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Types of offshore drilling platforms

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Abstract. The Russian Energy Strategy for the period up to 2035 estimates the development of the hydrocarbon resource potential of the continental shelf of the Arctic seas as the most important geopolitical and technical challenge for the Russian oil and gas sector. An adequate response to it means sufficient production of hydrocarbons in the country beyond the time horizon of 2035. Russia's continental shelf includes the following oil and gas bearing provinces: West Barents, East Barents, Timan-Pechora, West Siberian, Khatango-Vilyui, Laptev, East Arctic, Novosibirsk-Chukotka, Okhotsk, Baltic and Caspian regions. The first eight provinces are located in the Arctic shelf zone, which is a strategic region in the context of resource potential and opportunities for the development of available mineral resources. The estimate for the initial recoverable hydrocarbon resources is 100 billion tons of standard fuel. The methods and equipment used for drilling offshore wells (offshore drilling) are very similar to those used for onshore drilling. In contrast to onshore drilling, the functional scheme for offshore drilling is complicated by the presence of a water column between the wellhead and the drilling rig. This paper gives an overview of existing offshore drilling rigs: fixed, semi-fixed and mobile platforms. It also includes description of pros and cons of such offshore platforms.

1 Introduction

Russia is the world's richest country in terms of offshore oil and gas hydrocarbon reserves. Field operations with said reserves are carried out on the shelf of the Western Arctic and Far Eastern seas (foremost in the Barents Sea and off the coast of Sakhalin).

Offshore drilling is much more difficult and expensive than drilling on shore. Specific hydrological and meteorological conditions of the sea limit the possibilities and reduce the efficiency of drilling methods, equipment and technologies used during onshore drilling. Therefore, efficiency gain during offshore drilling remains one of the key problems in the process of involving offshore mineral resources into production.

New technologies are evolving at a rapid pace. Designs of mobile, semi-submersible, floating drilling rigs are already well-known. The conditions of platform construction in the open sea at great depths require that it can be dismantled quickly during its relocation and subsequent operation at another field.

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Russian shipyards are planning to increase the output. According to the forecast of the Ministry of Energy, the number of offshore platforms on the Russian shelf will reach 30 units by 2030. By 2024, 100 projects aimed at development and exploration drilling shall be implemented under current commitments.

In 2020, there were 15 drilling platforms operating on the Russian shelf. Eight of them were fixed production platforms designed for drilling of oil and gas wells, and the other seven were drill ships, designed for well drilling. As of 2023, the Russia has as many as 11 floating drilling rigs.

All offshore drilling rigs (platforms) can be divided into three main categories: fixed — permanent foundations, decks, artificial islands; semi-fixed – floating (jack-up) drilling rigs; mobile – drilling ships, barges, and other floating devices (semi-submersible rigs).

2 Main categories of offshore drilling platforms

2.1 Fixed platforms

A fixed offshore drilling platform is a structure that consists of a topside and a supporting structure. It is fixed in the seabed. The design features of such systems may vary, so several types of fixed rigs are recognised [1–3]:

- Gravity-based — the stability of these structures is achieved through the own weight of the structure and ballasting.
- Pile-supported structures — they gain stability due to piles driven into the soil.
- Tension-leg platforms — the stability of these structures is provided by guy high-tension moorings or the required buoyancy.

Depending on the depth of oil and gas development, all fixed platforms are divided into deep-water and shallow-water platforms.

Fixed offshore platforms are high-rise structures, most of which are immersed in the water column. Only the working platform (deck), raised high above sea level, can be seen above the water surface. It accommodates the drilling equipment, power plants, living spaces, warehouses, lifting equipment, and helicopter pads – everything that may be required for uninterrupted operation during several months of severe weather. The platforms are usually classified as one of two types: pile-supported and gravity-based platforms. The advantages of gravity-based platforms include a significant reduction in installation time, greater safety of platform towing with good stability, the ability to make storage tanks for the production output in the platform base with zero additional costs, and the ability to relocate the bases for their subsequent operation in another field. All of those things helped double the demand for such platforms during North Sea oil fields construction in the 1970s compared to other types of platforms. The most common types of gravity-based platforms are: Doris, Condeep, Monopod.

