

# Mechanical Performance Test and Analysis of DC Charging Cable for Electric Vehicles

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**Abstract:** The mechanical performance of the cable is directly related to the electrical performance of the cable, and even affects the safety, reliability and durability of the whole charging process. Electric vehicle charging cable is different from the traditional wire and cable, which has higher requirements for the mechanical properties of the cable. In this paper, the tension test is carried out on the insulation or sheath of the cable. By observing the phenomenon of "slipping" and "end breaking" in the process of the test, the structure of the flat push collet is optimized. It can be seen from the comparative test analysis that the improved chuck mechanism has a great effect on improving the test accuracy and reliability

## 1 Introduction

With the development of electric vehicle, the performance of charging cable as a basic component plays an important role in the whole charging process[1]. The mechanical performance of the cable is directly related to the electrical performance of the cable, and even affects the safety, reliability and durability of the whole charging process. Electric vehicle charging cable is different from the traditional wire and cable, which has higher requirements for the mechanical properties of the cable. At present, China's mechanical property test standards are based on two sets of standards GB/T 2951-2008 and GB/T 17650-1998, there are few methods for the mechanical strength test of the finished cable, only a new method for swing test and extrusion test is given.

The release of relevant standards provides test methods and theoretical support for the research of mechanical properties of electric vehicle charging cable. Also, the performance index obtained from the standard test is suitable for the reference of cable performance analysis, which is the key to the excellent performance of the feedback cable. So, it is very important to verify the applicability and improvement of the standard method.

In this paper, according to "The general test method for insulating and sheathing materials of cables and optical cables", the tensile test is carried out on the insulating or sheathing materials of cables. This paper analyzes the phenomena of "slip" and "end break" in the process of experiment, optimizes the structure of flat push chuck, and improves the precision and efficiency of experiment.

## 2 Mechanical property test of cable insulation

### 2.1 Specimens

The specimens are three kinds of insulating core materials of PVC/C insulation mixture type, at least five of which are used for mechanical property test before aging. A sufficiently long sample segment is cut from each tested insulated wire core sample, and the sampling length is required to be 100mm. All test pieces were stored in a cool place at room temperature ( $23 \pm 2^\circ$ ) at least to avoid the influence of aging caused by sunlight. The samples are copper conductor taken from the core samples, and the position is marked in the middle of each sample with an interval of 25mm for the extender to identify the relevant position of the test.

The outer diameter and thickness were measured with optical instruments, and the contact pressure shall not exceed  $0.07N/mm^2$ . The thickness error shall be less than 0.01mm, and the width error shall be less than 0.04mm. Two sections of circular inner surface and stranded conductor are selected, and the relevant thickness data of three test pieces are shown in Table 1:

Table 1. Charging cable sample

Specimen type	Blue 1	Red 2	Green 3
section profiles	Circular internal surface	Stranded conductor	Circular internal surface
thickness (mm)	0.895±0.01	0.933±0.01	0.855±0.01
outer diameter (mm)	4.288±0.04	3.836±0.04	3.695±0.04



**Fig.1** Specimen mounting diagram

This test is based on the electronic universal testing machine (model utm4204) developed by Shenzhen sانشizong company. According to the standard, when the non self tightening collet is used to clamp the test piece, the total spacing between the control collets is about 85mm, and then the extensometer is evenly clamped on both ends of the test piece to ensure the spacing is 25mm. The clamping test piece was centered between two chucks as much as possible. The effect of clamping the test piece before the test is as shown in Figure 1.

## 2.2 Analysis of test data

The extensometer transmits the real-time tension value collected to the industrial computer, and extracts the maximum tension after processing. At the same time, the distance between the two marked lines is measured on the same test piece.

(1) Calculation formula for tensile strength[2]:

$$\sigma = \frac{F_b}{A} \quad (1)$$

$F_b$ ——Maximum tension, Unit: Newton (N), Measure according to the standard and round to 2 decimal places.

$A$ ——Cross section area, Unit: Square millimeter( $\text{mm}^2$ ), Measure according to the standard and round to 2 decimal places.

(2) Calculation formula of elongation at break[2]:

$$\varepsilon_t = \frac{L_2 - L_1}{L_1} \times 100\% \quad (2)$$

$L_1$ ——Distance between marker lines before stretching, Unit:millimeter(mm). Measure according to the standard and round to 2 decimal places.

$L_2$ ——Distance between marker lines after stretching, Unit:millimeter(mm). Measure according to the standard and round to 2 decimal places.

According to Eqs (1) and (2), relevant data collected by Material Test 4.1 platform was substituted to obtain relevant data. The relevant data of three types of insulation test pieces of blue, red and green are arranged as shown in Table 2.

