Unbreakable Active Optical Cable (UB-AOC)

1. Outline

Active optical cable (AOC) are optical harnesses equipped with photodetectors that enable long-distance high-speed transmission of optical signals (e.g., 100 m, 40 Gbps) over multimode fiber.

In recent years, there has been increasing attention in the medical and industrial machinery sectors for the replacement of metal wiring with AOCs using optical fibers to suppress electrical noise in high-speed signal transmission paths. However, in certain applications, metal wiring is still necessary for power supply and other needs, making hybrid AOCs that combine metal wires and optical fibers essential. Additionally, with the miniaturization of devices and an increase in moving parts within the same sectors, there has been a growing demand for robust mechanical reliability in wiring materials. Yet, the difference in mechanical reliability between optical fibers and metal wires has become a concern.

This report introduces the Unbreakable Active Optical Cable (UB-AOC), developed by enhancing the mechanical reliability of metal wires, which are generally less reliable than optical fibers. We have implemented a specialized resin coating on our proprietary Thick Copper Covered (TCC) wire.

2. Background

AOC can be broadly classified into two types: external harnesses and internal harnesses.

Especially, the internal harness of AOCs requires not only high-speed transmission technology but also miniaturization of the harness size to fit the device size, as the entire harness is housed within the device. Moreover, there is a strong demand for mechanical reliability in movable parts (e.g., bending, twisting, and sliding).

Currently, insulated wires made of commonly used copper materials, which are widely utilized as power lines, as well as flexible printed circuits (FPCs), are small in size but can suffer from fatigue failure due to severe repetitive bending and sliding motions. This has posed a challenge for their application in products with many moving parts and limited internal space.

3. Special Features

3-1 Power line

In the UB-AOC, the power lines use TCC, a composite material consisting of copper and steel with a high-strength steel core wire (Fig. 1). The electrical conductivity is adjusted within the range of 20–60% International Annealed Copper Standard (IACS) for power line applications, and stranded wire processing is employed to ensure mechanical reliability. Customization of conductivity and wire diameter is available according to specific applications.

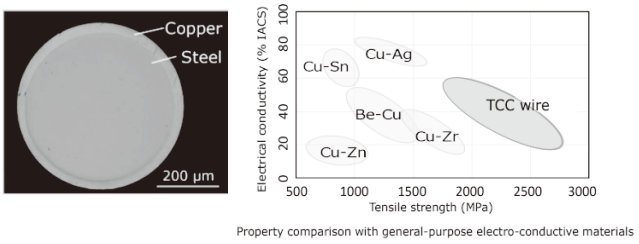

Fig. 1. Structure and characteristics of TCC[1]

Wiring materials for power applications require an insulating covering. Ensuring insulation and mechanical reliability involves a trade-off between the thickness of the covering and the properties of the covering resin. However, the UB-AOC utilizes our coating technology to implement a single structure, as shown in Fig. 2 (a), allowing for the application of covering materials and adjustments to the outer diameter to fit the internal structure of the device.

3-2 Signal line

When power supply and high-speed signal transmission are conducted simultaneously through optical fiber within a system, matching the outer diameter of the optical fiber signal line with that of the power line included in the UB-AOC enables the uniform distribution of external forces, particularly in movable parts, ultimately enhancing mechanical reliability. The optical fiber used as the signal line in the UB-AOC is composed of a unit structure with coating, as illustrated in Fig. 2 (b).

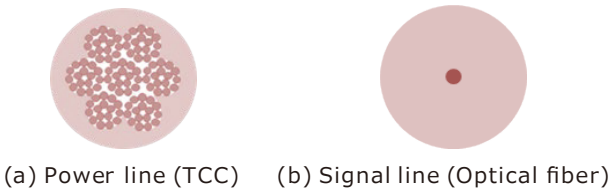

Fig. 2. Structure of power line and signal line

3-3 Fiber bundle structure

Depending on the hardware design of the connection destination, the number of power lines and optical fiber cores in the UB-AOC can be flexibly adjusted by the unit structure shown in Fig. 2. For example, as shown in Fig. 3, it can be configured as a structure integrated flatly according to its application.

