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Study on the general layout of semi-submersible offshore drilling platforms based on process flow

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Abstract: The general layout of 6th generation semi-submersible drilling platforms is the main factor impacting the efficiency of their drilling operations. This paper provides a compound/integrated algorithm based on process flow that is aimed at improving efficiency, while giving attention to stability and safety at the same time. The paper describes the process flow of dual drilling centers and a hierarchical division of rigs based on the different modes of transportation of various drilling support systems. The general layout-centripetal overall arrangement spatially was determined based on drilling efficiency. We derived our modules according to drilling functionality; the modules became our basic layout units. We applied different layout algorithm to mark out the upper and lower decks. That is, the upper deck was designed based on the lowest transportation cost while the lower deck's calculations were based on the best-fit scope. Storage configurations in columns and pontoons were also considered for the layout design. Finally the center of gravity was taken into consideration and the general layout was adjusted accordingly, to result in an optimal center of gravity. The methodology of the general layout can provide a reference for implementation of domestic designs of semi-submersible rigs.

Keywords: semi-submersible drilling platform; general layout; drilling process flow; layout optimization; group technology

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1 Introduction

China National Petroleum Offshore Engineer Corporation implemented the 863 Project–the key technique research on semi-submersible drilling platform (SSDP) in 2006. The main properties of the 6th generation **s**emi-submersible drilling platform are that it can operate in worse sea condition, remarkably increase the operating depth and variable load; it has higher automatic and intellectualized level of equipment; it adopts dynamic positioning and dual derrick rigs and other new techniques. The aim of this project is to design the 6th generation drilling platform that has the capability of working in the water of 3 000 m deep and the maximum drilling depth of 10 000 m, and the busywork sea area of it is the South China Sea's deepwater area. The platform has a configuration of dual derrick rigs system, variable drilling loads up to 9 000 t and is provided with the functions of drilling, well workover, testing, operation, completion, etc. The orienting modes are anchor positioning and dynamic positioning with DP-3. Many new techniques and equipments need to be used to enhance the design level, especially the general layout design of drilling equipment. The authors studied the general layout based on the process flow for the purpose of improving operation efficiency. The emphases are put on the upper and lower decks and lower pontoon's arrangement. The intermediate deck is not extensively discussed for there is little region in the upper shell.

Layout is the key factor of collectivity capability of the general layout. It directly influences the operation performance which is based on stability, security and work efficiency of rigs. Besides, it is the main basis of the following design and calculation.

2 General layout project

The general configuration of SSDP is a three-dimensional layout with behavior constraints. The 3-D layout with behavior constraints has not been resolved perfectly, especially in engineering practice, though many scholars have provided different models. This paper presents a compound/integrated algorithm based on the process flow aiming to improve efficiency, and to pay attention to stability and safety at the same time.

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2.1 Layout principle

1) Fitting for operation requirement. Drilling operation is the core and centric function of the SSDP, so the drilling equipment has to be arranged to ensure the convenience and efficiency of work.
2) Planning layout based on operation cost.
3) Human factors must be taken into account, especially in the operating space and control cabin, etc[1].
4) Lower the centre of gravity as far as possible to ensure stability.
5) Reserve large space as far as possible for operation safety and efficiency, which will be beneficial to function upgrading in the future.
6) Related design guidelines and criteria.

2.2 General layout programming

We can regard the SSDP as a mobile drilling center supported by platform. Two key factors are efficient rigs and material transportation system. So the layout programming is worked out:

1) Planning operation flow—layout basis.
2) Planning four transportation modes according to different materials from the operation flow.
3) Layers are divided in accordance with the modes of transportation.
4) Group layout, dividing modules according to operation functions.
5) Different algorithms are adopted in different layers.
6) Adjusting the center of gravity according to the result of the center of gravity to enhance stability of SSDP.

3 General layout implementing

According to the layout programming, we took the 863 Project in the scantling design as an example, implementing the layout of SSDP in details.

3.1 The structure of SSDP

The structure of SSDP has obvious influence. Different deck structures have different layouts, for example, the layouts between integrated decks and modularized decks topside are different.

The object rigs adopt mainstream configuration of semi-submersible units—two pontoons, four columns, brace connecter and box deck. The dimension of upper hull is 78.40 m×78.00 m×8.50 m. It is square-formed mode framework. The lower pontoon, side shell and bulkhead are longitudinal frameworks. There are water-tight compartment and plane frame in the columns[2], and slurry, fuel oil, brine, drill water and base oil in the columns and lower pontoons.

