Купить книгу "Theory and Technology of Drilling Engineering"

Zhichuan Guan
Tinggen Chen
Hualin Liao

Theory and Technology of Drilling Engineering

中国石油大学出版社
CHINA UNIVERSITY OF PETROLEUM PRESS

Springer

Drilling Rigs and Tools

2

Abstract

This chapter discusses the components and functions of a drilling rig and drilling tools. A drilling rig usually has six necessary subsystems classified as hoisting system, rotary system, circulating system, well control system, power and transmission system, and monitoring systems. Drilling tools are used to describe drill strings and drill bits for rock breakage in a wellbore. A drill string usually consists of kelly, drill pipes, drill collars, and other tools such as stabilizers and reamers, which are included in the drill string just above the drill bit.

2.1 Drilling Rig

A drilling rig is a complete set of drilling equipment for oil and gas exploration and development. It is a joint multi-functional working unit consisting of many kinds of machines. To satisfy the demand of drilling technology, the whole set of drilling rig has six basic systems classified as power system, hoisting system, circulating system, rotary system, well control system, and monitoring system. And the abilities of tripping, rotary drilling, and circulating the drilling fluid must be possessed.

To adapt to various geographical environment and geological conditions, various special drilling rigs have appeared in recent years, such as desert drilling rig, cluster drilling rig, inclined well-drilling rig, top drive drilling rig, slim-hole drilling rig, and coiled tubing drilling rig and so forth, which are called individual drilling rigs.

Since the 1990s, China has independently developed a series of different types of specialized drilling rigs, forming a diversified system of oil drilling rigs. After producing the first new electric drive drilling rig ZJ70D, some new oil drilling equipment has been built, including the world's first artificial island 7000 m circular orbit mobile module drilling rig, and the ultra-deep drilling rig with the designed drilling depth of up to 12,000 m.

© China University of Petroleum Press and Springer Nature Singapore Pte Ltd. 2021

Z. Guan et al., *Theory and Technology of Drilling Engineering*,
https://doi.org/10.1007/978-981-15-9327-7_2

2.1.1 Requirements of Drilling Technology to a Drilling Rig

The configuration of rig equipment is closely related to the drilling methods. Currently, the drilling methods widely used in the world are the rotary drilling method, that is, using drilling string hook, traveling block, crown block, top drive system (TDS), winch to trip the drill string; using drill pipe to deliver the drill bit to the bottom; using the rotary table or top drive system to make drill string and drill bit rotate, or using a downhole motor to make drill bit spin directly; using bit turning to crush the rock-forming borehole; using mud pump to circulating high-pressure drilling fluid and bring out the debris from the bottom.

Rotary drilling method requires the drilling machinery and equipment to have the following three necessary abilities.

2.1.1.1 The Capability of Rotary Drilling

Drilling technology requires the drilling machinery and equipment to provide a specific torque and speed for drilling tools(drill string and drill bit) and maintain a certain weight on bit (the gravity of drill string acting on drill bit).

2.1.1.2 The Capability of Tripping

Drilling technology requires the drilling machinery and equipment to have a specific lifting capacity and lifting speed, which can trip-in and out all drill strings and casing strings.

2.1.1.3 The Capability of Wellbore Cleaning

Drilling technology requires the drilling machinery and equipment to have the capacity of cleaning the bottom and carrying rock debris. The system could provide relative high pump pressure to make drilling fluid through drilling strings flow to bit nozzle, wash the bottom of the well, return to the wellhead through borehole annular space, and bring the cuttings out.

Besides, considering the flexibility of drilling operations, the drilling equipment should be easily installed, disassembled, and transported. The application and maintenance of the drilling rig must be simple and easy, and the vulnerable parts of the drilling rig should be easy to replace.

The configuration of the drilling rig device and the working ability and the technical index of various equipment are determined by the above three basic requirements of drilling technology to drilling rigs. The basic parameters of the drilling rig put forward the conditions about the torque and power of the rotary table, the lifting weight, and control of the hook and the permissible pump pressure and power of the mud pump. In these three sets of parameters, the torque of the rotary table, the lifting weight of the hook, and the permissible pump pressure of the mud pump are all limited by the strength of the machine parts.

Under the condition of the strength satisfying the requirements of operation, the rotary table should provide a specific rotating speed, the hook should give an appropriate lifting speed, and the mud pump should provide a certain displacement and pump pressure.

Otherwise, the drilling operation cannot go smoothly. The joint requirements of the torque and rotating speed of the rotary table, the lifting weight and lifting speed, and the pump pressure and displacement are the ones for the power and strength of the working machine. To ensure a specific rotating speed, lifting speed, and displacement, the engine should supply a certain required amount of power to the drilling machinery.

