Finite Element Analysis of a Large Power Station Shelter

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Abstract. This paper discusses the structural design of the structural design of a large power station shelter. In order to meet the lifting and weight control requirements of the shelter, the sub-frame and the shelter are integrated and lifted from the sub-frame during lifting. The solid model of the framework is built under the environment of CREO 2.0, and the finite element model of the cabin and the sub-frame structure is established according to the material attributes of the cabin and the sub-frame. The boundary condition is set in hoisting condition, and the static analysis of cabin and sub-frame structure is carried out under hoisting condition. The stress and strain state are obtained to ensure that the design of cabin structure meets the requirements of rigidity and strength of the system. The structure is optimized according to the analysis results, which can provide reference for the structural design of similar products in the future.

1. Introduction
The shelter of a large 3 x 250kW power station is a device that provides mobile power for high-power radar. With the rapid development of equipment, the high maneuverability of large mobile power station shelter is also required. There are two requirements for the cabin structure of the large-scale power station: one is that the power station and its related accessories are self-weight, a large number of ventilation doors and windows are arranged around the cabin, while the self-importance of the cabin is small enough, the design strength of the cabin must meet the requirements of hoisting; the other is that the height of the whole vehicle should be strictly controlled within the railway transport limit, and the net height and cabin should be increased as much as possible. The size of the door meets the requirements of ergonomics. In order to meet the above requirements, the finite element analysis technology is introduced in the design of power station shelter [1]. The rationality of the design is verified by analysis and calculation, and the structure is optimized.

2. The structure of shelter
2.1. Overall layout of shelter
The power station square cabin adopts 9.45m large plate corner-cutting square cabin. The overall dimension of the cabin (length * width * height) is 10285 mm * 3200 mm * 2078 mm (including front end decorative cover and sub-frame). The interior of the cabin is in the form of a middle partition wall, which is divided into single unit room, single radiator room, single unit air intake room, control room, double unit room and double radiator room from the front to the rear. The schematic layout of the
equipment is shown in Fig. 1. In order to meet the requirements of ventilation and heat dissipation, a number of doors and windows are arranged around the cabin, as shown in Fig. 2.

![Figure 1. Schematic layout of equipment in shelter.](image1)

![Figure 2. Sketch chart of the contour of the shelter.](image2)

When the shelter is hoisted at full load, there will be overload at the moment of hoisting. The static load on the shelter is the largest, and the working condition is seriously affected. Therefore, before full-load hoisting, the stress of cabin should be checked to meet the requirements of safe use; at the same time, the static deflection of cabin floor reaches the maximum under this condition, so it should be ensured that the static deflection deformation of cabin floor will not damage the cooling pipeline, and the deformation of cabin cannot cause extrusion damage to doors and windows and affect the normal opening of doors and windows.

2.2. Design of shelter structure

Large openings in the cabin seriously destroy the overall structural strength of the cabin, and the cabin needs to carry about 12 tons of weight. Therefore, the cabin and the sub-frame are screwed together to form a whole. When lifting, the sub-frame is lifted from the lifting point to ensure the lifting performance of the cabin [2].

According to the use requirements of the shelter and the existing mature technology of the shelter, the shelter adopts skeleton large plate shelter structure. The shelter is composed of six composite plates, cast steel corner parts, edge wrapping and skidding. The composite plate is reinforced sandwich structure, steel profile welded skeleton, filled with sound insulation and heat insulation polyurethane foam plate in the middle of the skeleton, and the hard aluminium alloy plate is bonded on the inner and outer surface of the skeleton as the inner and outer skin. In order to make the cabin have better rigidity and strength, the following measures are adopted in the structural design.

The whole cabin board is designed with steel skeleton, and the skeleton is made of square steel tube, which is welded on the elevation to form a force-bearing whole to ensure the overall rigidity and strength of the cabin board skeleton. Most of the equipment in this project is fixed on the embedded board in the cabin board, and the welding between the embedded board and the cabin skeleton forms an effective connection. The force on the embedded board will be distributed to the cabin board through the skeleton, which effectively guarantees the reliability of the stress points on the cabin board. Matters needing attention in the process: After the welding of steel skeleton is completed, surface sandblasting and anti-rust treatment are needed to avoid the risk of skeleton rusting and delamination between skin and skeleton.

The main structural connection between deck and deck is welding; angle aluminium has the effect of sealing and appearance as a whole; because steel frame is used in the deck, it is possible to use welding connection between deck and deck. Riveting is used between the large plate and the large plate in the conventional shelter. Compared with riveting, the rigidity and elastic deformation of the joints are higher and smaller. The following points should be paid attention to in the welding process: 1) when welding, cooling and protective treatment should be carried out around the welding site to avoid damage to the cabin; 2) after welding, rust prevention treatment should be carried out on the surface to reduce the potential rust hazard.
The sub-frame is composed of longitudinal beam, cross beam and side beam, all of which are formed by pressing and bending with high quality steel plate. The main longitudinal beam, side beam and front and rear crossbeams are integral structures, while the middle crossbeams and reinforced beams are sectional structures. All beams are welded joints, so that the whole sub-frame becomes a frame bearing body with sufficient stiffness and strength [3].

3. Shelter modelling and finite element analysis

Whether the rigidity and strength of the shelter structure can meet the requirements needs to be verified and analyzed. Because of the complexity of the system structure, it is difficult to calculate the traditional theory of stress and strain. The finite element analysis method can quickly verify the structure and eliminate the structural design defects. This analysis mainly carries on the finite element analysis to the power station cabin and the auxiliary frame, and analyses the structure deformation and stress distribution under the hoisting condition, in order to check whether its stiffness and strength meet the design requirements, and to provide the theoretical reference and basis for the subsequent improvement design.