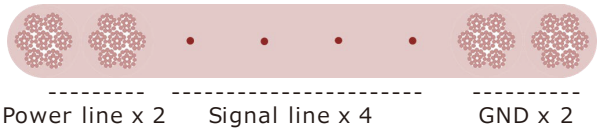

Fig. 3. UB-AOC flat-arrayed structure

3-4 Mechanical reliability

Within the moving parts of devices in the medical and industrial machinery sectors, various external forces such as bending, twisting, and sliding, act on the harness products. Therefore, to evaluate the mechanical properties of the UB-AOC, a particularly rigorous sliding test, as shown in Fig. 4, was conducted as an important indicator of the product's lifespan.

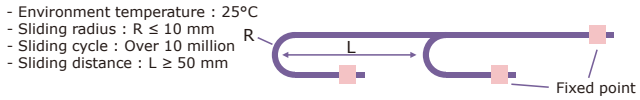

Fig. 4. Sliding test condition

Both ends of the test sample were fixed and the bending section had an outer radius of 10 mm or less, allowing lateral sliding in this condition. 10 million or more sliding motions were performed to check for any breakage in the TCC and optical fiber.

Table 1 presents the specifications of the UB-AOC samples evaluated in this test (comprising TCC power line and optical fiber signal line) compared with general-purpose samples (insulated wire made of copper wire and optical fiber code).

Table 1. Specifications of tested samples

Power line	UB-AOC/TCC	Insulated wire (General Cu)
Wire diameter [mm]	0.05	0.10
Jacket O.D. [mm]	1.50	0.65

Signal line	UB-AOC/Optical fiber	Optical fiber code
Fiber diameter [mm]	0.25	0.25
Jacket O.D. [mm]	1.50	1.70

Figure 5 shows the condition of the samples after 10 million cycles of testing. In contrast to the insulated wire used for comparison, which experienced breakage after 52,000 sliding motions, the UB-AOC/TCC showed no breakage, including in the wire, even after 10 million cycles, with no change in resistance value, indicating no issues for use as a power line.

The UB-AOC/optical fiber experienced slight wear on the coating surface after 10 million cycles, but there was no breakage of the fiber itself, resulting in no issues. In contrast, the general-purpose fiber cord confirmed breakage after 4 million cycles.

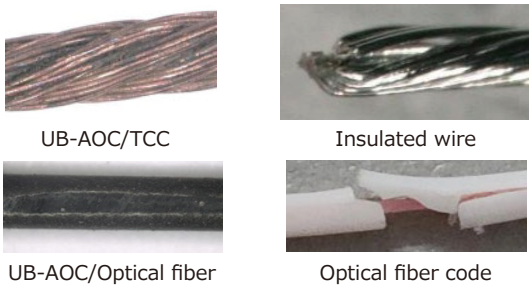

Fig. 5. Appearances after 10 million cycles

4. Conclusion

This paper presents an introduction to the structure of the UB-AOC, a wire material for AOCs that combines metal wire and optical fiber, along with an example of mechanical reliability achieved through core material technology and coating processing technology. In recent years, as robotics expands across various fields, not only in the medical and industrial machinery sectors, there is a growing trend toward miniaturization of devices and an increase in movable parts, leading to strong expectations for the application of wiring materials with high mechanical reliability in compact device interiors.

We hope to contribute to ensuring the reliability of the whole society, which has advanced in robotics, through this product.

Reference

(1) K. Matsuoka, A. Hoshima, and D. Sato, "Copper-Coated High-Strength Electrical Wire," SUMITOMO ELECTRIC TECHNICAL REVIEW No.92, p.57-61 (2021)