Exploration of Mechanical Problems and Improvement of Lifting System of Offshore Drilling Rig

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Abstract: Drilling equipment is a giant equipment in the upstream of offshore oil industry. As the core of offshore drilling rig, the lifting system is a very complex mechanical vibration system, its working performance directly affects the working performance of the whole rig. In order to ensure the safety of offshore drilling, we must explore the common mechanical problems and improvement measures of offshore drilling rig lifting system. This paper mainly analyzes the mechanical failure of winch, traveling system and derrick, and then proposes some improvement measures to effectively prevent these mechanical failures.

1. Introduction

The level of offshore drilling technology mainly depends on the equipment level of its drilling equipment, and the design and manufacturing level of drilling equipment, to a certain extent, reflects the production technology level and equipment manufacturing capacity of the country's petroleum industry. With the development of offshore oil, offshore platforms and equipment are unreliable and cause frequent failures. Accidents of platform collapse and casualties caused by platform overturning and explosion also happen occasionally.

As one of the three major units of the drilling rig, the lifting system is a very complex mechanical vibration system, which is the core of the drilling rig. In the initial stage of drilling rig tripping, the impact and vibration of drill string are very obvious under the action of lifting acceleration. If the dynamic load of the lifting system is too large, the drill string will be damaged. Therefore, in order to ensure the safety of offshore drilling, we must explore the common mechanical problems and improvement measures of offshore drilling rig lifting system.

2. Composition of Lifting System of Offshore Drilling Rig

Offshore drilling rig is a set of comprehensive unit to realize offshore drilling production. The level of offshore drilling technology largely depends on the equipment level of its drilling equipment. Offshore drilling rig is generally composed of lifting system, rotating system, mud circulation system, power system, blow out prevent (BOP) system, control system and auxiliary system of drilling rig. The lifting system is the core of the drilling rig, and it directly affects the working performance of the entire drilling rig. The structure of the offshore drilling rig lifting system is shown in Figure 1.

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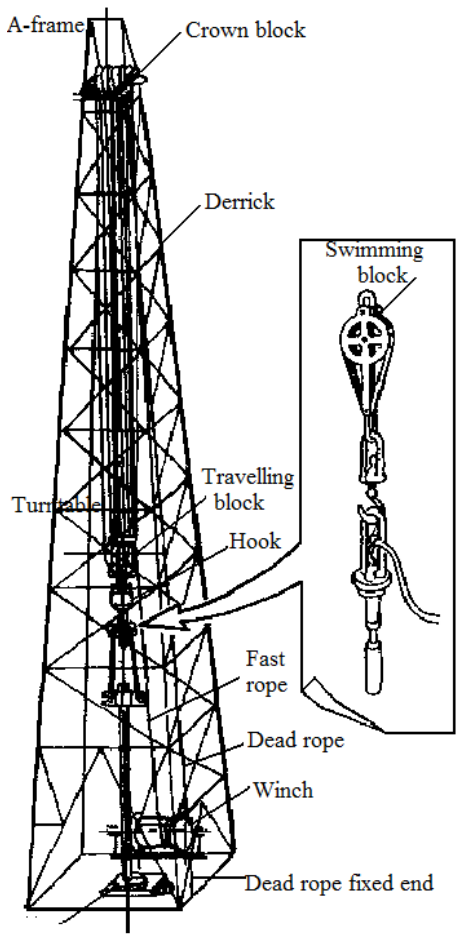

Figure 1 The Structure of the Offshore Drilling Rig Lifting System

2.1 Derrick

The derrick is a truss structure installed on the drilling platform. The main body of the derrick is welded from large-size steel into square steel with a rectangular section as the column, and the whole derrick body is connected by high-strength bolts into a whole by four uprights and several transverse webs. All exposed components are dipped galvanized to enhance the corrosion resistance of the derrick. With sufficient carrying capacity, good overall stability and spacious interior space, the derrick is very suitable for working under complicated offshore conditions.

The derrick used on the offshore drilling rig is mainly composed of the following parts:

a) Derrick body: mostly a space truss structure composed of profiles;

b) Crane tower: install the crane and heave compensation device and use it as a workbench for maintenance of the crane;

c) Racking platform: racking platform is a worktable for tripping operation and discharging standpipe;

d) Working ladder.