The first gravity-based platform made of prestressed reinforced concrete was Doris Ekofisk platform (Figure 1).

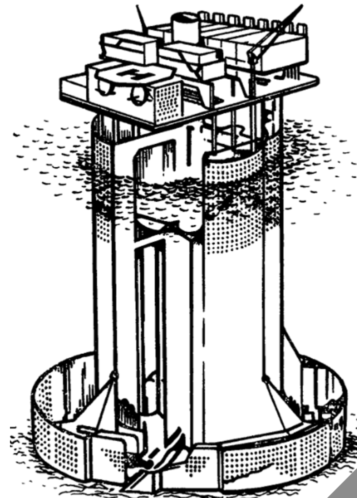

Fig. 1. Doris type gravity-based platform.

Built in 1973, this platform was installed in the North Sea at a depth of 70 metres, with plan dimensions of 50×50 m and a height of 90 m. 80,000 m^3 of concrete was used for its construction. The structure was surrounded by a perforated breakwater wall, made to absorb up to 70 per cent of water energy, which was attached to the platform by transverse braces. The structure had a diameter of 95 m [4, 5].

At roughly the same time, the French company Sea Tank built three reinforced concrete platforms: Brent C, Cormorant A, Frigg TP1. The first two were used for production drilling, oil production and storage, the latter was used for gas processing. The sea depths at which the platforms were installed ranged from 100 to 140 m.

The platform "Cormorant A" included the following main parts: a square base with plan dimensions 100×100 m, 3 m thick, with 4.5 m long projections embedded in the ground and preventing horizontal movements of the platform, a lower hull 58 m high (the distance between the axes of the column was 35.4 m), consisting of 64 storage cells with plan dimensions 11.8×11.8 m each (30 cells with a total capacity of 160,000 m^3 were used for oil storage), 120,000 m^3 of concrete and 17,000 t of steel reinforcement, including 1000 t for pre-stressed elements, were used for lower hull construction; 4 columns 114 m high with a diameter of 14 m at the lower base and 8 m at the upper base.

The construction of gravity-based platforms, as a rule, is carried out in three stages. During the first stage, the lower hull is being constructed in the pit as close as possible to the site with a height that provides it with the required buoyancy as well as the required draft to guarantee that it can be removed from the pit. During the second stage, the pit wall is dismantled, then the pit is flooded with water, which is followed by partial outfitting of the lower hull afloat and construction of the columns. During the third stage, the structure is moved to a greater depth, where the finishing works are done while the platform is in submerged state [6, 7].

Sea Tank Company has performed works on the development of gravity-based platforms designed for operation at sea depths up to 600 m.

One of the disadvantages of reinforced concrete platforms is the too-great draft during towing, which required deep water fairways and significant water depth in the area of platform construction. The company “Strabag Bau AG” has developed a design of a platform, according to which, in order to reduce the draft of the platform, the upper deck would be able to be moved vertically along the columns with the help of winches and cables. One of such platforms was designed for operation in the North Sea under the following conditions: sea depth — 160 m, wave height — 30 m, wave period — 14–17 s, wind speed — 56 m/sec. The storage capacity of the platform is 160,000 m^3, the plan dimensions of the base are 130×130 m.

When the platform is being towed, the upper deck is located on the lower hull, after placement of ballast in the cells of the lower hull it starts to submerge, while the upper (displacement) deck remains afloat at all times. When the platform touches the seabed and rests on it, the top deck is lifted by ropes to a height of 25 m above sea level.

One of the unique designs of gravity concrete platforms was the Condeep platform developed by Aker Group (Fig. 2). Its foundation consists of 19 cylindrical oil storage sections on conical concrete columns protruding from the water, supporting a 4,000 m^2 working steel platform raised to a height of 30 m above sea level.

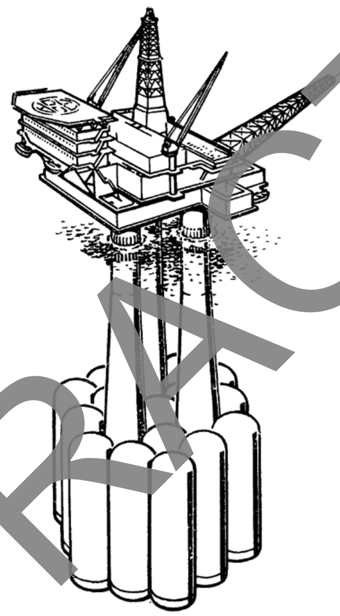

Fig. 2. Condeep type gravity-based platform.