**Table 2.** Data sheet of tensile test

Parameter	Thickness	Outer diameter	Elongation at break	tensile strength	maximum force	
						Unit
Specimen 1#	1	0.895	4.288	242.1135	12.9763	123.803
	2	0.897	4.287	256.5645	13.5276	129.065
	3	0.894	4.288	249.6856	13.8884	132.448
	4	0.895	4.289	236.1023	14.0745	134.293
	5	0.894	4.288	245.5783	13.3423	128.762
	maximum	0.897	4.289	256.5645	14.0745	134.293
Specimen 1#	1	0.933	3.836	204.7335	18.1429	138.331
	2	0.933	3.836	173.2756	16.8752	128.664
	3	0.934	3.838	183.6445	17.5014	133.455
	4	0.932	3.835	192.3580	18.7736	143.152
	5	0.933	3.835	198.1883	18.2074	138.793
	maximum	0.934	3.838	204.7335	18.7736	143.152
Specimen 1#	1	0.855	3.695	246.5734	15.8076	120.583
	2	0.857	3.694	245.7545	15.3464	117.064
	3	0.854	3.695	243.8356	15.4072	117.531
	4	0.855	3.696	244.7736	15.3876	117.435
	5	0.854	3.695	245.7682	14.8793	116.245
	maximum	0.857	3.696	246.5734	15.8076	117.531

## 3 Problems

According to GB/T 2951.11-2008[3] "Measurement method for mechanical properties of insulating and sheathing materials", the results of any test piece pulled at the collet shall be voided. The calculation of tensile

strength and elongation at break requires at least 4 valid data, otherwise the test shall be repeated[4]. However, in the actual use of wedge-shaped chuck and push chuck, the phenomenon of "slipping" and "end breaking" are easy to appear, which can not effectively clamp the test piece, so that the test fails.

**"Slip"**: refers to the sliding between the test piece and the bayonet, even falling out of the block at one end (as shown in Fig.2). This phenomenon causes the test to fail and the test piece to be scrapped. The residual condition is shown in Fig.4 for specimens numbered "1", "8" and "9". This phenomenon often occurs in the second half of the test, when the specimen has undergone significant plastic deformation.

**"End break"**: means that the test specimen is pulled off from the flush end of the collet at one end in the early stage of the test (as shown in Fig.3). In this case, the test results of any test specimen are invalid. As shown in the test pieces with serial numbers "2" to "7" in Figure 3.14, the test pieces did not undergo stretch whitening, that is, the test pieces were scrapped before they were still in the elastic stage or the yield stage.



Fig.2 Failure figure of "slip"

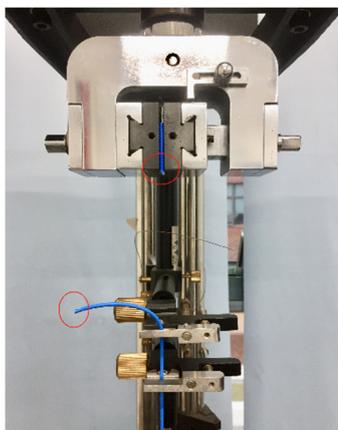


Fig.3 Failure figure of "end break"

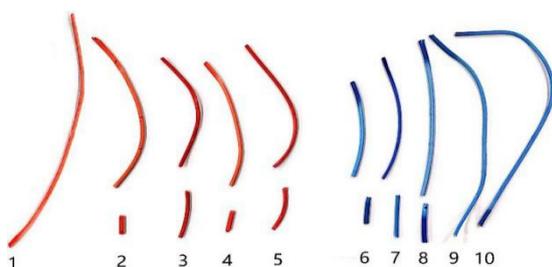


Fig.4 Failure specimen chart

From the force-displacement curve obtained in the experiment, it can be seen that the force displacement curve presented by each sample is relatively discrete. Combined with the displacement of the abscissa and the force data of the ordinate, it can be judged that the failure test process is extremely unstable.

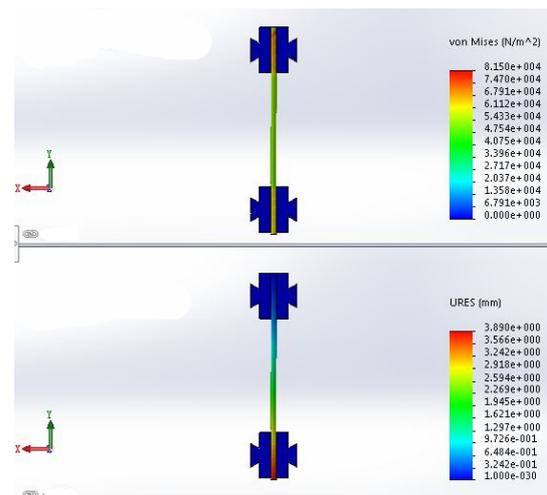
In the case of "end breaking", the curve will soon fall back at a smaller displacement. At the same time, the failure phenomenon of "end breaking" in two stages can be judged by the radian when falling back. In the "elastic stage" fracture, the curve fall back radian is large. In this stage, except the ductile fracture can not be recovered, the load can be recovered after withdrawing, which mainly occurs in the displacement of 30mm. During the "plastic stage" fracture, the curve fall back radian is small. In this stage, the specimen has undergone elastic-plastic deformation. After the load is removed, part of the curve can be recovered, mainly distributed between 83mm and 126mm displacement. This two stages can not reflect the real performance of the material.

