Hydraulic lifting technology of steel grid roof of a hangar

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Abstract. The grid structure is more and more widely used in the civil engineering industry, but due to the large number of rods and complex installation, it is extremely difficult to construct at high altitude. In order to overcome this problem, engineers proposed a hydraulic jacking method. The mechanical properties of steel structures are more complicated, especially in the construction process, the force situation and the design load is quite different. In order to explore the reliability of the hydraulic lifting process of the steel grid, this article takes the hydraulic lifting technology of the steel grid roof of a hangar as the engineering background. This project uses Sap2000 finite element analysis software to model, simulate the construction process of the jacking grid, analyze the mechanical characteristics and stability of the grid during the jacking process, and use it to guide the construction. The results show that: for large grid structures constructed at high altitudes and hydraulic jacking technology can effectively improve the construction efficiency and safety.

1. Introduction

With the rapid development of my country's aviation business, the maintenance requirements for aircraft are getting higher and higher, so the demand for the construction of hangars is also increasing. Due to the restriction requirements of the plane layout and structural height, the span of the hangar is generally very large. In order to reduce the load of the structure itself, and the steel structure has the characteristics of high strength, light weight, and small section, the roof of the hangar is generally a steel grid structure. The hangar grid has a high installation height, numerous structural members and a large dead weight. If the conventional split high-altitude bulk solution is used, a large amount of high-altitude scaffolding needs to be erected, and the construction is difficult. If a large crane is used to lift the overall installation, a large tonnage crane is required, and there are high requirements for the ground foundation, and there is certain safety risk. Considering the overall assembly of the steel structure on the ground, and using the "super-large hydraulic synchronous lifting construction technology" to lift it in place at one time, which can reduce the difficulty of construction.

Hydraulic jacking technology has broad application prospects in the civil engineering industry. In terms of bridges, Wu [1] conducted research on deep water levels and high beams that are often encountered during bridge construction, and concluded that appropriate use of hydraulic synchronous jacking and lifting methods in bridge construction can effectively solve such problems; In terms of super high-rise buildings, Ba et al. [2] introduced its composition principle based on the widely used electro-
hydraulic proportional synchronous jacking system, and analyzed the key technologies that affect its effectiveness. Finally, based on engineering practical experience, the causes of typical failures were analyzed and improvement measures were put forward; in the airport, Zhang et al. [3] took the grid jacking of the Jingmen Airport project as the research object, and focused on solving the synchronization, stability and correction measures of the grid jacking. Similar projects provide experience for reference; Zhang et al [4] based on the Zhangjiajie Hehua Airport terminal project as a background, combined with the characteristics of the project and the actual conditions of the construction site, the installation process and installation points of the grid jacking construction method They elaborated in more detail, and put forward the key issues that should be paid attention to in construction. This construction uses hydraulic jacking technology, combined with a computer control system, to efficiently complete the entire construction process.

2. Project overview
This project is a special construction for upgrading the steel grid roof of an airport maintenance hangar project. Among them, the plane size of the hangar roof is 334m×107.65m, the total weight is about 5150t, and the lifting height is about 30m. The main steel structure is shown in Figure.1.

![Figure 1. Schematic diagram of main steel structure](image)

3. Scheme ideas
The installation height of the steel structure grid is relatively high, and the vertical and horizontal span is large. There are many structural members and heavy weight. If the conventional split high-altitude bulk solution is adopted, a large amount of high-altitude scaffolding needs to be erected, which is difficult to construct, and will have a great impact on the construction period of the entire project, and the technical and economic indicators of the solution are poor. If a large crane is used to lift the overall installation, a large tonnage crane is required, and there are higher requirements for the ground foundation, which poses a certain safety risk.

According to the successful experience of similar projects in the past, if the steel structure is assembled on the ground as a whole, the "super-large hydraulic synchronous lifting construction technology" is used to lift it in place at one time, and then install the post-installed rods reserved for the top of the column. Greatly reduce the difficulty of installation and construction.

