Latest Technologies and the OCC-SC300 Optical Submarine Cable

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Abstract

This paper describes the technical features and characteristics of the OCC-SC300 cable as used in the latest optical submarine cable systems. It also introduces DMF optical fiber, as applied to recent ultra-long distance D-WDM systems. In addition, a sea trial conducted for the integrated evaluation of the final stage of development of the OCC-SC300 cable is reviewed.

Keywords

optical submarine cable, D-WDM, DMF, OCC-SC100, OCC-SC300, tight-type structure, loose-type structure

1. Introduction

Now that more than two decades have elapsed since the initial deployment of optical submarine cable systems, optical submarine cables have changed greatly, reflecting improved optical fiber properties and advancements in transmission technologies. In addition, the recent significant advances in IT have increased the need for optical submarine cables to be faster, less expensive, more reliable and easier to deploy.

This paper describes the structure and characteristics of our latest optical submarine cable (OCC-SC300), together with the results of an experiment conducted at an actual seabed area.

2. Optical Submarine Cable for Repeatered Systems (OCC–SC300)

The Trans-Pacific optical submarine cable system has a length of about 10,000 km and it can reach depths in excess of 8,000 meters. The most important characteristic required for optical submarine cables for use in the construction of such long-distance repeatered systems is to protect the optical fibers from external forces. It should also maintain stability and structural integrity for 25 years or more in the environment in which the cables are laid.

The OCC-SC100 optical submarine cable developed in the 1980's has already been manufactured and deployed for more than 140,000 km in various parts of the world. This is a tight type cable using cores composed of optical fibers twisted around a central steel wire and a UV-hardening resin filling.

Following the recent increases in transmission capacities, large core fibers for D-WDM (Dense Wavelength Division Multiplexing) transmission are often used and we have already succeeded in developing OCC-SC100 optical cables employing such large core fibers (LMF: Large Mode-field Fibers) [1), 2)] . However, it was anticipated that tight type cable would have PMD characteristic limitations when optical transmissions of higher density and larger capacity are considered.

Therefore, we have developed a loose type optical submarine cable (OCC-SC300) that exhibits less stress on the fibers while maintaining the excellent mechanical and electrical characteristics of the OCC-SC100 cable. **Fig. 1** compares the PMD distribution of LMF in a tight structure with that of a loose type structure. The data shows that the loose type of cable can decrease the PMD, from its reduced fibers stresses. As seen here, the OCC-SC300 cable structure makes it possible to reduce

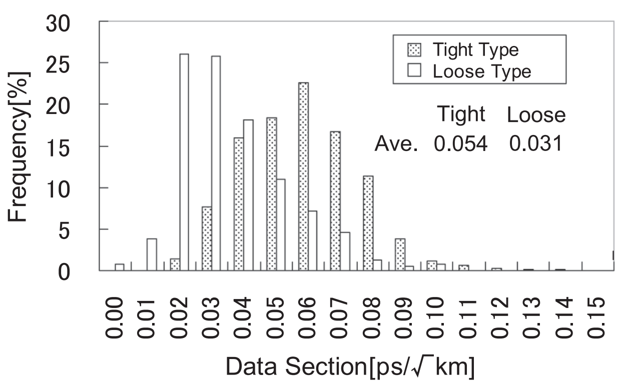

Fig. 1 Distribution of PMD.

costs while maintaining excellent optical characteristics, therefore currently being our main product for the optical submarine cable market [3), 4)] .

2.1 Optical Fibers

The present subsection examines the latest optical fibers to be used in long-distance optical submarine cable systems for D-WDM transmissions.

Recent long distance optical submarine cable systems employ Dispersion Management Fibers (DMFs). DMFs include two kinds of fibers; a fiber with positive dispersion and a positive dispersion slope (hereinafter DMF+) and a fiber with negative dispersion and a negative dispersion slope (hereinafter DMF-). They are configured with a line length ratio of about 2:1 so that the wavelength dispersion slope is almost 0 (null). **Table 1** shows the characteristics of DMF+ and DMF-.

DMF+ and DMF- also differ in their effective areas characteristic. The DMF+ with a large effective area is placed on the optical signal power input side and the DMF- with a small effective area is placed on the output side where the signal power is weakened in order to reduce nonlinear optical effects.

2.2 LW Cable

Fig. 2 shows the structure of the OCC-SC300 LW (Light Weight) cable.

OCC-SC300 cable is characterized by the direct insertion of optical fibers into a 3-divided steel segment pipe together with a water blocking compound. This design allows omission of the unit process, thereby reducing both thermal stress on the optical fibers and manufacturing costs.

Steel wires are twisted around the 3-divided steel segment pipe; a copper tape is then formed around those, with the joint section TIG (Tungsten Inert Gas) welded. The welded copper tube encloses the steel wires, producing an integrated structure.

Due to the use of fine tension control, slack control and stable copper tube welding technologies, long cables of (80 km or more) with up to 16 optical fiber cores can be manufactured in a single continuous length.

Table 1 Characteristics of DMF+ and DMF- (@ 1550 nm).

