Calculation and analysis of landing double rocker arms holding pole based on finite element simulation

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Abstract. Landing double rocker arms holding pole are widely used in the erection of UHV construction towers. Most of the construction arms are based on experience in engineering application, and there are some potential safety hazards. In this paper, the finite element model is established based on the relevant parameters of 700×700mm² double rocker arm holding pole, and the actual lifting conditions of the pole are analysed. The finite element method is used to simulate nine working conditions for stress analysis. The results show that the double rocker arm holding pole has good mechanical properties under rated load conditions, which verifies the reliability of the arm design. Asymmetric moment hoisting is an important factor threatening the safety of holding pole, which must be strictly controlled.

Keywords: double rocker arms holding pole, finite element method, rated load, unbalanced moment.

1. Introduction
UHV transmission system has the advantages of small transmission loss, long transmission distance, large transmission capacity and small occupied area, which plays an important role in solving the allocation of power resources in China [1, 2]. Double rocker arm of landing holding pole is a common hoisting machinery in UHV transmission system when lifting large components to assemble iron towers. Its reliability is directly related to the safety and quality of tower assembly construction, and it is also an important guarantee for the smooth progress of transmission projects [3]. In this paper, the finite element simulation method is used to simulate and analyze the mechanical performance of the landing double rocker arms holding pole. The research results can provide reference for the construction application and optimization design of the landing double rocker arms holding pole.

2. Working principle and parameter analysis of landing double rocker arms holding pole
As shown in Figure 1, it is the construction schematic diagram of hoisting with landing double rocker arms holding pole, which is located in the center of the iron tower. The tower body is stabilized by stay wires, and the power mechanism symmetrically lifts the tower materials through pulley blocks to complete the hoisting operation. Because the cross arms on both sides of the corner tower are different and asymmetric, it is necessary for the double rocker arms holding pole to have certain unbalanced
hoisting capacity, and the size of the moment of force is determined according to the requirements of the double rocker arms holding pole products.

1-Attach the pull wire; 2-The tower body; 3-The rocker arm; 4-The tower cap; 5-Inner stay wire; 6-Rocker arm cable; 7-Lifting wirerope; 8-Hanging Parts

**Figure 1.** Schematic diagram of landing double rocker arm holding rod construction

In this paper, the parameters for finite element modeling are as follows: the main rod section of holding pole is 700×700mm² (main material is 80×6, auxiliary material is 63×6), the height of main pole is 12m, main material is 90×8, auxiliary material is 63×5, and 45° inner stay wires are set. The length of the rocker arm is 12m, the size of the main rod is 500×600 (width×height), the main material is 63×6 and the auxiliary material is 50×6. Two ends adopt variable cross-section design, one end is connected with the rotary joint, and the other end is connected with the lifting and rolling pulley block. The mast of the holding pole is 12m long, the main pole size is 700×700, the main material is 90×8 and the auxiliary material is 60×6. The top is designed with variable cross-section, the top head is connected with undulating pulley blocks on both sides, and the root is designed as a reinforcing joint, which is connected with the main pole of the holding pole. The maximum lifting weight of the boom is 2×4 tons (lifting synchronously on both sides).

3. **Analysis of load conditions of landing double rocker arms holding pole**

Referring to DL/T 319—2010 General Technical Conditions and Test Methods for Holding Pole in Overhead Transmission Line Construction [4], nine working conditions, such as different working range and moment of force, are designed under different loads, as shown in Table 1 for details.

Azimuth angle of boom refers to the angle between rocker arm and tower body after horizontal rotation, as shown in Figure 2.
Table 1. Working conditions of finite element simulation