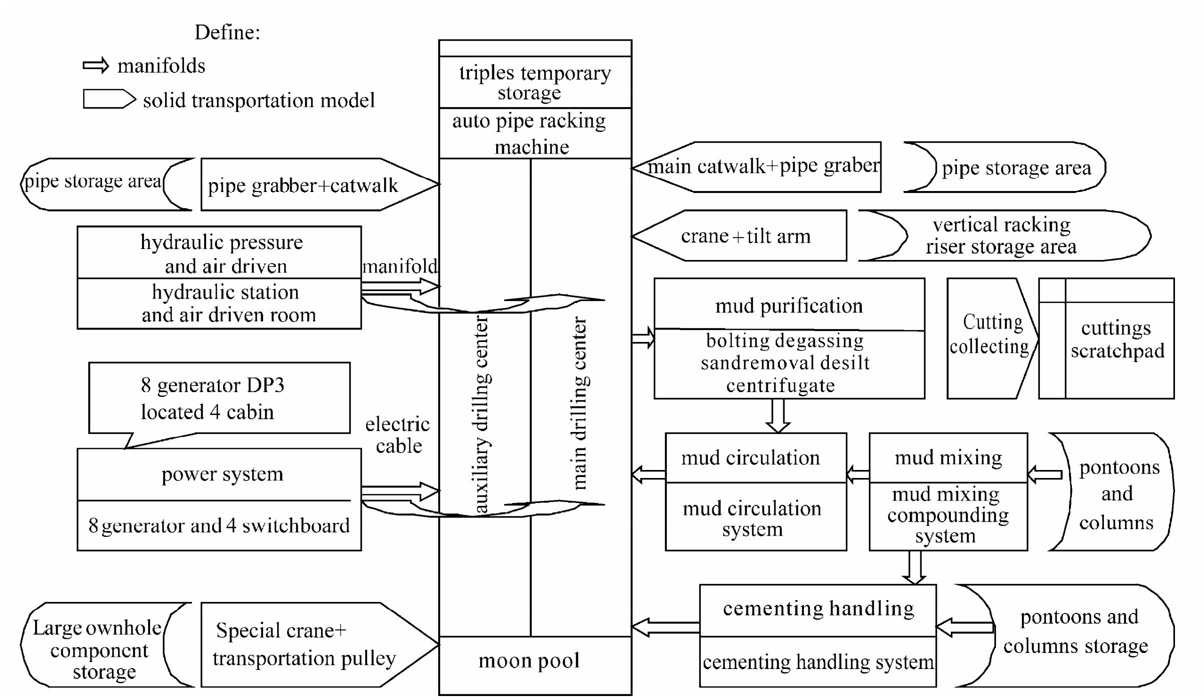

Fig.1 Process flowchart of semi-submersible drilling platform

3.2 The operation flow

The main function of SSDP is drilling, and the topside layout should fit for operation. The dual derrick rigs lie in the focus of the platform, which is not only the hub of the framework, but also the drilling operation center. Other facilities provide power, drilling materials, instrument, mud and other services. The process flow is illustrated in Fig.1. From the figure, we can found out the following points: the dual derrick rigs are the drilling operation focus; the drill supporting/serving systems provide all kinds of essential services support including drill pipe, casing, riser transported by tubular handling system, stored by automatic pipe racker and exchanged at 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 disposal, electrical maintaining and air-drying provided by logistics system; and living domicile including the mooring system, dynamic positioning, etc.

3.3 transportation modes

There are four transportation modes according to different materials from the operation flow: tubular transportation through pipe grabber's picking up and catwalk transporting; major special facilities' transportation to moon pool through special elevator lifting and special pulley; mud, power (electric power, hydraulic pressure, air-driven) fed by pipelines. It is worthy of notice that the riser is different from the other materials for it has two storage modes-vertical racking and horizontal racking. Vertical racking riser's transportation to drill floor is done through riser grabber lifting and tilt arm transporting. The transportation mode of vertical racking is similar to the handing mode of tube[3].

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

Transportation modes are different for the materials are different from shape and quality to material modality, which leads to divergence of cost and efficiency of transportation. The cost and efficiency of transportation lead to different layouts for tubular transportation is highest in cost, largest in efficiency of space occupation and lowest in efficiency while the mode of transportation by pipeline is on the contrary.

3.4 Layers division

Three layers are divided by the mode of transportation from upper layer to lower layer—drill floor, upper deck and lower deck in turn (Fig.2). Drill pipes, casing and riser etc. are received in the region of the drill floor. The upper deck is used not only as an area of storage, but also as an operation area of large equipments and handled 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 that they could be transported to the center of drilling activity by manifolds or they are separated from the drilling activity. Their distances have little impact on the operation cost.

