Finite Element Analysis on Rig Bracket Rotary Shaft Based on SolidWorks

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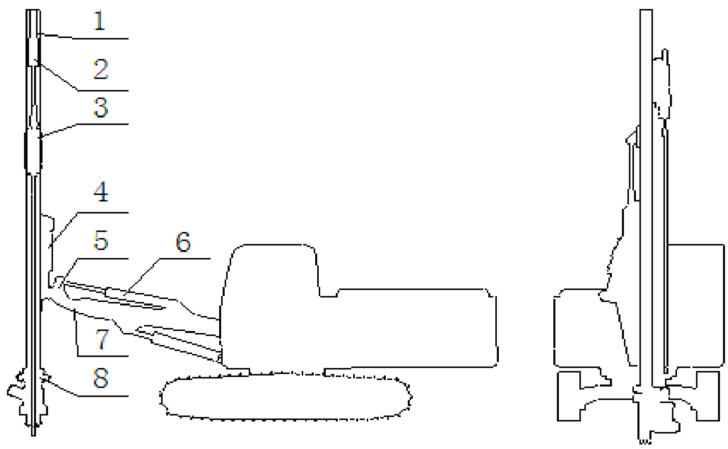
***Abstract*—Bracket rotary shaft, a major component of full-hydraulic drilling rig, is also a main force-bearing component in the conditions such as rock drilling and drill lifting. The work analyzed the intensity of bracket rotary shaft under the worst working condition of rock drilling rig and maximum load in each of the two working conditions. It provided theoretical basis for designing bracket pin.**

***Index Terms*—Racket rotary shaft; Finite element analysis; Solidworks**

I. INTRODUCTION

The main components of the full-hydraulic drilling rig in Fig.(1) consisted of propelling beam, propelling cylinder, rock drill, bracket, bracket rotary shaft, bracket cylinder, boom and drilling tool. The bracket rotary shaft played an important load-bearing role in the entire device, where its structure intensity ensured the drilling process [1-2]. In fact, the bracket rotary shaft was also the most fragile component [3]. This work established a three-dimensional model of bracket rotary shaft which calculates its structural intensity in rock drilling and drill lifting; the model served as a theoretical underpinning of the bracket rotary shaft design.



1. propelling beam 2.propelling cylinder 3.rock drill 4.bracket 5.bracket rotary shaft 6.bracket cylinder 7.boom 8.drilling tool

Fig.1. Whole structure of open-pit full-hydraulic drilling rig

1. BRACKET ROTARY SHAFT MODEL AND ANALYSIS

A. Geometric Model

When the cylinder was at rest, the effects of vibration from rock drilling could be negligible. The bracket rotary shaft bore static force; at the moment it supported the cantilever beam.

Bracket rotary shaft used material 42CrMo with yield strength σ= 930MPa and tensile strength σ= 1080MPa. For fatigue loading, the safety factor was selected from 1.5 to 2, and its minimum allowable strength [σ] = 930/2 = 465MPa.

Bracket rotary shaft was the rotary positioning load-bearing bearing component for the propelling beam. Fig.(2) showed finite element analysis model.

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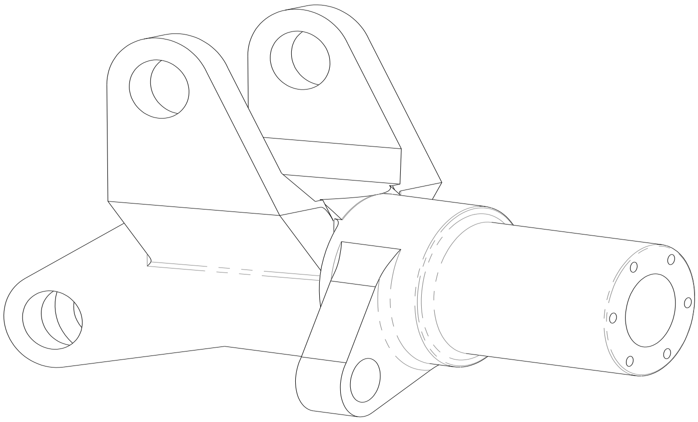

Fig.1. Bracket rotary model

B. *Loading Analysis in Different Working Conditions*

The working conditions of full-hydraulic drilling rig included drilling, drill lifting, variable amplitude, rotary rigs and steering, wherein drilling and drill lifting had greater impact on the force borne by bracket rotary shaft. In other working conditions, bracket rotary shaft only bore its gravity, smaller than the previous two conditions. So we only analyzed the intensity of bracket rotary shaft in drilling and drill lifting.

