Spacecraft Matrix Cable Assembly Process Research

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Abstract. The matrix calbe can effectively realize lightweight and high reliability of spacecraft cable network. This paper focus on the assembly process of matrix cable which has multi-line characteristics, introduce the assembly process and related parameters. The result was verified by appearance inspection, tensile test, voltage drop test and metallographic experiment. Make sure that the assemble process of the cable is high quality and reliability.

Keywords: Spacecraft; Matrix Calbe; Assembly Process.

1. Introduction

The cable network is a channel and hub to realize the functions of power transmission, instruction transmission, information exchange and other functions between the whole system engineering of the spacecraft, the instruments and equipment of each subsystem [1], and the reliability of its installation is one of the key factors related to the success or failure of the spacecraft. Lightweight and high reliability are important development directions for spacecraft cable assembly technology. At present, the electrical connectors in the conventional cable network, due to the limitations of the design, mostly use a single-point single-wire design method, but with the increase in the number and type of transmission signals in the cable network, if the design is continued, it is bound to increase a large number of cables, resulting in an increase in the weight of the cable network. A new design of single point and multiple lines is required to meet the transmission needs of the signal. The design of the matrix cable came into being, the matrix cable network as a whole adopts a fishbone topology, the typical structure is shown in Figure 1[2], the matrix cable is output by the main component connector of the load integrated service unit matrix circuit, and the load comprehensive service unit matrix circuit backup connector is returned after traversing the communication hatch equipment. This design reduces the number of nodes, which in turn reduces cable length and number of plugs, resulting in reduced weight and reliability. This paper focuses on the characteristics of this new type of matrix cable, carries out process research, and implements tensile test, voltage drop test, SEM test, etc. on the cable after the assembly, aiming to ensure the quality and reliability of the assembly and ensure that it meets the needs of the model product.

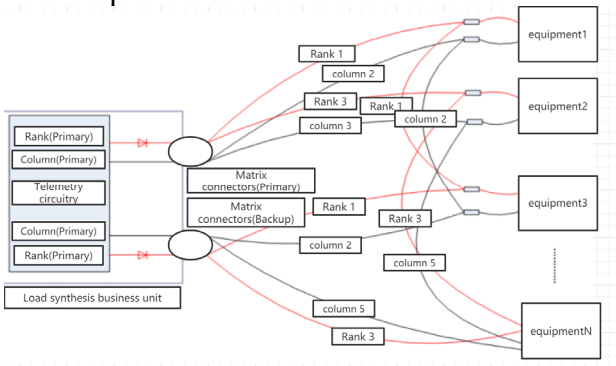


Fig 1. Schematic diagram of matrix cable network

2. Matrix Cable Features

Due to the use of matrix instructions, matrix telemetry design, to achieve this design requires a single solder joint to weld at least 2 wires, and at this stage of the spacecraft cable network used in the welded electrical connector internal space is small, the solder joint cross-sectional area is also very small. The relevant standards stipulate that the crimp type electrical connector can only be crimped to one conductor in a crimping tube, and the above design cannot be realized. The double redundant design that realizes the backup of electrical functions in some models can also be used to add a termination module outside the electrical connector, as shown in Figure 2 and Figure 3, but this termination module is not easy to protect during use due to its structural design, and there have been many quality problems such as wire breaking from the root during use, and its external material resistance to the space environment is poor. This is the new requirement for the matrix cable network assembly.

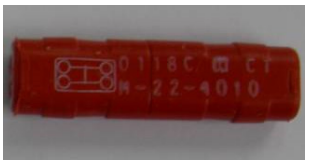


Fig 2. Typical 1 CAM-22 module



Fig 3. Typical 2 CTJmodule

3. Test Materials

According to the design requirements, the D-436 crimp terminal is selected as the wire distribution connection device, and the material characteristics are as follows:

a. The terminals are made of metal, and the outer sheath is made of insulating organic materials;

b. Divided into two kinds of wire connection and termination, the connection method is crimping, and multiple wires can be placed in the same crimping tube;

c. small size, light weight.

