Development of the New Fusion Splicer Series S123/S153/S178

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ABSTRACT As the transmission volume of information increases in the 2000s, wavelength multiplexing in optical communications has been implemented along with the upgrading of the communication speed. Such advancement has made optical fiber fusion splicers one of the essential industrial equipment for the implementation of the communication networks and the manufacturing of optical components. Also, in the non-communication fields present in sensing technology using strains in optical fibers and laser technology for power transmission, the use of optical fiber is rapidly growing. The fusion splicers are used in these non-communication fields as well.

In light of this, we have been developing new fusion splicers with sufficient performance and functions to meet requirements from the special market segments in response to customers' needs. Simultaneously, we have been developing new products that provide superior robustness required from all market segments.

Recently we have developed, around the same time, seven models of fusion splicers in three series - namely S123, S153 and S178 in addition to our mainstay product of direct core monitoring type. We have thus been successful servicing all of our customers in the different segments by providing them with a range of applications with a state-of-the-art technology of Furukawa Electric.

1. INTRODUCTION

In many high technology countries, the diffusion rate of the fiber to the x (FTTX) has surpassed 20%, and it now shows a steady growth despite its tendency to flattening out. In developing countries, on the other hand, the diffusion rate is still low, and it will probably increase hereafter.

In terms of the use ratio of optical fiber in communication networks, (it is acknowledged that this index generally increases up to 50% rather smoothly), the use ratio is below 50% in most countries worldwide, so that in the developing countries in particular, the use of optical fiber in telecommunications trunk line networks is expected to increase in the future.

In non-communications fields, on the other hand, the laser and the sensor technologies are representative of the areas of optical fiber use, and the use is anticipated to increase hereafter as well.

These situations suggest that optical fiber use will definitely increase in the future and that all installation aspects of the optical fiber ranging from the trunk line networks to the premises wiring, along with all application fields of optical fibers, will require their specific purpose-designed fusion splicers, an important component to promote the optical fiber use in communications fields as well as in the non-communications fields.

Seven fusion splicer models in three series have all together been developed here to cover all these specific purposes. Their features will be described in this paper.

2. APPLICATIONS OF FUSION SPLICERS

The application areas of fusion splicers are diversified in accordance with the application area of the optical fibers.

2.1 Trunk Line Construction

It refers to, as indicated by its name, the connection scope of work of the optical fibers to build a trunk line network using optical fibers. The optical fiber cable contains as many as 1000 fibers, and a multi-fiber splicing machine is mainly used for the connection scope of work.

2.2 FTTX

This is a generic term referring to the branching networks from the trunk lines down to every home, condominiums and buildings, where a single-fiber fusion splicing machine is mostly used. In the fiber to the home (FTTH), extremely low splicing losses are rarely required, because these sections are at the end portions of a communication network.

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2.3 Field-Installable Connector

In connection field sites for optical fibers, a connector connection is sometimes adopted instead of fusion splicing. And in such connector connection, special fusion splicing for the boot of a connector must be carried out to set the connection length optimized for the site plan. A single-fiber fusion splicing machine provided with a field connector splicing function is typically used for this application.

2.4 Optical Components Manufacturing

In the manufacturing area of optical components that realize long-distance transmission and wavelength multiplexing by sophisticatedly combining optical fibers of various characteristics, a single-fiber fusion splicer capable of core monitoring and core alignment is mostly used.

3. OUTLINE OF FUSION SPLICERS

The outline of the seven models in three series of fusion splicers are shown in Tables 1 and 2, and their pictures are shown in Figures 1 and 2.

Table 1 shows the outline of the fusion splicer with fixed V grooves for the self alignment of the optical fibers, while Table 2 shows those with movable V grooves enabling the adjustable alignment of the optical fibers.

Table 1 Outline of S123 Series with fixed V grooves.

Model name	S123A/C	S123M4	S123M8	S123M12
Number of fibers	1	1 − 4	1 − 8	1 − 12
Observation method	Cladding			
Alignment method	Self alignment based on outer diameter			
Specification of splicing loss	SM: 0.05 dB			
Main applications	FTTX Field connector	FTTX Trunk line construction	Trunk line construction	Trunk line construction

Table 2 Outline of S153A and S178A with movable V grooves.

Model name	S153A	S178A
Number of fibers	1	
Observation method	Cladding	Core
Alignment method	Alignment based on cladding	Alignment based on core
Specification of splicing loss	SM: 0.04 dB	SM: 0.02 dB
Main applications	FTTX	FTTX Trunk line construction Optical components manufacturing

Figure 1 Appearance of S123A.