There are several types of gravity-based platforms that combine the advantages of a reinforced concrete underwater storage facility with the advantages of a steel truss [8]. These are so-called hybrid platforms. Their distinctive feature is the possibility of simultaneous construction of three main elements of the platform at different plants and elimination of complications related to towing in shallow waters, since these elements (a bottom block which holds approximately 160 thousand tons of oil, a steel truss and a working deck mounted directly at sea) are transported separately.

One of the world's largest reinforced concrete platforms was built for the Brent field 160 km north-east of the Shetland Islands. The weight of the platform is 300 thousand tons. The depth of the sea in the area of the installation is 138 m, the deck height above the water surface is 30 m, at the base of the platform there is a 54m high chamber divided into sections of 28 m^2 each. The area of the bearing plate is 11 thousand m^2.

High-strength fixed metal platforms are mainly operated in the Arctic seas, which can be one of two types: platforms with a complicated multi-column system of support against the seabed and single-support platforms — monopods.

An example of a Monopod-type platform is a drilling rig developed by Imperial Oil for operation at depths up to 12 m. The weight of the platform is 15 thousand t.

In some structures, in addition to cylindrical columns, conical structures are used to facilitate the creep of moving ice along their inclined surface and its destruction. According to calculations, the load on a 23 m diameter cone (at water level) does not exceed 32–43 MN, which is three times less than the load applied to a 9 m diameter cylindrical column tested under similar conditions. The central cylindrical part of the platform and the frame of the lower cone are formed by a system of concentric steel pipes with a diameter of 12 m. To make the support structure stronger and more stable, during installation above the point of operation, the cavities of these pipes are filled with ice formed by freezing seawater.

A one-of-a-kind technology of underwater well drilling on the deep-water Priyamal shelf of the Kara Sea was developed by the Central Design Bureau Lazurit, Nizhny Novgorod. The technology opens up opportunities for the development of offshore oil and gas fields in the ice-covered areas of the Arctic and Far Eastern seas. The distinctive feature of this method as compared to the methods for developing onshore fields in the polar tundra is its environmental friendliness, as the soil cover is not disturbed, and its low cost.

A technology of offshore field development has recently been discovered that would make it possible in some cases to completely eliminate the use or significantly reduce the number of offshore platforms. It is known as the monodiameter well technology [9]. With regard to the Russian shelf, this technology opens the way for development of offshore fields located up to 15 kilometres from the shore or a field located onshore but with an underwater extension.

The monodiameter well technology is the most promising step in the development of expanding pipe product technologies, which are already being actively used by leading domestic and foreign oil and gas companies.

2.2 Semi-fixed rigs

Semi-fixed rigs primarily include floating drilling rigs (FDRs). A floating drilling rigs (FDRs) must comply with the following requirements:

- construction and installation works at sea within tight deadlines;
- the ability for quick relocation from one drilling point to another;
- possibility of multiple use;
- seaworthiness in a floating state for short-distance transitions in limited weather conditions and one-time transitions over long distances without limitation of weather parameters;
- the ability to be installed at the drilling point within the period of sufficient reliable weather forecast;
- autonomy, i.e. availability of sufficient materials for drilling; ensured normal living conditions for the drilling crew and other personnel who can stay at the FDR for 3–4 weeks;
- being complete with a full set of drilling equipment for drilling of an exploration or production well [10, 11].

Jack-up mobile drilling rigs (JMDR) are designed for drilling exploration and production wells. They consist of three units: floating hull (pontoon), which accommodates all process, power and auxiliary equipment, as well as tools and materials; hydraulic or electromechanical lifts; support legs.

The main advantages of this type of rigs are [12–14]: the possibility of drilling in relatively deep water due to strong support legs or open-truss legs with high transverse stiffness; applicability in a wide range of sea depths determined by the length of the retractable legs; periodic use in areas with varying sea depths and wave conditions, which improves the working conditions of support legs due to the possibility of changing the position of the periodic wetting zone, where the corrosion impact is very intensive.