The lighter weight wave proof sleeve is selected as the material for the continuity of the shielding wire shield; High temperature resistant black heat shrinkable sleeve is selected as the protective material after terminal crimping and shielding continuously. The supporting materials are shown in the table below:

Table 1. Main supporting materials

serial number	Material name	serial number	Material name	remark
1	Polyimide film	3	Wave-proof sleeve	Masking processing
2	Silver plated copper wire	4	High temperature sheath	

4. Test Procedures and Procedures

The process flow of the crimp connection between the D-436 terminal and the wire is shown in Figure 4.

1) Calculation and analysis of the applicability of different specifications of wire sub-wiring connection devices and different wire diameter wires

a. The way in which the wire is placed into the wire branch connection device. According to the requirements of the relevant crimping standards, the cross-sectional area of the conductor that can be accommodated in the crimping tube should correspond to the model of the selected crimp terminal. Multiple conductors are placed in the same crimping tube, and the sum of the cross-sectional area of the wires should correspond to the model of the selected crimp terminal, and the wires should be placed parallel and not twisted.

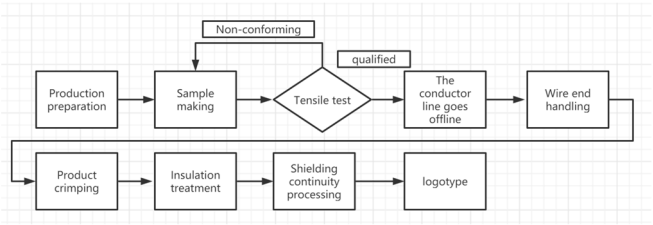


Fig 4. Process flow diagram

b. Terminal and wire matching. D-436 short terminal inner diameter is divided into three specifications, by color scale distinction from fine to thick are red, blue, yellow, three specifications of the wire connection distribution device can accommodate the cross-sectional area of the wire as shown in Table 2, different wire nominal cross-sectional area as shown in Table 3.

Table 2. The range of terminals that hold the cross-sectional area of the wire

serial number	Color stops	The range of terminals that hold the cross-sectional area of the wire(mm2)
1	Red	0.15-0.75
2	Blue	0.39-1.34
3	Yellow	0.95-3.37

Table 3. The standard cross-sectional area of the conductor

serial number	Wire gauge (AWG)	Wire cross-sectional area(mm2)
1	26	0.15
2	24	0.24
3	22	0.38
4	20	0.61

2) Crimping process test of wire distribution connection device

Through the study of different specifications of wire distribution connection device and wire matching, a variety of different terminals and different wire combination results were obtained, according to the above results, the crimping process test of the wire distribution connection device was carried out, several process parameters were obtained, and the process method and process parameters of crimping were mastered.

a. Wire end treatment. The length of the wire end treatment should be controlled at 7mm+0.5mm (inconsistent with the rest of the crimp terminals), see Figure 5. Too long will cause the spacing between the insulation layer and the inner core wire to be too large, and the core wire to expose the insulation terminals is too long, affecting the tensile strength of the terminals and wires; Too short will cause the conductor core to enter the length of the crimp barrel is insufficient, resulting in unqualified specimen quality.

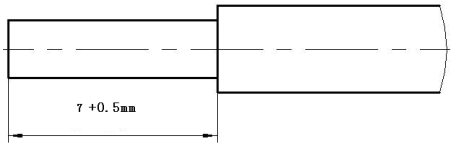


Fig 5. Wire end handling length

b. Wire distribution connection device and wire assembly. The distance between the conductor insulation layer and the crimper is ≤ 0.5mm and cannot enter the crimper.

c. Crimping of test pieces. Special crimping tools are used. Crimp 3~5 crimp test pieces.

A typical sample of the completed assembly is shown in Figure 6.

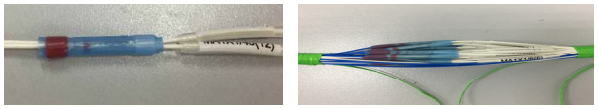


Fig 6. Typical sample

5. Test Validation Results

After the specimen is completed, refer to the relevant standards [3] to first conduct a visual inspection of the crimp position of the cable, check the state of the pressure pit, and whether there are defects such as cracks, bends, and burrs. Then the tensile test and voltage drop test are used to determine the crimp strength and good contact. Finally, the profile of the crimp part is micro-observed by metallographic test to determine whether the deformation of the crimp site is uniform, whether there is a crack inside, whether the coating has peeling off and other damage.

