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Stability analysis and optimation design of roof timber for minerals

The virtual prototyping assembly of hydraulic support was established using CAE technology. The investigation firstly tested the location analysis, namely, dynamic analysis of hydraulic support (ZY10500/20/36) for minerals is helpful to obtain the angle changes between roof beams and cover beam, and the movement test is concerned essentially with the different location and kinematics and dynamic analysis. In addition, this study investigated the model designed in motion the project meets the safety, reliability and stability claim through the motion curve. Especially, this work carried out kinematics and dynamic analysis to achieved the trajectory, velocity, acceleration curve, force and reaction curves of the hydraulic support beam within the safe range when load concentrated in the centre of the roof timber or under the condition of serval various loads, including the rated load axial loads and eccentric load , then found out the maximum stress and figured out the most dangerous place of the top beam under different loading ways, including partial load force, intermediate concentrated load, concentrated load at both ends. Additionally, this work examined stress distribution and dangerous part in the case of torsional loads. Consequently, this study ensured the safety and reliability of the whole equipment, and optimized the structure parameters to achieve coal mining mechanization. Moreover, this study provided a new way of thinking and theoretical reference to newly proposed relevant technical standard.

Keywords: *Hydraulic support, roof timber, reliability and stability, optimation design.*

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1. Introduction

Hydraulic support is one of the key facilities in the integrated mechanization technology of working face [1]. Generally, roof timber of hydraulic support bears huge pressure and strong airflow impact formed gangue dropping from the goaf at work, so the design requirement of hydraulic support is higher. Therefore powered support for minerals must be optimized on the account of guarantee perfect performance including strength and reliability. Although, it is difficult to find the most optimal parameters because many standards often depend on experience and skills of the designer before 1950's, the optimization design greatly was improved inconsequence of computer technology [2-3], a bridge was built between mathematics and engineering design. Thereby it was feasible to obtain the optimal design parameters due to enormous computing power of the computer, and the traditional design approach was also fundamentally reformed [4-5]. Obviously, the optimization method of combining mathematical theory and engineering practice can solve many practical engineering problems [6-7].

Therefore, a large number of pioneers made many useful exploration on optimization design in the field of mechanical design [8-10]. Cooper and Charnes firstly applied the stochastic programming methods to solve the parameters optimization problem of engineering design [11-13], then this method was widely used in security design structure. Hilton and Feigen were a pioneer in reliable optimization design, and put forward the reliable optimization design formula based on the smallest weight [10, 14]. Barczak and Burton introduced the concept of hydraulic support structural stiffness in mechanical calculation and finite element strength of hydraulic support [15], and established elastic model stents, furthermore found the basis of mechanics calculations. Bensehamdi analysed the stability of hydraulic support using plastic finite element method [9, 16-17]. Hence, the design of hydraulic support prototyping, including traditional prototyping, testing, and design came into developmental period. Accordingly, the designer combined analog design and experience design in the two-dimensional plane, and avoided the irrational product structure during the design phase, thus to devote more energy into more design work and abstain the mechanism of interference phenomena.

However, research of hydraulic support roof timber associated with reliability and optimal design method is also less in recent year [18-20], especially, effective and reasonable calculation and optimization has not been established. In addition, there are still some outstanding issues, including whole modeling and overall strength. For the hydraulic support (ZY10500/20/36), this study had two aspects to be addressed, the first question involved location analysis, kinematics and dynamic analysis of roof timber, the second problem deal with finite element method (Called FEM), which ensured its safety and reliability, and optimized the structure parameters to provides theoretical foundation for the design of hydraulic support for minerals.

2. Methods and compuational details

This type of hydraulic Support is under the regulated conditions of Chinese standard "General technical conditions of MT312-2000 hydraulic support" [21]. Its maximum height of ZY10500/20/36 support is 3600mm, and the minimum height is 2000mm. This test height is 3070mm, and the force of the top beam applied is 1.1 times the rated working pressure, and the applied force is bigger than the rated load of 5250KN.

