Static mechanic analysis of J-clamp connection mechanism for 10kV electric distribution network

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Abstract. J-type clamp is used for bare wire live connection work. It is a power connection device for transmission and distribution systems. Its performance and the size of the installation torque will directly affect the power transmission. If the installation torque is too large, the cable deformation will seriously affect the service life of the cable. If the torque is too small, the cable will be in poor contact or even the cable will fall off. In this paper, the three-dimensional finite element analysis model of j-type clamp was established. The stress and displacement of the clamp were analyzed by ANSYS Workbench simulation analysis software, and the analysis cloud map of the whole line clamp and main components was obtained. The analysis results can provide reference for the overall optimization of the clamp, and provide guidance for the standard installation of the clamp.

1. Introduction

With the continuous improvement of the social and economic level and the quality of life of the people, the society's requirements for the safety and reliability of power supply are constantly increasing. Therefore, the State Grid Corporation requires that the implementation of the distribution line must comply with the principle of “no power outage” [1], as far as possible in the form of non-blackout operations, in order to improve the reliability of power supply. At the same time, various cable connecting devices have been continuously developed, The uninterrupted operation mode of the J-type clamp overcomes the problems of cumbersome operation and insufficient safety in the past installation process, and greatly improves the work efficiency of the construction personnel [2]. Some problems are exposed during the long-term use of the J-type clamp, and the quality of the insulated J-type clamp itself is a big reason for the failure of the distribution line clamp operation. The quality problem is concentrated on the excessive torque of the torque nut and the stress concentration of the material of the clamp itself. The quality problem is also concentrated on the unbalanced conductive performance and the excessive deformation of the wire when clamping. Therefore, understanding the stress distribution of the clamp during the working process and the overall deformation of the clamp are important prerequisites for ensuring the safe and reliable operation of the clamp. The model is used to simulate the displacement distribution and stress distribution of each part of the J-type clamp, these analytical calculations provide guidance to ensure the design and installation reliability of the J-type clamp, It is an important prerequisite for ensuring the safe and reliable operation of the clamp, and also the key technology for the research of the clamp [3-5].

In this paper, the solid three-dimensional model of the J-type clamp is established by using SolidWorks software, Then the J-shaped clamp finite element analysis model is established in ANSYS Workbench. The model is used to simulate the displacement distribution and stress distribution of each
part of the J-shaped clamp, and these analytical calculations provide guidance to ensure the design and installation reliability of the J-clamp.

2. Model building

2.1. J-type clamp working principle

The J-type clamp is different from the puncture clamp for removing the insulation layer as shown in Fig. 1. The J-type clamp is used for the live connection of the bare conductor, and it’s a power connection device for the transmission and distribution system. The J-type clamp consists of two elastic J elements with the same wedge part and a fixed torque bolt. The upper and lower J elements are tightly fitted by the tightening of the fixed torque bolts, which acts as a current carrying. At present, the installation method of the wire clamp is the vertical arrangement of the bolt, The insufficient torque of the bolt may make the wire and the clamp unable to maintain good contact, and the local temperature is too high during the flow passage, which may lead to the burning accident [6], and even make the wire fall off and separate from the clamp under the action of its own gravity. Conversely, If the mounting torque is too large, the bolt will bear a large axial load, and the bolt will be deformed too much, thus reducing the mechanical strength. Therefore, the installation of the clamp requires an appropriate mounting torque, which ensures good contact between the clamp and the wire and enables the deformation of the bolt and the clamp J component to be within a safe range.

2.2. Model building and simplification

There are many types of J-type clamps, and their mechanical mechanisms and shapes are roughly the same. The SolidWorks 3D modeling software is used to establish the J-shaped clamp stereo model according to the physical model 1:1. If the clamp and its components are necessary to be simplified and replaced during the modeling process, the analysis model can be optimized to a large extent. Due to the complicated structure of the physical model of the J-type clamp, the model needs extra fine processing when meshing and the calculation will also increase the solution time of the software [7]. For these problems, the J-type clamps model is simplified as follows:

1) Remove the tiny protrusion in the insulation shell, chamfer at the edge of the wire clip, thread of bolts and nuts, etc.

2) Since the metal part of the actual cable is stranded with multiple strands of wire, if it is introduced into the simulation, it is necessary to consider the contact setting between the single-stranded wires, and the complexity of the structure requires extremely precise division results. This leads to unnecessary computer memory in the analysis, And there will be interruptions as the operation proceeds. which makes the simulation fail. Therefore, the power line and the branch line are simplified to a single-strand round wire of the same wire diameter.

2.3. Model parameters and boundary conditions

(1) Material model

All materials are assumed to be continuous, homogeneous and isotropic, The analysis materials mainly include aluminum alloy, galvanized copper alloy, no. 35 steel and rubber pad [8]. The analysis
model is based on a 10KV single-core JKLYJ insulated aerial cable 240/150, in which the cable material is aluminum, the wire clamp material is galvanized copper alloy, the bolt and the nut are made of 35 steel, and the gasket is made of rubber material. The material attribute data of each component is shown in the table.

| Material        | Density $kg/m^3$ | Poisson's Ratio | Young's Modulus $MPa$ |
|-----------------|------------------|----------------|----------------------|
| Aluminum alloy  | 2700             | 0.34           | 6.8E+10              |
| Galvanized copper alloy | 8300         | 0.34           | 1.1E+11              |
| 35 steel        | 7850             | 0.31           | 2.12E+11             |
| Rubber mat      | 7750             | 0.31           | 1.93E+11             |

(2) Meshing

When the j-type wire clip finite element is meshed, it is not better to be more precise, the result of the division needs to consider the actual analysis needs. In this paper, the static analysis module of ANSYS Workbench is used to analyse the clamp assembly. At the same time, for the J-type clamp with irregular structure and shape, the division method of the tetrahedral mesh is adopted, and the division correlation is set to 100, and the grid size is 3 mm. Due to the standard cylinder of the wire, the hexahedral meshing method is used when meshing, and the mesh size is also 3 mm. Since the bolts and nuts are subject to the main force in the analysis and the shape is relatively complicated, the mesh is divided into tetrahedral meshes with a mesh size of 1.5 mm. The final mesh division is shown in Figure 2. After partitioning, 305052 nodes and 111643 cells are obtained.

