Static analysis of rectifier cabinet for nuclear power generating stations based on finite element method

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Abstract. In order to obtain the deformation map and equivalent stress distribution of rectifier cabinet for nuclear power generating stations, the quality distribution of structure and electrical are described, the tensile bond strengths of the rings are checked, and the finite element model of cabinet is set up by ANSYS. The transport conditions of the hoisting state and fork loading state are analyzed. The deformation map and equivalent stress distribution are obtained. The attentive problems are put forward. It is a reference for analysis method and the obtained results for the transport of rectifier cabinet for nuclear power generating stations.

1 Introduction

The cabinet is the basic structure of electrical and electronic equipment, and then, the rectifier cabinet for nuclear power generating stations is steel cabinet in order to support the main components belongs to the main circuit topology. The steel structure has the advantages of high strength, light weight, good seismic performance, fast construction speed, and has been widely used in the cabinet design, but no matter what the form of the steel structure, the structural deformation problem will be faced in the production or transportation process. In view of more equipment and heavy load, the hoisting transport or fork loading transport can be used. So it is necessary for the mechanical simulation and analysis for the transportation state of the cabinet, at the same time, the mechanical processing is combined with the computer simulation technology, which can shorten the cycle of the design and process test, save a lot of money, and carry out the assessment of the various links in the design stage.

In this paper, the quality distribution of structure and electrical are described, the selection of the cabinet material are regulated, the tensile bond strengths of the rings and the cabinet are checked, and the finite element model of the cabinet is set up by ANSYS. The hoisting state and fork loading state are analyzed, and then, the deformation map and equivalent stress of various transportation conditions can be obtained. It is a reference for analysis method and the obtained results for the transport of rectifier cabinet for nuclear power generating stations.

2 The structure design of the cabinet

2.1 The layout design of the cabinet

The 3D model of the rectifier cabinet for nuclear power generating stations has been created by Pro/E software, and the model is shown in Fig.1. The main installation components are composed of the circuit breaker, the large power frequency transformer, the thyristor module, the inductors, the capacitors, the diode module, the doors and so on. The detailed quality and quantity can be seen in table1.
The main components of the layout for the cabinet can be described. The left cabinet are mainly composed of the left side door, the inductance, the capacitors and the diode module, the center cabinet are mainly composed of the center door, the large power transformer and thyristor module, and then, the right cabinet are mainly composed of the right side door, circuit breakers and other components.

### Table 1: The detailed information

| Name                  | Components          | Quality | Quantity | Total |
|-----------------------|---------------------|---------|----------|-------|
| Electrical equipment  | circuit breaker     | 1       | 255      | 256   |
|                       | power frequency transformer | 1       | 1450     |       |
|                       | thyristor module    | 2       | 30       |       |
|                       | inductance          | 2       | 255      |       |
|                       | capacitor           | 2       | 30       |       |
|                       | diode module        | 2       | 20       |       |
|                       | others              | 1       | 50       |       |
| Structural equipment  | simplified frame    | 1       | 550      | 550   |
|                       | Side door           | 4       | 35       |       |
|                       | Center door         | 2       | 50       |       |

2.2 The material requirement of the cabinet

The material requirement of the cabinet is a very important link in the design of mechanical parts. The main function of the cabinet is supporting the load of the main components. So, the selected materials require yield strength, strong rigidity, welding performance, and have good mechanical properties to meet the electromagnetic field corresponding to the working environment of the low temperature.

1) The spraying parts must use the electrostatic spraying technology and the common indoor powder. At the same time, the coating thickness is more than 60 µm, and then, the surface has been no obvious color difference and the defects, such as, the scratch and the stomatal myoma. In addition, the adhesion can meet the requirements.

2) The parts of the cold plate material with the scratch before plating can be polished and smoothed, but the polishing area can not be left with a deep sense of polishing stripes, and the smoothed substrate must meet the requirements of parts size.

The parts of the aluminum zinc coated plate should be adopted in Taiwan Hui Ye plate production, without zinc removal, no crack in the situation of 180° bending.