4. Improve overall layout
4.1. Lifting point layout
According to the characteristics of the grid structure, the lifting points of the grid are set up. The layout of the lifting points is shown in Figure.2. The gray is the first lifting area, and the green is the area increased by the overall lifting.
4.2. Improve the construction process

The main process of this project's grid upgrade is shown in Figure 3. The specific operations are as follows:

1. Assemble the grid structure on the ground, set up a lifting platform on the top of the column, install lifting equipment and steel strands, and debug the hydraulic system.

2. After the assembly of the net frame is completed, the overall inspection and acceptance are carried out, and the pre-lifting is carried out, that is, the staged loading makes the net frame as a whole out of the tire frame by about 100mm, and the overall inspection is performed again. After confirming that there is no abnormal situation, the lifter is mechanically locked. Let stand for about 12 hours.

3. Carry out a comprehensive inspection, measure the deformation of the grid frame and the settlement of the column foundation, and after confirming that everything is normal, carry out the overall lifting operation of the grid frame, which is raised about 8 meters high, and is connected to the gate truss as a whole.

4. Remove the temporary lifting frame and continue the overall lifting operation.

5. Raise the grid to the design position and install the grid inserting rods.

6. After the installation of the grid inserting rods is completed, after the acceptance is passed, the lifter is unloaded, the lifting equipment and temporary measures are removed, the lifting operation is completed, and the next process is transferred.
5. Simulation and analysis of grid lifting process
The mechanical properties of steel structures are relatively complex. Especially in the construction process, the force condition and the design load are quite different, and mechanical simulation must be carried out to ensure the safety of construction.

5.1. Finite element model
The finite element software Sap2000 is used for checking calculations. In the model analysis, the nodes of all the members of the grid are hinged, and the members of the gate truss are rigidly connected. The calculated length is taken as the original length L of the rod. The position of the lifting point imposes vertical constraints and horizontal springs to simulate the constraints of the steel strand on the lifting point.

Regarding the load, the main consideration is the self-weight of the grid, purlin, horse track and other auxiliary structures. The total weight of the grid frame of this project is about 5150t, and the load sub-factor is 1.4. There is a certain degree of height deviation when each lifting point of the roof rises synchronously during the lifting process. Therefore, it is necessary to consider the influence of the asynchronous lifting point on the structure during the lifting process. Asynchrony mainly affects the stress of the members around the lifting point. According to engineering experience, consider an overload factor of 1.2 times. Therefore, the total sub-factor when checking the strength of the members is $1.4 \times 1.2 = 1.68$, and the sub-factor when checking the deformation of the grid is 1.0. The lifting operation time is about two days, the weather factors are within controllable range, and the roof is a hollow structure, which bears less wind load. Therefore, the effect of wind load is not considered for the time being in the analysis of lifting conditions. In the overall lifting condition, the temperature load is not considered.

5.2. Finite element analysis of the lifting process
In the analysis of lifting conditions, the overall lifting deformation is about 1.5 times of the first lifting deformation. The specific results are shown in Figure.4 and Figure.5.
The rod stress ratio of the grid is controlled within 0.85, and the specific results are shown in Figure.6. According to "Grid Design and Construction Regulations JGJ7-91", the slenderness ratio of the tension member is less than 300 (less than 250 near the support), the slenderness ratio of the compression member is less than 150, and the members that do not meet the conditions need to be replaced. From the calculation results, it can be seen that the maximum lifting deflection is about $144\text{mm} \leq L/250=576\text{mm}$, there are 673 rods that need to be replaced, and the lifting requirements can be met after replacement.

6. Program implementation

In order to ensure the smooth and safe lifting process of the structural unit and the main building structure, according to the characteristics of the grid steel structure, it is planned to adopt the synchronous lifting and unloading of "balanced lifting point oil pressure, structural attitude adjustment, synchronous displacement control, and staged unloading in place". Position control strategy.

6.1. Synchronous promotion process

(1) Improve hierarchical loading. Through the observation and monitoring of the grid structure, lifting facilities, and lifting equipment system during the trial lifting process, it is confirmed that the calculation and design conditions of the simulated working conditions are met to ensure the safety of the lifting process. Based on the reaction force value of each lifting point calculated by computer simulation, as shown in Figure.7. Load the grid steel structure units in stages. The pressure of the hydraulic lifting system at each lifting point should be gradually increased in stages, 20%, 40%, 60%, and 80%; after
confirming that there is no abnormality in each part, it can continue to be loaded to 90%, 95%, and 100% until the steel structure of the grid frame is completely separated from the assembled tire frame.

