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Structural Analysis of High-power Cycloidal Pinwheel Drive for Drilling Rig Winch

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Abstract: Because the maximum power that can be transmitted by the ordinary cycloidal pinwheel reducer cannot meet the transmission applied to the drilling rig winch, the transmission part is improved, and the high-power cycloidal pinwheel transmission mechanism is designed. The three-dimensional model of the cycloidal pinwheel transmission mechanism was drawn by SOLIDWORKS software, the design of the two-piece cycloidal wheel in the ordinary cycloidal pinwheel reducer was changed to four cycloidal wheels, the needle tooth shell was partially reinforced, and finally the strength finite element analysis of the needle tooth shell and cycloidal wheel structure of the cycloidal pinwheel transmission mechanism was carried out by ANSYSWorkbench finite element software. Through the improvement, compared with the ordinary double-piece cycloidal pinwheel structure, the stress and deformation are reduced by 68.7% and 57%, and this new structure is more suitable for high-power cycloidal transmission.

Keywords: Drilling rig winch; High-power cycloidal transmission; four cycloidal wheels; Finite element analysis.

1. Design Background

In order to meet the needs of the on-board drilling winch of shallow wells, medium and shallow wells and small boreholes, it is necessary to reduce the weight and volume of the drilling rig winch as much as possible under the premise of maintaining the original normal function of the drilling rig winch.

Consult the relevant information and find that the cycloidal pinwheel transmission mechanism as a kind of transmission machinery that adopts the KHV less tooth difference transmission principle and cycloidal needle tooth meshing, due to its many advantages such as large number of simultaneous meshing teeth, compact structure and small size, high transmission efficiency, etc., has been widely valued at home and abroad, and is widely used in the driving and deceleration transmission mechanism in the fields of textile printing and dyeing, light industry and food, metallurgy and mining, petrochemical industry, lifting and transportation and construction machinery.

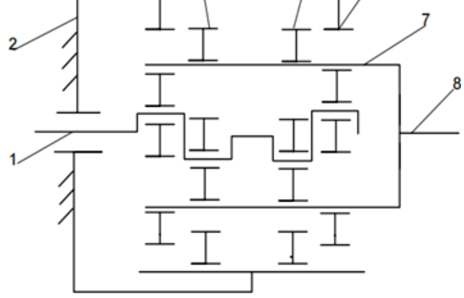
At present, the transmission power of the domestic cycloid pinwheel planetary drive is less than 132kW, and the transmission power of the ordinary horizontal direct-connected one-stage cycloidal pinwheel planetary reducer is lower, which is completely less than the output power required for the transmission of the drilling rig winch.

2. Transmission Scheme Design and 3D Modeling

According to the oil drilling rig winch standard SY/T5609-1999, it can be known that the maximum fast rope tension of the 10-level drilling rig winch needs to be 115000N, and the diameter of the drum is set to 0.4m, therefore, the torque of the output shaft of the drilling rig winch drum needs to be at least T(N•m)=23000, and the transmission ratio of the high-power cycloidal pin wheel reducer for the drilling rig winch is designed and calculated. According to the formula of formula 2-1 for calculating the output torque of the general reducer, the data T=23000N•m, P=120kw, n_H=1480r/min, η=0.9, and i =33 are obtained

$$T\ (N\bullet m) = 9550\frac{P}{n_H}\bullet i\bullet \eta \tag{2-1}$$

Referring to the introduction of the structure of the planetary transmission of large cycloidal pinwheels in the new edition of the mechanical design manual by Academician Wen Bangchun, an academician of the Chinese Academy of Sciences, it is proposed that under the same radial size, as long as the axial size is slightly greater than the width of the two rotor bearings, the transmitted power and torque can be doubled. In this paper, the structure is changed on the basis of the ordinary two-piece cycloidal pinwheel transmission, and the high-power cycloidal pinwheel transmission mechanism of the four-piece cycloidal wheel is designed, the input power is P=120kw, the input speed is n_H=1480r/min, and the transmission ratio is i =33, and its motion diagram is shown in Figure 1, the basic parameters are shown in Table 1, and the three-dimensional model is shown in Figure 4.5.6.



1. an input shaft; 2 needle tooth shells; 3. Cycloidal wheel No. 1; 4. Cycloidal wheel No. 2; 5. cycloidal wheel No. 3; 6. Cycloidal wheel No. 4; 7 pin pins; 8 output shafts

Figure 1. Schematic diagram of the movement of cycloidal transmission

Table 1. Basic parameters of cycloidal needle tooth transmission

Parameter Name	Parameter Value	Parameter Name	Parameter value
The number of cycloidal teeth	33	the number of pins	34
The number of pinwheel teeth	34	the cycloidal tooth width	60
The diameter of the center circle of the pinwheel	640	the diameter of the cycloidal pin hole	100
Eccentricity	7	short amplitude factor	0.74