The main disadvantage of this equipment is its instability when erected on weak or muddy seabed soils.

Jack-up mobile drilling rigs differ in design and shape of the body (rectangular or triangular), number (from 3 to 14) and type of support columns, and lifting systems. The support legs can be vertical or slant, the jack-ups can feature solid cylindrical or quadrangular open-truss legs. Slant legs are used to increase the base of the foundation and to ensure the required stability of the structure in the working position, in which case the rig should be equipped with a leg tilting mechanism.

The full cycle of a jack-up rig consists of the following operations: towing to the drilling point; lowering of the support legs to the seabed; pressing of the support legs into the seabed soil; lifting of the hull to the required height above sea level; preparation for the installation of a fixed unit by a crane vessel; installation of the fixed unit by a crane vessel; preparation of the drilling rig; drilling operations; preparation of the well for operation on the fixed block of the platform; launching of the rig hull; pulling out and lifting of the support legs; transportation of the rig from the drilling point.

2.3 Mobile platforms

The construction of fixed platforms involves significant financial risks in the event of unsuccessful exploration drilling. With the development of offshore oil fields at increasing depths, fixed platforms and floating drilling rigs became impracticable, as structures resting on the seabed are too bulky, metal-consuming and expensive. The above has triggered the need for the development of fundamentally new offshore oil and gas field structures — floating and mobile drilling rigs, the most widespread types of which are listed below [15–18]: submersible drilling barge; submersible base; drill ship; submersible or semi-submersible drilling rig.

Initially, submersible barges were used, which are mainly applicable in wetlands and inland water bodies with depths not exceeding the height of the side [19, 20].

A drill ship (DS) is a conventional offshore vessel with deck space and cargo capacity sufficient to accommodate a drilling rig and a stock of miscellaneous materials. Conventional transport vessels are often modified to DSs.

These features include: DS oscillations during rocking make impossible the use of a chute cleaning system with gravity flow of the drilling fluid, so the drilling fluid circulation system should have closed forced circulation; as a rule, only one well is drilled from one DS rig, which eliminates the need to install a derrick with travelling crown blocks or a tilting derrick; during DS drilling operations, due to ship oscillation, it may be difficult or even impossible to install drill pipes on the rack inside the derrick during launching and lifting operations, which is why mechanised racks are used to speed up the assembly and disassembly procedures. When such racks are used, the pipe feeding to the bridges from the warehouse (racks on the DS deck) is done mechanically; the drilling rig is usually electrified, i.e. all mechanisms are electrically-driven.

Since the early 60s, drill ships with special submerged hulls (so-called semi-submersible drilling rigs (SSDRs)) have been put into operation. The SSDR hull has three main elements:

- pontoon;
- columnar legs;
- upper working platform.

During transportation, the SSDR (Figure 3) floats on pontoons with minimal ballast. Then, the structure takes ballast into pontoons at the drilling point, after which it is submerged to the specified depth. In the operating position, the pontoons are underwater and the upper working platform is above water [21].

The main advantages of floating platforms are as follows: SSDRs and DSs are fully manufactured at shipyards, including the installation of field and drilling equipment; no more need to construct bulky and expensive hydraulic structures based on the seabed; special-purpose vessels have high seaworthiness, which enables them to move afloat to the area where the next well is to be drilled after completion of drilling operations at one location; it is possible to use the same rig for well drilling in a wide range of sea depth variations.

The main advantage of these rigs is the possibility of their being used on weak seabed soils, as the presence of an independent pontoon resting on it provides significant reduction of the soil pressure, while their main disadvantage is the high location of the centre of gravity of the base, which makes the rig unstable when afloat, in particular in stormy weather and in deep water.

During its towing to a new location, the platform is pre-submerged to a certain depth and finally lowered to the seabed at the drilling point. According to practical experience, the platform positioning over the centre of the well can be done within an accuracy of a few inches. This complicated operation is carried out with the help of a special mooring system.

Fig. 3. Floating semi-submersible drilling rig Polar Star.

3 Conclusion

In conclusion, it should be noted that the vastness of the Russian shelf is immense, which is why the task of development of high-tech, cost-effective and efficient hydraulic structures such as oil and gas production platforms will always remain relevant, especially in the Arctic conditions.

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