Item	Unit	DMF+	DMF-
Attenuation	dB/km	0.19	0.24
Effective area	μm²	100	30
Dispersion	ps/nm/km	19	-38
Dispersion slope	ps/nm²/km	0.06	-0.12

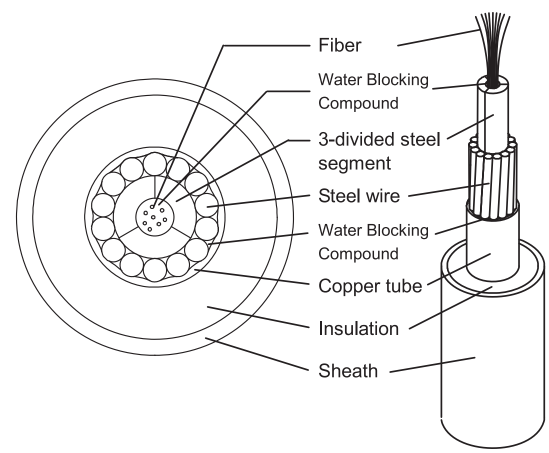

Fig. 2 OCC-SC300LW cable structure.

The LW cable is finally coated with a polyethylene sheath to electrically insulate the copper tube from the external environment.

2.3 LWS (Light Weight Shielded) and Armored Cables

Optical submarine cables are provided with various structures for protecting them against external damage depending on deployment environments. Particularly, in shallow sea areas near landing stations, cables are protected with an outer armor made of single or double layer of stranded steel wires to prevent stress damage from fishing tools, anchors, etc. As the potential for damage decreases proportionally with increased depths, LWS cables with light outer sheathing using iron reinforcement sheathing are used in all deep sea areas.

Fig. 3 shows cross-sections of the structures of two types of OCC-SC300 cables, the LWS and the SAL (Single Armored Light) types that are representative of outer armored cables. **Table 2** shows the characteristics of various types of OCC-SC300 cables.

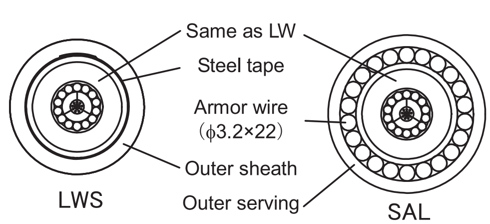

Fig. 3 LWS and external cables structure.

Table 2 Characteristics of OCC-SC300 cable series.

Item	Unit	Cable Types				
		LW	LWS	SAL	SAM	DA
Outer diameter	mm	20.4	27	32	34	47
Weight in air	kN/km	7.9	11.0	23.5	30.6	64.2
Weight in water	kN/km	4.7	5.4	16.8	22.9	50,0
Cable breaking load	kN	98	98	310	380	800
Water pressure resistance	MPa	≧ 78				
Water ingress	m	≦ 250 @ 9.8 MPa × 2 weeks ≦ 1,000 @ 78.4 MPa × 2 weeks				
DC resistance (3°C)	Ω/km	≦ 0.8				
Insulation resistance	-	15 kV x 25 years (design life)				
Applicable water depth	m	≦8,000	≦6,000	≦2.000	≦1,500	≦500

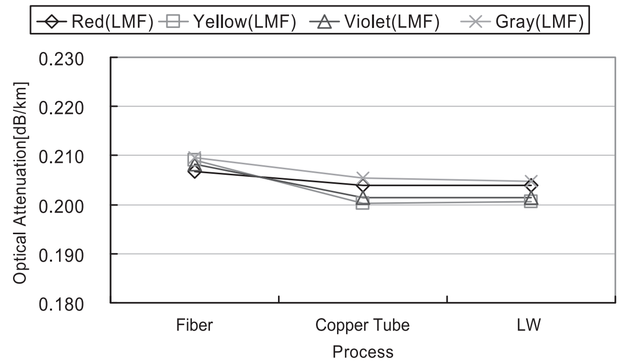

Fig. 4 Variation of manufactured cable loss.

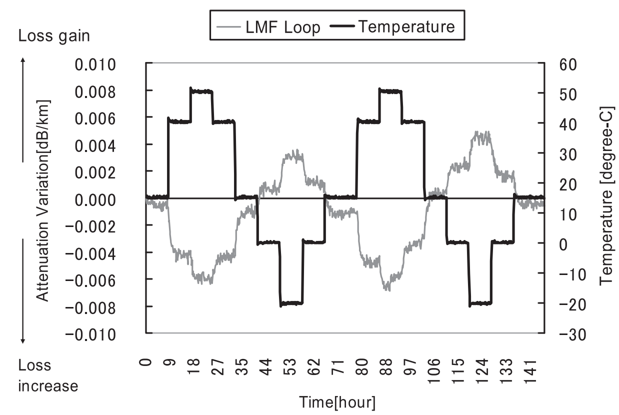

Fig. 5 Temperature stability.

3. Characteristics of the OCC–SC300 Optical Submarine Cable

3.1 Changes in Loss between Cable Manufacturing Processes

Identifying changes in loss between cable manufacturing processes is one of the key issues in cable product. Particularly, as LMF with a large core is wound around a reel before it is used in manufacturing a cable, losses caused by this reel winding are important. This loss decreases after cable manufacturing since the fiber is loosened, but it is an important system design consideration to identify such changes in loss between manufacturing processes.