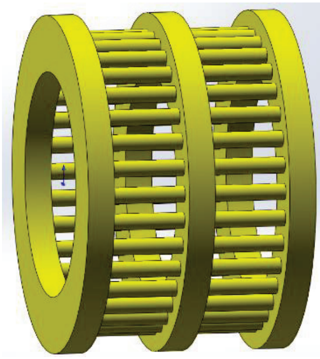


Figure 2. Geometric Model of Needle Gear Shell

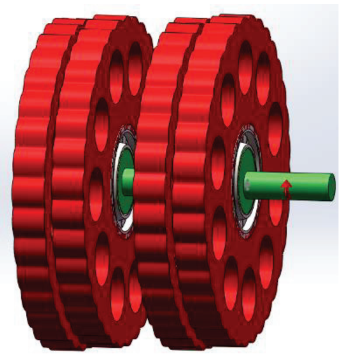


Figure 3. Geometric model of cycloidal wheel

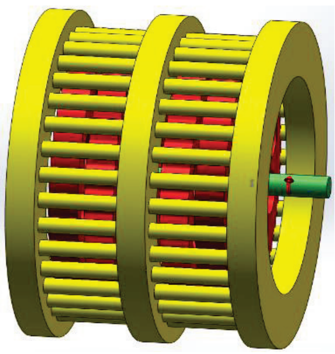


Figure 4. Cycloidal Pinwheel Transmission Model

3. Finite Element Analysis of Key Components

Based on the finite element analysis method, the contact state of the cycloidal wheel and the needle wheel under the loading condition is studied, and the analysis can quickly find the critical point of the structure, that is, the position where the maximum stress and deformation occur, and determine the possibility of failure, so as to facilitate better improvement of the structural design.

3.1. Model import and simplification

The simplification of these models is often crucial, and if they are not simplified, they may not pass the software check, and if the inspection needs to be very small, and the smaller the element, the longer the computer will take to solve, which will not work. Therefore, the model is simplified as follows:

1. The needle tooth and the needle tooth shell are made into an integrated design, eliminating the need to add bearings at both ends of the needle tooth in order to reduce friction;

2. The input shaft and the bearing, and the bearing and the cycloidal wheel are regarded as one.

In the SOLIDWORKS software environment, save the built 3D model in .x_t format, and it can only be named in English and cannot contain Chinese name, otherwise it is difficult for the system to recognize, and then import it into ANSYSWorkbench software, select the entity format for display.

3.2. Meshing and Material Attribute Settings

Due to the large size of the cycloidal wheel and the tooth, in order to facilitate convergence, the mixed division method of tetrahexahedral is selected, the 5mm mesh is selected for the tooth part, the 10mm mesh is selected for the contact surface of the cycloidal wheel, and the automatic default mesh is selected for the surface of the remaining parts.

Because the needle teeth and cycloidal wheels are wear-resistant parts, relying on friction between each other to transmit power and speed, so the choice of GCr15 steel, that is, the representative steel grade of high carbon chromium bearing steel, its quenching and tempering hardness is high and uniform, with high wear resistance, high elastic limit and high contact fatigue strength, the basic parameters of CGr15 material are shown in Table 2.

Table 2. Basic data of GCr15 material of high-carbon chromium steel bearing steel

Material Name	High Carbon Chrome Steel Bearing Steel (GCr15)
Density	7850kg/m3
Hardness	HRC58~62
Young's modulus	2.19e+11
Poisson's ratio	0.3
Allowable safety stress σ_{HP}	1000~1200MPa

3.3. Boundary conditions and load application

Before applying the load, the two end face support of the needle tooth shell are selected according to the general working state. Because it is a static analysis, and in order to ensure the safety and reliability of the structure, the huge torque transmitted by the input shaft is directly applied to the cycloidal wheel, so as to completely reflect the force deformation of each part of the structure when the cycloidal wheel transmits torque.

Each cycloidal wheel in the ordinary double-piece cycloidal wheel will bear 0.55 torque (is the total torque transmitted), which is approximately equal to 12929, and each cycloidal wheel in the improved four-piece cycloidal wheel will bear 0.3 torque, which is approximately equal to 7053.