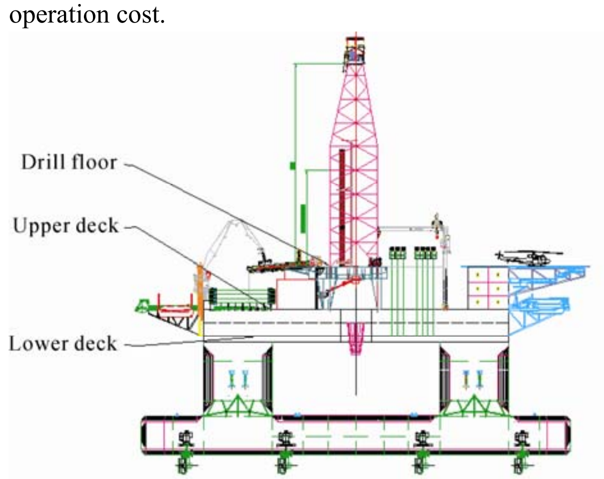

Fig. 2 Hierarchical division of rigs' arrangement

3.5 Modules division

To realize better layout of complex system, the module partition technology is introduced to the process of general programming. The principle of dividing modules is based on the drilling operation function and adjacent position. Modules are basic layout units. Each module can be schemed again according to the same rule.

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

Dual derrick rigs system has three modules—the drilling center module including dual derrick rigs, drill floor and moon pool system, the drilling auxiliary power module including hydraulic pressure station, air-driven station and riser heave compensator system and the platform 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 includes 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 subsea component are used for two-sided landing, namely the blowout preventer (BOP) storage and handling module and another large subsea component storage and handling module.

Two power modules are divided equivalently to meet with the requirement of dynamic positioning DP3. The target platform is equipped with 8 generators. They are arranged into 4 engine rooms. The arrangement conforms to the safety requirement of DP3 for rigs.

Mud system is divided into four modules 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 the supporting and controlling module which supplies operation sustaining including anchor positioning and dynamic positioning, another is the master control module which is the heart that controls the whole rigs.

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

3.6 Layout algorithm

Because SSDP is a very complex and huge system and single algorithm cannot figure out the optimum solution. Different algorithms are adopted in different layers. The drilling floor and upper deck employ the algorithm of lowest transportation cost and highest operation efficiency. The layout is put into practice from top to bottom, and the upper equipment is permitted to occupy lower space.

3.6.1 Drilling floor layout

The drill floor is higher than the main deck. It is the main workaround which accepts drill pipes, casing and riser. The drilling tubular handing module and vertical racking riser module locate in the drill floor layer. The main and auxiliary catwalks faced to window opening are used for tubular transport whose reel is pipe grabber and the storage area is used for tubular handling. The pipeline storage area is arranged in accordance with the working frequency, and drill pipe with priority. The riser storage area lies in the rear of drill floor which crosses from the main deck to the lower deck so as to reduce the center of gravity [3-5].

3.6.2 Main deck layout

The main deck (upper deck) is centered around dual rigs. The two large subsea 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, a BOP guidance system, a BOP suspending and moving trolley and a lifting device, which can fulfill BOP operation. The right side is the other subsea component module including a crane, a trolley and the lifting device. The operation procedure of subsea component is that the crane lifts the Xmas tree on the trolley and transports it to the moon pool, then the jacking gear device sets it down. The foreside of dual rigs is mud purification module located behind catwalks which can perform the mud solid phase handling and gathering.

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 be mainly put on the upper deck because the lower deck can not add big equipment easily.

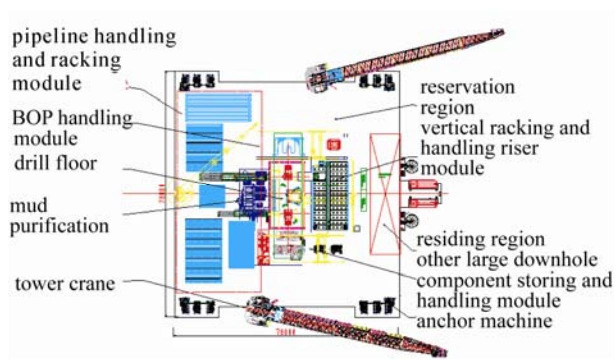

Fig.3 Main deck and drill floor layout

3.6.3 Lower deck layout

The lower deck adopts layout algorithm of best-fit space. The character of equipment in lower deck is that it could be transported to the drilling center by manifolds or it is separated from the drilling center. Distance has no/little impact on the operation cost and efficiency. Otherwise, the following three factors should be taken into account:

relation of modules; principle of human factors; safety route way, which is classified between or in the modules.

The features of the lower deck are:

1) The lower deck is an irregular and discrete region spatially, for rigs use square-formed mode framework. The deck is separated by moon pool running in the center of rigs and is divided into cabins to strengthen structure.