Figure 2 Appearance of S178A.

3.1 S123 Series

The S123 Series fusion splicers are characterized by the fixed V grooves, on which a pair of optical fibers is placed in opposed positions for splicing. The fibers splicing consist of a fusion by arc discharge at their end faces, and brought in touch with each other to complete the splicing.

3.1.1 S123A

This is a single-fiber fusion splicer specialized for FTTX, featuring the lowest price among fusion splicers.

3.1.2 S123C

This is a single-fiber fusion splicer, suitable for FTTX and field-installable connectors.

3.1.3 S123M4

This fusion splicer is suitable from a single fiber to four-fiber ribbons, thus suitable for splicing of a 300-fiber cable as well as for FTTX construction. Due to its superior portability, a splicer of this model can meet any splicing scope of work, aerial or underground.

3.1.4 S123M8

Since this device is applicable to fusion splicing of a single fiber to eight-fiber ribbons, it is suitable for construction scope of work of trunk lines consisting of multi-fiber cables. With its size slightly larger than that of S123M4, this fusion splicer has two battery slots, whereby the number of fusion splicing cycles has increased.

3.1.5 S123M12
This is a multi-fiber fusion splicer capable of simultaneous splicing of up to 12-fiber ribbons. Except for the number of applicable fiber counts, it has the same functions as those of the S123M8.

3.2 S153A
This is a skill-less fusion splicer provided with an optical fiber alignment function based on cladding monitoring. By means of its alignment mechanism, axial misalignment caused by dirt on a fiber is automatically adjusted to null, thereby achieving low-loss splicing.

3.3 S178A
This fusion splicer is characterized by its optical fiber alignment mechanism based on core monitoring, whereby the core of an optical fiber is directly monitored for measurement of axial misalignment to allow a low-loss splicing of optical fibers. Moreover, in case two fibers to be spliced are of different kinds, the conditions of the right and left cores are evaluated by means of image processing, and the ark discharge is automatically repeated based on the prediction to minimize the splicing loss.
Furthermore, the splicer is provided with an attenuation splicing function to realize an attenuation-controlling splicing procedure, as well as with a wide-range of fusion splicing capabilities of the core diameter from $\phi 80\ \mu m$ to $\phi 150\ \mu m$. Thus, the device is best suitable not only for FTTX splicing scope of work but also for manufacturing of the optical components.

4. FEATURES OF FUSION SPLICERS

Features of the new products will be presented below, including options developed here.

4.1 Size Reduction
While the conventional S177 used a 7.5-power objective lens and a complementary metal oxide semiconductor (CMOS) camera with a cell pitch required for core alignment, the S178 uses a 3-power objective lens and a newly developed CMOS camera, securing an optical resolution required for core alignment. The reduction of lens magnification power has resulted in a smaller lens, succeeding in reducing the distance between the optical fiber and the CMOS camera.
This success has constituted a major factor in reducing the size of the fusion splicer: depth from 260 mm of the conventional to 199 mm, and the height from 138 mm to 105 mm.
With respect to the width, all models have been reviewed for the design of the optical fiber carrier called "Z platform" along with its driving motor and the layout of the driving mechanism, and in the multi-fiber fusion splicers, the width has been reduced from 140 mm of the conventional to 127 mm.
As a result, the size of the S178 has been reduced by 43%. And the S123M8, S123M12 and S178 have the smallest size in the world for this class of fusion splicers.

4.2 Weight Reduction
For the purpose of weight reduction, materials for the structural components and exterior components of the fusion splicers have been changed from aluminum alloy to magnesium alloy that provides superior specific strength and specific rigidity.
With respect to the weight reduction of electronic components, the use of programmable logic devices such as field programmable gate array (FPGA) has been expanded to reduce the number of electronic components and the area of glass-epoxy substrate, resulting in a weight reduction of 7% from the conventional device. The S123M8, S123M12 and S178 have the lightest weight in the world for this class of fusion splicers.

4.3 Reduction in Power Consumption
As a result of the implementation of a new central processing unit (CPU), the heat generated by the CPU has been reduced from that of the conventional devices, which in turn has resulted in power reduction of cooling fans, thus making a contribution to reducing the secondary power consumption.
A new heater has been designed together with its control program to realize a shortening of the shrinkage time for the heating reinforcement (HR) sleeve, which has led to a reduction in the power consumption per cycle of the HR process.
A new motor has been considered eliminating the need for an excitation current for holding the motor position, leading to a reduction in the consumption of power.
As a result of these efforts, the power consumption has been reduced by 29% from the conventional splicers.

