Study on the General Layout of Semi-submersible Offshore Drilling Platforms Based on Drilling Operation Flow

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Abstract

The design of general layout of the 6th generation of semi-submersible drilling platforms is the main impact factor of drilling operation efficiency. The paper sets up the drilling operation flow of dual drilling center and the hierarchical division of rigs based on the different modes of transportation of various drilling supporting systems. The general layout—centripetal overall arrangement spatially was determined based on drilling efficiency. We plot out the module according to the drilling operation function, which is the basic layout unit. We apply different layout algorism to mark out the upper deck and low deck. The upper deck was design based on the lowest transportation cost. The lower layer deck's calculation was based on the best-fit scope. Project storage mode of column and pontoon is also used to for the layout design. Finally the center of gravity of arrangement is taken into consideration of the design execution and the general layout is adjusted according to result of barycenter. The methodology of the general layout can provide the reference implementation opinions to the domestic design of semi-submersible rigs.

Keywords: **s**emi-submersible drilling platforms; general layout; drilling operation flow; optimization of layout.

Introduction

CNOOC and CNOE(China National Petroleum Offshore Engineer Corporation) had jointly put in practice the 863 project—《The key technique research on **s**emi-submersible drilling platforms》. The project was launched since 2006. The aim of the project was to design the 6th generation of drilling platform that have the capability to work in water depth of 3,000m and maximum drilling depth of 10,000m. The main property of the 6th generation of **s**emi-submersible drilling platforms is that: remarkably increase operating depth, operation in worse sea area situation, highly increase variable load, equipment automation higher, intellectualization higher, dynamic positioning and dual rigs and other new techniques. Many new technique and equipment is needed to be used to enhance the design level, especially the general layout design on drilling equipment. The paper studies the general layout design based on operation flow. The objective is to improve operation efficiency. The emphases is put on the up and lower deck and lower pontoon's arrangement. The twin deck is not extensively discussed for there is little region in the upper shell

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1 The Design Goal and the Structure of Semi-submersible Rigs

The target platforms is oriented to 6th generation semi-submersible rigs and adopted dual rigs. The detail technical guideline is that:

- Busywork sea area: south China sea's deepwater area;
- Water Depth: 3,000m, Maximum Drilling Depth: 10,000m;
- Dual rigs system;
- Variable Drilling Loads upto 9,000T (included of columns);
- Mode of orientation: anchor positioning and dynamic positioning;
- Service with drilling, well workover, testing, operation, completion, etc.

The object rigs adopts mainstream mode of semi-submersible rigs—two pontoons, four columns, brace connecter and box deck. The dimension of upper hull is 78.40×78.00× 8.50 m. It is square-formed mode framework. The lower pontoon, side skin and bulkhead are longitudinal frameworks. There are water-tight bin and plane frame in the columns [1]. Slurry, fuel oil, brine, drill water and base oil in the columns and lower pontoons

2 The Principle of Layout

Rigs' layout is the key factor of collectivity capability of general layout. It not only directly influences the operation performance that based on stability, security and work efficiency of rigs, but also forms as the main basis of the following design and calculation. One objective of the layout design is to improve the operation efficiency which is determined by arrangement mode for rigs' fabricating. The building cost and daily rent charge is remarkably increased due to the feature of high cost, high technology and high risk of offshore oil and gas exploration and development. So the goal of layout is to increase efficiency during of stage of conceptual design

The Principle of Layout is made out:

- Fitting for operation requirement. Firstly drilling operation is the core and centric the function the drilling platform. So the drilling equipment has to be arranged to ensure work conveniently. Human factors must be taken into consideration too [2].
- Planning layout based on operation cost. The system with high transportation cost must be arranged with high priority. The equipment with low transportation cost can be far from dual rigs. For example equipment transported with manifold may be far away drilling centre. Because its distance has little influence to the total cost.
- Dividing modules according to operation functions. The general layout planning should base on module of the functions. Inside each module the planning can be divided again according to the same rule.
- Drop rigs centre of gravity as far as possible to ensure stability.
- Reserved large space as far as possible for safety operation and efficiency. This will also benefit function upgrade in the future.