2.1.2 The Primary Working System of a Drilling Rig

The working system of the drilling rig is vast, and the working conditions and working characteristics of each unit are different. According to the requirements of rotary drilling method to a drilling rig, drilling rig mainly includes hoisting system, rotary system, circulation system, well control system, power and transmission system and control system, in which hoisting system, rotary system, and circulation system are three primary systems directly serving the drilling process and are the essential working systems of the drilling rig. The hoisting system, rotary table, (or top drive system) and mud pump are known as the three primary working machines of the drilling rig.

2.1.2.1 Hoisting System

To trip the drilling tools, lower the casing, control the drilling load, feed into a bit, and so on, drilling rigs are equipped with hoisting system to assist operations of drilling and completion. This set of equipment mainly is composed of drawworks, auxiliary brake, traveling system (including wireline, crown block, traveling block), hook, and derrick, besides, wellhead tools and mechanized equipment for tripping operation(such as rings, elevator, slip, power tong, stand transfer mechanism.).

Derrick

- Major functions of derrick

The derrick is an essential part of the oil drilling rig. It is a metal truss structure with a certain height and space, whose primary functions include

– Set the crown block, hang the traveling block, hook and specialized tools (such as tongs), and trip the drilling tools and lower the casing during the drilling.
– Used for depositing the stand during the process of tripping. The total length for depositing stands is called stacking stand capacity.

- Compositions of derrick

The derrick is mainly composed of the following six parts.

– The main body of derrick is mostly the space truss structure composed of section bar.
– Crown platform used for setting the crown block and gin pole.

– Crown frame used for installing and maintaining the crown block.
– Monkey board includes a platform for derrickman conducting tripping operation and fingerboard for depositing the stands.
– Stands platform assembles and disassembles a fire-hose operating platform.
– Working ladder.

- Properties of the derrick

The derrick should possess the following three properties:

– Enough bearing capacity, guarantee to trip a drilling string, or a casing string a certain depth. So-called enough means to be suited to hook nominal lifting weight (maximum drilling string weight) and hook maximum lifting weight equipped with the derrick.
– Enough dimensional space. The higher the height of derrick, the longer the length of the stand, which can save time; the bottom and the top of derrick should have necessary size to install the crown block and ensure the traveling system device run smoothly when tripping; guarantee that drilling floor has sufficient area to arrange equipment and install the tools, making workers operate safely and driller a good vision.
– Guarantee assembly and disassembly conveniently, and transfer quickly.

- Types of derricks

According to the main characteristics of basic structure form, drilling derricks could be divided into tower derrick, cantilever derrick, A-type derrick, and mast derrick, etc.

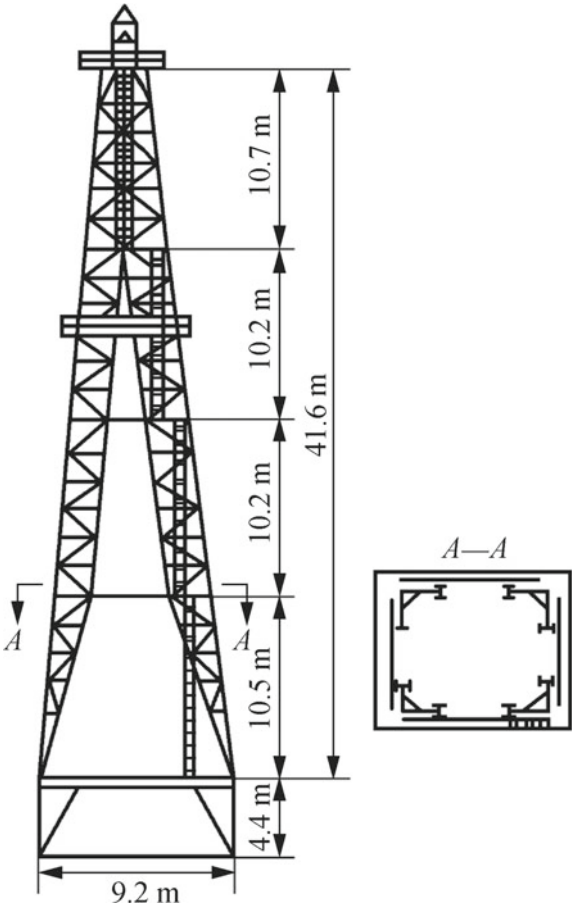
– Tower derrick.

As Fig. 2.1 shows, tower derrick is a space structure of four towers, whose cross section is usually square. The derrick itself is divided into four parallel trusses, every truss is divided into some, and tetrahedral truss at the same height in the space constitutes a layer of the derrick, so the derrick itself can be seen to consist of many layers space trusses.

