Development of flame retardant and fire-resistant optical cable based on ceramic sheathing materials

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Abstract

In this paper, a kind of flame retardant and fire-resistant optical cable is prepared with ceramic sheathing materials. Its structure is mainly composed of cable core, longitudinal covering a layer of two-sided synthetic mica tape outside cable core, inner sheath packed with ceramic sheathing materials, steel wire armor outside inner sheath, wrapping a layer of two-sided synthetic mica tape outside armor and then outer sheath extruded LSZH. Proceeding flame retardant and fire-resistant test, LOI of ceramic sheathing materials and temperature index of cable according to EN ISO 4589 are up respectively to 40% and 370℃. Light transmittance of flame retardant and fire-resistant optical fiber cable is more than 68% according to IEC61034. According to IEC60331-11/25, maximum change in attenuation of optical fibers is 0.16dB under 90 minutes fire alone at 750℃ and 15 minutes cooling time condition. According to BS6387 category "CWZ", maximum change in attenuation of optical fibers is less than 1.00dB under 180 minutes fire alone at 950℃ condition; maximum change in attenuation of optical fiber is 0.22dB under 15 minutes fire alone and 15 minutes fire with water at 650℃ condition; maximum change in attenuation of optical fibers is 0.78dB under 15 minutes fire with mechanical shock at 950℃ condition. The flame retardant and fire-resistant cable meets IEC60332 1-2: single cable flammability and IEC60332 3-24: multiple cable flammability requirements. The novel flame retardant and fire-resistant optical cable which can broadly be popularized to extent of subway base station, tunnel traffic and so on, with ultra-high performance of flame retardant and fire-resistant, has great value in the application fields.

Keywords: ceramic sheathing materials; flame retardant & fire-resistant; optical cable; circuit integrity; subway base station.

1. Introduction

With development of series of the optical cables, special optical cables are more and more popular to most countries. Part of special cables is flame retardant and fire-resistant cable which was studied many years causing immeasurable profit and untouchable influence.

Existing common optical cables is difficult to supply and remedy the existing communication drawback, especially in the event of fire. The ordinary optical fiber in cables is susceptible to damage so as to loss of communication and even larger catastrophe occurred. Initially, each company has developed several traditional flame retardant and fire-resistant cables, which are primarily composed of ordinary parcel layers of refractory materials. The most common flame retardant and fire-resistant cables use mica tape and lower-level refractory materials, which are not able to effectively block heat transfer, so heat can, over time, gradually deep into the optical fibers and other materials. Attenuation of optical fiber can easily lead to variation in the heat and fire, so in a long time it is difficult to maintain the flowing of the optical fiber communication, causing loss of the ability to transmit information. It is proved that fire resistance can't be unilaterally sustainable by ordinary low smoke zero halogen and conventional mica tapes. The companies are also subjected to further explore the development of a series of flame retardant and fire-resistant cables, however the cables which are applied in the field of refractory in real time and achieved great effects are few, so the development of comprehensive performance of superior flame retardant and fire-resistant cable is extremely urgent.

In the paper, we try our best to develop a kind of flame retardant & fire-resistant cable with excellent comprehensive performance, which can give full play to the performance of a variety of materials to achieve flame retardant and fire resistant standards at domestic and abroad. Its structure is composed mainly of cable core, longitudinal covering a layer of two-sided synthetic mica tape outside cable core, inner sheath packed with ceramic sheathing materials, steel wire armor outside inner sheath, wrapping a layer of two-sided synthetic mica tape outside armor and then outer sheath extruded LSZH. It is a new type of optical cable which can be widely used in subway, rail transportation and other areas.

2. Application of materials

2.1 Two-sided synthetic mica tape

Two-sided synthetic mica tape is based on two mica tapes covered three layers of E-glass fiber clothes with high temperature silicone, just like "2+3" structure. This mica tape can resist 1100℃, so it can be suitably applied to flame retardant & fire resistant optical cables.