2.2 Crown Block and Traveling Block

In single axle crown block or traveling block, the shaft is generally double supported, and the diameter of the shaft is larger, axial and radial grease holes are drilled on the shaft, and yellow oil is introduced to lubricate the bearing. The shaft of single axle crown block or traveling block also has multiple supports, and the diameter of shaft and bearing is smaller than that of double support, and its disadvantage is that it is not easy to support uniformly.

There are three types of heave compensation devices: dead rope or fast rope constant tension heave compensation device, heave compensation device on crane and heave compensation device between big hooks of traveling block. The structure of heave compensation device on crane is shown

in Figure 2.

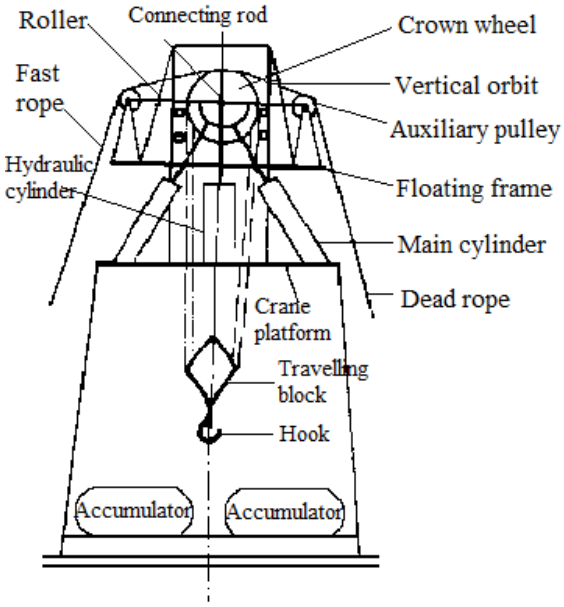

Figure 2 The Structure of Heave Compensation Device on Crane

The crane is supported by the main cylinder, and the gas of these four main cylinders is supplied by the accumulator installed on the derrick. When the platform rises, the crane moves downwards relative to the derrick along the track; when the drilling operation is performed, the crown block is locked with a locking device so that it does not move up and down with the drilling; when drilling normally, the gas pressure in the accumulator is controlled by the pneumatic regulating valve to maintain the bottom hole weight-on-bit or adjust it.

2.3 Rig Winch

Drilling winch is the key equipment of semi-submersible drilling platform. Its main function is to pull and run drilling tools, casings, risers, underwater appliances and all drilling tools and bits. The lifting capacity of rig winch is not only one of the important landmark parameters of the drilling platform, but also the reference basis for other related drilling equipment configuration. As a multi-functional crane, all types of winches have similar functional structural components in essence. The winch is generally composed of the following parts:

a) The drum and shaft assembly are the core components of the winch;

b) Braking structure, including mechanical brake and electromagnetic brake;

c) Transmission system, distributing power and transferring movement, including drive shafts, roller shafts, cat head shafts, chains, gears, shafting parts and turntable intermediate drive shafts, etc.;

d) Control system, including jaws, tooth type, starting clutch, driller console, control valve, etc.;

e) Lubrication system, including grease lubrication, drip lubrication, sealed transmission, splash or forced lubrication, etc.;

f) Support system, including welded frame type bracket or closed box type seat frame.

2.4 Brake Mechanism

The brake mechanism of the winch includes the main brake and the auxiliary brake. During normal drilling, the brake mechanism controls the rotation of the drum to adjust the weight on bit; when drilling down, it slows down or brakes the drum to control the speed of the lowering.

The auxiliary brake of the offshore drilling rig adopts electromagnetic eddy current brake. Electromagnetic eddy current brake is a new type of auxiliary brake, suitable for marine and land drilling rigs. It uses the principle of electromagnetic induction to perform nondestructive braking, and has the advantages of no wearing parts, good braking performance, long service life, simple operation and maintenance, etc.

3. Common Mechanical Problems of Offshore Drilling Rig Lifting System

Failure of lifting system equipment would cause drilling accidents. Particularly, the broken shaft of the drum and the damage of the wire rope belong to the Level II failure type, which will cause heavy losses after occurrence, and they are irreparable failures. Other component failures belong to Level III failure, which is less harmful and can be repaired. The failures level and description are shown in Table 1.