2) Modules have different relationships. The relationship should be taken into account when arranging them. For example, the operations of mud modules–slurry mixed and compounded module, mud circulation module and well cementing module are related to each other and should be arranged close to each other. They should also be located close to the 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 in large region with high priority while small modules are put in the rest area reasonably. There are three large modules, including a mud handling module and two power modules. The mud handling modules are the largest modules. They can only be put in the region in front of the moon pool. The two power modules can be put in the left and right sides 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 lie in two cabins and one of them 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. The drilling auxiliary power module and rig power control module belonging to the dual rigs system are collocated to the two sides of riser storage.

3.7 Pontoons and columns storage layout

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

Target platform is square-formed mode framework. Columns extend to the main board and have four layers from top to bottom. 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 tanks in the two lower layers and mud tanks, powder tanks, heavy spar tanks and drinking water tanks in the two upper layers of columns.

There is a large storage space in the pontoon for 8 watertight tanks of drilling water, saline, base oil, fuel oil, drinking water, ballast water and 8 pump tanks and 8 propeller compartments besides supplying adequate tonnage. Two pontoons use similar rule in the arrangement.

3.8 Layout adjusting according to the centre of gravity

It is essential to calculate the centre of gravity to check the rationality of layout. Equipment layout makes a great impact on the center of gravity for hull's shape is regular and symmetrical in principle which is of little influence. Referring to the criteria of Transport Ship Weight Classify and Center of Gravity Calculation, the coordinates are set out[6]. The origin of coordinate system is located at the intersection of midship, centerline, and baseline, where the X-axis is positive forward, the Y-axis is positive toward starboard, and the Z-axis is positive vertically upward.

Calculation of the center of gravity is carried into execution and the general layout is adjusted according to the result of center of gravity to enhance stability of SSDP. The initial calculation result meets the anticipation. The result is obtained through counting weight square based on the position of the equipment. The detailed results show a vertical center of gravity of 25.7 m above baseline, a longitudinal center of gravity of –2.1 m toward the stern, and a horizontal center of gravity of 0.1 m toward starboard. There is a great deviation for pipes store yard. The reason is that mud system lies in the area of stern which has large weight while the upper deck's equipment reserved are not calculated and household goods are not taken into account in the residing area (Fig.4). The layout of lower deck is adjusted. Two power modules are pre-displaced which leads to moving of the center of gravity. This leads to noise and vibration increasing which could not meet with the principle of human factors.

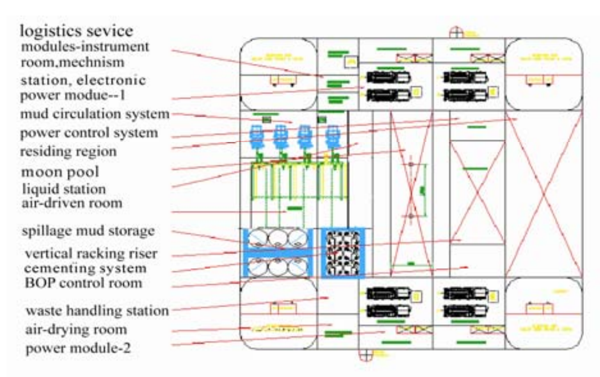

Fig.4 Lower deck layout

4 Conclusion and discussion

The general layout of SSDP is discussed in this paper and an engineering method is provided. The upper and lower decks' layout is mapped out and the columns and pontoon's storage are programmed.

The layout of SSDP is complex systems engineering which is relevant to safety, efficiency, human factor, environmental protection and rigs' structural mechanics. All these factors are taken into account in this paper.

The next work is to adopt multidisciplinary analysis method to further perfect layout of semi-submersible platform.

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基于作业流程的深水半潜式钻井平台总体布局规划研究

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摘 要：第六代半潜式钻井平台装备复杂，尤其双钻井中心应用对平台布局带来新变化，总体布局设计是平台钻井作业效率的重要影响因素．本文系统研究总体布局设计，提出工程使用布局设计方案．首先建立双钻井中心钻井作业流程图，确定布局原则，以钻井效率为基本出发点，对平台各支持/服务系统输送方式进行规划设计，按各种输送方式对平台层次进行划分，确定以双钻井中心为中心的空间向心布局方案，按作业功能对平台设备设施进行模块划分，以模块作为基本布局单元，对上、下甲板采用不同布局算法进行布局规划，上层平台以输送成本最低利于输送算法布置，下层平台采用最适合面积算法，优先布置大尺寸模块，并对立柱、下浮体存储进行规划．最后研究布局对平台重心影响，进行重心计算并依据重心变化进行布局调整．本文针对半潜平台复杂大系统，采用层次划分和模块分解方法进行布局规划方案对我国半潜式钻井平台设计有一定借鉴意义．

关键词：半潜式钻井平台；总体布局；钻井作业流程；布局优化