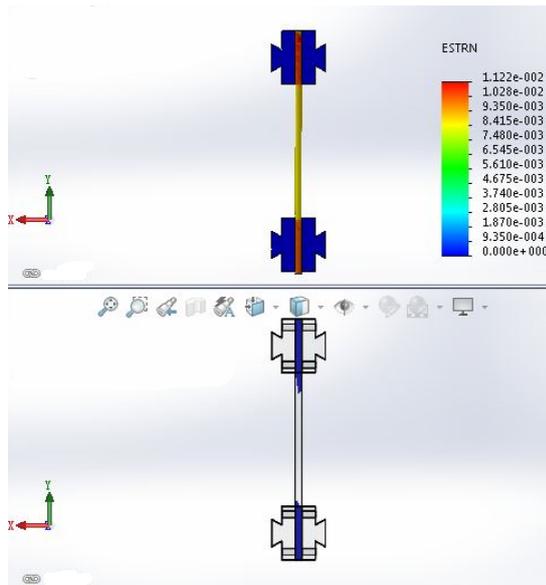
When "slip" occurs, there is no difference between the curve in the initial and intermediate stages, that is, it can smoothly go through "elastic stage" and "plastic stage". However, with the increase of tensile load, the specimen began to slide between the clamps, specifically at the displacement of 111mm, the curve had obvious fluctuations.

So when the test piece appears "slip" and "end trimming" phenomenon, the degree of dispersion of the tensile curve generated by the feedback is large, which brings great error to the test results, and the real mechanical properties of the material can not be tested.

## 4 Improvement of test chuck

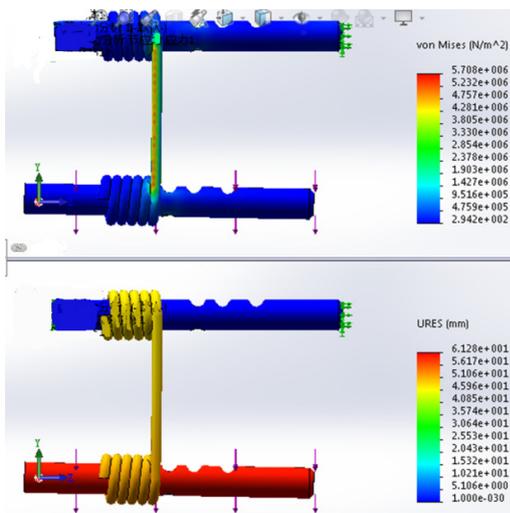
### 4.1 Comparison of clamping effects





**Fig.5** FEM diagram of direct clamping

Read the relevant literature and learn that there is another way of winding clamping [5-7]. Use SolidWorks software to carry out three-dimensional modeling of the main structure and import it into the simulation finite element analysis plug-in to simulate two kinds of clamping effects, as shown in Fig. 5 and Fig.6.



**Fig.6** FEA diagram of winding clamping

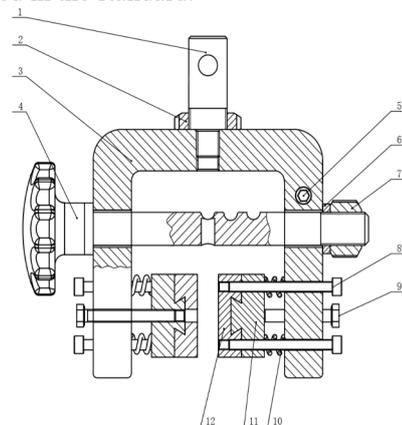
Through theoretical and finite element simulation analysis, the problem of stress concentration caused by direct clamping can be avoided by winding the test piece on the support rod for clamping, so as to avoid the phenomenon of "end breaking" caused by extrusion deformation. In order to verify the feasibility of the winding clamping method, an auxiliary winding clamp was made for testing.