Table 1 Failures Level and Description

Failure level	Failure description	Consequences
Level I	Fatal	May cause death or system damage
Level II	Serious	May cause serious injury, serious occupational disease or main system damage
Level III	Critical	May cause slight injury, slight occupational disease or secondary system damage
Level IV	Negligible	Will not cause injury or occupational disease, and the system will not be damaged

3.1 Mechanical Problems of Winch and Its Power Equipment

Winch is composed of console, transmission system and brake system, which is the core component of the whole rig. The common mechanical problems of winch mainly appear on the brake mechanism and drum shaft.

(1) Bending and fatigue fracture of roller shaft

In the process of long-term use, the winch needs to bear various loads. The cost of offshore drilling is very high. In the process of tripping out, sometimes in order to save time, high-speed tripping may be used in case of large load of drilling tools, which may lead to serious overload of winch, bending of drum shaft and fatigue fracture.

(2) Wear of brake disc and brake block

The failure mode of brake disc is mainly caused by the friction and wear between the brake discs, resulting in the gradual thinning of its thickness. When the brake disc is worn to the extent that the brake clearance cannot be adjusted, which affects the safe operation, it will be regarded as failure. The main brake and auxiliary brake are combined to lower the drilling tool in place, and the main brake is used more frequently, which makes the brake disc wear more serious.

(3) Brake failure

If the brake fails, the light one will cause the drilling stop accident and cause economic loss. Serious accidents will result in pier drilling and drilling slippage, even equipment hitting turntable accidents, major equipment accidents and personal accidents.

3.2 Mechanical Problems of Traveling System

The traveling system mainly includes crown block, traveling block, steel wire rope, hook and other parts. The main parts that are prone to mechanical problems are wire rope and pulley block.

(1) Wire rope wear and failure

The working conditions of steel wire rope are bad, and the steel wire rope has high movement speed and large load. In the practical operation of offshore drilling rig, due to heavy and unstable load, the wire rope or wire is easy to be broken due to overload. In addition, serious wear of steel wire in high speed operation will also lead to wire fracture. When a certain section of the wire rope is twisted or bent, the strand will become more or less thick, causing it to suffer more wear when passing through the sheave. The marine environment determines that the wire rope is easy to be damaged by corrosion. In addition, poor lubrication, fatigue and extrusion fracture may lead to wire rope fracture.

(2) Improper lubrication of pulleys

Because the lubricating oil itself is not clean, there are impurities in the lubricating oil, or after a

period of use, it is unclean due to air oxidation, pollution, etc., and loses its lubrication protection. Drying of the grease in the oil passage will block the oil passage and the lubricating oil cannot enter the bearing, which may cause the bearing to burn or rotate inflexibly.

3.3 Mechanical Problems of Derrick

The derrick is the most complicated part of the entire drilling rig with the most rods, and it is also one of the weakest links of the offshore drilling rig. The derrick is often deformed under the action of wind load and other loads, which will cause safety hazards. In addition, during drilling construction, when dealing with downhole sticking engineering accidents, they will often be in conditions of excessive operation or excessive load. The most likely occurrence of the derrick is the risk of collapse, which is also the type of accident that has the most occurrences of the derrick. Once the derrick collapses, it will cause equipment damage, casualties and other consequences, and may also cause downhole drilling tools to fall and cause complex drilling accidents.

There are many reasons for the collapse of the derrick. The steel structure of the main part of the derrick is prone to damage, and corrosion and other factors can also cause the derrick to collapse. Once the load-bearing reaches or exceeds the critical value for the stability of the derrick, the derrick will suddenly lose its stability and collapse, which will bring serious consequences. In addition, according to the force characteristics of the derrick under various working conditions, if the frequency of the dynamic load acting on the derrick is close to or an integer multiple of the natural frequency of the derrick, this vibration will cause the resonance of the derrick structure, and the resulting resonance is also one of the main reasons for the collapse of the derrick. In addition, the derrick of offshore drilling rigs has been exposed to corrosion for a long time, and corrosion is also one of the reasons for the collapse of the derrick.

4. Improvement Measures of Offshore Drilling Rig Lifting System

4.1 Conduct Anti-Corrosion of Offshore Drilling Platform

Part of the mechanical problems in the lifting system of offshore drilling rigs are caused by corrosion, so anti-corrosion measures should be taken for offshore drilling platform equipment. The surface and fasteners of the platform structure need special anti-corrosion treatment, which has high anti-corrosion ability, and the anti-loose performance of bolt and nut is good. The environmental conditions, structural parts, service life, possibility of construction and maintenance of the platform should be considered in the determination of anti-corrosion measures.