5.1 Visual Inspection

The position of the pressure pit is reasonable, the pressure pit is uniform, symmetrical left and right, no cracks, the pressure tube has a good appearance, no coating uplift and shedding, no bending, no burrs, and the appearance meets the requirements of the standard. This is shown in Figure 7.

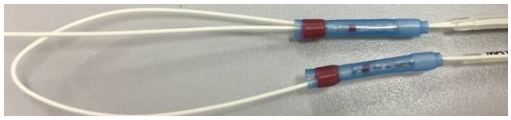


Fig 7. Appearance of the specimen

5.2 Tensile Test

The tensile strength of the sample is measured by the tensile tester, the tensile speed is (25~50) mm/min, the value is measured until the pull break, and when multiple wires are crimped, the tensile force test is carried out on the wires in the pressure tube in turn, and the tensile value is recorded. The tensile force value of the crimped part shall not be less than 70% of the tensile force value of the conductor, and it shall be judged as qualified. The test results are shown in Table 4:

Table 4. Tensile test results

serial number	Specimen number	Tensile value N (Standard requirements)	The test value N	outcome
1	sample1	500	467	qualified
2	sample2	320	241	qualified
3	sample3	230	198	qualified
4	sample4	155	132	qualified
5	sample5	90	72	qualified
6	sample6	60	51	qualified

After tensile testing, the specimens meet the tensile force value requirements.[4]

5.3 Voltage Drop Test

Measure the voltage drop of the crimp connector using a digital voltmeter with an accurate value of 0.01mV;

To test the pressure, drop at both ends of the wire, the two stylus should be 14 mm apart, as shown in Figure 8.

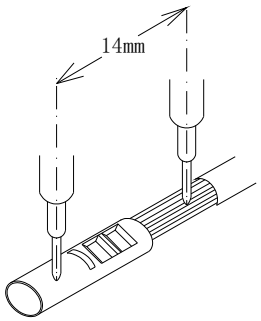


Fig 8. Pressure drop measurement of the D-436 terminal

The test results are shown in Table 5:

Table 5. Test results

serial number	Wire specifications	Test current(A)	Maximum voltage drop(mV)	outcome
1	sample1	1.5	5.0	qualified
2	sample2	2.0	4.0	qualified
3	sample3	3.0	4.0	qualified
4	sample4	5.0	4.0	qualified
5	sample5	7.5	4.0	qualified
6	sample6	1.5	5.0	qualified

After the voltage drop test, the specimen meets the voltage drop requirements.

5.4 Microscopic Profile Test

The microsection test of the crimped part should meet the following requirements:

a) Uniform deformation of the crimping part of the crimping cylinder;

b) The circular cross-section of all cores in the crimping tube is deformed, and the gap area between all the cores and between the core and the inner wall of the crimping conduit is less than 10% of the total cross-sectional area of the core, and the airtight connection between the conductor and the crimping tube is airtight;

c) The deformed crimping cylinder shall not be cracked or damaged, and the coating shall not be bulging, peeling and shedding;

The sample profile after the test is shown in Figure 9:



Fig 9. Test cross-section

As can be seen from the above figure, the crimping part of the crimping tube of the sample is uniformly deformed, the circular section of all the core lines in the crimping tube is deformed, the gap area between the core, the core and the inner wall of the crimping tube is much less than 10% of the total cross-sectional area of the core, the wire and the crimping tube are airtightly connected, the

deformed crimp tube has no cracks or damage, and the plating layer has no uplift, peeling and shedding. The crimping is in good condition and can meet the needs of the actual model.[5]

6. Summary

Due to its special network structure, matrix cable can effectively reduce the number of nodes in the cable network, achieve lightweight and high reliability. However, due to the special structure that requires multiple sub-wiring, it is quite different from the traditional process. In view of this, this paper studies the assembly process of such cables, calculates and analyzes the applicability of different specifications of wire distribution devices and different wire diameter wires, and the crimping process test to ensure the high quality of the assembly. The assembly effect is verified by visual inspection, tensile test, voltage drop test and microscopic profile test, ensuring the high reliability of matrix cable split connection.

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