Design and Manufacture Research of Jack-up Platform Jacking System

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Keywords: Jack-up offshore platform, Jacking system, Climbing gear, Prototype test.

Abstract. The self-promotion platform jacking system has been dependent on imported equipment for a long time, independent research and development made the jacking system. According to the characteristics of operating conditions, the static bending strength of the tooth root of the climbing gear under the storm maintenance load was checked, and the calculation results of the three strength checking methods were given and compared. The gear material is made of high-quality alloy steel 40CrNiMo, which guarantees the good comprehensive mechanical properties after the heat treatment. By improving the CNC cutting machine, CNC flame cutting process produced crude tooth, adopting the precision CNC gear milling process made of refined tooth.

Introduction

Jack-up drilling platform is an offshore mobile platform, which is an important equipment for offshore oil and gas exploration and development. Due to its strong positioning ability and good operational stability, it plays an important role in oil and gas exploration and development in the continental shelf. Jack-up drilling platform is mainly composed of hull structure, pile leg, lifting system, locking device, drilling device and living building. The lifting system is the key and core component of jack-up drilling platform, and it is also the difficulty in the design and manufacturing of jackup drilling platform. Its performance directly affects the safety performance, service performance and economy of the platform [1,2].

Some European and American countries started early in Marine engineering equipment research and development, the development of a long time, accumulated the overall construction of Marine engineering equipment and key supporting experience, monopolized the lifting device market. China has a short starting time and little experience in the development of jack-up drilling platform, so we have to rely on imported equipment. Therefore, it is very important to independently design and develop the lifting device of jack-up drilling platform [3].

Design and Analysis of climbing gear

Key Points of Climbing Gear Design

Given the load requirements of lifting unit and lifting speed, the total speed ratio of lifting unit and the selection of motor type depend on the parameters of climbing gear (modulus and number of teeth). As an important part of the output part of the lifting unit, the climbing gear meshes with the rack of the pile leg to achieve the following functions:

1) Lifting and lowering pile legs under the floating state of the platform;
2) Lifting and lowering platform when the pile leg is standing;
3) Keep the platform stable during drilling or storm conditions.

Based on the research on the parameters of climbing gear adopted by the lifting unit of jack-up drilling platform at home and abroad, the meshing transmission analysis of climbing gear and rack of pile leg was conducted, and the strength check was carried out according to relevant standards and classification society requirements. The main technical parameters of climbing gear were determined as follows: modulus \(m=100\text{mm}\); Number of teeth \(z = 7\); Alpha = 30 ° pressure Angle.

Climbing Gear Strength Check

As an important part of large torque output, climbing gear has the characteristics of low speed and heavy load. The climbing gear meshes with the rack of the pile leg for the open-type rack and gear transmission, and the working condition is harsh. Its rated design life is 225 hours, rated lifting
speed is 0.457 m/min, and the cumulative fatigue stress cycle is only 2808 revolutions. Therefore, the tooth mainly tests whether the static bending strength of the tooth root meets the requirements under the storm load. The climbing gear bearing is loaded with large torque and bending moment. It must check whether the shaft static strength under storm load meets the requirements.

Finite element analysis was used to analyze the loading torque of 3114440 Nm under storm retaining load, and the load and boundary conditions of climbing gear were detailed in figure 1. It can be seen from figure 2 that the equivalent bending stress of the climbing gear root is 560 MPa when the storm holds the load, which can meet the strength requirements.

Finite element method was used to check the static bending strength of climbing gear root under storm load. The check results are shown in table 1. It can be seen that the change of regional stress around the loaded tooth part is obvious.

Table 1. Climbing gear static bending strength check results.

| Strength check method | Root stress/MPa | Safety factor | Allowable safety factor |
|-----------------------|-----------------|---------------|------------------------|
| GB/T3480-1997         | 1133.63         | 1.41          | 1.25                   |
| DNV NO.41.2           | 1338.4          | 1.27          | 1.25                   |
| The finite element method | 560          | 1.43          | 1.11                   |

**Mechanical Test of Materials**

The materials of quenched and tempered gears adopt 40CrNiMo, in which the shape of climbing gear is more complex, and it can bear the large output torque of lifting unit. The tooth part and shaft part of climbing gear have higher mechanical performance requirements.

Confirmation test scheme for climbing gear shaft: the dimensions of tensile test samples and impact test samples shall be implemented according to the classification society's specifications, and 5 sets of mechanical performance test samples shall be taken. Sample 1 and sample 2 from the shaft end, between 180 ° vertically; Sample 3 and sample 4 were taken from different alveolar, longitudinal; Sample 5 was taken from the tangential direction near the root of the tooth.

In order to ensure the quenched and tempered hardenability and uniformity of the finished tooth shape, the tooth part of the climbing gear is first roughened and then treated with quenched and tempered heat treatment (see figure 3-4). The test results show that a series of technological measures can ensure the climbing gear material to achieve the required mechanical properties.
Lifting Unit Manufacturing Technology Research

Crude Tooth

The coarse teeth of climbing gear (see figure 5) are cut by oxygen-gas numerical control flame. Climbing gear tooth width of 300mm, wide width, in order to adapt to the requirements of flame cutting large modulus gear rack, CNC cutting machine to improve the linear precision of its guide rail, running accuracy and running stability, and increase the air source pressure. Cutting with oxygen, acetylene and propane.

![Figure 5. Crude tooth.](image)

Refined Tooth

CNC planer milling machine is adopted to process refined teeth. The process planning and implementation are as follows:

1) Draw CAD tooth shape of climbing gear. The involute profile of the climbing gear is drawn with certain accuracy, which is usually fitted by spline curve, and the accuracy deviation is controlled at 0.001mm and below.
2) Generate numerical control program from CAD tooth shape. The CAD profile is generated by nc program software.
3) Alignment of climbing gear. Clamping climbing gear on the worktable with special tooling, CNC gantry milling machine tool alignment, to ensure that the final tooth shape machining tooth part axis and climbing gear shaft center line coaxiality control in the required accuracy range.
4) Fine milling teeth. CNC precision milling teeth (Fig. 6), the processed climbing gear tooth surface is in good condition, the tooth surface roughness can be controlled in R_a 6.3. The length and deviation of the common normal are controlled within the range of technical requirements, and the variation of the common normal of each climbing gear is controlled within 0.25mm. In addition, the hardness of tooth surface and root was tested to meet the technical requirements.

![Figure 6. Refined tooth.](image)

Conclusion

1) The climbing gear material is 40CrNiMo of high quality alloy structural steel, which has good comprehensive mechanical properties after tempering and heat treatment and is suitable for manufacturing large section parts. According to the characteristics of working conditions, the static
bending strength of climbing gear root under storm load is checked, and the results of three strength checking methods are given and compared.

2) CNC flame cutting process is adopted for rough teeth. By improving the CNC cutting machine, the machining capacity and precision are improved. A reasonable process is developed.

References

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