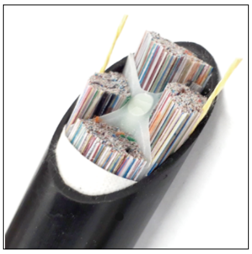


Small-Diameter and High-Density 6912-Fiber-Count Cable

Kenta TSUCHIYA*, Yuuki SHIMODA, Fumiaki SATO, Ken TAKAHASHI, Satomi IDO, and Takao HIRAMA

This paper describes the structure, characteristics, and workability of the small-diameter 6912-fiber-count cable with 200 μm Freeform Ribbon fibers for data center applications. In the 200 μm Freeform Ribbon, fibers meet and split out in turns in a longitudinal and transverse direction, thus allowing high fiber density and mass fusion splicing. Having a non-preferential bend axis, the cable can easily be installed in space-constrained areas. By optimizing the structure and improving the micro-bend resistance of the fiber, we have realized a reduction of the cable cross-sectional area by about 34% compared to the conventional cables. Furthermore, while the conventional cable was pulled into a 2-inch pipeline, the small diameter 6912-fiber-count cable can be applied to a 1.5-inch pipeline, with the same pull-in tension as before.

Keywords: small diameter and high density, Freeform Ribbon, slotted core, cable installation workability

1. Introduction

Recently, a growing number of large-scale data centers (DCs) have been constructed around the world due mainly to the advancement of cloud computing. Demand for high-density optical fiber cables that connect DCs and reduction in construction cost has been growing to meet the need for increased transmission capacity.

Cables that connect DCs are usually installed in outdoor ducts. Technology for achieving high-density installation of optical fiber cables in limited duct space plays a key role.

Sumitomo Electric Industries, Ltd. developed and commercialized a 6912-fiber-count optical cable in 2017. This optical fiber cable consisted of the highest number of fibers in the world at that time. The company also developed wiring solutions, as shown in Fig. 1, and contributed to increasing wiring density and improving workability at entire DCs.

To increase the number of fibers housed in a duct, improve workability, and reduce the environmental impact, we have further reduced the diameter and increased the density of a 6912-fiber-count optical cable.

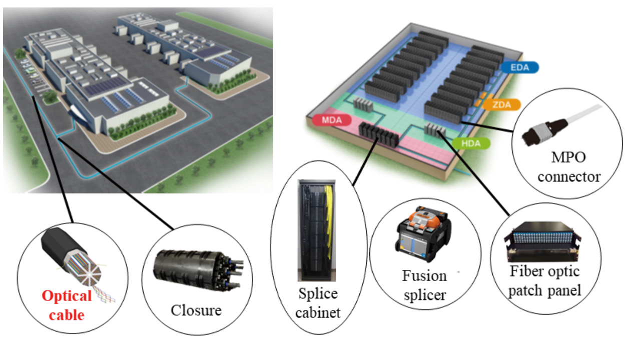


Fig. 1. Schematic diagram of wiring between DC buildings

2. Design and Characteristics of 200 μm Freeform Ribbon

2-1 Design of 200 μm optical fiber

The 200 μm Freeform Ribbon, which is packaged into the cable, is a pliable 12-fiber ribbon, which is mainly used outside Japan. The schematic diagram and characteristics of Sumitomo Electric's Freeform Ribbon are shown in Fig. 2.

