Strength analysis of feeding device of coal-bed methane truck-mounted drilling rig

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Abstract. Feeding device is the main working part of coal-bed methane truck-mounted drilling rig. In this paper, through analyzing the structural strength characteristics of the feeding device of the CBM truck-mounted drilling rig, the secondary feeding device and the pulley frame, which are the main bearing components, are selected for strength analysis. The three-dimensional model of the feeding device drawn by solidedge was imported into ABAQUS and the finite element model was established to analyze the main load-bearing parts under the limit condition of strong pulling. The analysis shows that under this working condition, the strength of the feeding device fully meets the design requirements. Finally, through the physical prototype performance test, the strength analysis results of the feeding device of the CBM drilling rig are verified.

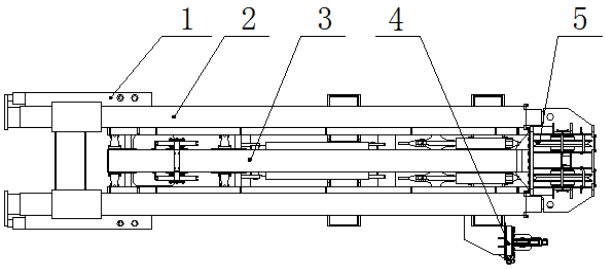
1. Introduction

CBM truck-mounted drilling rig has the advantages of fast drilling speed, simple operation, convenient auxiliary operation, suitable for a variety of drilling processes, convenient disassembly and transportation, and is widely used in CBM extraction hole construction [1,2] .

The feeding device is the main working part of the coal-bed methane truck-mounted drilling rig. Ensuring its reasonable functional structure and high structural strength plays a vital role in the overall performance and safe operation of the drilling rig. Most of the CBM truck-mounted drilling rigs adopt mast type tower. According to the installation and working mode of the power head, the drilling tower of the CBM truck-mounted drilling rig mostly adopts the front opening structure [3]. The main structure is designed as a truss structure or a solid-web structure. The feeding device of CBM drilling rig designed in this paper adopts the double-speed structure of steel wire rope of telescopic feeding mechanism with solid-web structure as the main body, which has the advantages of short device and long stroke, and is easy to transport [4-6].

2. Overall structure

According to the drilling process characteristics of the CBM truck-mounted drilling rig, the overall structure of the feeding device of the CBM truck-mounted drilling rig is designed as shown in Figure 1, mainly including: mechanical support, secondary feeding, primary feeding, auxiliary boom, pulley frame, etc.



1-Mechanical support 2-Secondary feed 3-Primary feed 4-auxiliary boom 5-pulley frame
Fig. 1 Overall structure of the feeding device

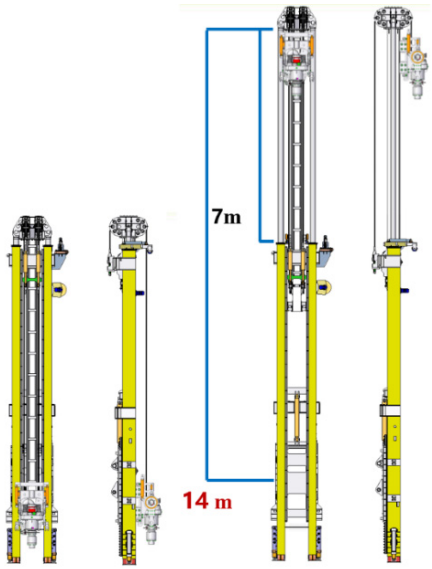


Fig. 2 working process of the feeding device

The feeding device adopts a wire rope speed doubling structure of a telescopic feeding mechanism with a solid-web structure as a main body, the oil cylinder pushes the

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first-stage feeding to slide along the second-stage feeding, and the power head is driven to move along the first-stage feeding through the wire rope speed doubling mechanism. The cylinder end of the feed cylinder is fixed with the second-stage feed through a pin shaft, and the piston rod is fixed with the first-stage feed. The structure of the feeding device can obtain long stroke on a short device, the motion is stable, and the rigidity of the device is good. The working process of the feeding device is shown in Figure 2.