2.2 Ceramic sheathing material

Ceramic sheathing material uses low smoke zero halogen ceramic polyolefin, of which LOI and temperature index according to EN ISO 4589 are up respectively to 40% and 370℃. When the optical cables prepared by ceramic sheathing material encounter conflagration, it is prone to form ceramics, like a dense protective layer, which blocks flames and heat transfer thus the optical fibers free from heat damage.

3. Structure

Its structure is consist of cable core, covering two-sided synthetic mica tape, a layer of steel tape packed with ceramic sheathing materials, steel wire armor wrapped mica tape and outer sheathing. Its structure diagram is shown in figure 1.

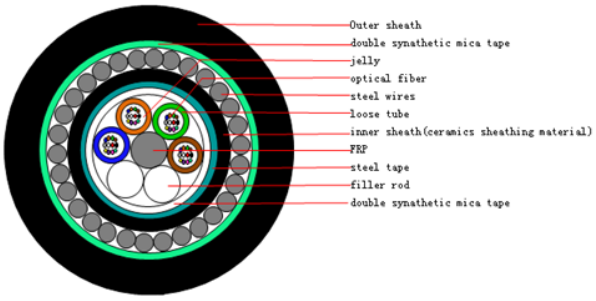

Figure 1. Diagram of the structure

The new structure, together with two layers of fire-resistant tapes, two layers of different flame retardant materials and two types of armored layers, is viewed as three kinds of six layers of flame retardant and fire-resistant mode to achieve synergistic effect. The layers of flame retardant outer sheath can absorb most of the heat and block fire, while mica tape can further complete the task, and inner sheath can absorb continuous remaining heat. It is flame retardant mechanism that inner sheathing material encountered heat can quickly occur to ceramic which further isolated flame and oxygen, so that the optical fiber can be maintained the integrity of optical circuit in long time.

4. Experiment and analysis

The flame retardant & fire-resistant optical cables mainly focus on mechanical properties, temperature cycling, flame retardant properties and fire-resistant properties. Considering application and customer acceptance, the optical cables must meet basic requirements and testing performance, so a series of experiments were carried out.

4.1 Mechanical properties and temperature cycling

The mechanical properties reflect ability to resist external damage to the optical cables. The mechanical properties mostly pay attention to attenuation change. The temperature cycling mainly pays judgments on applicability of optical cables in different environment. Its test results are shown in table 1.

Table 1. Mechanical properties and temperature cycling test

Item	Test Method	Acceptance Condition	Test Result
Tensile Strength IEC 60794-1-2-E1	- Load: 5000N - sample Length 50m	- Fiber strain ≤ 0.33% - No fiber break and no sheath damage.	Qualified
Crush Test IEC 60794-1-2-E3	-Load: (4000N/100mm)	- Loss change ≤ 0.1dB@1550nm - No fiber break and no sheath damage.	Qualified
Impact Test IEC 60794-1-2-E4	- Impact points: 5 - Times of per point: 5 - Impact energy: 10J	- Loss change ≤ 0.1dB@1550nm - No fiber break and no sheath damage.	Qualified
Cable bend IEC 60794-1-2-E11	-Diameter of mandrel:10 x OD -Number of turns:4 -Number of cycles:3	- Loss change ≤ 0.1dB@1550nm - No fiber break and no sheath damage.	Qualified
Temperature cycling IEC 60794-1-2-F1	- Temperature: -40℃~+60℃ - Time of each step: 24h - Number of cycle: 2	- Loss change 0.05dB/km@1550nm - No fiber break and no sheath damage.	Qualified

Figure 2a. Process of cable bending testing

Fig 2b. The fiber attenuation after bending testing with 20D Bending radius

Above table 1, it is reflected that mechanical properties and temperature cycling test results are qualified.

Especially, the fiber attenuation preformed at 1550nm after bending testing with 20D bending radius is 0.02dB, as seen in fig.2. The well mechanical properties are because of utilizing dozens of steel wires spirally in optical cables which can strengthen tensile strength. Double armor layers and double sheath layers can immensely facilitate the optical cable to resist crush and impact, so the optical cable can pass the mechanical performance.