3 The Operation Flow

Drilling rigs of the 5th and 6th generation of semi-submersible rigs is very complex large system with a large collection of equipment and manifolds. In fact the rigs are the drilling center supported by hull from logistics' point of view. Dual rigs lie in the focus of the platform, which is not only the hub of the framework, but also the drilling operation center. And other facilities provide power, drilling material, instrument, mud and other services. The operation flow is illustrated in Fig 1. From the Fig, we can found out the following points: Dual rigs are the drilling operation focus; Drilling supporting/serving systems provide all kinds of essential services support including drill pipe, casing, riser handling system transportation tubular service stored and exchanged by automatic pipe racker and pipe transient area; mud fed by slurry handling system; electric power supplied by power supporting system, hydraulic pressure，air driven and compensation function; machine maintaining waste handing, electrical maintaining and air dryness provided by logistics system; and living domicile including of mooring system, dynamic

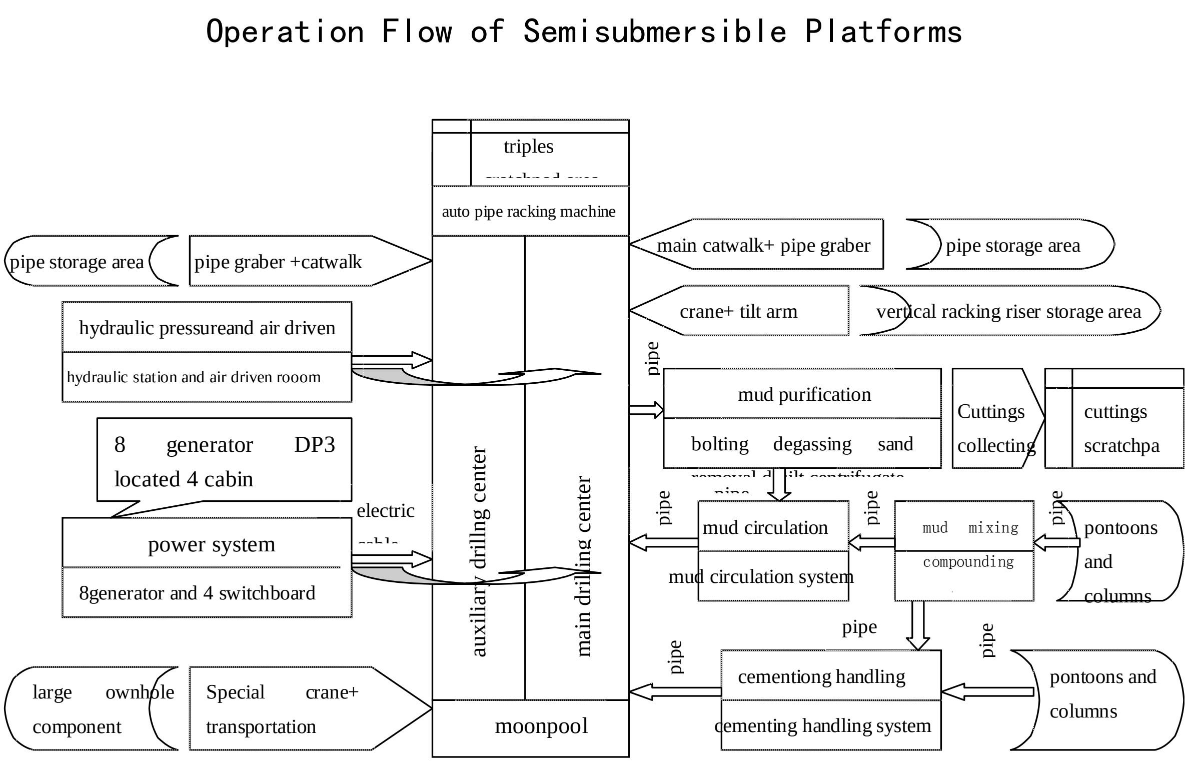

Fig 1 drilling operation flow chart of semi-submersible rigs positioning etc.

4 Layout Based on Operation Flow

Because semi-submersible platforms is a very complex and huge system, and single arithmetic cannot figure out the optimum solution. Analytical hierarchy process and modularity could be adopted to carry out the general layout planning. The method of centripetal overall arrangement spatially is selected, and every function module center on dual rigs and provide service for it.

According to the operation flow and layout principle, centripetal overall arrangement spatially is established. The layers and modules are separated. Layout is planned based on basic modules. Specific arithmetic algorithm is: dual rigs are the work center, hierarchical division takes into effect through transportation mode, which is divided into function module. Different arithmetic algorithm is adopted on different arrangements. The algorithm for the upper deck try to minimize of the cost and the algorithm for lower deck mean to best-fit space, which means large dimension modules are laid out with high priority. The arithmetic algorithm of best-fit space is to optimal allocate for object rigs' square-formed mode framework and moon pool divided lower deck into abnormity region while some modules can not divide once more.