The main characteristics of the integral structure form of tower derrick are

a. The derrick itself is a closed integral structure. Overall stability is excellent, and bearing capacity is large.
b. The whole derrick is a detachable structure made up of single components connected by bolts.
c. The size of derrick is not restricted by transportation conditions, allowing the vast inner space of derrick, tripping conveniently and safely. Still, assembly and disassembly work of a single piece is significant, working high above the ground, unsafe.

Fig. 2.1 Tower derrick



– Cantilever derrick (Π-type derrick)

As shown in Fig. 2.2, the main features of Π-type derrick are as follows:

a. The whole derrick body is divided into four–five sections, and each section is generally welded as an entire structure, the sections are positioned by tapered pins and connected by bolts, assembled on the ground or near the ground level, the whole derrick is lifted and placed, and transported in sections.
b. Because of the restriction of transportation size, the cross-sectional size of derrick itself is smaller than tower derrick. To facilitate traveling system devices moving up and down smoothly and depositing the stand, the derrick is made of a non-enclosed spatial structure of a front fan opening and Π-type cross section. Some of the upper parts of Π-type derrick is made into a four-sided closed structure to enhance overall stability.

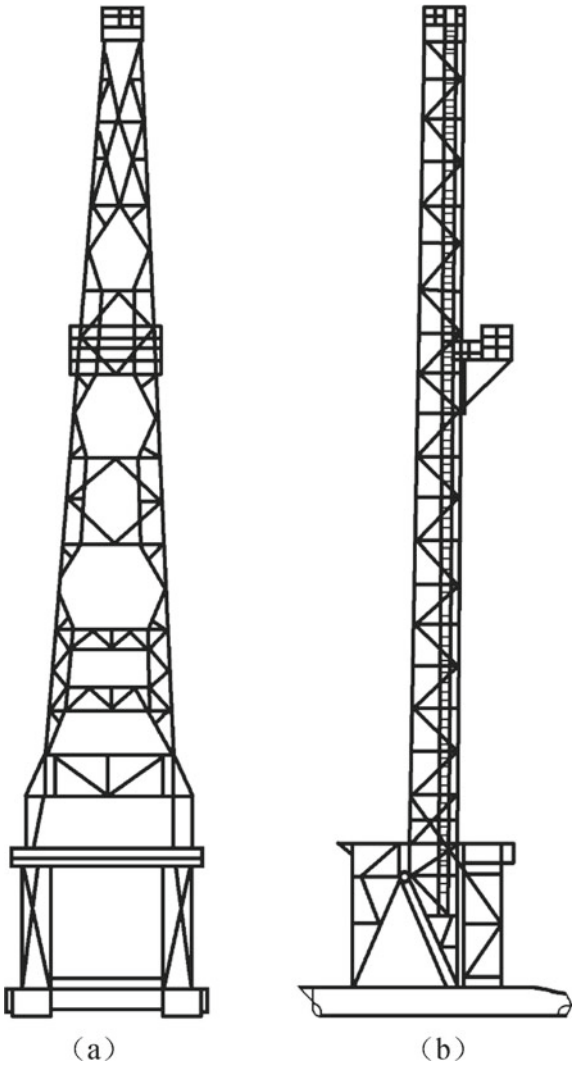


Fig. 2.2 Π-type derrick

c. The structure form of two sections of fan truss in each part of the derrick is the same. To ensure the driller has a good vision, back fan adopts different belly bar arrangement, such as rhombus and so on. Back fan crosswise bars of some Π-type derrick are composed of taper pin and detachable structure connected by the left and right side segments for the convenience of segmented transportation.

– A-type derrick

The main features of A-type derrick are as follows:

a. Two legs connect into A-type through a crown platform, racking platform, and additional rod. In front of the thigh or behind the herringbone support, it constitutes a complete spatial structure. Entire derrick is installed horizontally on the ground or near the ground, erected up and down, transported separately.
b. Legs can be spatial bar structure, divided into three–five segments. According to the different profiles, sections of legs generally are divided into rectangular and triangular. Using pipes as leg chords mostly adopt triangularly and using angle steel mainly takes square for the convenience of manufacturing. Bracing rods have a rod string structure and rectangular section welded column structure or pipe column structure.
c. Each leg of A-type derrick is enclosed integral structure, and bearing capacity and stability are relatively good. But because there are only two legs and the connection between legs is relatively weak, the overall balance of the derrick is not ideal.

Figure 2.3 indicates a transformation of A-type derrick. The upper part is made into an enclosed integral structure to enhance the overall stability of the derrick.

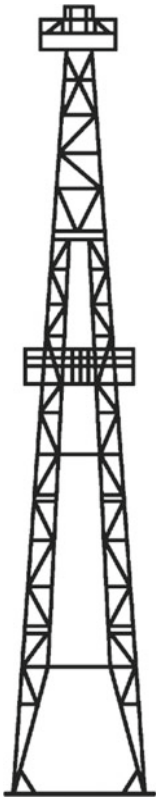


Fig. 2.3 Upper closed A-type derrick

– Mast derrick

Mast derrick is a single column derrick composed of a section or several sections rod structure or column structure, holistic, and retractable two kinds. Mast derrick generally uses a hydraulic cylinder or hoist system to erect up and lay down, which could be transported as a whole or several disassemble parts.

