The overall process of high-deck float-over for the large platform in paralic zones

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Abstract. As the demand for oil and gas resources continues to grow, the development of oil and gas resources in paralic zones is also increasing. Because the water depth is very shallow in paralic zones, large construction equipment cannot enter the construction area, so the offshore installation of large platforms is facing a great challenge. The float-over installation method has the advantages of large lifting capacity, short operation period, and low construction cost. At the same time, it can effectively reduce the amount of dredging work and is more suitable for the offshore installation of large platforms in paralic zones. In this paper, the installation process and key technologies of hi-deck float-over for the large platform in paralic zones are emphatically introduced. The key technologies include the barge motion response analysis technology, the barge ballast adjustment technology, the positioning and buffering technology and motion monitoring technology, etc.

1. Introduction
In recent years, as the demand for oil and gas resources continues to grow, the development of oil and gas resources in paralic zones is also increasing. Among them, the oil and gas resources in paralic zones of Bohai Bay are very rich, and the scale of exploration and development is large. At present, the State Council has banned the approval of new reclamation projects in Bohai Bay, and the oil and gas resources in paralic zones within 5 meters of water depth must rely on offshore platforms for development. Because the water depth is very shallow in paralic zones, large construction equipment cannot enter the construction area, so the offshore installation of large platforms is facing a great challenge.

At present, there are two kinds of installation technologies for the large platform topside in paralic zones: the hoisting of module components and the float-over installation. The offshore installation operation is simple with the hoisting of module components, but it increases the workload of offshore
installation, and the offshore commissioning time is long because some equipment and cables cannot be installed early. The float-over installation can meet the overall installation demand of the platform topside, shorten the offshore installation time and commissioning time, reduce the engineering cost, so as to realize the rapid production of the platform[1-3]. At the same time, because the draft of the ship used for the float-over installation is shallow, the dredging work can be reduced, thus saves the engineering investment. Compared with the two methods, the float-over installation has the advantages of large lifting capacity, less dredging work, short operation period, and low construction cost, which is more suitable for the offshore installation of large platforms in paralic zones.

2. The process of float-over installation
Since 2002, the float-over technology was introduced for the first time in China Bohai Zhao Dong oilfield and successfully implemented on the ODA platform. After nearly 20 years of development, the safety and reliability of float-over technology are becoming more and more mature. Among them, the hi-deck float-over technology is the most applied and mature one in China. It mainly realizes the weight transfer of the platform topside through the ballast adjustment system of the barge. Its principle is simple and its operation is convenient and reliable. The main equipment of float-over installation includes mooring system, barge, pile leg mating unit (LMU), deck supporting unit (DSU), fender system, and auxiliary positioning system[4]. The hi-deck float-over means that the barge transports the offshore platform into the jacket, transfers the heavy platform from the barge to the jacket through load adjustment and tidal variation, and then withdraws the barge after the load transfer is completed. The main installation process is shown in Figure 1.

2.1. Dredge the installation area
The purpose of dredging is to ensure that the barge carrying topside can enter and exit the jacket area safely. According to the barge size, draft, and dredging method, the dredging area and depth are determined by considering the influence of Over-excavation depth, wind load, and current.

2.2. Shipment
After the platform topside is constructed and debugged on land, the topside and the supporting structure loadout to barge as a whole. For large platforms, slippage shipment is generally adopted. After the shipment, it needs to be bound and fixed, and the DSU can be sandbox type or hydraulic type, etc.

2.3. Transportation
After confirming that the meteorological conditions at sea are within the allowable range of operation, and predicting that construction time is enough, then transport the platform topside by barge to the installation area. In paralic zones, the barges used for float-over installation are usually non-self-propelled and need tug towing. In the transportation phase, attention should be paid to the stability and total longitudinal strength of the barge, and the structural strength and center of the topside.
2.4. Enter the ship
When the barge carrying the platform topside enters the sea near the jacket, the mooring system shall be arranged. During this period, it is necessary to carry out some preparatory work before installation, such as cutting for part of the temporary binding and commissioning of the ballast system, etc. When the barge is ready and the environmental conditions meet the requirements of the installation, the barge will be slowly dragged into the jacket notch using the tug and mooring line. In this process, the length and tension of each mooring line should be adjusted to control the speed and direction of the barge. Meanwhile, the horizontal movement of the barge should be controlled as much as possible to reduce the impact force of the barge on the pile leg. During the phase of the ship entering, it should be ensured that enough safety distance is left between the support legs of the topside and the LMU on the jacket to prevent a severe collision. Continue dragging until the surge fender (stop device) on the barge contacts with the jacket. At this time, the platform topside carried by the barge is just above the jacket, and the support legs of the platform topside are aligned with the LMU on the jacket.

2.5. Transfer the load
When the support legs of the topside are aligned with the LMU, the barge is lowered by the ebb tide or sunk by ballast until the support legs of the topside contact with the LMU. At this time, cut the remaining binding and fixing. Ballasting continues and the weight of the topside is slowly transferred to the LMU. During the weight transfer of the topside, the DSU on the barge is gradually separated from the topside.