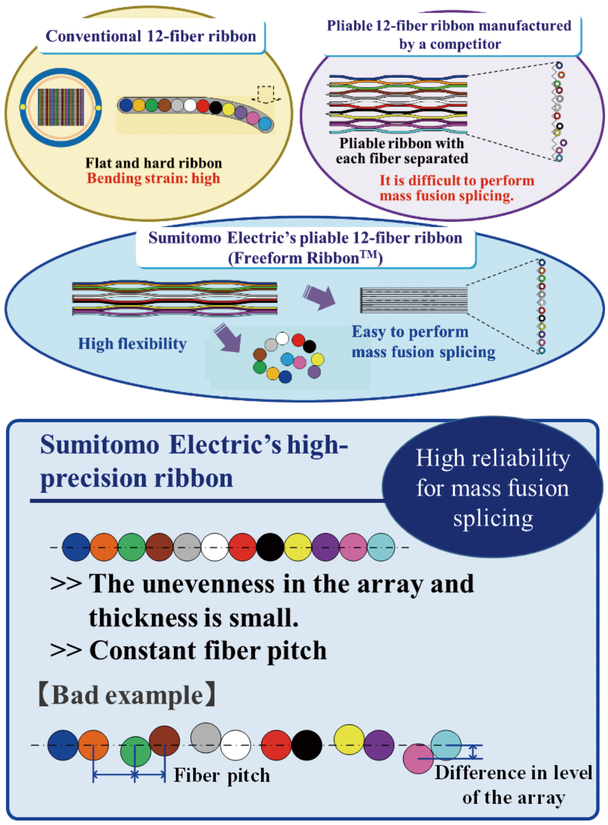


Fig. 2. Schematic diagrams and characteristics of pliable ribbons

As shown in Fig. 2, Sumitomo Electric's pliable 12-fiber ribbon employs a structure that achieves both easy workability of mass fusion splicing and ribbon flexibility, which factors in the cable characteristics, such as the transmission characteristics, by ensuring the high-precision array and optimizing the pliable structure in which two optical fibers are bonded.

2-2 Fusion splicing technology for 200 µm Freeform Ribbons

We also developed a mass fusion splicing technology (see Fig. 3) by taking into account the fusion splicing compatibility with conventional 250 µm ribbon fibers and one-fiber optical fiber cables.

When the distance between adjacent fibers (fiber pitch) is 200 µm (Case A of Fig. 3), we confirmed that fusion splicing can be easily performed by using a custom fusion splicer for the 200 µm fibers.

When the fiber pitch is 250 µm, which is indicated in Case B, we confirmed that fusion splicing can be performed by using a pitch conversion holder, which converts the fiber pitch of 200 µm Freeform Ribbons to 250 µm, without modifying a conventional 250 µm mass fusion splicer.

In all the cases, the estimated loss was equivalent to that of conventional 12-fiber ribbons. We confirmed that there would be no problem in practical applications.

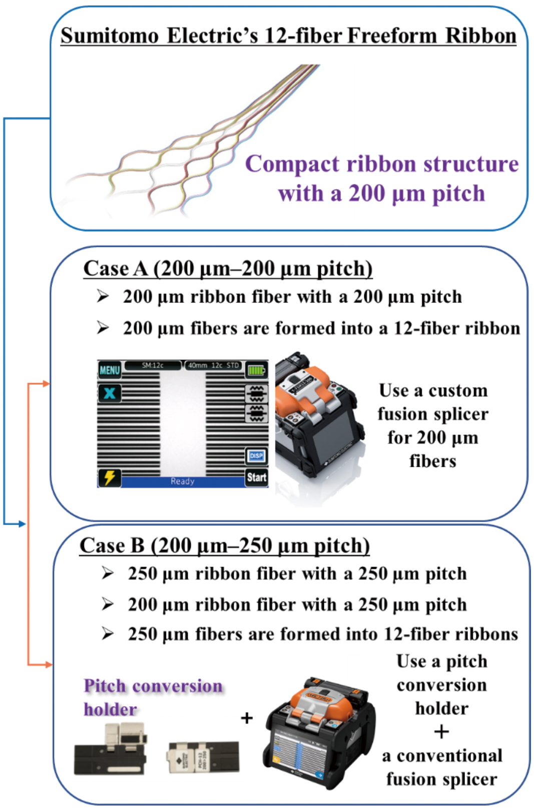


Fig. 3. Mass fusion splicing technology for 200 µm Freeform Ribbons

3. Structure and Characteristics of the Optical Fiber Cable

3-1 Structure of the cable

The slotted core cable structure design has been used to ensure high flexibility in all directions by inserting a fiber reinforced plastic (FRP) strength member*[1] through the center of the core, as in the case of the conventional 6912-fiber-count cable. Figure 4 shows the cross section of the small diameter 6912-fiber-count cable.