The structure of the telescopic feeding device can not only meet the requirements of long working stroke and sufficient working height, but also the length of the mast of the drilling rig extending out of the chassis is very short during transportation, which is convenient for access to narrow sites [7-8].

Due to the harsh working conditions and frequent load changes in coalbed methane drilling, especially when lifting the drilling tools for the feed circuit, the load is high. Once the pipeline of the oil cylinder ruptures or leaks oil, the drilling tools it carries will accelerate and fall to the bottom of the hole, causing drilling accidents and even endangering the safety of the feed device and operators. To ensure that pipeline rupture does not affect drilling safety, protective functions are added to the inlet circuit. Explosion proof valves are installed on the rodless chamber oil port of the oil cylinder. When there is oil leakage in the pipeline, the explosion-proof valve can automatically lock to avoid drilling accidents.

3. Main performance parameters

The CBM drilling rig is mainly used for the development and construction of CBM horizontal wells and butted wells on the ground. The lifting force of the drilling rig is relatively small, but the lifting force of the drilling rig needs to be more than 100 t [9] in the drilling construction through the goaf. In the construction of opening and shallow holes, the drilling rig is required to have the ability to actively pressurize, so the feeding device has a feeding capacity of about 20 t [10] . Because of the use of standard oil drill pipe and related inclinometer, the power head of the feeding device needs 14 m of travel. In this paper, the performance parameters of the feeding device of the CBM drilling rig are determined as shown in Table 1.

Table 1 Main Performance Parameters of Feeding Device

Name	Parameter
Maximum lifting force	1000 kN
Maximum feed force	200 kN
Power head stroke	14 m
Derrick extension height	20.6m
Retraction height of derrick	13.6m
Rapid lifting system pressure	34MPa
Auxiliary hydraulic system pressure	28MPa

4. Strength Analysis of Feeding Device

As the main working part of CBM truck-mounted drilling rig, it is particularly important to ensure the reliability and safety of the feeding device. In this paper, the strength analysis and optimization design of the feeding device are carried out to ensure that its structural strength meets the design requirements.

4.1. Force analysis of feeding device model

Combined with the working principle of the feeding device of the CBM drilling rig, the stress analysis is shown in Figure 3. The feeding device is fixed on the lifting frame at the tail of the coal bed methane drilling rig through the supporting plate. The main loads applied on the feeding device are the thrust F of the oil cylinder and the tension F_1 of the wire rope. The maximum lifting force of the feeding device is 1000kN.

$$F_1=500kN \quad (1)$$

Thrust of feed cylinder

$$F=1000kN \quad (2)$$

Tension of wire rope to secondary feeding

$$F_2=500kN \quad (3)$$

The reaction force of the feed cylinder on the secondary feed upper cylinder seat is F_3 = 1000 kN, and the direction is downward. From the analysis, it can be seen that the secondary feed and pulley seat bear a large load, and the strength analysis is carried out below.

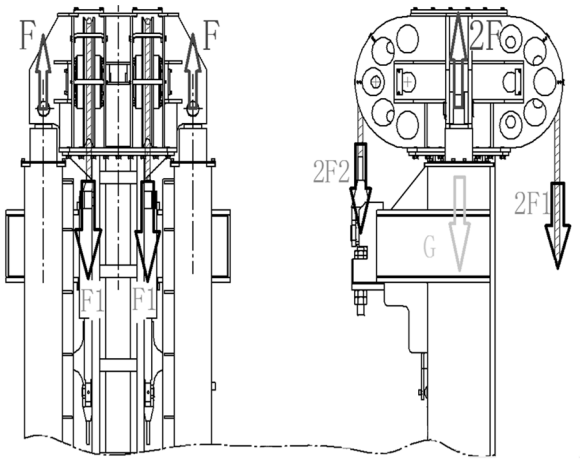


Fig. 3 Force analysis model of feeding device

4.2. Secondary feed strength analysis

A two-stage feed model is established and converted into a finite element model. In order to ensure the accuracy of the analysis and the integrity of the geometric characteristics of the model, the solid four-sided element mesh [11] is used for the secondary feeding in ABAQUS, and the overall mesh size is set as the length of the mesh element is 2 mm, so the mesh is relatively uniform. In total, 70115 grid cells and 116456 nodes are divided.