#### 4.2 Design of Clamping heads

As shown in Fig. 7, it is a schematic diagram of a new type of winding chuck given in this design. The main structure of the chuck is divided into upper and lower

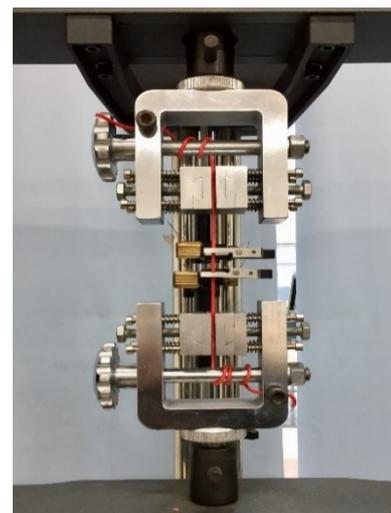
parts according to its function. The upper part is the clamping and alignment function structure, mainly composed of plum handle, rotatable support rod with centering hole and bolt. The lower part is the pre tightening and positioning function structure, mainly composed of guide rod, spring, clamp block and bayonet.

As shown in Fig. 8, it is a new type of chuck produced by trial production. The main material is #45 steel. According to the method given in the standard, the test is carried out on UTM4204 electronic universal testing machine, and the control test is carried out with the flat push type chuck. All the test pieces used are a batch of insulating materials of the same model and specification. The only difference is that the length of the test piece used for the new chuck is 200 mm, not 100 mm as specified in the standard.



1. Fixture connection 2.lock nuts 3.clamping 4.Plum handle support rod 5.Bolt 6.Spring gasket 7.Back nut 8.Locating screw 9.Guide screw 10.Bayonet 11.Clamping block 12.Spring

**Fig. 7** Structure diagram of winding collet



**Fig.8** Winding collet prototype



**Fig.9** Horizontal pushing clamp

**Table 3.** Experiments 'Data Comparison

Horizontal pushing clamp				New clamp			
Parameter	Elongation at break	Tensile strength	maximum force	Parameter	Elongation at break	Tensile strength	maximum force
Unit	%	KgF/cm <sup>2</sup>	N	Unit	%	KgF/cm <sup>2</sup>	N
1	0.0000	12.3738	86.539	6	276.9431	15.8526	90.361
2	262.9045	14.8970	88.608	7	278.1683	15.3737	89.590
3	111.4672	8.9436	76.315	8	277.8935	16.5961	92.753
4	265.7580	16.5115	92.747	9	277.9045	16.1270	91.608
5	274.5584	16.3115	92.596	10	278.8945	16.8544	93.114
maximum	274.7580	16.5115	92.747	maximum	278.0935	16.8544	93.114

In order to determine whether the new collet has an impact on the test results, the extracted relevant data are sorted out as shown in table 3 below.

According to the data in the table above, when the flat push chuck test was used, the "slip" phenomenon occurred in the specimen with the serial number "1", which showed that the curve fluctuated in the later section and then dropped. The specimen with serial number "3" had a "end trimming" phenomenon, showing that the curve suddenly changed abruptly during the rise. In contrast, the use of the new chucks has ensured the normal conduct of the test. Therefore, the curves of the failed test pieces are excluded for analysis, and the remaining 8 tensile curves are concentrated, which is in accordance with the characteristic curve of the insulating material.

(1)From the perspective of the maximum tensile force, except for the data of the failed test pieces with serial numbers "1" and "3", the rest of the data are concentrated between 88N-93N. It can be considered that the tension value obtained by using the new type of collet test is more stable than that of the flat collet.

$$\sigma_{Old}^2 = \frac{\sum(X - \mu)^2}{N} = 3.6842 \quad (3)$$

$$\sigma_{New}^2 = \frac{\sum(X - \mu)^2}{N} = 1.83 \quad (4)$$

$$\sigma_{Old}^2 > \sigma_{New}^2 \quad (5)$$

(2)From the perspective of tensile strength, there is little difference in the data obtained from the successful

test of two collets.

(3)In terms of elongation at break, the value obtained by using the new collet is larger than that by using the flat collet. This is because the specimen selected for the new chuck is 200mm, and with the increase of material modulus, it can naturally withstand a longer stretching distance during the stretching process.

## 5 Conclusion

It is verified by the prototype that the new type of winding collet can facilitate the correct clamping of the test piece, ensure that the stress of the test piece is even during the test process, and solve the problems of "slip" and "end breaking". The measured data is stable and has little difference with the value measured when using the specified chuck, which can ensure the accuracy and reliability of the test results. Moreover, it improves the success rate and efficiency of the test, and achieves the test results required by the standard. It provides an improved method and reference for selecting mechanical chuck to clamp the soft material samples of cable insulation and sheath for tensile test. Since the new collet is a non-standard part, the corresponding test method should be improved simultaneously for the use of the collet.

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