There are four transportation modes according to different material from the operation flow, that is: tubular transported through pipe grabber picking up and catwalk transporting, major special facilities transported to moon pool through special elevator lifting and special pulley, mud, power (electric power, hydraulic pressure，air-driven) fed by pipelines; vertical racking riser transported to drill floor through riser grabber lifting and tilt arm transporting. It is worth to note that the riser is different from the other material for it has two storage mode, that is vertical racking and horizontal vertical racking. The transportation mode of vertical racking is similar to the handing mode of tubular.

The concrete layout of transportation mode is: settings main and auxiliary catwalks to transport respectively casing (including large diameter casing and riser with horizontal racking mode) and drill pipe, casing, racking of riser is adopted mixed mode: 75% vertical racking +25% horizontal racking, which is more efficient for vertical racking can improve efficiency and fall gravity center and horizontal racking is standby. Vertical racking riser is set up special storage area and transported by special crane, rail and pulley. At present, mode of double side dropping is planed for it is superior to mode of single side from point of view of operation efficiency [3,4].

Transportation modes are different for material is different from shape and quality to material modality which leads to divergence of cost and efficiency of transportation. It is cost and efficiency of transportation that leads to different layout for tubular transportation is highest cost, largest efficiency of space occupation and lowest efficient while mode of transportation by pipeline is contrary.

Three Layers are divided by mode of transportation from upper layer to lower layer which are drill floor, upper deck and lower deck in turn. Drill pipes, casing and riser etc are received in the region of the drill floor. The upper deck is used not only as area in storage, but also as operation area of large equipments and handle solids control system. The slurry handling system, power supporting system and logistics system are arranged in the lower deck. The feature of this kind of systems is they could be transport to the center of drilling activity by pipelines or they are separated from the drilling activity. Their distances have little impact on the operation cost.

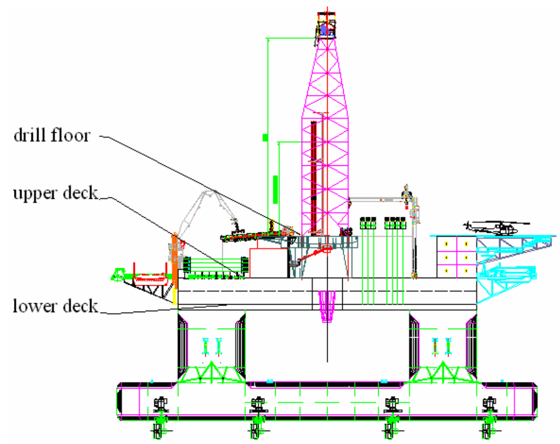

Fig 2 hierarchical division of rigs' arrangement

According to the grade of relationship with the dual rigs and cost affected by distance from the operation flow, all equipment is divided into 22 modules which are listed below:

Dual rigs system has three modules. They are drilling center module including dual derrick rigs, drill floor and moon pool system, drilling auxiliary power module including hydraulic pressure station, air-driven station and riser heave compensator system and drilling rig power control module. The drilling rig power control module is used to support VFD/MCC service.

Tubular handing system has two modules. The drilling tubular handling module included tubular store yard, main and auxiliary catwalks and pipe grabber. The module works as tubular storage and transportation. The vertical racking riser module handles riser storage and transportation.

The two modules of sub sea component are used for two-sided landing. The BOP (blowout preventer) storage and handling module included BOP crane, transportation pulley, BOP guidance system, BOP suspending and moving trolley and lifting device. The other large sub sea component storage and handling module is similar to BOP module. Some equipment can be shared with each other in the moon pool.

Two power modules are divided equivalently to meet with the requirement of dynamic positioning DP3. The target platforms has configured 8 generators. They are arranged into 4 engineer rooms. The arrangement is conform to the safety requirement of DP3 for rigs.

Mud system is divided into four modules which are slurry mixing and compounding module, mud purification module, mud circulation module and well cementing module.

There are two rigs supporting and controlling modules. One is supporting and controlling module which supplies operation sustaining including anchor positioning, dynamic positioning. Another is master control module which is the heart that controls the whole rigs.

Six logistics service modules are living, instrument, mechanism maintain, waste handling and air-drying modules.

5 Implementation of General Layout

Drill floor is higher than the main deck. It is the main workaround which accepts drill pipes, casing and riser. Drilling tubular handing module and vertical racking riser module located in the drill floor layer. Main and auxiliary catwalks faced to window opening are used to transport tubular whose reel is pipe grabber and storage area used to handle tubular. Pipeline storage area is arranged by working frequency, and drill pipe with priority. Riser storage area lies in the rear of drill floor which cross from main deck to lower deck to reduce the center of gravity [3].