4.2 Flame retardant properties

The first test of the flame retardant & fire-resistant optical cable is about light transmittance, which reflects smoke density. The bigger light transmittance, while the small smoke density. Light transmittance is ruled no less than 60% according to IEC 61034-2:2005. Light transmittance of the flame retardant and fire-resistant optical cable is up to 68% greater than above standard, shown in fig.2. Light transmittance is principally relative to the sheathing materials named low smoke zero halogen ceramic polyolefin.

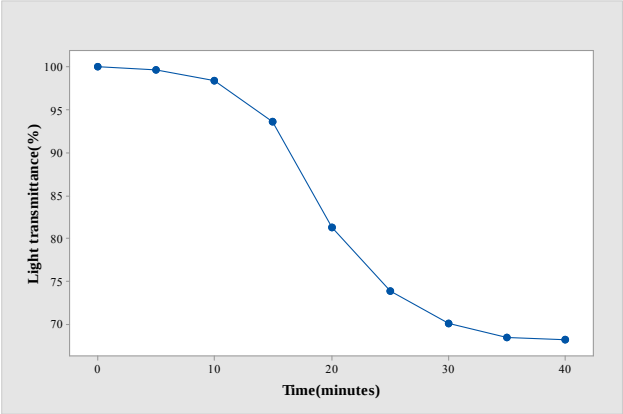

Figure 2. Diagram of light transmittance

We also carry out flammability test of the optical cable according to IEC 60332, because flammability test is very vital to the flame retardant optical cable. The test results are proved that the flame retardant and fire-resistant cable meets IEC 60332 1-2: single cable flammability and IEC 60332 3-24: multiple cable flammability requirements, shown in table 2.

Table 2. Test results of flame retardant performance

Item	standard	Acceptance criteria	Test results	Assessment
Single cable	IEC 60332-1-2:2004	Distance between the lower edge of upper support and the onset of charring is more than 50mm.	70mm	Qualified
		Lower charring expansion from lower edge of upper support is less than 540mm.	480mm	Qualified
Bunched cables	IEC 60332-3-24:2009	Flame length is less than 2.5m.	1.1m	Qualified

4.3 Fire-resistant performance

The fire-resistant performance greatly verifies sustainability of optical fiber communication with fire field around cable. We well and truly test fire-resistant properties according to IEC 60331-11/25 and BS6387 category “CWZ”. Test results are listed in table 3 and figure 3.

Table 3. Test results of fire resistant performance

Standard	Test condition	Acceptance criteria	Test result	Test VS standard
IEC 60331-11/25	90 minutes fire alone at 750℃ and 15 minutes cooling time	Average attenuation change ≤3dB@1550nm	0.16dB	Better
BS 6387 Category C	180 minutes fire alone at 950℃		Less than 1dB	Better
BS 6387 Category W	15 minutes fire alone and 15 minutes fire with water at 650℃		0.22dB	Better
BS 6387 Category Z	15 minutes fire with mechanical shock at 950℃		0.78dB	Better

