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.
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.

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

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).

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).

Figure 7 shows the changes in attenuation of the small diameter 6912-fiber-count optical cable throughout the heat cycle.

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Conventional 6912-fiber-count cable</th>
<th>Small diameter 6912-fiber-count cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross section</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside diameter</td>
<td>37 mm</td>
<td>≥ 30 mm</td>
</tr>
<tr>
<td>Fiber density</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Number of grooves</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Fiber</td>
<td>Normal fiber</td>
<td>Fiber with improved microbend resistance</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Test method</th>
<th>Evaluation result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attenuation coefficient</td>
<td>IEC60793-1-40 λ=1550 nm</td>
<td>&lt;0.25 dB/km</td>
</tr>
<tr>
<td>Temperature cycling</td>
<td>EIA/TIA-455-3 -40~+70°C×2 cycles</td>
<td>Changes in loss &lt;0.15 dB/km</td>
</tr>
<tr>
<td>Compressive loading</td>
<td>EIA/TIA-455-41 200 N/100 mm</td>
<td>Changes in loss &lt;0.10 dB</td>
</tr>
<tr>
<td>Impact test</td>
<td>EIA/TIA-455-25 4.4 N, Drop (twice) λ=1500 nm</td>
<td>Changes in loss &lt;0.10 dB</td>
</tr>
<tr>
<td>Cyclic flexing</td>
<td>EIA/TIA-455-104 Bend radius: 10 D, 25 cycles (D: outside diameter of the cable) λ=1500 nm</td>
<td>No abnormality found with the appearance of the cable</td>
</tr>
<tr>
<td>Cable twist test</td>
<td>EIA/TIA-455-85 ±180°/2 m</td>
<td>Changes in loss &lt;0.10 dB</td>
</tr>
<tr>
<td>Long tensile loading</td>
<td>EIA/TIA-455-33 During installation: 2,670 N, after installation: 800 N</td>
<td>When strain of 2,670 N is applied: Fiber strain &lt;0.2%, when strain of 800 N is applied: Fiber strain &lt;0.1%</td>
</tr>
</tbody>
</table>

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.
(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.

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.

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.

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 consump-
tion. 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.

* Freeform Ribbon is a trademark or registered trademark of Sumitomo Electric Industries, Ltd.
* SUPERJET is a trademark or registered trademark of Plumettaz S.A.

**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.

**References**


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