Research and Development of Strain Clamp and Connecting Tube of 1520mm^2 Large-section Conductor

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Abstract. ±1100kV Ultra-high Voltage DC Engineering will adopt JL1X/G2A-1520/125-481 large-section aluminum twisted line of steel core, 1520 mm^2 large-section aluminum twisted line of steel core is of four-layer structure and has the same aluminum strand layers of 900 mm^2 and 1000 mm^2 large-section aluminum twisted lines of steel core applied in the previous engineering, but the armor clamp grip cannot be easily guaranteed due to its large aluminum section. By virtue of design optimization, trial-manufacture and test & research of strain clamp and connecting tube, the grip of researched & developed supporting strain clamp and connecting tube of 1520mm^2 aluminum twisted line of steel core in this Paper meets 95%RTS.

Introduction

Constructing ±1100kV DC Power Transmission Engineering and transporting the coal power resources in Ningdong to Zhejiang load center are an concrete embodiment to carry out the strategy of China Western Development and transform the western coal resources advantages into economic advantages; meet the strategic planning of "one-ultra and four-large" of state grid, and are an embodiment of reasonable utilization of power transmission corridor, investment saving and sustainable development road, and a strategic measure for carrying out the scientific development outlook.

The to-be-adopted JL1X/G2A-1520/125-481 aluminum twisted lines of steel core in the engineering are researched & developed and applied for the first time in China. Compared with aluminum steel, it is more difficult to realize the grip of JL1X/G2A-1520/125-481. Therefore, the effects of JL1X/G2A-1520/125-481 strain clamp and connecting tube structure and aluminum single-thread strength on the conductor grip are focused on in this paper.

Design of Strain Clamp and Connecting Tube

Material Selection.

The steel anchor of strain clamp and steel tube of connecting tube adopt Q235 materials, and their rigidity is not greater than 133HB. The aluminum tube adopts 1050A materials and squeezing process and the tensile strength is not less than 80Mpa.

Structural Design

Inner Diameter of Lap Joint of Steel Tube of Connecting Tube

Inner Diameter of Butt Joint between Steel Anchor and Connecting Tube. The inner diameter of steel tube is 1.07 times of steel core diameter and increases by 0.2mm, so d1=15.4mm.

Inner Diameter of Aluminum Tube. The inner diameter of aluminum tube is 1.07 times of conductor diameter and 55.5mm.

Effective Compression Joint Length of Aluminum Tube and Pull Pin Length. The effective compression joint length of aluminum tube of strain clamp and connecting tube of 1520mm^2 conductor is 5.4 times of conductor diameter. The effective compression joint length of aluminum tube of supporting armor clamp of conductor shorter than the previous conductor of aluminum strand structure of three layers or fewer is 6.5 times of conductor diameter.

The pull pin length of aluminum is 180mm, which is 3 times of conductor diameter. Refer to Figure 1 for the schematic diagram of strain clamp NYX-1520/125.

Refer to Figure 2 for the schematic diagram of butt joint connecting tube JYX-1520/125.

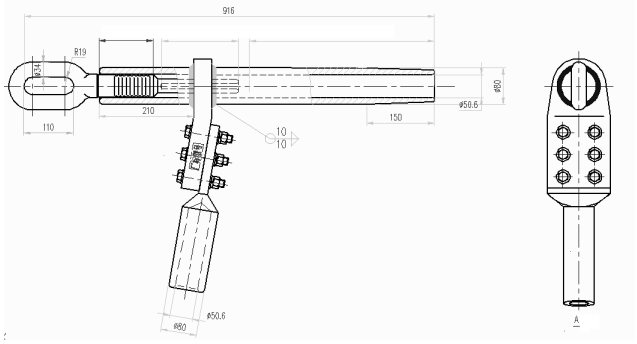

Figure 1 Design Drawing of Strain Clamp NYX-1520/125

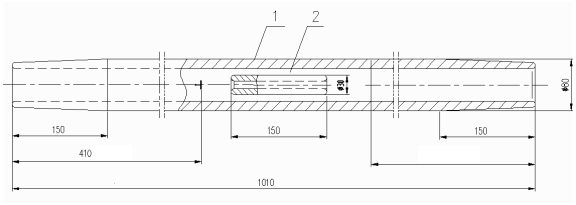

Figure 2 Schematic Diagram of Butt Joint Connecting Tube JYX-1520/125

Refer to Figure 3 for the schematic diagram of butt joint connecting tube JYX-1520/125.

