Structural design and optimization of wellhead platform for coal mine rescue rig

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Abstract. The existing ground emergency rescue truck-mounted drilling rig integral wellhead platform has the following disadvantages: inflexible structure form, small opening aperture, difficult assembly and disassembly, and cannot meet the lowering of large diameter drill bits and casing. In response to the above-mentioned shortcomings, it is proposed that a general scheme of modular large-opening intelligent wellhead platform for vehicle-mounted drilling rigs which combines the requirements of the rescue construction. The modular wellhead platform has the characteristics of fast centering, clamping, automatic leveling and meeting the requirements of multi-series large diameter drilling tools. The numerical simulation method is used to analyze the U-shaped wellhead platform, and an optimized structure is proposed based on the analysis results of the original structure. The results show that the stress of optimized structure is better than that of original structure, which provides important support for product design.

1. Introduction
Drilling through roadway rescue is an effective means of disaster emergency rescue in coal mine. When safety accidents occur in coal mines, vehicle-mounted drilling rigs can be used to accurately and rapidly construct large-diameter boreholes and accurately connect the target roadway. The large-diameter borehole on the ground of the mine has the advantages of flexible borehole location, free from the influence of the complex roadway conditions in the underground coal mine, shortening the pipeline laying distance and so on, and can be used as a channel for the investigation of mine accidents, drainage, transportation of supplies and rescue of trapped miners. The wellhead platform of the vehicle-mounted drilling rig is the key component of the rescue vehicle-mounted drilling rig, which determines the maximum hole diameter of the drilling and the clamping range of the supporting drilling tools. Its performance and reliability directly affect the construction efficiency[1].

The existing mine rescue drilling rig wellhead platforms shown in Figure 1 are TX200XD (SCHRAMM), RB-T90 (BUER) [2], CMD100 (Beijing Tianhezhongbang) [3] and ZMK5530TZJ100 (China Coal Science and Industry Group Xi’an Research Institute Co., Ltd.) [4-7] vehicle-mounted drilling rig wellhead platforms, respectively.
The appellant rigs generally have the following problems.

1) They all adopt one-piece structure, which generally has the characteristics of large weight and poor capacity of complex road conditions.

2) The connection with the feeding device of the main engine is fixed, causing the transport height of the truck-mounted rig to exceed the limit. It cannot meet the requirements of GB 1589-2016 "Limits on the outline dimensions, axle load and mass of automobiles, trailers and automobile trains", which stipulates that the outline dimensions of the special operation vehicle to which the truck-mounted drilling rig belongs cannot exceed 14.5 m × width × height × 2.55 m × 4 m.

3) Large-diameter drilling requires dismantling the wellhead platform to meet the requirements of large-diameter drilling tools. The holehead platform of the drilling rig shown in Fig. 1 cannot meet the requirements for the passage of drilling tools such as large-diameter tooth wheel bits and casing above 810mm.

2. Modular large opening wellhead platform

Figure 2 Modular large opening wellhead platform
1. rotary clamping assembly; 2. punching clamp assembly; 3. hydraulic outrigger
4. hydraulic chuck; 5. U-shaped platform base assembly; 6. U-shaped platform welded body assembly; 7. extended platform; 8. support frame assembly
The coal mine rescue truck-mounted[8-10] drilling rig wellhead platform shown in Figure 2 consists of eight modules: rotary buckling clamp assembly, punching mouth clamp assembly, hydraulic outrigger, hydraulic chuck, U-type platform base assembly, U-type platform welding body assembly, extension platform and support frame assembly.

As shown in Table 1, the U-type wellhead mechanical platform consists of two parts: U-type platform base assembly and U-type platform welded body assembly, with lightweight, large opening diameter and 170t bearing capacity of outriggers. The hydraulic chuck can meet the clamping and passing of multi-spec drilling tools by replacing different combinations of chuck tiles. The unscrewing clamp assembly (one key to unscrew drilling tools) has manual and automatic dual control functions. The overall width of the unscrewing pliers is small and the diameter of the upper unscrewing buckle ranges from 114-254mm, which can meet the requirements of both traditional drilling and hydraulic crane drilling processes. The maximum torque of the power head is 50kNm.