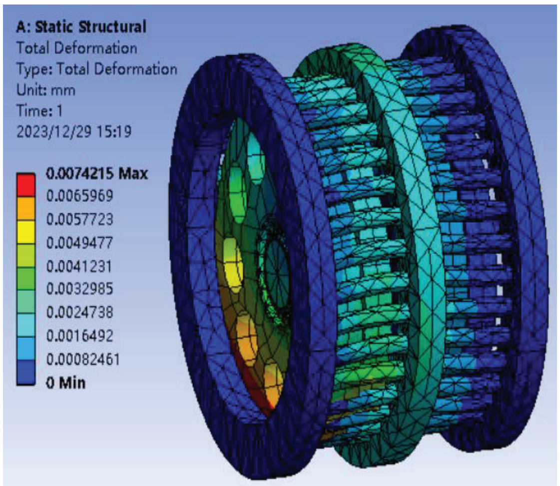


Figure 5. (only two swing wheels) deformation cloud map of total load bearing

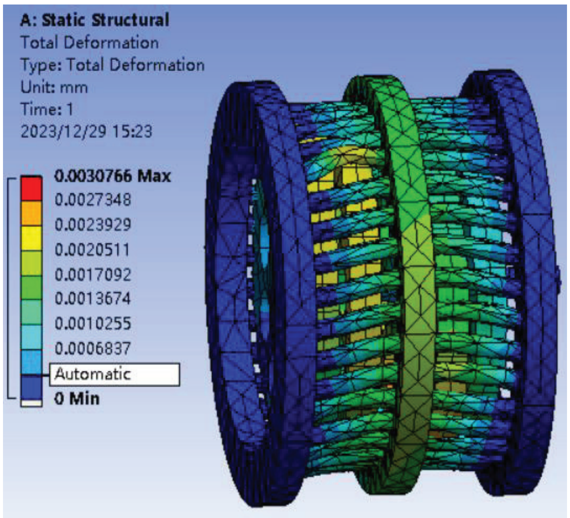


Figure 6. (Cloud diagram of load deformation borne by four swing wheels)

From the cycloidal pinwheel deformation cloud diagram of Fig. 7 and 8, it can be seen that the maximum deformation of the ordinary double cycloidal wheel is 0.007mm, and the maximum deformation of the four-cycloidal pinwheel is 0.003mm, which is reduced by 57% compared with the ordinary double-cycloidal wheel transmission mechanism. It can be seen from the two deformation contours that relative to the whole structure, in the process of transmitting torque, the largest deformation is the cycloidal wheel, not the needle teeth, so although the needle teeth are stressed more, the structure is stable, and under the same interaction force, in the high-power cycloidal pinwheel transmission design, the torque transmitted along with the cycloidal wheel is greater, and the structure of the cycloidal wheel should need to be strengthened.

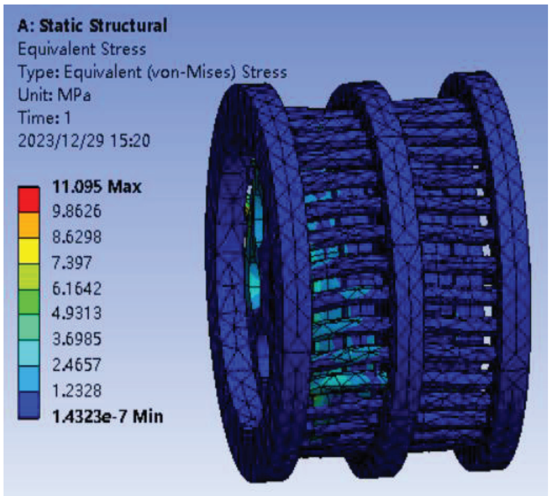


Figure 7. (stress cloud map of the total load borne by only two swing wheels)

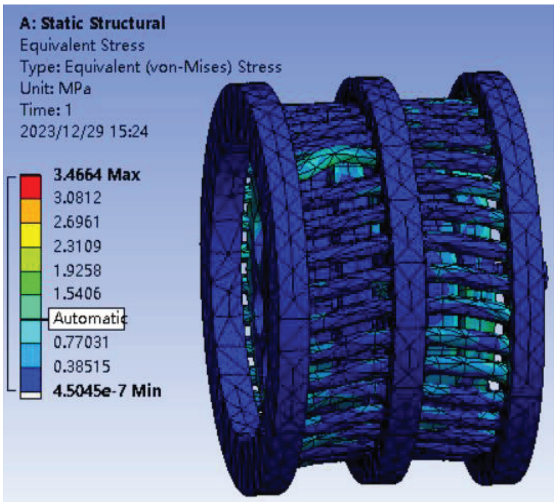


Figure 8. (Cloud Chart of Load Stress on Four Cycloidal Gears)

It can be seen from the stress contour diagram of the cycloidal pinwheel in Fig. 9 and 10 that the maximum stress of the ordinary double cycloidal wheel is 11.095MPa, and the maximum stress of the four-cycloidal pinwheel is 3.466MPa, which is 68.7% less than that of the ordinary double-cycloidal pinwheel transmission mechanism. In summary, it can be seen that when transmitting the same torque, the four-cycloid wheel has significant structural advantages, with smaller structural deformation and less stress.

4. Conclusion

(1) When designing the needle tooth shell structure of high-power cycloidal reducer, compared with the traditional two beams, it can be considered to add a circle of beams in the middle position, and the design width of the beam is kept as much as possible with the thickness of the front and rear beams of the needle tooth shell, and the advantages of this design will be more significant in the process of high-power and high-torque transmission.

(2) Because the four-cycloid structure bears less stress, the contact surface between the cycloid wheel and the needle teeth will produce a small deformation, thereby indirectly improving the meshing rate of the cycloidal needle wheel transmission, which also improves the transmission efficiency and reduces the mechanical energy loss.

(3) Whether it is an ordinary double cycloid structure or a quadrichoidal structure, the maximum stress occurs at the needle tooth part, so it is necessary to pay attention to the structural strength of the needle tooth part, and different materials can be used for the shell and the needle tooth part

(4) Under the condition of satisfying the volume limit, from the economic consideration, the four-cycloid pinwheel bears less stress, so it is not necessary to consider the expensive and wear-resistant bearing steel material.

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