Research on High-strength Flexible Insulation Rod of Ultra High Voltage Live Working

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Abstract. Insulation pull rods are commonly used tools and instruments in the replacement of insulators for live work. Traditional hard insulated pull rods are difficult to transport and assemble due to their large deflection, especially due to the long and heavy weight of insulated pull rods used in UHV live operations, the difficulties in the above links are more obvious. In view of the existing problems in the use of the existing insulated pull rods, by studying the overall processing type, the soft pull rod weaving process, the technology of tightly combining the core rod and the protective cover, the technology of connecting the core rod and the metal, etc., a new type suitable for live transmission lines has been developed. Large-tonnage soft insulated pull rod for operation. Effectively solve a series of problems caused by the large deflection of the hard insulated pull rod.

1 Introduction

Energy production area and energy demand are extremely unevenly distributed, so UHV power transmission plays an important role in my country's west-to-east power transmission and national interconnection. Traditional power outage maintenance is far from being able to meet the operation and maintenance requirements of high-standard UHV lines. Therefore, technical means of live work must be used to ensure the safe and stable operation of UHV lines and the continuous supply of clean energy.

Existing insulating rods are mainly divided into hard insulating rods and soft insulating rods.

Hard insulating rods are currently commonly used types of insulating rods. In UHV live work, due to its longer length and greater deflection. When storing, it takes up a lot of warehouse space, which is not conducive to the efficient use of the warehouse. During the transportation process, the length of the transportation vehicle is relatively high. In the process of installing the insulator clamp, the operation freedom of the live working personnel when hooking the clamp is low. The soft insulating pull rod has undergone improved material formation. Literature 1 mentions a kind of soft insulated pull rod, the weight is only 34.6% of the same specification hard pull rod, the weight of the end joint is only 1/10 of the original steel joint, and the strength is increased by 2.85 times, and it can be coiled Circle transportation and storage, which solves the original problem of difficult transportation and storage of long pieces. However, the elongation of the aramid fiber and the thermoplastic material is inconsistent, the plastic recovery is inconsistent, and the inner core is not treated with moisture. As a result, the service life of the pull rod is short, which is not widely used.

2 Manufacturing process of large-tonnage soft insulated pull rod

The large-tonnage soft insulated pull rod manufactured in this paper is made of aramid or PBO material for the inner core. The overall manufacturing process is shown in Figure 1.

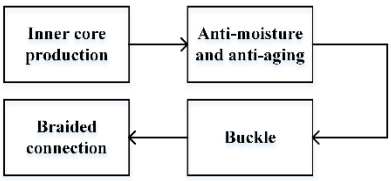

Fig. 1 Manufacturing process flow of soft insulating pull rod

2.1 Inner core production

According to actual production needs, purchase aramid fiber, monofilament, PBO fiber monofilament (2000D specification). The purchased aramid fiber or PBO fiber is combined and separated by a doffing machine. In the stage of stock control. The inner core of the draw bar is woven by a 12-spindle core-making machine. Each spindle is 1 strand. The diameter of the strand is determined according to the breaking force of the draw bar. The twist of each strand is determined by the diameter of the inner core.

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Adjust each wire The tension is the same, the normal twist is 10-15, the twist distance is 20-30mm, and the breaking tension loss is about 35%. A twelve-spindle braiding machine (6 spindles on the front and back) is used to adjust the tension of each spindle to make the inner core evenly stressed during the production process.

2.2 Moisture-proof and anti-aging treatment

Cut according to the required length of the pull rod (including the length of the buckle), and handle it gently during the process to prevent the strands from being scratched. Chemical treatment is then carried out. In the spinning process, chemical fibers must be immersed in a spinning finish and then drawn and stretched, and then converted into fiber filaments. Therefore, the spinning finish must be removed before the moisture-proof insulation treatment to obtain a uniform and stable treatment effect.

The degreasing process prescription is made of 2g/L sodium carbonate and 5g/L degreasing agent. The oil removal process conditions should meet the liquor ratio ⩾ 1:10. In an environment of 130°C, the treatment liquid is treated by a one-way mercury circulation method from the inside to the outside for 45 minutes.