Figure.7. Lifting point reaction force diagram

(2) Check the structure from the ground. After the grid structure unit is about 100mm away from the assembled tire frame, it is locked by the hydraulic lifting system and stays in the air for more than 12 hours for a comprehensive inspection. The inspection is normal and correct, and then the formal lifting is carried out.

(3) Posture detection and adjustment. Detect the ground distance of each lifting point with a measuring instrument, and calculate the relative height difference of each lifting point. Adjust the height of each lifting point through hydraulic lifting system equipment to make the structure reach a horizontal posture.

(4) The overall simultaneous improvement. Taking the adjusted height of each lifting point as the new starting position, reset the displacement sensor, and maintain the posture until it is raised to the vicinity of the design elevation during the overall lifting process of the structure.

(5) Increase speed. During the overall lifting construction process, the main factors affecting the lifting speed of the components are the length of the hydraulic tubing and the number of pump stations. According to the equipment configuration of this plan, the overall lifting is about 10 meters per hour.

(6) Fine-tuning of the lifting process. During the lifting and lowering process of the structure, the height needs to be fine-tuned due to the adjustment of the air attitude and the matching of the rods. Before the fine-tuning starts, switch the computer synchronization control system from automatic mode to manual mode. According to the needs, the hydraulic lifter of each lifting point in the entire hydraulic lifting system is synchronized inching, or a single hydraulic lifter is fine-tuned. The precision of micro-motion adjustment can reach the millimeter level, which can fully meet the precision needs of the installation of the grid steel structure unit.

6.2. Lift in place
When the structure is lifted to the design position, the suspension is immediately suspended. The fine adjustment of each lifting point enables the chords of the main grid to be accurately lifted to the design position. The hydraulic lifting system equipment is suspended to maintain the air posture of the structural unit. The chords of the middle section of the main grid are welded and fixed to the end sections. The oblique web bars are installed and the sections are installed to form an overall stable force-bearing system with the sections installed at both ends.
6.3. Uninstall
After all the post-installation rods are installed, unloading is carried out. Based on the calculated lifting load, all lifting points are lowered and unloaded by 10% at the same time. In this process, the phenomenon of load transfer occurs, that is, the point where the unloading speed is faster transfers the load to the point where the unloading speed is slower, so that individual points are overloaded. Therefore, it is necessary to adjust the frequency of the pumping station, slow down the rate of decline, and closely monitor the pressure and displacement values in the computer control system. If the load of some lifting points exceeds 10% of the load before unloading, or the displacement of the lifting points reaches 10mm asynchronously, the unloading at other points will be stopped immediately, and these abnormal points will be unloaded separately. Repeat this way until the steel strand is completely loosened.

7. Conclusions
(1) For this project, the installation height of the structure is relatively high, and the wind load has a certain influence on the lifting process. In order to ensure the absolute safety of the structure lifting process, and taking into account the high-altitude requirements for accuracy, when the steel structure grid stays in the air or encounters greater wind impact, the lifting operation is suspended, and the lifting equipment locks the steel strands. At the same time, the structure is connected to the surrounding structure through the guide chain, which can limit the horizontal swing and displacement of the structure. According to the basic wind pressure once every 10 years, the wind load on the structure is about 45t. In actual construction, at least 10 must be configured. The 5t guide chain is used for the horizontal tie of the grid structure.

(2) In the hierarchical loading process, after each step of hierarchical loading, pause and check the deformation before and after loading, such as the upper lifting point, lower lifting point structure, and the grid structure, as well as the stability of the main building structure. Under all normal conditions, the construction staff will continue to load in the next step.

(3) When the structure is about to leave the assembled tyre frame, there may be points that are different from the ground at the same time. At this time, the lifting speed should be reduced, and the ground clearance of each point should be closely observed, and if necessary, a "single point movement" should be used. Ensure that the grid steel structure is stable off the ground and all points are synchronized.

(4) As long as mechanical simulation and reasonable construction monitoring is done, hydraulic jacking technology can effectively improve the efficiency and safety of large grid construction.

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