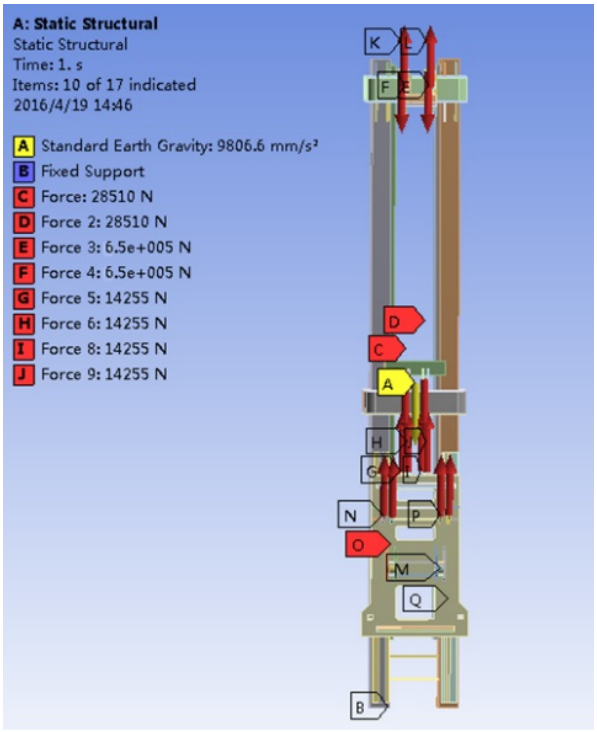


Fig. 4 Boundary Conditions of Two-stage Feeding Model

Through comparative analysis, the low-alloy high-strength structural steel Q345 with high strength, good weldability and cold bending workability is selected as the main component material of the secondary feeding.

Due to the measurement unit of mm in the three-dimensional solid modeling process of the joint body, in order to maintain unit consistency, the length and displacement units in the analysis model are in mm, the force unit is in N, and the strength unit is in Pa. The specific material characteristics are shown in Table 2.

Table 2 Material Parameters (Q345)

parameter	numerical value
Density/kg/m3	7850
Elastic modulus/Pa	2×10^{11}
Shear modulus/Pa	7.69×10^{10}
Poisson's ratio	zero point three
Yield strength/Pa	7.85×10^{8}
Tensile strength/Pa	9.80×10^{8}

According to the actual working conditions of the feeding device during drilling and in combination with the stress analysis results of the feeding device model, constraint conditions are added to the secondary feeding structure, and the final secondary feeding boundary conditions are shown in Figure 4.

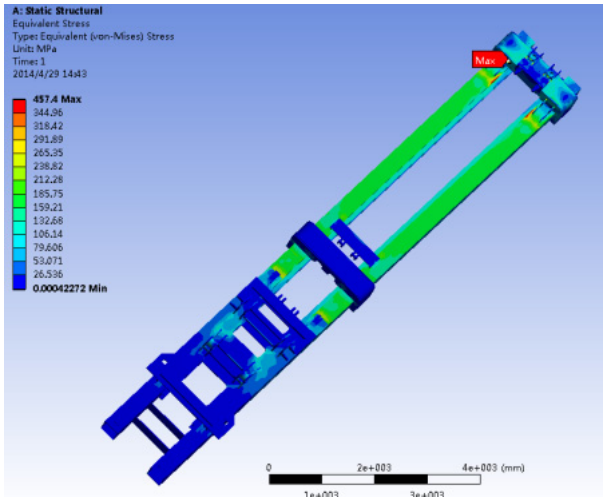
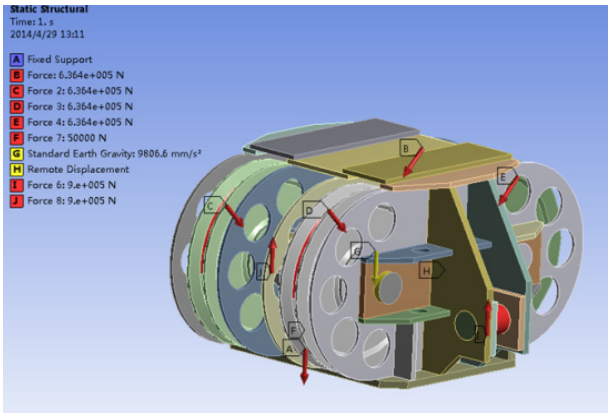