2.3 Checking the strength of the rings
The position of the suspended material should be the equilibrium point between the gravity of the suspended material and the center of upward force of the lifting force. In this equilibrium state, the position of the object should be used to determine the force of the rope in the structure. The tensile bond strength condition of the rings can be given in the formula (1).

\[ \sigma = \frac{F}{\pi \left(\frac{d}{4}\right)^2} \leq \left[\sigma\right] = \frac{\sigma_s}{S} \]  

(1)

Where, \( \sigma \) is the stress test; \( \sigma \) is the lifting force; \( d_i \) is the equivalent diameter; \( \left[\sigma\right] \) is the allowable tensile value; \( \sigma_s \) is the yield limit of the material; \( S \) is the wire length of the steel wire.

In view of the rings with the 20 steel material, the yield limit is 245MPa. The screw specification of rings is the M16, and the screw of rings had been forged using 20 steel material in GB825 or 25 steel material in GB699. Therefore, the wire length of the steel wire is 5 m, the tensile bond strengths of the rings are checked in the formula (2) and (3). Where, the quality is 4, the specification is M16, the forged steel is 25 steel material.

\[ \sigma = \frac{F}{\pi \left(\frac{d}{4}\right)^2} \leq \frac{27900 + 4N}{\pi \left(\frac{d - 1.0825P}{4}\right)^2} = \frac{27900 + 4N}{\pi \left(\frac{16 - 1.0825 \times 2}{4}\right)^2} \approx 46.421 \text{MPa} \]  

(2)

\[ [\sigma] = \frac{\sigma_s}{S} = \frac{245 \text{MPa}}{5} = 49 \text{MPa(20#Steel)} \]  

(3)

Therefore, it can meet the safety requirements for lifting eyebolt.

3 The finite element simulation analysis

3.1 The finite element

The 3D model can not be directly used for the finite element calculation. The finite element model can be formed with mesh generation which will directly affect the accuracy of the results of finite element calculation. The simplified model of mesh generation has been created by ANSYS software, and the model is shown in Fig.2.

![Fig.2 The simplified model of mesh generation](image-url)

3.2 The hoisting state analysis
The loads will be applied based on the load layout of the cabinet from the Fig.1 and the constraint condition is the fixed constraint of the 4 rings of the both sides top inside of the cabinet. After the load conditions and constraint conditions were applied, the deformation map and equivalent stress distribution based on the hoisting state can be shown in Fig.3 and Fig.4.

It can be seen from the simulation in Fig.3 that the maximum structure deformation is 0.582mm happened in the middle position of supporting transformer, and the deformation can meet the requirements of the allowable value of the flexural deflection set in GB50017-2003. And then, it can be seen from the simulation in Fig.4 that the maximum equivalent stress is 346.86MPa occurred the ring hole and belonging to the stress concentration points, and the the equivalent stress of the parts is less than 100MPa. Therefore, the framework does not occur structural yield phenomenon, but the welding ring hole must need a full weld to strengthen. So, the hoisting state scheme is feasible based on the 4 rings of the both sides top inside of the cabinet.

3.3 The fork loading state analysis

The loads will be applied based on the load layout of the cabinet from the Fig.1 and the constraint condition is the vertical direction displacement constraint at the bottom of the fork. After the load conditions and constraint conditions were applied, the deformation map and equivalent stress distribution based on the fork loading state can be shown in Fig.5 and Fig.6.
It can be seen from the simulation in Fig.4 that the maximum structure deformation is 0.365mm happened in the middle position of the supporting transformer, and the deformation can meet the requirements of the allowable value of the flexural deflection set in GB50017-2003. And then, it can be seen from the simulation in Fig.5 that the maximum equivalent stress is 292MPa occurred at the bottom of the supporting transformer and belonging to the stress concentration points, the bottom of the supporting transformer beam can be welded firmly and the the equivalent stress of the overall structure is less than 50MPa. Therefore, the maximum deformation is relatively much smaller and the fork loading state scheme is feasible and safe.

4 Conclusion
The quality and distribution of structure and electrical of the rectifier cabinet for nuclear power generating stations are described. The tensile bond strengths of the rings are checked and can meet the tensile strength check condition. Where, the quality is 4, the specification is M16, the forged steel is 25 steel material. The finite element model of cabinet is set up by ANSYS. The transport conditions of the hoisting state and fork loading state are analyzed. The deformation map and equivalent stress distribution of the state are obtained and can be analyzed visually. Therefore, the structure deformation of the fork loading state is relatively small, the structure material will not have the yield phenomenon, and it is the best transportation condition.
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