| Load situation       | Working condition serial number | Working condition description                                                                 | A hook Working range (m) | A hook load (kN) | B hook Working range (m) | B hook load (kN) | Azimuth (°) |
|----------------------|---------------------------------|-----------------------------------------------------------------------------------------------|--------------------------|------------------|--------------------------|------------------|-------------|
| rated load           | 1                               | The corresponding minimum amplitude under the maximum rated lifting load.                      | 2.5                      | 40               | 2.5                      | 40               | 45          |
|                      | 2                               | The corresponding rated lifting load under the maximum working range.                          | 14                       | 40               | 14                       | 40               | 45          |
|                      | 3                               | The corresponding rated lifting load at the middle working range.                             | 9.9                      | 40               | 9.9                      | 40               | 45          |
| Unbalanced load      | 4                               | Maximum rated moment of force state and corresponding rated lifting load.                    | 14                       | 40               | 14                       | 30               | 45          |
| (design value)       |                                 |                                                                                             |                          |                  |                          |                  |             |
| 1.25 times           | 5                               | 1.25 times the maximum rated lifting load.                                                   | 2.5                      | 50               | 2.5                      | 50               | 45          |
| rated load           | 6                               | 1.25 times the rated lifting load under the maximum working range.                           | 14                       | 50               | 14                       | 50               | 45          |
|                      | 7                               | 1.25 times the rated lifting load at the middle working range.                               | 9.9                      | 50               | 9.9                      | 50               | 45          |
|                      | 8                               | Maximum rated moment of force state, and corresponding 1.25 times rated lifting load.       | 14                       | 50               | 14                       | 37.5             | 45          |
| 1.5 times rated      | 9                               | 1.5 times the rated lifting load under the maximum working range.                           | 14                       | 60               | 14                       | 60               | 45          |
| load                 |                                 |                                                                                             |                          |                  |                          |                  |             |
4. Safety technical conditions for landing double rocker arms holding pole
Safety factor (yield strength) of complete machine with landing double rocker arm holding: working condition ≥ 2.0, safety factor of hoisting wire rope ≥ 4, safety factor of luffing wire rope ≥ 4; The holding pole is lifted under hydraulic pressure, and the safety factor of hydraulic lifting mechanism is ≥ 2 when the holding pole is at full height. The full height of holding pole is 28m (including mast).

5. Establishment of the finite element model and calculation results

5.1. Establishment of the Finite Element Model
The finite element model of the double rocker arm landing pole under 45° horizontal rotation angle is established, as shown in Figure 3. The stress model of double rocker arms holding pole mainly includes the stress of steel structures such as shaft standard section and rocker arm standard section and flexible rope of rocker arm stay. Therefore, beam element is adopted as finite discrete element for steel structures such as shaft standard section and rocker arm standard section. Each angle steel of the standard section structure is welded, which will be subjected to tension, compression, bending and torsion stress, and the beam unit meets its main stress requirements. Truss element is used as a finite discrete element in the flexible structure of rocker arm cable, the stress characteristics of this element are only tensile stress, not bending and torsion stress, which meets the stress requirements of flexible rope [5-6].

According to the actual working conditions, restrain the three rotational degrees of freedom and three translational degrees of freedom at the root of the shaft, and apply the load conditions in Table 1 to both
ends of the rocker arm. At the same time, given the vertical downward gravity field of the whole structure of the holding pole, the actual gravity is simulated.

5.2. Calculation results

Through the above-mentioned finite element model of landing double rocker arms holding pole, the nine working conditions listed in Table 1 are calculated respectively. Stress distribution of the holding pole for working condition 4 is shown in figure 4 and the calculation results of other working conditions are shown in Table 2:
Figure 4. Stress distribution of each component for working condition 4

Table 2. Statistics of maximum stress and displacement of each part of the holding pole under various working conditions