2.6. Exit the ship
When there is enough safety distance between the DSU and the topside, and the distance between the bottom of the barge and the seabed or the bottom of the jacket notch is within the safe range (to avoid the barge touching the bottom), drag the barge out of the jacket notch. After the barge has completely left the jacket, open the sand valve of LMU until the weight of the topside is completely borne by the jacket, and then weld and fix the topside and the pile legs.

3. Key technology of float-over installation
The installation of hi-deck float-over is a complex offshore construction project. In order to ensure the reliability, safety, and economy of the installation process, many factors need to be considered. Therefore, the overall scheme design should be done well in the whole float-over installation process. This paper discusses some of the key technologies.

3.1. Barge motion response analysis technology
During the shipment, transportation, and installation of the topside, the barge will be shaken irregularly by wind, wave, current, or other environmental loads. Especially in paralic zones, because of the extremely shallow water depth, the shallow water effect will occur in the barge and its motion characteristics will change greatly. Previous studies have shown that as the distance from the bottom of the barge to the seabed decreases, the horizontal motion increases, which increases the mooring forces of the mooring system and intensifies the collision among the barge, the topside, and the jacket. Therefore, it is necessary to analyze the motion response of the barge in time-domain.

According to the load coupling effect of wind, wave, and current, the time-domain motion equation of barge is obtained as follows:

\[ A \ddot{X} + B \dot{X} + CX = F_{\text{wave}} + F_{\text{cur}} + F_{\text{wind}} + F_{c} \]  \hspace{1cm} (1)

Where \( A \) is the mass and additional mass of the floating body, \( B \) is the damping coefficient, \( C \) is the restoring force coefficient of the floating body, \( F_{\text{wave}} \) is the wave force, \( F_{\text{cur}} \) is the flow force, \( F_{\text{wind}} \) is the wind force, and \( F_{c} \) is the collision force [5].
3.2. Barge ballast adjustment technology
The process of weight transfer of the topside is accomplished by using ebb tide and barge ballast. When the tide in the construction sea is not available or the tide range is small, the implementation of hi-deck float-over installation of the topside must rely on the ballast adjustment system to achieve the weight transfer of the topside [6]. In order to achieve the uniform sinking of the barge, the regulated water volume of the barge ballast system must be calculated precisely and the barge ballast process must be designed reasonably. The regulating capacity of the ballast adjustment system is precisely designed according to the change of tide, the barge displacement per unit draft, and the load transfer rate, and the necessary margin must be ensured.

3.3. Positioning and buffering technology
Due to the combined effect of wind, wave, and current, the collision will occur between the barge, the platform topside, and the jacket. The motion of the barge can be controlled by setting the mooring system, and collision force can be reduced by installing the fender system and buffer equipment. The mooring system can control the guiding tips of the topside support legs within the capturing range of the LMU (as shown in Figure 2), and realize the automatic alignment of the topside support legs to the LMU. The fender system is composed of the sway fender and the surge fender, which can reduce the horizontal collision force of the barge as much as possible. The function of the sway fender is to reduce the latitudinal collision between barge and jacket, and the surge fender is used to limit the longitudinal movement of the barge. In order to avoid the steel-to-steel collision between the platform topside and the jacket and between the barge and the platform topside, the LMU and DSU (as shown in Figure 3) are needed to reduce the vertical impact force as much as possible to ensure the smooth installation of the float-over.

![Figure 2. Structure diagram of LMU.](image)

![Figure 3. Schematic diagram of DSU.](image)

3.4. Motion monitoring technology
In the process of float-over installation, the movement of the barge in all directions is inevitable. In order to ensure the safe installation of the topside, motion monitoring is an essential process. The motion monitoring system is responsible for continuously monitoring the motion of the barge in six degrees of freedom, i.e., longitudinal swing, vertical swing, transverse swing, longitudinal rolling, transverse rolling, and yawing, and evaluating the motion response of the barge [7]. The motion monitoring system is used to obtain real-time motion data, and the data are processed in real-time to guide the on-site construction operations based on the statistical results of motion data. In addition, the video monitoring system allows observation of the position of the guiding tips during docking and the movement of the DSU during separation, which provides a guarantee for the safe operation of the float-over installation.
4. Conclusions
In the process of development and construction of oil and gas fields in paralic zones, due to environmental conditions, it is a difficult construction area where "offshore equipment can’t enter and onshore equipment cannot go down", especially the offshore installation of large platforms is facing challenges. The float-over installation method has the advantages of large lifting capacity, low dredging word, short operation period, and low construction cost, which is more suitable for the offshore installation of large platforms in paralic zones. Float-over installation requires mastering the key technologies such as the barge motion response analysis technology, the barge ballast adjustment technology, the positioning and buffering technology and motion monitoring technology, etc. It has an important reference significance for the follow-up development and construction of oil and gas fields in paralic zones and the offshore installation of large platforms.

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