assets idling. Current economic downturn has forced many of the Rig owners to refurbish existing rigs rather than build new ones. Generally repairs to the Rigs are done on land in a dry environment. In very rare cases repairs are done in water by creating a dry environment. The former is achieved either in dry docks, reverse launching the rigs on yard by using semi-submersibles, SPMT’s (self propelled modular transporter), skid beams etc. For undertaking repairs with the rig in water, Cofferdam technique is required.

L&T has undertaken project of refurbishing a hurricane damaged Jack-up rig named “FD VII” at our Fabrication yard at Oman (MFY). The rig heavily damaged by hurricane “Rita” had lost all its Legs, Spud cans, Helideck, Derrick etc. Due to unavailability of Semi-Submersible barge it was decided to adopt cofferdam technique to refurbish the damaged jack up rig.

Cofferdams are structures designed for creating dry work environment within a water environment. The cofferdam is attached to a submerged portion of the hull and water is removed from within the
cofferdam creating a dry environment. Cofferdam is usually a welded steel structure which can either be permanent or dismantled based on the requirement.

For the refurbishment of FDVII Jack-up rig, two cofferdams were designed and built. The Leg well area of the rig being submerged was inaccessible. Cofferdams were used to create dry work environment around them and repairs were carried out on the hull, leg guides etc and new legs were installed successfully.

**Design Of Cofferdam**

**Sizing**

For Rig Refurbishment, L&T viewed cofferdam as a long term asset. Hence the cofferdam design needed to be versatile, catering to the different Rig Designs. The first step in the design of cofferdam started with sizing the cofferdam. The cofferdam needed to be sized such that it could be used for different Jack-Up rig designs and not for one of project. The cofferdam was sized for the largest leg well (based on various Jack-Up Rig designs) and operational access considerations (access behind the leg guides etc). It was decided to design a 12 sided cofferdam with a circumscribed circle dia of 18m (Fig 1).

![Figure 1 – 12 Sided Cofferdam Showing Tanks](image)

**Optimization**

The cofferdam was to be designed as a 12 sided structure capable of providing sufficient buoyancy to maintain position during maneuvering under the hull and withstand 10m water head. The design was carried out by vendor using first principles.

Initially when the cofferdam idea was proposed the weight of cofferdam was estimated by designer to be around 75 MT. Based on the estimate the complete schedule was prepared. Final design proposed a weight of 127 MT which was not acceptable, economics and schedule wise. Also the plate sizes (1050mm deep girders) provided by the designer were not fabrication friendly. Since these were higher than the standard plate sizes there was going to be increased fabrication time and huge amount of material wastage.

Necessity for optimization of the Cofferdam design, to reduce the weight and plate sizes to minimize wastage was felt. Review of the design submitted by the designer indicated use of higher factor of safety. Reduction of FOS was proposed but the designer was not willing to take the responsibility. It was decided that we would take the responsibility for reduced FOS. In-house team carried out detailed finite element analysis using ANSYS.

Cofferdam quarter section was modeled using shell elements (Fig 2).
Figure 2 – Quarter Symmetry Model of Cofferdam

Symmetry boundary conditions on the edges and vertical restriction on the inner edge of the tank region was applied to simulate the cofferdam connection with the hull. Uniform pressure loading was applied on the base plate simulating the effect of external water pressure on removal of water from inside the cofferdam. The results (Fig 3) of the analysis proved that the reduced FOS was acceptable and cofferdam design was still safe. Optimization of the design was also carried out incorporating lower girder sizes (980mm deep instead of 1050mm). Higher girder size would have resulted in wastage of approximately 23MT of steel and increased fabrication time. The reduction in girder size helped utilization of the standard plate (2m wide plate – two girders 980mm deep could be fabricated instead of one) to the fullest extent.

Final optimized design weighed 105MT compared to the 127MT design proposed by the designer.

Figure 3 – Deflection and Stress Plots

Hydrostatic Stability

Once the cofferdam is installed underneath the Rig, huge amount of buoyancy (700MT) is generated which can cause the Rig to excessively heel & trim. If this change in heel and trim is not accounted for correctly there is very high probability of the rig capsizing. Damaged tanks in the Rig add to the complexity in maintaining stability.

In order to mitigate the risk, in-house team carried out a detailed Hydrostatic Stability check using AUTOHYDRO software for the Rig during the cofferdam installation operation and subsequent Rig refurbishment (Fig 4). Detailed ballast calculations and stability charts for the different loading conditions encountered were provided. The in-house team was actively involved during the various cofferdam operations and provided real time support to the yard. The proactive measures taken by L&T in ensuring Rig stability was highly appreciated by the Client.
Accomplishing the above mentioned steps, significant amount of work & Coordination was involved. Detailed planning was done in close coordination with Project management team and yard, leading to successful fabrication, installation & operation of cofferdam.

Conclusion
L&T has successfully carried out refurbishment of FDVII Jack-Up Rig using the unique Cofferdam technique. The cofferdam was one of the biggest (weighing 105MT and measuring 18m dia on the outside) used in Rig Refurbishment.
In-house sizing of cofferdam was carried so that it could be a generic design and used for most of the Rig designs available in the world.
Optimization (involving reduction of Factor of safety compared to used by designer) of cofferdam design using FEM techniques was carried out to reduce the weight from 127 MT proposed by designer to 105MT.
FEM techniques also helped in arriving at optimized girder size of 980mm saving nearly 23MT of material going waste and fabrication effort.
Real Time support for Hydrostatic stability calculations was provided to Yard mitigating associated risks.

The cofferdam solution was implemented by L&T to repair the Leg well & Bottom Guides of FDVII Jack-Up rig followed by successful installation of the Jack-Up Legs.
Cofferdam ready for installation
Cofferdam placed in water
Cofferdam supported by Buoyancy Bags
Cofferdam successfully installed
Damaged Bottom Guides
Refurbished Bottom Guides
First Leg Section Installed
Legs Installed at Two Locations