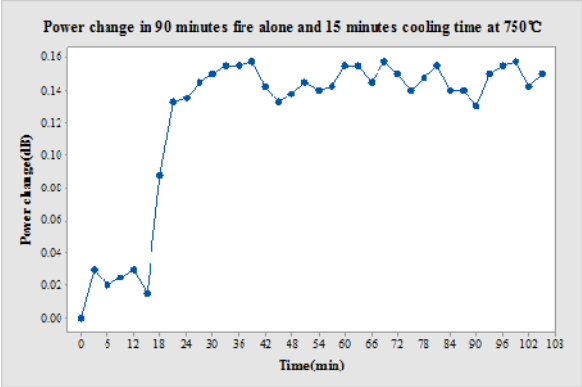

Figure 3a. Power change of optical fibers according to IEC 60331-11/25

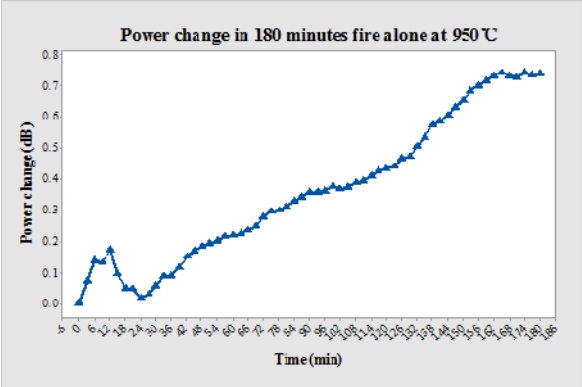

Figure 3b. Power change of optical fibers according to BS 6387 Category “C”

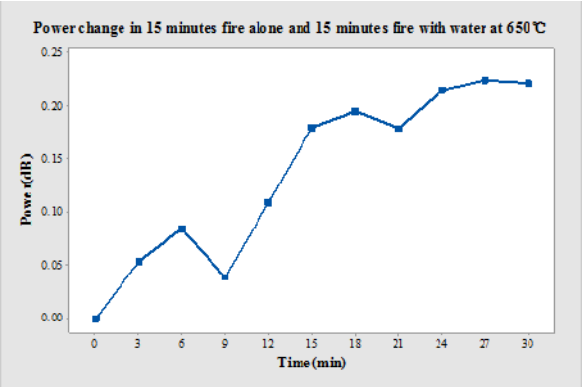

Figure 3c. Power change of optical fibers according to BS 6387 Category "W"

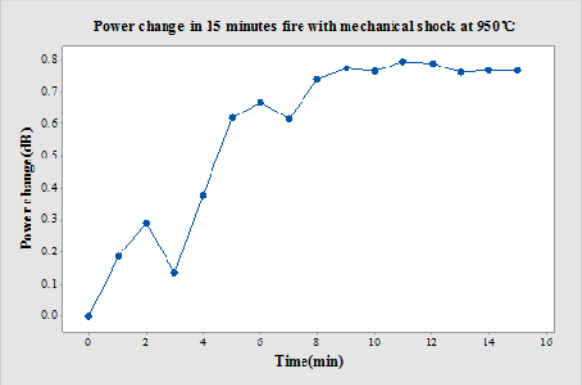

Figure 3d. Power change of optical fibers according to BS 6387 Category "Z"

Providing above the test results, it is known that two layers of refractory mica tapes withstood 1100℃ and double excellent flame retardant ceramic sheathing materials can suitably maintain fire-resistant properties of the optical cable. When the optical cable encounters flame or heat, the ceramic sheathing materials can quickly form ceramic layer which can absorb and further block flame and heat. When flame heat gets access into the cable center through the fourth thermal insulating layers, the remaining heat is gradually absorbed and dispersed.

4.4 Summary of test results

The comprehensive performances of the flame retardant & fire-resistant optical cable are outstanding, so it is demonstrated that using of steel wire, two-sided synthetic mica tape and low smoke zero halogen ceramic polyolefin is successful. It is found that the structure design is reasonable and matched to technical requirement.

5. Conclusion

The structure design of the optical cable can be beneficial to facility of equipment and convenience for production. A series of accessory optical cables which cause immeasurable profit and untouchable influence have produced. Considering excellent properties of the flame retardant & fire-resistant optical cable, it can be broadly applied to the extent of subway base station, tunnel traffic and so on.

6. Acknowledgments

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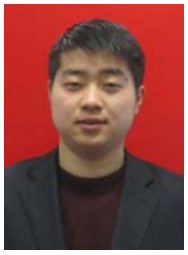

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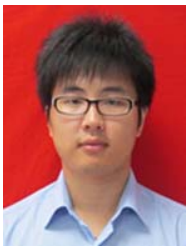

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