Drilling conditions: When the drill rigs worked in open pit, the straightness of hole depth had to reach the requirements. Therefore, in the rock drilling the propelling beam needed to be well positioned with good directing effect. So the load borne by propelling beam of open-pit rock rig in drilling conditions was shown on the left in Fig.(3).

For this rig model, the maximum working propulsion is 15kN, and the propelling cylinder's counterforce on propelling beam F1 = 15kN; when the rig was working, in order to stabilize the beam, the cylinder needed to exert a downward pressure F3 on the beam through the bracket; according to the characteristics of force, facing the beam there was a counterforce F2 and F3 = F1 + F2. In practice, as the beam needed to be stable during drilling, we made the front end of the rig incline to be off by applying a force through the bracket cylinder. According to size and weight of the rig, it could be found that F2 = 60kN, and F3 = F1 + F2= 75kN. The opposite counterforce borne by bracket rotary shaft F axis = 75kN, directing upward.

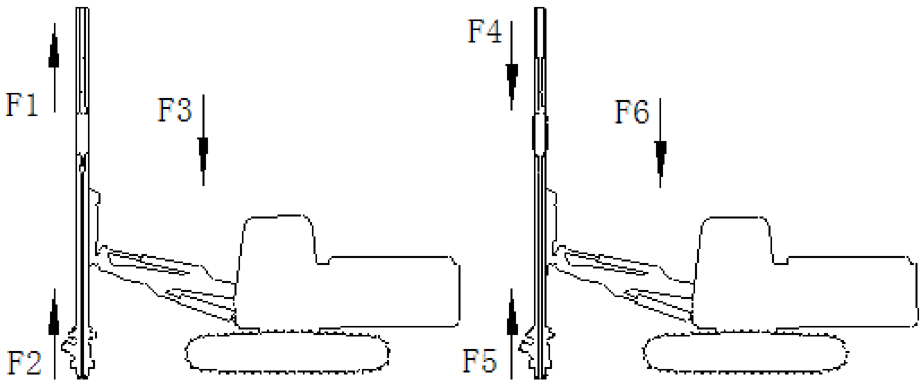

Fig.3. Free body diagram illustrating the force borne by the propelling beam of rock rig

For drill lifting conditions, when the drill rig finished working in open pit, it needed to retrieve the drilling tool. In this case the cylinder applied an upward lifting force on tool, which created a downward counterforce on propelling beam. So in drill lifting condition, the force borne by the beam was shown in the right of Fig.(3).

For this rig model, the maximum working propulsion was 20kN, and the propelling cylinder's counterforce on propelling beam F4 = 20kN. when the rig was working, in order to stabilize the beam, the cylinder needed to exert a downward pressure F3 on the beam through the bracket; according to the characteristics of force, facing the beam there was a counterforce F5 and F6 = F5 - F4. In practice, as the beam needed to be stable during drilling, we made the front end of the rig incline to be off by applying a force through the bracket cylinder. According to size and weight of the rig, it was found that F5 = 60kN, and F6 = F5 - F4= 40kN, directing upward.

So the opposite counterforce borne by bracket rotary

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shaft F axis = 75kN.

II. STATIC ANALYSIS OF PROPELLING BEAM STRACTURE

A. *Meshing*

Meshing was a prerequisite for finite element analysis, and the default mesh density blocks indicated by SolidWorks simulation would be in the middle of the entire slider. In this example we adjusted the mesh density to fine, where the grid units appeared as 14.69mm, with 5% tolerance of the number, and displayed as 0.735mm. The grid of bracket rotary shaft generated 88,333 nodes and 58,451 units [4] in Fig.(4).

Fig. 4. Bracket rotary shaft grid

B. *Exerting load and solving*

(1) Constraints: load and fixed constraint were added at the connection of cylinder and beam of the bracket rotary shaft.

(2) External load: load directing along the rail down with gravity load g = 9.81; upward loading force F axis = 75kN.

(3) Solving the maximum load: the stress distribution of bracket rotary shaft under maximum working load (See Fig.(5)).