In order to reduce the complexity of calculation and analysis, the influence of shelter skin on the overall structure is not considered, so the analysis is conservative, and the elastic modulus of foam is relatively small, which is neglected. The analysis is conservative without considering the influence of shelter edge on the overall structure analysis [4].

3.1. Establishment of finite element model for shelter structure

The skeleton entity model is built under the environment of CREO 2.0. The main types of steel tube and some bending parts of the cabin panel skeleton are 80 mm (high)*50 mm (wide)*3 mm (thick), 50 mm (high)*50 mm (wide)*3 mm (thick), 50 mm (high)*40 mm (wide)*2 mm (thick), 40 mm (high)*40 mm (wide)*2 mm (thick). The inner partition panel skeleton of the cabin body is welded and formed by 9mm (high) x 50mm (wide) x 2mm (thick) aluminum profile welding forming. The auxiliary frame is mainly formed by bending and welding of Q345 steel plate. The model drawings are shown in Fig.3.

3.2. Meshing of finite element model

The geometric model established in CREO 2.0 is imported into the finite element analysis software to divide the meshes and establish the finite element model. The established finite element model is shown in Fig.4. In the analysis, the following assumptions are made for the model:

1) The material properties of the welded joint are the same as those of the adjacent structural parts, regardless of the change of the material properties of the welded joint.
2) The deformation of the structure is small.
3) There is enough welding strength between the contact surfaces of each structure.

Assuming that it is based on the need to simplify the actual model, it will not essentially affect the results.
3.3. Material parameters
The material properties used in the shelter are shown in the following table.

| Material           | Elastic Modulus MPa | Poisson's Ratio | Density kg/mm³ | Yield Strength MPa |
|--------------------|---------------------|-----------------|----------------|------------------|
| Steel Q235         | 2.1×10⁵             | 0.288           | 7.85×10⁻⁶      | 235              |
| Aluminium plate 5053 | 7.1×10⁴             | 0.3             | 2.70×10⁻⁶      | 165              |

3.4. Boundary Conditions and Load Layout
The rigidity and strength of the cabin are checked and calculated by taking the hoisting of the cabin from the bottom corner as the analysis work. In the analysis, the vertical displacement of the four corners of the cabin floor is restrained. The load on the cabin is mainly the self-weight of each sub-equipment [5].

1) Load Layout of Power Station Cabin and Subframe
This analysis mainly considers the loads on the cabin and the auxiliary frame of the power station when the cabin is hoisted. In the analysis, the power station shelter is simulated and loaded according to the actual load arrangement.

2) Treatment of boundary conditions
In the finite element model, the contact surfaces are treated by MPC and bonded method. Bonded method is to bind the degrees of freedom of the joints at the joints of all parts, which are not separated in the normal direction, not allowed to slip in the tangential direction, and couple the degrees of freedom of the contact joints.
3) Constraint Model of Power Station Cabin and Subframe
In the analysis, the degree of freedom at the lifting point of the sub-frame is restricted.

3.5. Analysis results
In the finite element analysis software, the above models are analyzed and calculated. The corresponding stress nephograms are shown in Fig. 6. From Figure 8 and 9, it is known that the maximum stress occurs near the lifting point of the sub-frame, and the maximum stress is about 188MPa, the maximum stress of power cabin and sub-frame is less than 230MPa (yield limit of Q345 steel plate is 345 Mpa, taking 1.5 times safety factor) when hoisting.

![Stress Distribution map of power station shelter and subframe.](image)

**Figure 6.** Stress Distribution map of power station shelter and subframe.

Under operating conditions, the maximum displacement of the power station cabin and sub-frame is about 2.43 mm, which occurs in the middle of the floor. The overall displacement cloud of the power station cabin and sub-frame is shown in Fig. 7. In the analysis, only the power station shelter is considered. The actual bottom plate is sandwich plate structure, and the overall rigidity and strength are better than the frame structure, so the analysis is conservative. The actual floor deformation should be less than 2.43 mm.

![Overall displacement nephograms of power station shelter and subframe.](image)

**Figure 7.** Overall displacement nephograms of power station shelter and subframe.

From figs. 8 and 9, it is known that the maximum relative deformation of the left and right door frames is about 1.1 mm, which is less than the theoretical gap between the door plates and the door
frames 2.5 mm. Therefore, the deformation caused by hoisting will not cause extrusion and damage to the door plates.

![Displacement nephogram of left side plate.](image)

**Figure 8.** Displacement nephogram of left side plate.

![Displacement nephogram of right side plate.](image)

**Figure 9.** Displacement nephogram of right side plate.

### 4. Loading test of shelter

When the shelter is manufactured, loading tests are carried out to test the strength and stiffness of the shelter, respectively, as shown in Figure 10. In the loading test, according to the requirement of standard QJ 2575-93, the load applied on the bottom of the cabin is 1.5 times of the gravity load of the actual equipment, so as to simulate the instantaneous overload when lifting. After hoisting for 10 minutes, there were no phenomena such as the door could not be opened and the seals or sealing parts cracked and fell off. The test proves that the strength of the shelter meets the service requirements.

![Loading and hoisting test of shelter.](image)

**Figure 10.** Loading and hoisting test of shelter.
5. Conclusion
In summary, under hoisting condition, the deformation of the cabin door and other parts meets the requirements of the cabin; the maximum stress is within the elastic limit of the profile, and after loading test, the strength and stiffness of the cabin and the auxiliary frame of the power station meet the design requirements. This structure is safe and feasible. In addition, due to the strict weight requirement of the power station shelter, the material weight can be reduced appropriately in areas with less stress and deformation. At present, the power station shelter has been delivered to users. The acceptance test results show that the results obtained by the finite element analysis method adopted in this design are reasonable and credible, which provides a certain reference for the structural design of similar products.

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