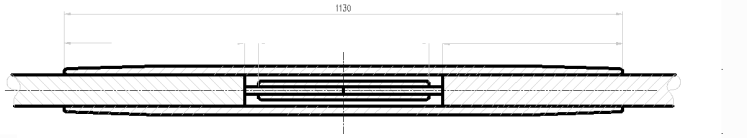

Figure 3 Schematic Diagram of Butt Joint Connecting Tube JYX-1520/125

Grip Test & Research

Test Methods

Pursuant to the requirements of GB/T 2314-2008 General Technical Conditions for Power Armor Clamps, the grip of compression armor clamps (strain clamp and connecting tube) against the twisted line should not be less than 95% of rated tensile strength (RTS) of twisted line. The calculated tensile strength of the conductor is 294.23 kN and the Required value of grip of armor clamp is 279.5 kN

Pursuant to GB/T 2317.1-2008 Test Methods of Power Armor Clamps Section 1: Mechanical Test, the grip test is conducted in the horizontal tensile machine of 1000kN electro-hydraulic servo and the test results are automatically recorded and kept by the computer. The sample of grip test of conductor is component of strain clamp at both ends and middle connecting tube.

Analysis of Test Data

Grip Test of JL1X/G2A-1520/125-481 Conductor. 31 groups of grip tests of connecting tube and strain clamp of 1520/125 conductor of the same batch are done in total, and the grip reaches 95% of rated tensile strength of conductor. Refer to Table 1 for the test data.

Table 1 (1520/125) Grip Test (a)

Connecting tube mode	Grip test results (kN)	Ratio of minimum value to rated tensile strength (%)
Lap joint	294.9; 294.4; 295.7; 293.2; 289.7; 299.4; 299.4; 297.3; 289.7; 290.9; 297.5; 298.1; 296.4; 298.0; 298.2; 298.6;	99.1
Butt joint	292.2; 293.6; 290.3; 294.8; 292.7; 292.2; 293.4; 293.4; 296.4; 295.4; 294.7; 300.0; 300.0; 295.0; 296.4;	97.9

Table 2 (1520/125) Grip Test (b)

Connecting tube mode	Statistical value of lap joint (kN)			
	Max. value	Min. value	Mean value	Dispersity
Lap joint	299.4	291.7	294.9	7.7
Butt joint	300.0	292.2	293.2	7.8

Since the butt joint and lap joint of steel core of connecting tube of 1520/125 conductor meet 95% of rated tensile strength of conductor, and the connecting tube of steel core lap joint is short and of easy construction, the grip of connecting tube may be analyzed based on the steel core lap joint. The steel core lap joint may be shorter than the connecting tube. It is suggested that the steel core of 1520/125 conductor should adopt the lap joint.

Certain strength losses will be caused after the hydraulic connection between armor clamp and conductor. In order to analyze the relations between armor clamp grip and conductor strength, the accumulated tensile strength of conductor and the survival rate of armor clamp grip are defined as follows: Accumulated tensile strength = actually-measured mean strength of aluminum line*nominal sectional area of aluminum line + actually-measured stress in 1% extension of steel line*nominal sectional area of steel line.

Table 3 1520/125 Grip Data Analysis (Lap Joint)

Mean strength of post-twisting aluminum single line (MPa)	Actually-measured stress in 1% extension of galvanized steel line (MPa)	Required stress in 1% extension of galvanized steel line (MPa)	Difference between actually-measured stress and required stress in 1% extension of galvanized steel line (MPa)	Min. grip (kN)	Accumulated tensile strength (kN)	Survival rate of armor clamp grip (%)
174	1507	1340	167	291.7	323.46	90.2

Survival rate of armor clamp grip = test value of armor clamp grip/accumulated tensile strength. Based on the calculation method of accumulated tensile strength of conductor and survival rate of armor clamp, the survival rate of armor clamp grip of 1520/125 conductor in the lap joint is obtained. Refer to Table 3.

Pursuant to the standards and regulations of GB/ T 1179-2008 Concentric Overhead Conductor of Round Line, the rated tensile strength of conductor is sum of tensile strength of aluminum part and tensile strength of steel part. The tensile strength of aluminum part is the product of nominal area of aluminum part and minimum value of tensile strength of pre-twisting aluminum single thread, and the tensile strength of steel part is the product of nominal area of steel core and 1% extension stress. The minimum value of tensile strength of pre-twisting aluminum single thread of JL1X/G2A-1520/125-481 conductor is 160MPa and the 1% extension stress of steel core is 1340MPa.

The survival rate of armor clamp is 90.2%. Considering the survival rate of armor clamp, if the conductor strength only meets the specified value in GB/ T 1179-2008, namely, the minimum value and mean value of tensile strength of post-twisting aluminum single thread are 152MPa and 157MPa respectively, which are 95% of minimum value and mean value of tensile strength of pre-twisting

aluminum single thread, and the 1% extension stress of steel core is 1340MPa, the requirement of 95% RTS of armor clamp grip cannot be met obviously. Therefore, the single thread strength must be properly raised.