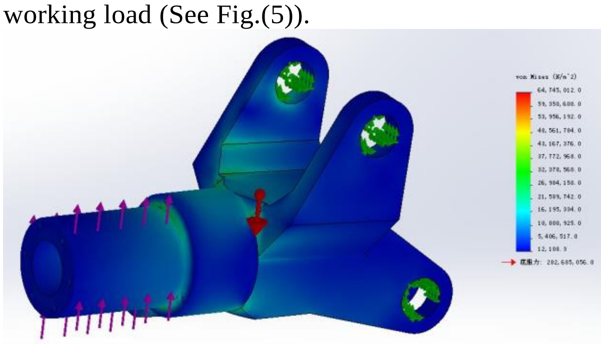


Fig. (5). 75kN stress distribution of bracket rotary shaft

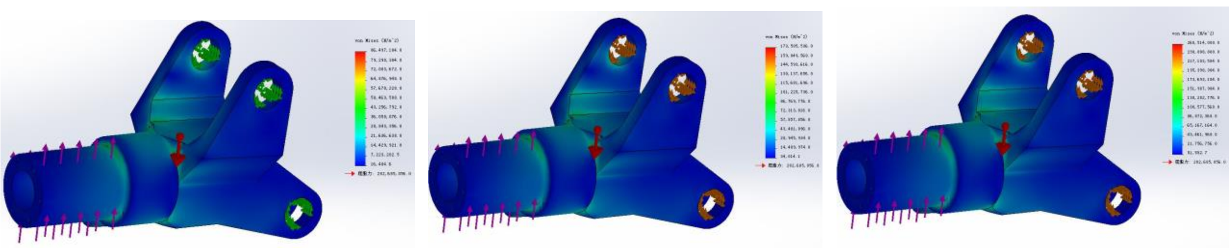
C. *Solving the stress distribution under different load*

Fig.(5) showed that the maximum stress of bracket rotary shaft was 64.75MPa, which concentrates at the corner of the shaft bottom. Depending on the material, the stress of the entire bracket rotary shaft should be in the range of yield strength. Therefore, the rotary shaft could meet strength requirements when the rig works normally.

Because of the complicated conditions in construction site, improper operation could cause increase in partial load. In order to determine the load F axis which could cause damage to bracket rotary shaft, it could analyze finite element by applying a sequence of load on the shaft. We got the stress distribution diagram under different loads (See Fig.(6)), where the loads, applied from left to right and top to bottom, were 100kN, 200kN, 300kN, 400kN, 500kN, 600kN, respectively.

From Fig.(6), we got the maximum stress of bracket rotary shaft under different loads (See Table 1).

Table 1 and Fig.(6) showed maximum stress was on the corner shaft bottom, requiring F_{axis}> 500kN to null the shaft. Actually, the maximum load was 75kN, far less than the failure load 500kN.



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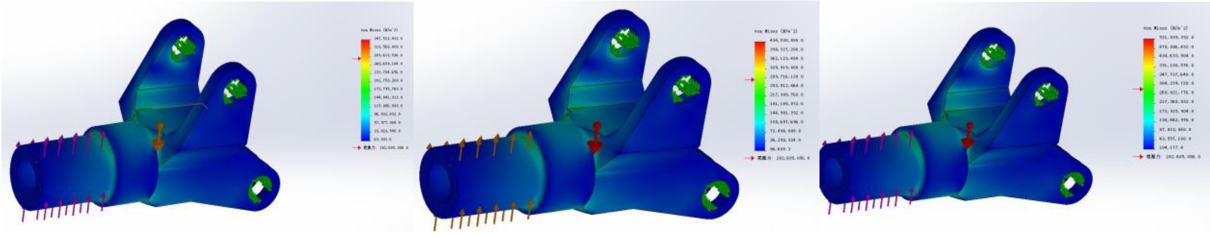

Fig.6. Bracket rotary shaft stress distribution under different load nephogram

TABLE 1.
LOADS APPLIED AND CORRESPONDING MAXIMUM STRESS

No.	1	2	3	4	5	6
Load F axis(KN)	100	200	300	400	500	600
Maximum Stress (Mpa)	84.90	173.50	260.51	347.52	434.53	521.53

III. CONCLUSIONS

Through finite element analysis, we got the nephogram of bracket rotary shaft stress distribution under different loads, with determination that the minimum load to null the shaft has to be greater than 500kN. However, the maximum load was 75kN, far less than the failure load 500 kN.

Therefore, when the rig is in normal working conditions, the maximum stress of bracket rotary shaft can hardly exceed the yield limit of the material, which means the design satisfies the requirement.

ACKNOWLEDGEMENT

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