Fig. 5 Stress Diagram of Secondary Feed Structure

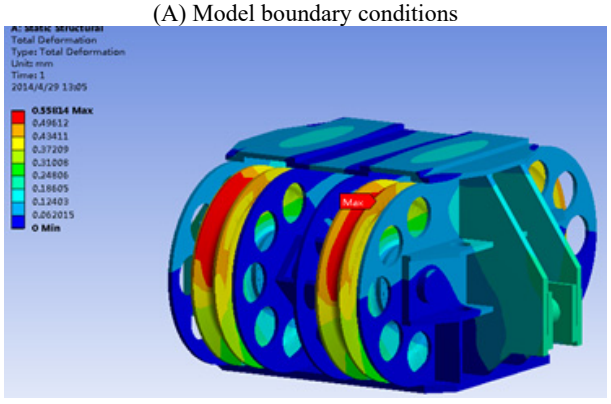
The static structure stress obtained by the finite element analysis of the static structure is shown in Figure 4. It can be seen from the figure that the maximum stress point occurs at the secondary feeding rectangular cylinder and the upper connecting plate, with the magnitude of 193MPa, as shown in figure 5, which meets the design requirements.

4.3. Pulley frame strength analysis

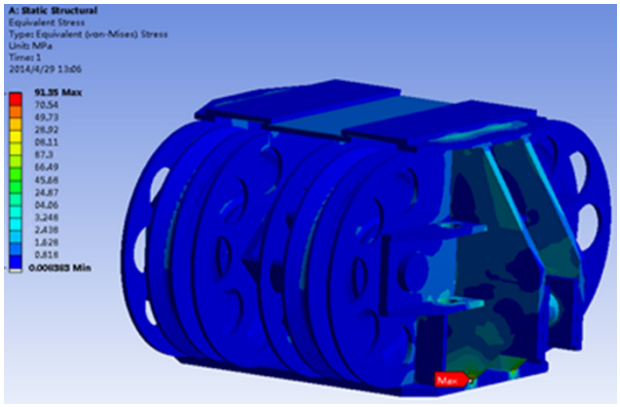
The pulley frame model is established and converted into a finite element model. Mesh it and add material properties (Q345) and boundary conditions. After static structure analysis, the static structure stress and strain are shown in Figure 6.



(A) Model boundary conditions



(B) Strain of pulley block



(C) Pulley frame stress

Fig. 6 Stress and Strain Diagram of Pulley Structure

It can be seen from the results of stress and strain that the maximum stress of the pulley frame occurs at the junction of the base mounting plate and the vertical plate, and the maximum strain occurs at the outer edge of the pulley frame wheel net, with the maximum deformation of 0.55mm; The maximum stress value is 91MPa. Pulley frame material Q345 has a tensile strength of 345MPa, which meets the design requirements [12].

5. Prototype performance test

The test rig of truck-mounted drilling rig is used to test the tensile performance of the feeding device of the truck-mounted drilling rig for coalbed methane. The maximum lifting force reaches 1000kN, and the feeding device has no deformation, which meets the design requirements. The test site is shown in Figure 7.

Fig. 7 Tension Performance Test of Tripping Grab

6. Summary

In this paper, through analyzing the structural strength characteristics of the feeding device of the CBM truck-mounted drilling rig, the secondary feeding device and the pulley frame, which are the main bearing components, are selected for strength analysis. The three-dimensional model of the feeding device drawn by solidedge was imported into ABAQUS and the finite element model was established to analyze the main load-bearing parts under the limit condition of strong pulling. The analysis shows that under this condition, the strength of the feeding device and pulley frame fully meet the design requirements. Finally, through the physical prototype performance test, the strength analysis results of the feeding device of the CBM drilling rig are verified.

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