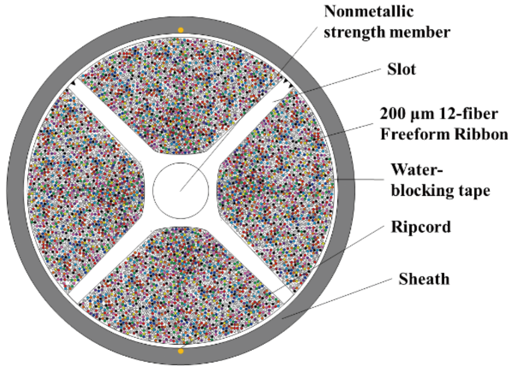


Fig. 4. Cross section of the small diameter 6912-fiber-count cable

Reduction in diameter and increased density were expected to increase the microbending loss*[2] due to the increased compressive load applied to fibers. Thus, we improved the microbending resistance of 200 µm Freeform Ribbons.

As shown in Fig. 5, the microbending resistance was improved by optimizing the resin of the optical fibers.

In terms of the cable structure, we expanded the area in which fibers can be packaged inside the cable and ensured the mechanical strength of the cable by reducing the number of slot grooves (from eight to four) and applying a high-strength sheath material.

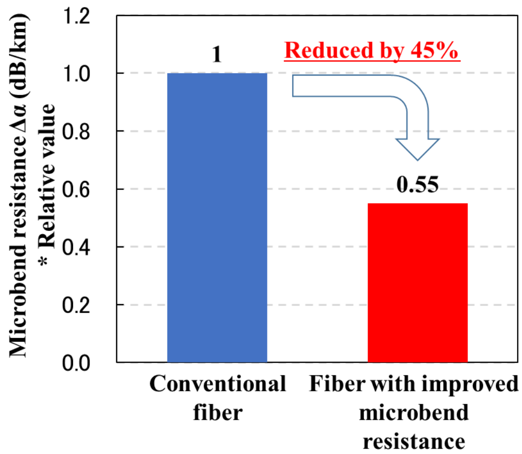


Fig. 5. Comparison of microbending resistance of 200 µm fibers

As a result, the optical fiber density per unit area (fiber density) increased by 1.5 times while the cross section was reduced by approximately 34% from the conventional product (Table 1).

Table 1. Comparison of the structure of 6912-fiber-count cables

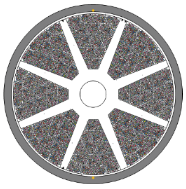
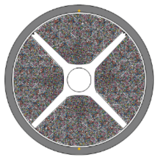
	Conventional 6912-fiber-count cable	Small diameter 6912-fiber-count cable
Cross section		
Outside diameter	37 mm	≥ 30 mm
Fiber density *Relative value	1	1.5
Number of grooves	8	4
Fiber	Normal fiber	Fiber with improved microbend resistance

Figure 6 shows a graph which presents the comparison of fiber density between a conventional ultra-high-fiber-count optical cable and the newly developed optical cable with a new structure (relative value with a conventional 6912-fiber-count cable as 1).

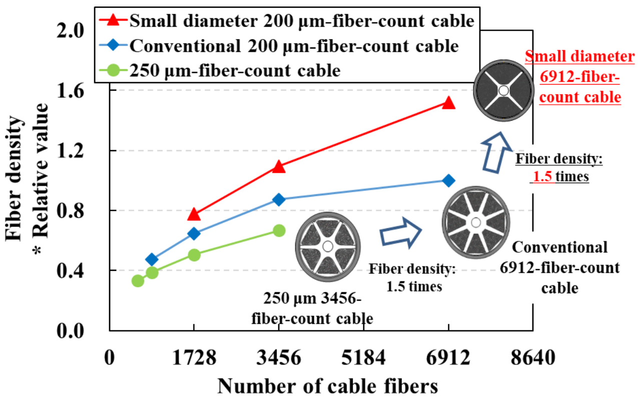


Fig. 6. Changes in fiber density of ultra-high-fiber-count cables

Application of the newly developed small-diameter and high-density structure can increase the unit length of cable wound on conventional drums and reduce the environmental impact by reducing the consumption of slot materials and sheath materials.

3-2 Evaluation results of cable

We evaluated the transmission characteristics and mechanical characteristics of the newly developed small diameter 6912-fiber-count cable.