If the survival rate of armor clamp is 90.2%, the stress in 1% extension of steel core of JL1X/G2A-1520/125-481 conductor is 1480MPa (140Mpa higher than the required value; generally, it is not less than such value according to the statistical results of type test of steel core), and the mean value of tensile strength of post-twisting aluminum single thread is 165Mpa (8MPa higher than the required value in the standard; in general, it is not less than such value according to the statistical results of type test of aluminum single thread), the grip may meet 95% of rated tensile strength of conductor.

As for the aluminum twisted line of JL/G3A-900/40 steel core adopted in Ningdong-Zhejiang ±660kV DC Engineering, according to the technical conditions, the mean strength of post-twisting aluminum single thread is 172MP (15MPa higher than the required value in the standard) and 1% stress of steel core is 1550MPa (140Mpa higher than the required value) for the purpose of meeting 95% RTS grip value. For the aluminum-steel ratio and mean strength value of post-twisting aluminum single thread of JL1X/G2A-1520/125-481 and JL/G3A-900/40 conductors.

Table 4 Aluminum-steel Ratio and Mean Strength Value of Post-twisting Aluminum Single Thread of JL1X/G2A-1520/125-481 and JL/G3A-900/40 Conductors

Conductor model	Mean strength value of post-twisting aluminum single thread	Aluminum-steel ratio
JL1X/G2A-1520/125-481	165	17.9
JL/G3A-900/40	172	22.5

As for the large-section conductor of 4-layer structure, the armor clamp grip will meet 95% RTS only after the single thread strength is properly raised.

The aluminum-steel ratio of JL1X/G2A-1520/125-481 is 17.87, the strength value of post-twisting aluminum single thread is increased by 8MPa, the aluminum-steel ration of JL/G3A-900/40 is 22.5, the strength value of post-twisting aluminum single thread is increased by 15MPa and the grip may meet 95%RTS.

Temperature Rise Test

Refer to Table 5 for the temperature rise test results of strain clamp NYX-1520/125 and connecting tube JYX-1520/125. The surface temperature of armor clamp is obviously lower than the that of conductor, and the test is qualified.

Table 5 Temperature Rise Test Results of Strain Clamp and Connecting Tube

Model/specification	Test current (A)	Surface temperature of conductor (°C)	Surface temperature of armor clamp (°C)
NYX-1520/125	1913	90.86	64.15; 64.82; 64.00; 65.07
JYX-1520/125			72.07; 71.96; 72.50; 72.33
Judgment: in the temperature rise electrification, the surface temperature of the sample does not exceed that of corresponding conductor and meets the standards and requirements.			

Resistance Test

Refer to Table 6 for the test results of connecting resistance after temperature rise of strain clamp NYX-1520/125. Refer to Table 7 for the test results of connecting resistance after temperature rise of connecting tube JYX-1520/125. The connecting resistance of armor clamp is less than the resistance of conductor of equivalent length, and the test is qualified.

Table 6 Connecting Resistance after Temperature Rise of Strain Clamp (Ambient Temperature 20°C)

Model/specification of armor clamp	Connecting length (mm)	Resistance when conductor of equivalent length is at 20°C (μΩ)	Connecting resistance actually-measured at 20°C (μΩ)
NYX-1520/125	1310	29.87	14.24; 14.90; 14.69; 14.48
Judgment: after the temperature rise, the connecting resistance of the sample does not exceed the resistance of corresponding conductor of equivalent length and meets the standards and requirements.			

Table 7 Connecting Resistance after Temperature Rise of Connecting Tube (Ambient Temperature at 20°C)

Model/specification	Connecting length (mm)	Resistance when conductor of equivalent length is at 20°C (μΩ)	Connecting resistance actually-measured at 20°C (μΩ)
JYX-1520/125	1100	25.08	14.80; 14.17; 14.35; 14.20
Judgment: after the temperature rise, the connecting resistance of the sample does not exceed the resistance of corresponding conductor of equivalent length and meets the standards and requirements.			

Summary

The test grip value of strain clamp and connecting tube of 31 groups of JL1X/G2A-1520/125-481 conductors researched and developed meets 95% of rated tensile strength of conductor. The test results further verify the reasonability of inner diameter value of steel core, inner diameter value of aluminum tube, and pull pin length value of strain clamp and connecting tube in the design. In other words, the recommended inner diameter of steel tube and aluminum tube is 1.07 times of conductor diameter, and the pull pin length is 3 times of conductor diameter.

According to the grip test results of JL1X/G2A-1520/125-481 conductor and steel core, it is recommended that the steel core of connecting tube of JL1X/G2A-1520/125-481 conductor should adopt the lap joint scheme, which may effectively shorten the connecting tube length.

In order to guarantee that the grip meets 95% of rated tensile strength of conductor, the mean value of tensile strength of post-twisting aluminum single thread should not be less than 165MPa and steel core 1% stress should not be less than 1480MPa.

It is suggested that the aluminum-steel ratio in the selection of large-section conductor of 4-layer structure should not be less than 20.

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