Table 1 Main design parameters of wellhead platform

| Maximum platform Opening diameter /mm | Maximum platform Height above ground/m | Powerhead Maximum torque/kNm | Drill tool clamping range /mm | Maximum load capacity of leg bearing /t |
|---------------------------------------|----------------------------------------|-----------------------------|-----------------------------|---------------------------------------|
| 930                                   | 1.9                                    | 50                          | 114-254                     | 170                                   |

2.1. U-shaped wellhead mechanical platform

U-shaped wellhead mechanical platform consists of two parts: U-shaped platform base assembly and U-shaped platform welded body assembly. The mechanical structure includes hydraulic outriggers, mechanical frame and detachable centering structure. The overall frame structure is adopted, and the platform is set up with connecting supports and the main beam of the body for quick installation with the main rig. The hydraulic legs are composed of four hydraulic cylinders with self-locking function, which can adjust the height of the mechanical frame. The mechanical frame is welded with steel sections, which has enough strength and rigidity to meet the load-bearing requirements of drilling tools in the well. Dual-axis inclination sensors are installed on the lower side of the horizontal surface of the wellhead platform, which can monitor and level the parallelism between the horizontal platform and the horizontal surface in real time.

2.2. Original structure of U-shaped wellhead mechanical platform

The simulation model of the original design structure of the U-shaped wellhead mechanical platform is established, and the simplification is completed according to the actual working conditions and the boundary conditions are imposed. Assume that the structural steel used is uniform and continuous, and the material parameters: Young's modulus is 2*1011pa, Poisson's ratio is 0.3 . The mutizone meshing method is used. This meshing method omits the segmentation step and generates a high-quality hexahedral mesh after setting the parameters. The grid type is hexahedral as the main grid cell, the average mass of the grid is 0.82, and the number of cells is 196497.
From Figure 3, the maximum equivalent stress value is 1322Mpa (the stress singularity), the actual maximum equivalent stress is about 470Mpa, as Figure 4 indicates that the maximum deformation is 13.53mm. The original structure exceeds the permitted stress range and cannot meet the design requirements, so we need to focus on the structural optimization of the location of the reinforcement and crossbeam. The structural strength can be enhanced by changing the size of the reinforcement and crossbeam, or by replacing the high-strength material to meet the requirements. Considering the convenience of manufacturing, the option of changing the size is preferred.
2.3. Optimized structure of U-shaped wellhead mechanical platform

The thickness of the reinforcement was increased from 10mm to 30mm and the thickness of the crossbeam was increased from 15mm to 20mm to obtain the improved structure. As shown in Figure 5, after analysis, the maximum equivalent force value is 306Mpa and as Figure 6 indicates that the maximum deformation is 3.80mm. The force at the reinforcement is reduced from about 470Mpa to 118Mpa compared with the original structure, and the force at the crossbeam is reduced from about 370Mpa to 50Mpa.

3. Conclusions

From the comparison of the simulation analysis results before and after the optimization of the U-shaped wellhead mechanical platform structure in Table 2, it can be seen that the dimensional optimization work done on the reinforcement and crossbeam has played a good role in the improvement, and the maximum stress and maximum deformation variables have decreased significantly to meet the design strength requirements.
Table 2  Comparison of results of structural optimization analysis of U-shaped wellhead mechanical platform

| Name | Thickness of reinforcement bars/mm | Thickness of crossbeam /mm | Maximum equivalent force of reinforcement /Mpa | Maximum total deformation of crossbeam/Mpa |
|------|-----------------------------------|---------------------------|-----------------------------------------------|------------------------------------------|
| Before structural optimization | 10 | 15 | 470 | 370 |
| After structural optimization | 30 | 20 | 118 | 50 |

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