(3) Load and boundary conditions

Ignoring the effect of wind load on the conductor and the influence of ground height difference in actual use, the main cable has a diameter of 14.6 mm, the calculated breaking force is 34680 N, and the branch cable diameter is 10 mm. The tension on both sides of the main line is 20% of the cable breaking force, the fixed torque bolt is set to 40N/m. Fixed constraints are applied at both ends of the main line and one end of the sub-line of the bolt. A fixed tension of 6935N is applied at one side of the main line, then vertical downward standard gravity is applied on the assembly, and bolt pre-tightening force is applied at last. According to the data, the relationship between the screw-breaking moment and pre-tightening force of the j-type clamp bolt is as follows [9-10]:

$$ T = \eta \cdot F \cdot D $$  \hspace{1cm} (1)

Where $T$ is the tightening torque, the unit is N m; $\eta$ is the tightening torque coefficient; $F$ is the pretightening force, the unit is N; $D$ is the nominal diameter of the bolt, the unit is m. The clamping force of the bolt is calculated to be 18750N.

3. Results and analysis

3.1. Bolt analysis
It can be seen from figure 3 that the main deformation of the bolt is concentrated in the joint of bolt, nut and wire clip J element, where the interaction between bolt, nut and wire clip J element exists, where resulting in a large amount of deformation of the bolt. It can be seen from Fig. 4 that the main stress of the bolt is concentrated in the middle position of the bolt polished rod, and the size is about 176.75 MPa, so the dangerous part is a bolt polished rod. The maximum stress of both is less than the yield strength, which meets the requirements.

![Figure 3 bolt displacement map](image1.png) ![Figure 4 bolt overall stress cloud](image2.png)

3.2. Result analysis of J - type wire clamp

Figures 5, 6, are displacement and deformation clouds of the J element above and below the clamp respectively. It can be seen from the figure that the deformation trend of J element 1 and J element 2 is different. The maximum deformation of the J element 1 is at the portion, where it is in contact with the branch line (red portion in the figure), and the maximum is about 0.022 mm, which is uniformly reduced from the maximum deformation to both sides. The maximum amount of deformation of the J element 2 is concentrated at the root of the J element 2, and the maximum deformation amount is about 0.028 mm, the J element 2 and the main line contact portion are partially deformed. According to the stress distribution diagrams of the two J components, it can be seen that the stress of the two J components is relatively concentrated in the parts in contact with each other, and the maximum stress are respectively 227.39 MPa and 186.71 MPa. Combined with the displacement distribution cloud diagram and the stress distribution cloud diagram, it can be seen that the dangerous parts of the J type clamp are respectively concentrate on the contact parts of the J element and the wire contact part and the two J elements, and the stress at the two places is concentrated and the deformation is the largest.

![Figure 5 Nephogram of displacement and stress distribution of J element 1](image3.png) ![Figure 6 Nephogram of displacement and stress distribution of J element 2](image4.png)
3.3. **Cable result analysis**

It can be seen from Fig. 7 and Fig. 8 that the maximum deformation of the main line is concentrated between the line clip and the fixed position at both ends of the main line, and the maximum deformation is about 0.043 mm. This phenomenon may be due to the addition of standard gravity in the overall analysis model. The cable is deformed by gravity. The maximum stress of the main line is concentrated in the middle of the cable. It can be clearly seen that the stress distribution in the main wire clamping part is uniform, and the maximum stress is 22.53 MPa. Because the branch line is placed in the assembly and tilted, and considering the influence of gravity, the displacement of the middle part of the wire is the largest in the displacement cloud diagram, which is about 0.062 mm. The stress of the branch line is mainly distributed in the part where the wire is clamped, and the maximum stress is 42.758 MPa.

![Figure 7 Main line displacement distribution cloud map](image)

![Figure 8 Main line branch line stress cloud](image)

![Figure 9 Branch line displacement distribution cloud map](image)

![Figure 10 Branch line stress distribution cloud map](image)
4. in conclusion
In this paper, on the basis of considering the structure and mechanical properties of j-type clip, the static analysis module in ANSYS is used to analyze the displacement and stress distribution of torque bolt, wire clip block and wire. Through simulation, the static characteristics of the J-type clamp can be effectively presented to the designer and the installer, so that the designer and the installer can understand the force and deformation of the J-type clamp during the installation process, and the they can understand the force of the J-clamp during installation. In this way, they can control the clamping force in the process of puncture installation, so that the wire clip can be installed in the best position, ensuring reliable connection, saving time, safety and efficiency, ensuring good conductive effect without damaging distribution cable, improve safety operation and maintenance level and insulation level.

Acknowledgement
1. Research on the State-of-the-art Anhui Provincial Electric Power Co., Ltd. Science and Technology Project Funding (52120518001M) Research on Intelligent Lifting Technology of Live Leading Device Suitable for Stripping Insulation Layer
2. Funded by State Grid Corporation of China (52120518000Q) Research on Key Technologies for Improving Safety and Efficiency of Uninterrupted Operation of Overhead Lines in Distribution Networks for Typical Projects

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