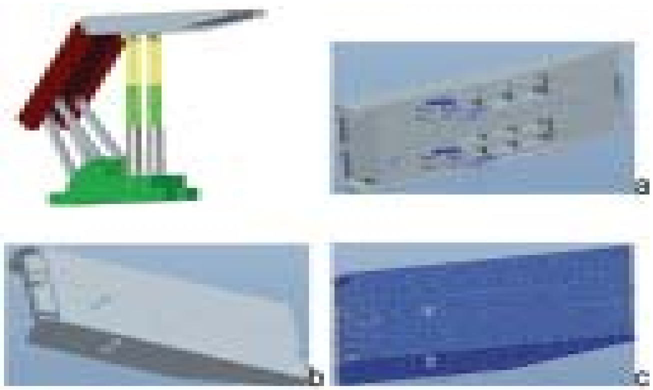

Fig.1 The geometric model (a-hydraulic support, b-roof timber, c-FEM model)

With regard to the three-dimensional geometric model of roof timber, as showed in Fig. 1a and b, it was modeled by software Pro/Engineer, and some parts were simplified to remove without affecting the structural strength of the holes, rounds, chamfers and other auxiliary features, also remove the flank guard parts. But the test must ensure that the basic strength of the structural characteristics are not simplified, and the main components remain the same size, as well as more potential stress concentration details of the site is not shortcutting. Additionally, the model is then imported Mechanic to mesh in Figure 1c, further to definite material parameters and constraints. Subsequently, this study carried the analysis of motion and force by FEM under different loading ways, the aim was to find out maximum torsional stress and dangerous parts of the roof timber in the cases of partial load, intermediate concentrated load and concentrated load.

3. Results and discussion

3.1 Motion analysis of roof timber

The movement simulation is concerned essentially with the location and kinematics and dynamic analysis of hydraulic support, and thus to test model designed in motion the project meets the safety, reliability, stability requirements through analysis of the motion curve. Since the motion of the hydraulic support pillar mainly by stretching to achieve, we add to the kinematic analysis of four identical servo motors on the column. With decreased speed of 100mm/s, the speed of each servo motor is accordingly set in Fig.2a, and roof timberis controlled in the range from 5500mm to 3500mm.

As showed in Fig.2b, the motion curve is lemniscate. The trend shows two inflection points, and the maximum fluctuation amount of support beam in endpoint level is less than the allowable level requirements 30mm, and also shows relatively flat. When we modified and re-sized institutional analysis, it was found that the original crash siteins are no longer colliding, and dynamic interference is solved. Which meet the design requirements of the actual movementand and job security of roof timber.

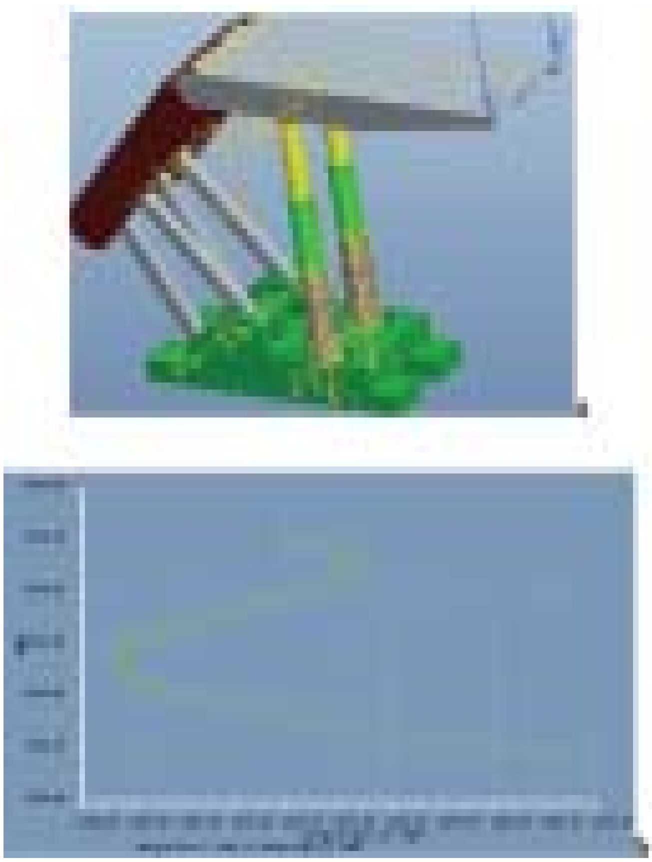

Fig.2 Motion analysis of roof timber (a-load definition, b-spot position trajectory curve)

3.2 Stress and displacement

This work investigated the deformation and forces of roof beam under four different conditions. Namely mainly analyzed displacement and stress contours, and then pointed out design and optimization suggestions. Fig.3 shows stress concentration. When load concentrated in the centre of the roof timber, maximum stress is 120Mpa and occurs in the loading position. Then both ends of the roof timber is subjected to a concentrated load, we find reinforcement plates to be withstand greater pressure. In this case, maximum stress is 159Mpa and concentrated in a column fossa. Under conditions of torsional load, stress mainly concentrated in the top beam column fossa, and maximum stress is 264Mpa there.