The anionic graft modification process of PBO and aramid fibers mainly makes the fibers react uniformly with the anionic grafting agent. The chemical structure of the anionic grafting agent is shown in Figure 2. The subsequent cationic waterproofing agent and cationic dye form uniform directional adsorption on the fiber, so that uniform, wear-resistant, strong moisture-proof insulation and anti-ultraviolet effects can be obtained after heat treatment. The treatment liquid is made of 0.2g/L sodium carbonate, 20g/L anion graft modifier, 0.5g/L nanotube. Satisfy bath ratio ⩾ 1:10. In an environment of 130°C. The treatment liquid is treated with a two-way pump cycle (forward and reverse ratio 1:1) for 60 minutes.

Moisture-proof insulation treatment mainly uses a very small amount of high light-fast cationic yellow and SG-601 water repellent to make the treatment liquid. The treatment conditions should meet the liquor ratio ⩾ 1:10. In an environment of 130°C, the treatment liquid is treated with a two-way pump cycle (forward and reverse ratio 1:1) for 60 minutes. Cool to below 80°C to drain residual liquid and do not clean after draining. Finally, dehydration and drying are performed.

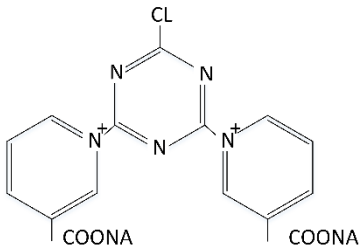


Fig2. Anionic grafting agent

2.3 Buckle

First, bake the chemically treated aramid and PBO inner core, set the temperature at 180°C for 60 minutes, then cool, straighten, and straighten it for use. Set the buckle length and mark it, and use a 36-spindle loom to overweave the two ends of the set buckle length, leaving enough length of the weaving outer skin to insert into the inner core. Should meet

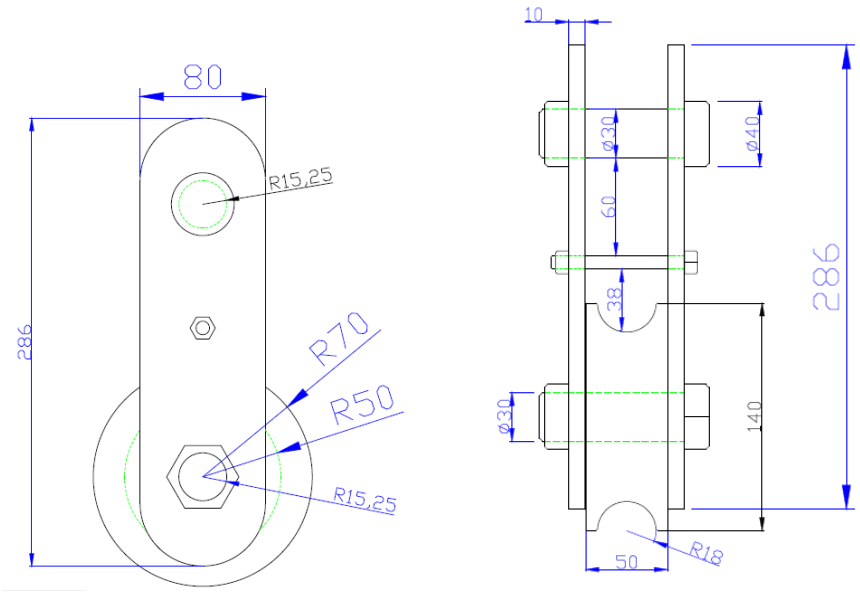
$$S \geq 4d \quad (1)$$

where S is the buckle length and d is the diameter of the soft drawbar.

The material used for the outer skin is AAA grade mulberry silk thread that has been treated with moisture-proof treatment. After that, the buckle is inserted, the buckle is even and flat, and the length of the insertion is about 1-1.5 meters, which increases the tensile strength and does not break off.