Main deck (upper deck) is centered around dual rigs. The two large sub sea component modules are arranged in each side of the main deck. The left side is BOP handling module including a BOP crane, a BOP pulley system, a LMRP trolley, BOP guidance system, BOP suspending and moving trolley and a lifting device, which can fulfill BOP operation. The right side is the other sub sea component module including a crane, a trolley and the lifting device. The job procedure of sub sea component is that the crane lifts the X-mas tree on the trolley and transports it to moon pool, then sets down by jacking gear device. The foreside of dual rigs is mud purification module located behind of catwalks which can performance mud solid phase handling and gathering.

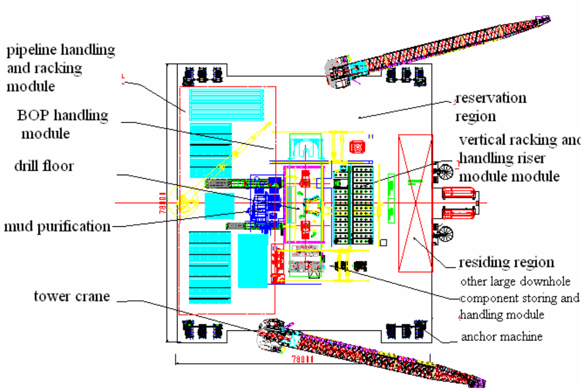

Fig 3 main deck and drill floor layout

Anchors lie at the corners of rigs and tower cranes lie in the two sides of rigs. Larger work space can improve operation security. The reserved space is also helpful to the upgrade in the future. The objective of the rigs design is to provide an integrated platform for drilling, testing, maintaining and operating. After the construction of rigs is completed, new equipments have to mainly put on the upper deck because the lower deck can not add big equipment easily

The features of the lower deck are:

1. Lower deck is anomaly and discrete region spatially for rigs uses square-formed mode framework. Deck is separated by moon pool running in center of rigs and is divided into cabins to strengthen structure.

2. Modules have different relationship. The relationship should be take into consideration when arrange them. For example, mud modules--slurry mixed and compounded module, mud circulation module and well cementing module' operation are related to each other and should be arranged near each other. They should also be located close to mud purification module in the upper deck. Two power modules should be far away from each other to meet with DP3 requirement. Based on the current condition, the best-fit space algorithm is adopted. Large modules are preferentially put into large region with high priority while small modules are put into the rest area reasonably. There are three large modules, including mud handling modules and two power modules. Mud handling modules are the largest modules. They can only be put into the region in front of the moon pool. The two power modules can be put into the left and right side of the shipboards of rigs. The above arrangement is the only feasible solution. So three mud modules are adjacent to each other and just fit into the mud purification module. Four mud pumps lies in two cabin and one of pumps lies in a cabin which can arrange auxiliary power module in residual cabin including hydraulic pressure station, air driven station and riser heave compensator system. Drilling auxiliary power module and rig power control module belonging to the dual rigs system are collocated to the two sides of riser storage.

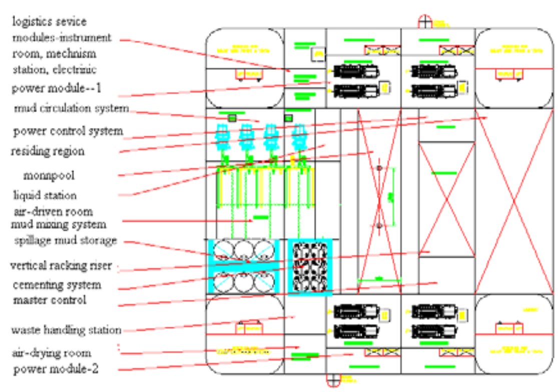

Fig 4 lower deck layout

Two power modules are symmetrically arranged compartment in the left and right of a hull to meet with dynamic positioning requirement of DP3. 8 generators are configured and arranged into 4 engineer rooms. Each room has independent panel room which controls two propellers to increase safety. This ensured position capability of the platform when two propellers are out of operation. Power modules should be apart from residing area, which located in the area of stem and has noise and vibration from the viewpoint of human factor. Five logistics service modules including living, instrument, mechanism maintain, waste handling and air-drying modules are arranged at the both sides of moon pool. Instrument room, machinery and electrical equipment repair and maintenance shop are located in the port hand. Waste handling room and air-drying house are arranged in the area of starboard.