Above three loading material is less than the allowable stress 350Mpa, so roof timber is safe. However, the stress is concentrated in the reinforcement plate, maximum stress 504.7Mpa beyond the allowable stress inconsequence of partial load, roof beams will be destroyed. Moreover, torsional load is relatively easy to form flaw, we should enhance the strength of the column nest or improve structural design and the use high strength materials.

According to Fig.4, displacements gradually increases from the front of the roof timber to the connection of cover beam. In the case of central concentrated load, maximum

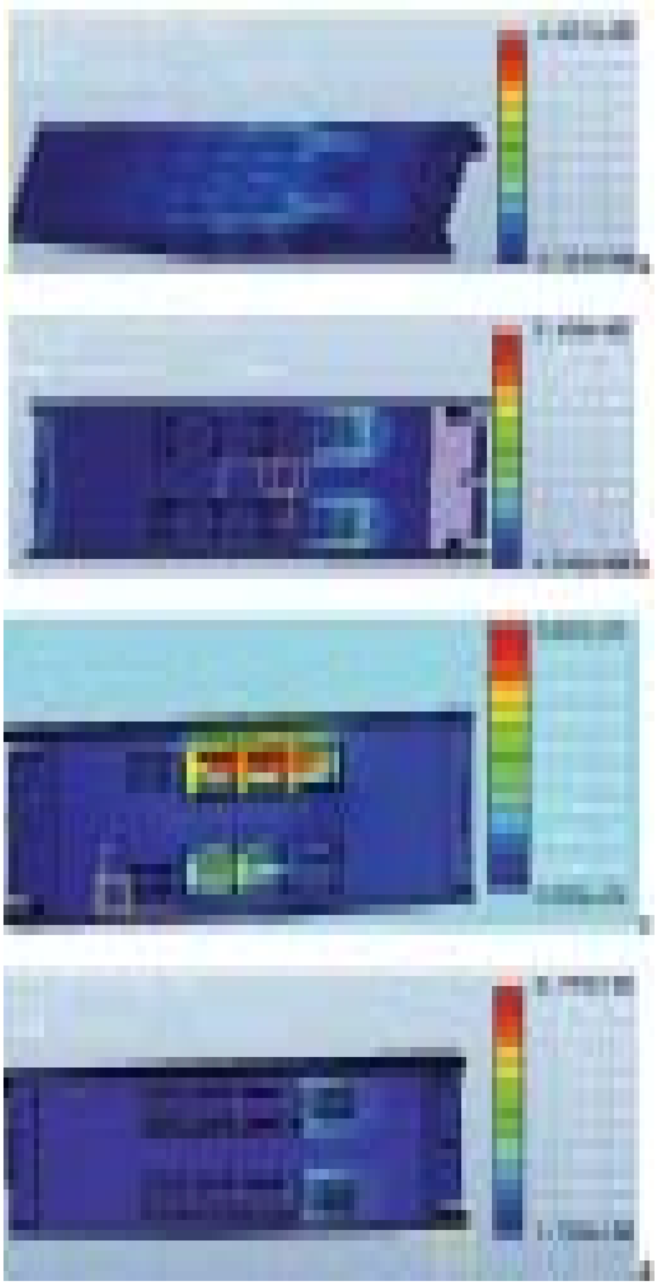

Fig.3 Stress contours (a-central bearing, b-ends of roof beam, c-unbalanced loading, d-torsion load)