2.4 Woven jacket and connection

A 36-spindle or 42-spindle braiding machine is used to wrap the inner core with moisture-proof treatment. The length is determined according to the needs. The 36-spindle or 42-spindle braiding machine is tensioned to adjust the surface wrap layer and the inner core to prevent loosening. Generally, the thickness of the coating is about 2mm, and the surface coating material is made of AAA grade mulberry silk thread. After moisture-proof treatment, it has better wear resistance, insulation and flexibility. After the outer layer is wrapped, the fiber threads on the surface layers at both ends are manually inserted into the buckle wrapper to tighten. The prepared moisture-proof pull rod is trimmed to 10%-20% of the tensile strength against breaking, so that the inner core is straight and the surface is soft. Pull rods are connected by pulleys, and the pulley structure is shown in Figure 3. Connect the screw at the upper end of the pulley to the screw rod or the lever hoist for tightening. The overall connection structure is shown in Figure 4.



(a) (b)

Fig.3 Structure diagram of connecting pulley with pull rod

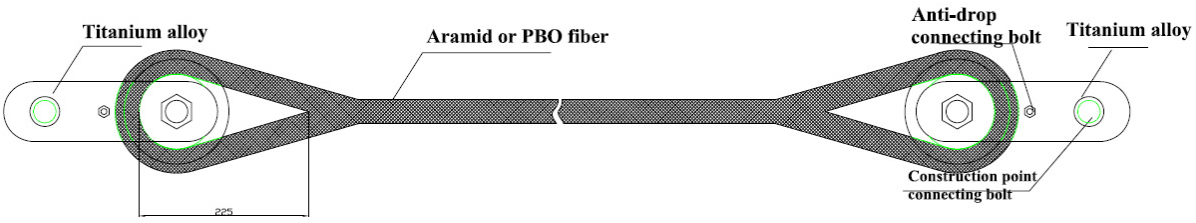


Fig.4 The overall structure of the soft insulating rod

3 Results and field application methods

According to the manufacturing process, the processing and manufacturing of the soft insulating pull rod for the ±800 kV UHV live operation is carried out. As shown in Figure 5, the inner core is made of aramid fiber. The elongation of the finished insulating rod after stretching is ⩽3%, the length of the soft rod is 7.8 meters, the inner core diameter is 28mm, the thickness of the protective cover is 2mm, and the rod diameter is 32mm. Weight 8kg. The weight of the existing hard insulated pull rods for UHV live working is 24kg, which is only 33% of the existing hard pull rods. The actual breaking force of large-tonnage soft insulated pull rods is 454.24kN. The breaking force of existing ordinary hard pull rods for UHV live working is 130kN, which is an increase of 249.4% in strength. The anti-cut connection fittings are made of high-strength titanium alloy materials, weighing 2.5kg/piece, and each soft pull rod and wire protection rope is equipped with two anti-cutting connection fittings to meet the requirements of live operation. The manufactured soft insulated pull rod meets the corresponding standards for UHV transmission line maintenance tools and the strength is qualified. The pull rod can be coiled into a diameter of 40cm for transportation and storage. After the field trial, the tool connection is reliable, and the operator is convenient to assemble.

Fig5 Physical picture of soft insulated pull rod

The application method of the soft pull rod is as follows:

(1) The person in charge of the work applies to the grid dispatcher to start work. According to the requirements of 8.1.7 of the "State Grid Corporation of Electric Power Safety Work Regulations (Power Line Part)", determine whether to deactivate the line reclosing device. If a line trip occurs, it shall not be forced to be sent without contact. Obtain the dispatch permission, check the dual name and pole number of the line.

(2) All working members lined up, and the person in charge of the work read out the work ticket, confided the

work tasks, safety measures and technical measures on the spot; checked (asked) the mental condition of the workers, the dressing situation and whether the tools and equipment were in good condition and flexible. Confirm dangerous points and preventive measures, clarify the division of labor, safety measures and precautions.

(3) The staff shall use the optical ohmmeter to check the insulation resistance of the insulating tools, check whether the load-bearing tools are intact and flexible, and assemble the insulating pulley block.