| Load situation | Working condition serial number | Working condition description | Rocker arm fluctuation angle (°) | lazy arm Azimuth (°) | Maximum stress of shaft (Mpa) | Maximum stress of rocker arm (Mpa) | Maximum stress of tower cap (Mpa) | Top displacement of shaft (mm) | Top displacement of tower cap (mm) |
|----------------|---------------------------------|-----------------------------|---------------------------------|---------------------|----------------------------|---------------------------------|-------------------------------|-----------------------------|-------------------------------|
| rated load     | 1                               | The corresponding minimum amplitude under the maximum rated lifting load. | 87                              | 45                  | 29.9                       | 29.22                           | 10.39                         | 0.032                        | 0.027                         |
|                | 2                               | The corresponding rated lifting load under the maximum working range. | 3                               | 45                  | 33.28                      | 51.9                            | 31.99                         | 0.036                        | 0.045                         |
|                | 3                               | The corresponding rated lifting load at the middle working | 45                              | 45                  | 31.65                      | 38.48                           | 14.54                         | 0.017                        | 0.036                         |
| Run | Range. | Max. rated moment of force state and corresponding rated lifting load. | force state and corresponding rated lifting load. | 1.25 times the maximum rated lifting load. | 1.25 times the rated lifting load under the maximum working range. | 1.25 times the rated lifting at the middle working range. | Max. rated moment of force state, and corresponding 1.25 times rated lifting load. | 1.5 times the rated lifting load under the maximum working range. |
|-----|--------|----------------------------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 4   | 3-45   | 111.5 | 49.73 | 103.9 | 7.15 | 126.3 |
| 5   | 87-45  | 35.0  | 35.98 | 12.54 | 0.038 | 0.032 |
| 6   | 3-45   | 39.23 | 62.98 | 39.47 | 0.043 | 0.058 |
| 7   | 45-45  | 37.19 | 44.62 | 17.94 | 0.042 | 0.037 |
| 8   | 3-45   | 165.4 | 61.47 | 128.8 | 3.9 | 153 |
| 9   | 3-45   | 45.18 | 74.07 | 46.94 | 0.049 | 0.07 |

5.3. Result analysis
The dangerous section of each working condition summarized by calculation results, as shown in Figure 5.
Can be seen from the calculation results:

1. The mechanical properties of the double rocker arms holding pole under rated load condition is good, which verifies the reliability of the design of the holding pole.

2. The greater the lifting load, the greater the maximum stress on each part of the holding pole. The greater the working range, the greater the maximum stress on each part of the holding pole; Therefore, during the field operation of the holding pole, the lifting of the holding pole should not exceed the designed rated load, and the working range can be as small as possible on the premise of meeting the requirements.

3. The stress of each part of the holding pole is very small under rated load. But the maximum stress of each part of the holding pole increases obviously under rated moment of force condition. Therefore, moment of unbalanced hoisting is an important factor threatening the safety of the holding pole.

4. Under the condition of maximum rated moment of unbalanced and corresponding 1.25 times rated lifting load (unbalanced lifting on both sides and horizontal rotation of 45°), the stress at C-C section is the maximum, with the maximum stress of 165.4MPa. Therefore, it is necessary to check whether the holding pole strength at this section can meet the requirements. The rod body at this section is made of Q355B with allowable stress of 355MPa and safety factor of 2.15, and the holding pole strength meets the standard requirements of safety factor ≥2.

5. The main rod body has a cantilever structure, and the horizontal displacement of the top of the rod body shall not exceed 1.34H/100(H is the free height of the holding pole). The horizontal displacement of the top of the holding pole shall not exceed 321.6mm. Under the working condition of moment of unbalance, the displacement of the top of the holding pole increases obviously which can be seen from Table 2. Therefore, it is necessary to verify whether the displacement of the top of the holding pole meets the requirements under the rated load moment of unbalance condition. It can be seen from Table 2 that the maximum horizontal displacement of the top of the holding pole under this condition is 126.3mm, which meets the standard requirements.
6. Conclusion

(1) Unbalanced lifting is an important factor threatening the safety of the holding pole. Unbalanced load must be controlled. During the holding pole operation, amplitude modulation should be synchronized and the bottom should be horizontal.

(2) Under the conditions of symmetrical lifting and synchronous amplitude modulation, even when the lifting load is 1.25 times and 1.5 times of the rated load, the mechanical properties of the landing double rocker arm holding pole is good, the maximum stress of the holding pole does not increase significantly, and the holding pole is still in a safe state. However, in practical use, it is impossible to carry out strict symmetrical lifting. If the symmetry is too large and the lifting load exceeds the rated load value, the moment of unbalance will inevitably increase, thus threatening the safety of the holding pole. Therefore, when working with the pole, the lifting load must be controlled within the rated load, at the same time, symmetrical lifting should be ensured as far as possible.

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