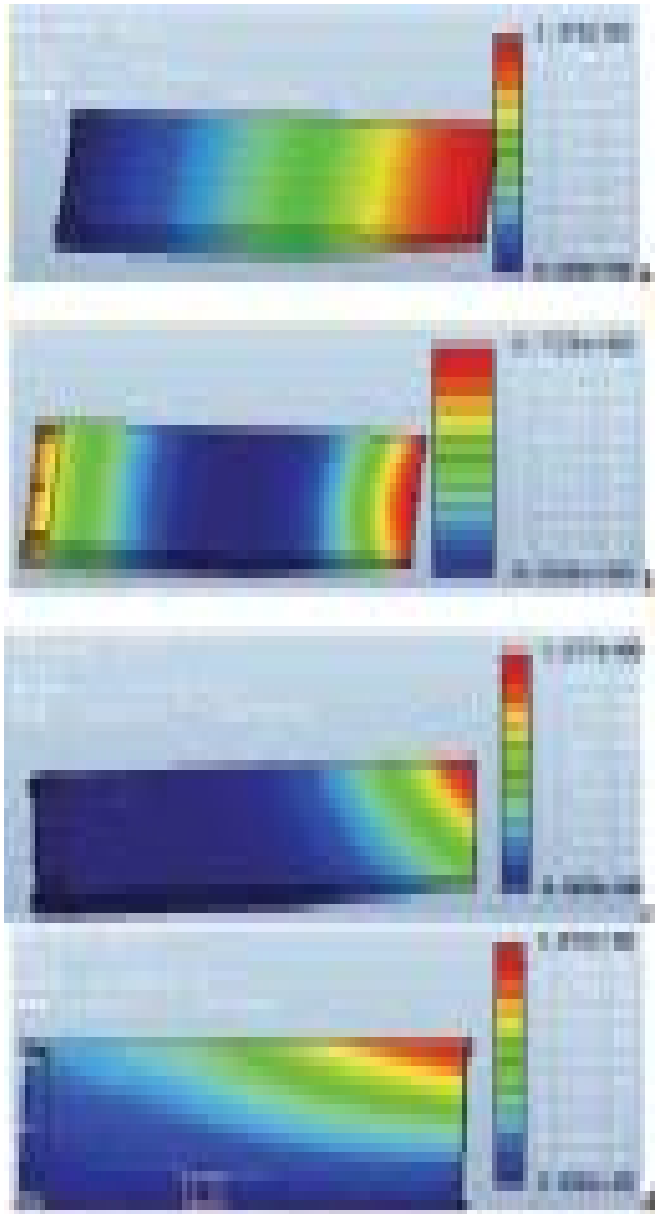

Fig.4 Displacement contours (a-central bearing, b-ends of roof beam, c-unbalanced loading, d-torsion load)

displacement is up to 14.76mm. If the load is subjected to both ends of the roof timber, maximum displacements (6,729mm) occurs at the front. Thereby It's worth noting that the maximum displacement occurs at the front end of the top left side of the torsion beams on the condition of torsional load, and other locations are not significant deformation. As a result, it is key to use the streng material to ensure the life and safety of the roof beams, and to increase two strengthening plates nest on top of the column. In order to ensure the strength of the stent. Additionally, we should improve the quality of welding in the connection reinforcement plate roof to reduce stress concentration.

3.3 Dynamic observation

3.3.1 Roof timber and shield beam

Dynamic analysis of hydraulic support is conductive to observe the angle changes between roof beams and cover beam. Therefore, the changed data are obtained within twenty seconds, and then is graphed in Figue 5, which can be more intuitive image of observing and analyzing the angle changes of the top beam pitch angle, including roof beams and shield beam.

Fig.5 demonstrates that the pitch angle range is within two degrees during falling of hydraulic support. Although the range is very small, consistent hydraulic support pitches angle range. When the pitch angle range is too large, it may affect the stability of exercise. In addition, Fig.6 shows the angle changes in between the shield beam and the top beam are in the range of thirty degrees. Consequently, angle requirements must be less than sixty-two degrees at the maximum height, and be greater than twenty-five degrees at the lowest height. Thereby the angle change of hydraulic support is clearly satisfied the condition.

3.3.2 Roof timber and columns

As the principal carrier member, the pillar plays an important role in connecting with the roof beams and columns. Some results certainly demonstrated that the connection force between roof timber and columns must be much larger than the force between the other components [22-24], and this work also found the apparent difference. Therefore, we should strictly compliance with the precision requirements for the pin shaft between two parts. This study loaded three and obtained stress distribution and displacement distribution of hydraulic support column, as showed in Table 1.