(4) Electricians on the tower wear a full set of qualified shielding suits.

(5) The ground potential electrician carries the insulating transfer rope to the cross arm, fasten the seat belt, and install the insulating pulley and the insulating transfer rope at the appropriate position of the work cross arm.

(6) After the ground coordinator connects the hanging basket and the insulated track rope, use the insulating transfer rope to transfer it to the ground potential work position. The ground potential electrician and the equipotential electrician cooperate to bind the insulated track rope firmly in the appropriate position and tie the hanging basket firmly. Install it in place, and hang the control rope on the gondola.

(7) The equipotential electrician checks the connection of each part of the shielding suit. After confirming that the connection is good, enter the hanging basket, fasten the seat belt, and hang the equipotential personnel backup protection rope at the same time. The ground potential electrician operates the control rope and pulls the hanging basket along the track. Lower it to a position 0.5 meters away from the wire, check the connection of the shielding suit, and prepare for equipotential.

(8) After the equipotential electrician reports to the person in charge of the work and obtains permission, the equipotential personnel quickly grabs the wire and enters the equipotential.

(9) After the electric potential electrician enters the electric field, fasten the safety belt and the backup protection rope, cooperate with the ground electrician and ground personnel, install the insulating soft pull rod to a suitable position, and tighten the wire separately by the equipotential electrician and the ground potential electrician. The rod is used to separate the insulator from the wire, and then cooperate with the ground personnel to hoist the new composite insulator in place by the method of "one string up and one string down", and the equipotential electrician and the ground potential electrician cooperate to reset the insulator.

(10) After completing the task, the equipotential electrician, the ground potential electrician and the ground personnel cooperate with each other to remove the insulating soft pull rod and lower it to the ground. The equipotential electrician enters the gondola, checks the connection of the shielding suit, fastens the safety belt and the back-up protection rope, applies for and gets permission from the person in charge of the work, and exits the strong electric field with the cooperation of the ground coordinator.

(11) After the equipotential electrician exits the electric field, the equipotential electrician and the ground potential electrician cooperate with each other to remove the tools, and the ground coordinator will pass it to the ground.

(12) After the electrician on the tower checks that there are no tools left on the tower, report to the person in charge of the work, and after getting permission, bring the insulating transfer rope down the tower.

(13) The ground electrician arranges all tools and instruments and cleans up the site, and the person in charge of the work counts the tools and instruments.

(14) The person in charge of work reports to the dispatcher.

Fig. 6 Tool field trial test

4 Conclusion

1) Adjust the tension of the protective sleeve and the inner core by adjusting the tension of each wire and each strand. Realize the close combination of inner core and protective sleeve. In this way, the elongation of the inner core and the protective cover material is consistent. The soft pull rod has better plastic recovery consistency.

2) By adjusting the size of the connecting part of the pull rod buckle and the pulley, the shear force of the connecting part is reduced, the pull rod is protected from cutting the metal part, and the strength of the original pull rod is maintained.

3) The internal moisture-proof and anti-aging treatment process effectively isolates external moisture from entering the inner core. Ensure the insulation level of soft insulated pull rods and improve the safety of live working.

4) Through the development of large-tonnage soft pull rods for UHV live work, the space occupied by the pull rods is reduced, the labor intensity in the handling and assembly process is reduced, and the degree of freedom of operation in the assembly process is improved. The efficiency of live work and enhance the safety of live work is effectively improved.

Acknowledgments

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References

1. W. Xiang Development of Soft Insulating Rod for UHV Live Working. [J]. China Power，2014（05）: 78-82.
2. Y. Hu，K. Liu. Live work on UHV/UHV AC/DC transmission lines [M].Beijing：China Electric Power Press，2011.
3. Q/GDW 1799.2-2013 《State Grid Corporation Electric Power Safety Engineering Regulations Line Part》 [S],2013.
4. DL/T 1242-2013《Technical specifications for live working on ±800 kV DC lines》[S].2013