Mast derrick at working is tilted to the wellhead, which needs to utilize guy-wires to keep the stability of the structure to give full play to its bearing capacity. This is the critical characteristic of mast derrick integral structure.

The construction of mast derrick is portable and straightforward, but its bearing capacity is inadequate. It is only suitable for mobile drilling rigs and workover rigs.

Figure 2.4 is a retractable mast derrick of XJ250 workover rig.

– Basic parameters of derrick

The basic parameters of derrick include

– Maximum hook load
  The maximum hook load of derrick refers to the maximum lifting weight of hook without wind load and stands load, the deadline fixed in the specified position, using the specified number of drilling ropes. Max hook load includes the self-weight of traveling block and hook (max hook load of drilling rig does not include the self-weight of traveling block and hook).
– Stand load
  Stand load refers to the horizontal direction force produced by the self-weight of stands and wind load it bears to the fingerboard of the racking platform.
– Height of the derrick
  The height of the derrick is defined based on its type.

a. The height of tower derrick: the vertical height from the bottom of the derrick leg floor to the bottom of the crown block beam;
b. The height of Π-type derrick and A-type derrick: the vertical height from the pin-hole center of derrick lower base angle to the bottom of the crown block beam;
c. The height of the mast: the vertical height from the contact point of the skid seat or wheels and the ground to the bottom of the crown block beam;
d. The effective height of derrick: the vertical height from the drilling floor to the bottom of the crown block beam;
e. The height of the racking platform: the vertical height from the drilling floor to the racking platform;
f. The capacity of the racking platform: the numbers of drill pipes deposited on the racking platform (installed on the minimum height);

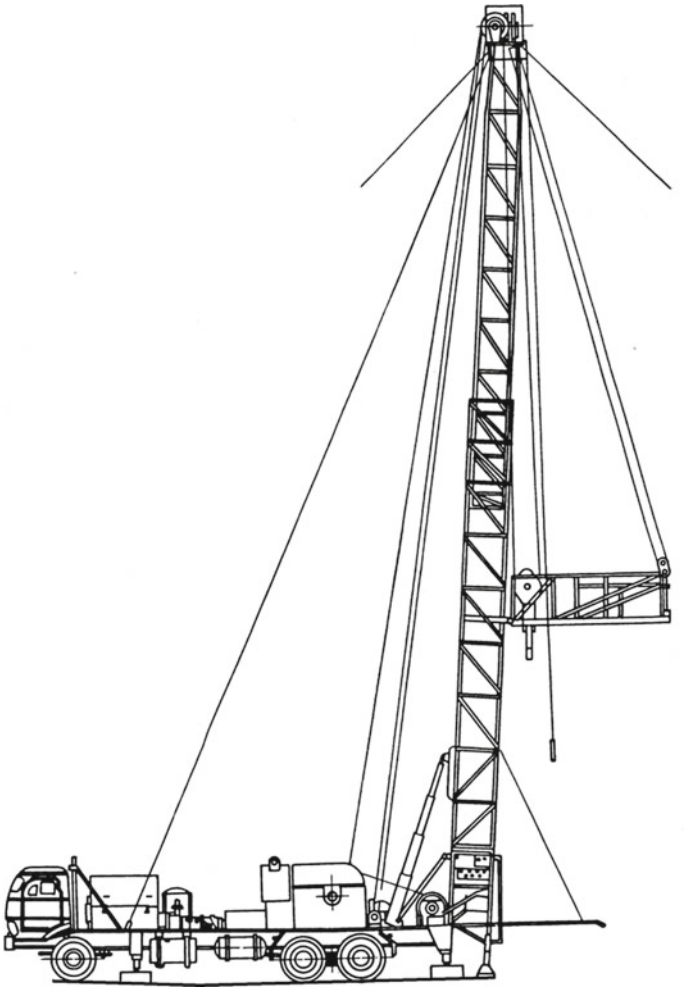


Fig. 2.4 Retractable mast derrick of XJ250 workover rig

g. The size of the upper base and the size of the lower base: the size of the upper base and the size of the lower base of tower derrick, respectively, refer to the horizontal distance between the upper and lower base axes of derrick adjacent legs. For a single angle steel leg, it refers to the distance between the outer edges of angle steel.
h. The height of V-door: The V-door opening height of tower derrick is the vertical height from the bottom of the drilling floor at the top of the V-door opening. The height of the V-door opening generally should be higher than 8 m to pull the joint to the drilling floor.