It is only framework layout after work is completed based on modules. Further planning works should be done to detail the layout planning inside each module whose layout design should base on operation flow. For example, mud purification module, including 5 grade solids control—bolting, degassing, sand removal, desilt, and centrifugate, 4 shale shakers, 2 mud cleaner, 2 deaerators, 1 medial speed centrifuge, 1 high speed centrifuge, 4 sand pumps, several accumlators tank, 1 cutting collecting system and manifolds. All of these should be further arranged based on the operation flow.

6 Pontoons and Columns Storage Layout

Self-sustaining capability is the important target of rigs. Columns and pontoons can store mud, powder, heavy spar, saline water, cement, drilling water, etc. Liquid is stored in pontoons and consumable solid is stored in columns. The arrangement is to facilitate their transportation

Target platforms is square-formed mode framework. Columns extend to main board and have four layers from above to below. Three layers are under the lower deck and one layer is above the lower deck. There are elevators and lifting device in the middle of columns and 12 chain lockers and mud bins in the two lower layer and mud tankers, powder tankers, heavy spar tankers and drinking water bins in the two upper layers of columns.

There is large storage space in the pontoon for 8 water tight bins including drilling water, saline, base oil, fuel oil, drinking water ballast water and 8 pump bins and 8 propeller bins besides supplying adequate tonnage. Two pontoon use similar rule in the arrangement.

7 Centre of Gravity Check

It is essential to calculate centre of gravity to check the rationality of layout. Equipments layout make a great impact on barycenter for hull's shape is regular and symmetrical in principle which is little influence to [5]. Referring to criteria of Transport Ship Weight Classify and Barycenter Calculation, coordinates is set out. Portrait (X): midship is benchmark, stem is positive; horizontal (Y): midline is benchmark, starboard is positive; vertical (Z): baseline is benchmark, up is positive[5].

The initial calculation result meets the anticipation. The result is obtained through counting weight square based on the position of the equipment. The detailed result is: vertical barycenter is 25.7m, portrait offset to stern is 2.1m and horizontal offset is 0.1m. There is a great deviation for tubulars store yard. The reason is mud system lies in the area of stern which has very weight while upper deck's equipment reserved are not calculated and household goods are not took into account in the residing area (refer to Fig 2 lower deck layout). The layout of lower deck is adjusted. Two power modules are pre-displacement led to barycenter moving. This leads to noise and vibration increasing which could not meet with the principle of human factors.

8 Conclusion and Discussion

The paper discusses the general layout of semi-submersible platforms. The platforms is a large complex system. Layer division and modules analysis are adopted for the planning. The upper and lower deck's layout are made out and columns and pontoon's storage is made a program.

The main result of this paper is: Setting up the operation flow for due rigs of semi-submersible platforms; Establishing the layout principle based on operation efficiency of drilling. Dividing the layers of rigs according to the mode of transportation; Establishing the general layout design methodology of centripetal overall arrangement spatially.

The modules are divided based on the function of rigs' equipment. Those modules are used as the basic unit of layout. The upper and lower deck's layout are planned based on different algorithm. The layout plan is adjusted by calculating the barycenter to keep rigs stability.

The layout of semi-submersible rigs is complex systems engineering which is relevant to safety, efficiency, human factor engineer, environmental protection and rigs structural mechanics.

The layout of semi-submersible platforms is complex systems engineering which comes down to security, efficiency, human factor engineer, environmental protection and rigs structural mechanics. The paper discuss layout based on efficiency and test by barycenter which lies unavoidably in some limitation. The next work is to adopt multidisciplinary analysis method to further perfect layout of semi-submersible platforms.

References

[1] Chen Xinquan. Research on Preliminary on Design of Deepwater Semi-submersible[D]. PhD thesis, Shanghai Jiao Tong University. 2007

[2] Yue Jixiang, Qi Yaoguang, Ren Xuhu. Study on the Driller Cabin of Semi-submersible Offshore Drilling Platforms Based on Human Factors Engineering[J]. China Offshore Platforms. 2008.23(2): 7-12

[3] Yue Jixiang, Qi Yaoguang, Xiao Wensheng, etc. Study on Configuration and Layout about Drilling Material Transportation System of Semi-submersible Drilling Platforms[J]. Ship & Ocean Engineering. 2008, 5: 31-36

[4] Liu Haixia. General Arrangement of Deep Sea Semi-submersible Drilling Unit[J]. China Offshore Platforms. 2007.22（3）: 7-12

[5] CB-Z319-1982. Transport Ship Weight Classify and Barycenter Calculation[S].