The results of a heat cycle test from −40°C to +70°C on the small diameter 6912-fiber-count cable are shown in Fig. 7. The changes in attenuation during the heat cycle were sufficiently low, which was confirmed to be equivalent to that of a conventional 6912-fiber-count cable.

The transmission characteristics and evaluation results of mechanical tests are shown in Table 2.

As shown in Table 2, we confirmed good characteristics in the evaluation of various mechanical tests.

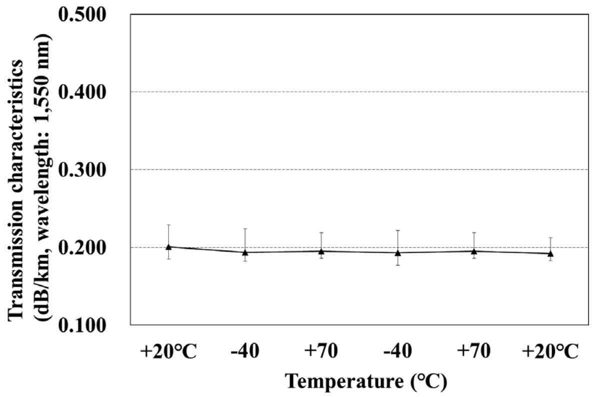


Fig. 7. Changes in attenuation of the small diameter 6912-fiber-count optical cable throughout the heat cycle

Table 2. Evaluation results of the small diameter 6912-fiber-count cable

Item	Test method	Evaluation result
Attenuation coefficient	IEC60793-1-40 λ=1550 nm	< 0.25 dB/km
Temperature cycling	EIA/TIA-455-3 -40~+70°C×2 cycles λ=1550 nm	Changes in loss <0.15 dB/km
Compressive loading	EIA/TIA-455-41 200 N/100 mm λ=1550 nm	Changes in loss < 0.10 dB No abnormality found with the appearance of the cable
Impact test	EIA/TIA-455-25 4.4 N, Drop (twice) λ=1550 nm	
Cyclec flexing	EIA/TIA-455-104 Bend radius: 10 D, 25 sycles (D: outside diameter of the cable) λ=1550 nm	
Cable twist test	EIA/TIA-455-85 ±180°/2 m λ=1550 nm	
Long tensile loading and fiber strain test	EIA/TIA-455-33 During installation: 2,670 N, after installation: 800 N	When strain of 2,670 N is applied: Fiber strain < 0.2%, when strain of 800 N is applied: Fiber strain < 0.1%

3-3 Cable installation workability

(1) Evaluation of cable handling

As shown in Fig. 8, the slotted core structure of the small diameter 6912-fiber-count cable has a strength member running through its center. Compared with a structure which has a strength member on both sides of a jacket as in the case of ultra-high-fiber-count cables manufactured by a competitor, we confirmed that the newly developed cable is more flexible in all directions and easier to handle when storing the excess length of cables in limited space.

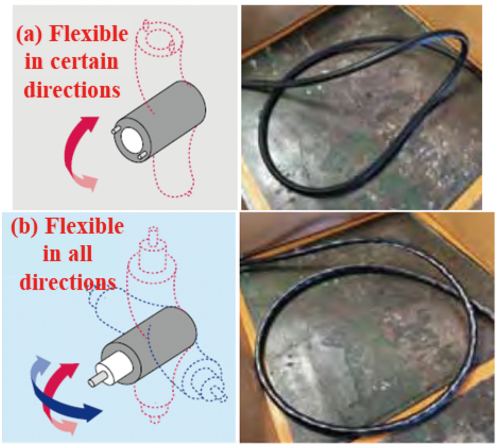


Fig. 8. Difference in handling characteristics depending on flexibility in directions

(2) Experiment to insert a cable into a duct (pulling method)

Previously, a 2-inch duct was required for the installation of a 6912-fiber-count cable. The newly developed small diameter 6912-fiber-count cable can be installed in a 1.5-inch duct.

To verify the installation workability of the small diameter 6912-fiber-count cable by pulling it through a duct, we used the experiment system shown in Fig. 9 to compare the tension when pulling a conventional 6912-fiber-count cable through a 2-inch duct with that when pulling the small diameter 6912-fiber-count cable through a 1.5-inch duct. The results are shown in Table 3.