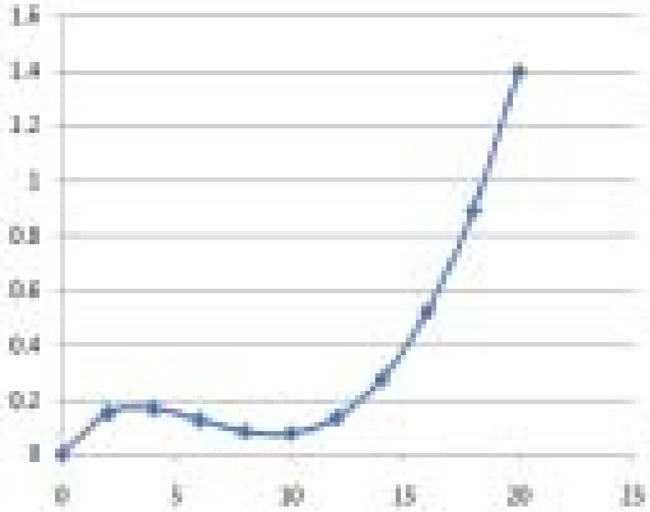

Fig.5 Pitch angle changes of the top beam

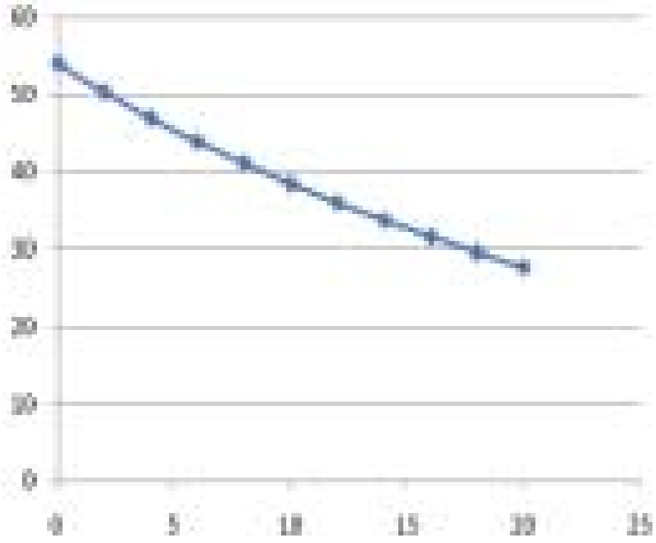

Fig.6 Angle changes between top beam and shield beam

This investigation examined the static analysis of the column on the condition of serval various loads, including the rated load axial loads and eccentric load. The results indicates that the most easily damaged parts are mainly concentrated in portions welded between the column and roof beams, in connecting parts of the outer cylinder and the cylinder, and also in the cylinder and the column. Especially, the connecting pin hole must be focused in different load conditions. As a result, the key site of roof timber should be

Table 1: Distribution of maximum stress and displacement

Loading	Axial rated load of full-stroke 1.5 times load	Axial eccentric of full-stroke 1.1 times	Axial rated load of 2/3 full-travel 2 times
Maximum stress	745.1MPa	859.1MPa	794.7MPa
Position of maximum stress	Near pinhole connected columns and beams	Near pinhole connected outer cylinder and the base	Near pinhole connected roof timber and columns
Maximum displacement	2.284mm	13.09mm	1.326mm
Position of maximum displacement	Pinhole connected columns and beams	Pinhole connected outer cylinder and the base	Pinhole connected roof timber and columns

thicker than in the design process, namely welding parts should be considered the higher strength steel, which is to ensure the security and stability of hydraulic support for minerals.

4. Conclusions

In summary, this work discussed the deformation and forces of ZF10500/20/36 hydraulic support roof timber for minerals under four different conditions, and put forward propose solutions based on analysis of displacement and stress distribution of the four kinds of conditions. In addition, this study anticipated the hazardous area or location of roof beams during working. The results found the most likely damage parts or positions, including pin hole between the top beam and cover portion, loading parts of the force and the column nest in the bottom. Furthermore, this examine suggest improvements on the design of roof timber, which will provide a reference for the design optimization of hydraulic support.

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