The anticorrosion of atmospheric structure can only be protected by coating. Coatings with strong corrosion resistance, wear resistance, impact resistance, high strength, strong adhesion and durability shall be used, e.g. inorganic zinc rich primer, high build epoxy intermediate paint and epoxy polyamide top coat, etc. Splash zone is the most difficult area to implement corrosion protection, and the method of increasing corrosion allowance is often used to prevent corrosion in this area. After the structure is surface treated, the area should be coated with at least 0.076mn thick inorganic zinc-rich paint (or epoxy resin, neoprene) coating.

4.2 The Operating Equipment of Offshore Drilling Rigs Should Adopt Anti-Vibration Design

The working environment of the platform determines that it is impossible for its equipment to adopt a concrete foundation with a large inertial mass. The basic design of the platform's operating equipment should be strengthened to improve its stability. Moreover, the operating speed of the equipment should be far away from its resonance frequency.

4.3 The Derrick Components and Substructure Must Be in Good Condition

The derrick shall be installed in a regular manner, with complete bolts or bolts and good fastening. During drilling construction, derrick workers should regularly check the lack and tightness of derrick screws or bolts, and timely supplement and tighten them. The ladder, pedal, platform channel and

railing of derrick must be complete and firm. When working on the derrick, the derrick worker must fasten the safety belt. In case of abnormal conditions, the derrick man cannot get down from the derrick ladder, he should quickly grasp the derrick guy rope at the four corners of the derrick racking board or go down to the ground by the safety pulley.

4.4 Key Equipment Shall Be Equipped with on-Line Automatic Monitoring Device

The online automatic monitoring device is equipped to prevent the occurrence of sudden failures. The functions that the automatic monitoring device should include: displaying and recording equipment operating status characteristic parameters; alarm or shutdown when characteristic parameter exceeds limit. If necessary, an expert system can be set up to determine the location, cause and trend of the fault and propose countermeasures.

4.5 Use and Maintain Wire Rope in a Standard Way

First of all, carefully check the rope pulley, drum and guide wheel. There shall be no sharp corners or rough surfaces on the wire rope path. When the tight wire rope passes through the sharp angle or rough surface at a high speed, the wire rope will be severely damaged by scraping. If the groove is too narrow, the wire rope will automatically cut the width of the groove when passing through, which will cause considerable wear and tear. If the groove is too wide, it will not be able to properly fix and support the wire rope.

5. Conclusion

The lifting system of drilling rig is the core of offshore drilling rig, and it directly affects the working performance of the whole rig. In order to ensure the safety of offshore drilling, we must explore the common mechanical problems and improvement measures of offshore drilling rig lifting system. This paper mainly analyzes the mechanical failure of winch, traveling system and derrick, and then proposes some improvement measures to effectively prevent these mechanical failures.

References

[1] Ren X G , Bai Y , Jia L S . Cantilever beam study of offshore jack-up drilling rig[J]. Journal of Ship Mechanics, 2011, 22(5): 108-133.

[2] Kaiser M J , Snyder B . Mobile offshore drilling rig newbuild and replacement cost functions[J]. Maritime Economics & Logs, 2010, 12(4):392-429.

[3] Kaiser M J , Snyder B . The five offshore drilling rig markets[J]. Marine Policy, 2013, 39(may):201-214.

[4] Zhaopan T , Junguo H , Xiangwei W , et al. Hook up and Calculation to the HZJ70DB Offshore Modular Drilling Rig[J]. Henan ence and Technology, 2017, 10(8): 23-40.

[5] Lu M. Discussion on the Equipment Failure of the Hoisting System of Offshore Drilling Rig and Pretreatment Measures[J]. Management and technology of small and medium sized enterprises, 2018, 000(022):165-166.

[6] Ren F S , Chen S L , Zhang F . Modeling and Simulation for Lifting System of the Gear and Rack Drilling Rig[J]. 2013, 39(2): 118-138.

[7] Liu Q. Design of Fire-fighting Water System for Offshore Platform Modular Drilling Rig[J]. Chemical engineering design communication, 2019, 045(002):46.