Based on the results presented in Table 3, we confirmed that the small diameter 6912-fiber-count cable can be installed in a 1.5-inch duct with a tension equivalent to or lower than that required for installing a conventional 6912-fiber-count cable in a 2-inch duct.

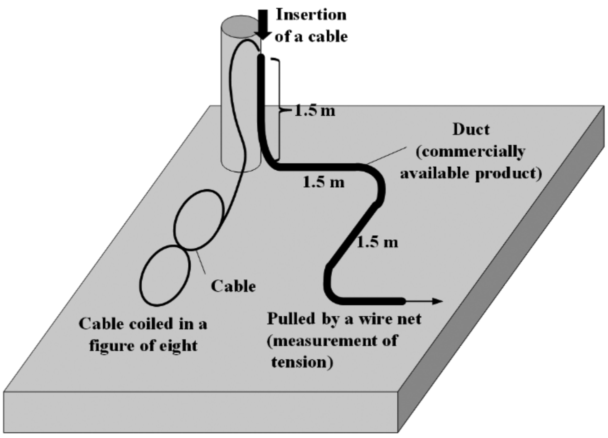


Fig. 9. Schematic diagram of an experiment to insert a cable into a duct

Table 3. Results of the pulling experiment

Conditions	Pulling tension *Relabive value
2.0-inch duct + conventional 6912-fiber-count cable	1
1.5-inch duct + small diameter 6912-fiber-count cable	0.9

This showed the possibility of inserting the small diameter 6912-fiber-count cable in a duct narrower than conventional ones, enabling installation in a conventional 2-inch duct with lower pulling tension than before.

(3) Study of the pushing and blowing method

The pushing and blowing method, as shown in the schematic diagram of Fig. 10, is the other cable installation method.

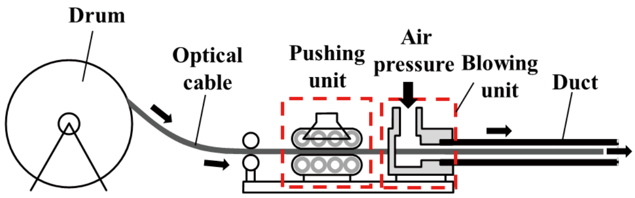


Fig. 10. Schematic diagram of the pushing and blowing method

We conducted an experiment (see Photo 1) to confirm the compatibility of the pushing and blowing method with the small diameter 6912-fiber-count cable using a blowing machine (SUPERJET) manufactured by Plumettaz S.A.

The test results found no deterioration of the surface appearance when the pushing force of the maximum load (100 kgf) of the blowing machine was applied. No problem was found with the cable strength.

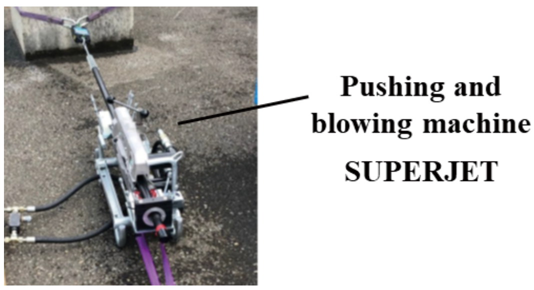


Photo 1. Pushing and blowing machine

Based on the test results above, the pushing and blowing method is expected to be used for long-distance installation.

4. Conclusion

We have developed a small diameter 6912-fiber-count optical cable, which can increase density and ensure the workability of optical cables, for installation in outdoor ducts that connect DCs. The cross section of the cable is 34% less than that of conventional cables, making it possible to manufacture long cables and reduce the environmental impact due to reduction in material consumption. We also found that the use of a strength member running through the center ensures flexibility in all directions and that the use of the slotted core structure achieves good characteristics, such as ease of handling and duct insertion.

Technical Terms

∗1 Strength member: A strength member relieves the tension that is applied to optical fibers during installation.

∗2 Microbending loss: Microbending loss refers to the loss generated by the bending of an optical fiber with a curvature radius smaller than the core diameter due to uneven pressure applied from the side.

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