Fig. 4 shows examples of changes in the loss between the LMF cable manufacturing processes. Notably, as a result of the cable manufacturing, fiber losses are improved by about 0.005 dB/km and that subsequently, their characteristics become stable. These results indicate that the cable manufacturing does not produce micro-bends, etc.

3.2 Temperature Characteristics

Cable is manufactured at a room temperature of around 25°C but the temperature of ocean floors where the cable is actually deployed for long-term service is about 3°C. In addition, the cable may experience significant temperature changes, for example between -20°C and +50°C, during transportation and storage. Since the cable cannot avoid these temperature impacts, it is essential to identify the temperature dependence of the optical loss characteristic with high accuracy and to reflect this in the system design.

With OCC-SC300, we have applied temperature cycle testing to cable samples and have confirmed the temperature dependency of the optical loss characteristic shown in **Fig. 5** . The figure shows that the temperature dependency of the LMF is 0.0001 dB/km/°C and that there is no residual degradation.

3.3 Cable Tensile Characteristics

Optical submarine cable is subjected to tensile stresses from its own weight during laying and retrieval. Particularly, retrieval stresses may be as large as twice the weight of the cable. Tensile stress testing is conducted to check changes in the optical characteristics and degradation of the component parts resulting from such stresses. Some examples of tensile testing results are shown in **Fig. 6** , illustrating tensile elongation and torque characteristics of SC300 LW cable. At OCC's tensile testing facilities, high-resolution optical measuring

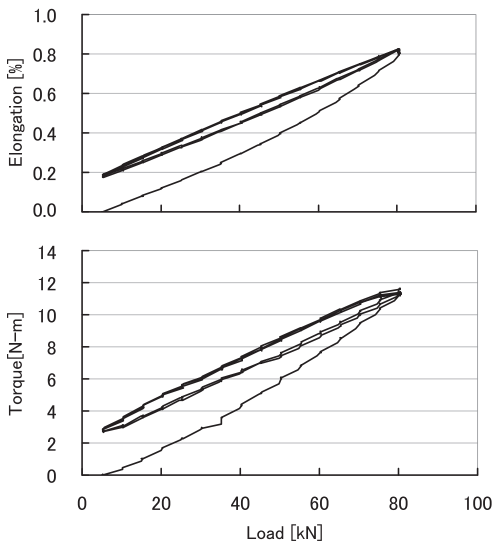

Fig. 6 Tensile elongation and torque characteristics of SC300 LW cable.

instruments are used to detect even small changes in optical characteristics and a long test length of 120 meters is applied to improve measuring accuracy.

SC300 cable has equivalent mechanical characteristics to the SC100 cable and it is a highly reliable design by its reduced production of torque and small residual elongation after stressing. It has also been confirmed with optical loss variation monitoring that there is no change in the optical fiber loss even after a tensile stress of up to NTTS (80 kN with LW cable) is applied.

4. Sea Trials

While individual characteristics such as temperature dependency and tensile stress dependency can be evaluated in land experiments as described above, sea trials are conducted as the final integrated evaluation for checking the degree of composite and dynamic changes. With OCC-S300, a deep sea trial was conducted on a span of LW cable about 40 km long in a seabed area with a maximum depth of 8,200 meters in the Izu-Ogasawara (Bonin) Trench in November 2002.

Although there was concern about the instability of the loss characteristic when the loose type submarine cable was laid on the ocean floor, the test proved that the cable presents a stable loss characteristic with no problems.

It has also been confirmed that no related issues were discovered in the handling properties of cables and jointing equipment during the actual laying procedure using a cable ship as well as for retrieval and re-laying.

A shallow sea trial was also conducted on about a 20 km span of outer-sheathed cables (4 km of DA, 4 km of SAM, 7 km of SAL and 6 km of LWS) in a seabed location with depths undulating between 700 and 2,700 meters to the east of Amami Oshima Island in February 2004.

Similar to the results of the deep sea trial, these test results were very favorable; the handling properties of the cables, repeaters and jointing equipment during the actual laying procedure using a cable ship were confirmed. There was no problem in the cable laying - retrieval - re-laying or re-retrieval of the entire cable system and no issues such as cable undulations occurred.

5. Conclusion

After completing evaluation for the application of UJs (Universal Joints) in July 2004, the evaluation of the OCC-SC300 cable design was completed. OCC-SC300 cable was first applied to the 350 km cable connecting India and Sri Lanka in 2006 and then for a 1,300 km cable in a project for the Maldives Islands in the same year. Since then, it has been applied in various projects worldwide, including a transpacific project in Asia and in other projects in North American waters. We were also able to accomplish the first application of a DMF cable in the IWM and Unity projects. The total amount of manufacturing up until completing the Unity project had by then reached 28,000 km.

In the future, OCC will continue to contribute to the construction of optical submarine cable networks both inside and outside Japan by continuing to supply high-quality cables.

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