4.4 Robust Design
Robust design has been carried out under the assumption of the outdoor use and the handling of a variety of issues including shock due to falling, dust in the air, impact of water such as rain and impact of wind. Efforts were made to develop a splicer with sufficient mechanical resistance against such adverse conditions.
With respect to protection against dust and water, the development was performed in compliance with the IP52 specified in the IEC60529 standard, equivalent to JIS C 0920. The IP5X is a standard for dust protection, which stipulates that normal operation of the device under test shall be assured when the test chamber is depressurized by 2 kPa, and 2 kg of dust below 25 μm in granularity is sprayed for 8 hr continuously.
The IPX2 is a standard for waterproofing property, which stipulates that normal operation shall be assured when the device is tilted back and forth and from side to side by 15°, and water is dripping to simulate a rainfall at the rate of 3 mm/min for 2.5 min at each tilt angle --for 10 min in total.
With regard to falling, the splicer was designed in accordance to the Telcordia standard which stipulates normal operation after falling from a 760-mm height.

4.4.1 Design to Shock Resistance

The device was designed to be protected from damage on the assumption that it undergoes a fall from a 760-mm height during transportation. A shock buffering material was provided at each of the four corners of the splicer, and as a result, splicing loss performance on optical fibers showed no adverse effects after falling with its 5 faces down, excluding the top face.

In the case of falling with its bottom face down in particular, the shock buffering material provided with a temporal shock dispersion function was used to temporally disperse the falling shock, thereby reducing the shock load on the fusion splicer. See Figures 3 an 4.

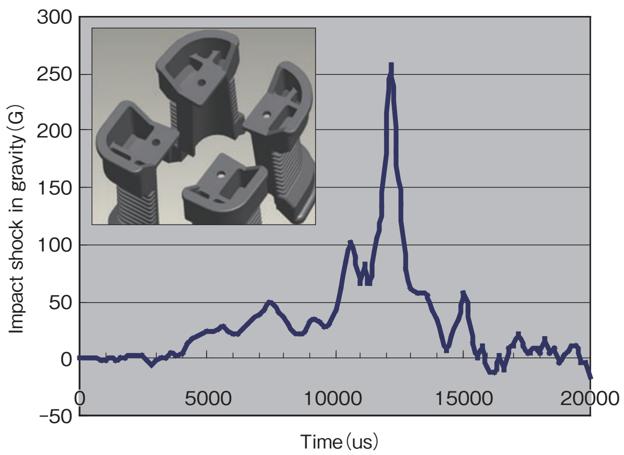

Figure 3 Time vs shock chart (I). Symmetric rubber pad without shock buffering function is applied.

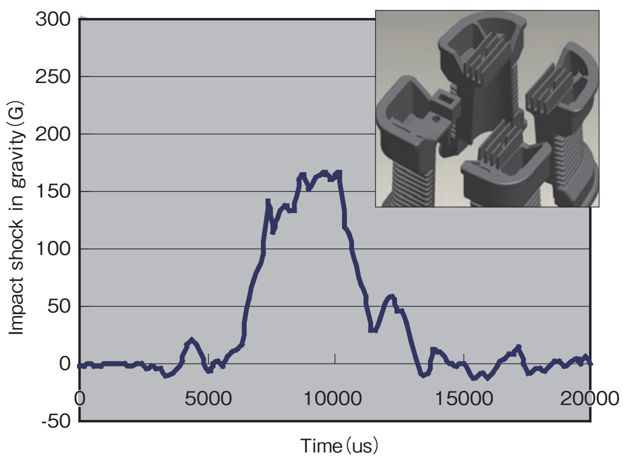

Figure 4 Time vs shock chart (II). Asymmetric rubber pad with shock buffering function is applied.

4.4.2 Design of Dust Protection and Water Proofing Properties

Since ingress of dust is almost the same as ingress of water in phenomenology, if the water-proofing design of a device is successful, it can be considered that the same level of success has been achieved in terms of dust protection design. Specific design examples will be presented below. The engagement portion between the body's bottom case and top case on one hand and that of battery doors on the other hand has adopted the socket and spigot engagement mechanism. This design proved to be very effective in preventing the ingress of water and dust within the engagement portions.

The connector portion of the USB and the power supply, used for external connections, was located on a recessed wall, on which a backboard was provided to prevent water creepage. Moreover, assuming an ingress of water running down the wall to enter the connector, the design provided a cap on the connector to prevent the ingress of water and dust.

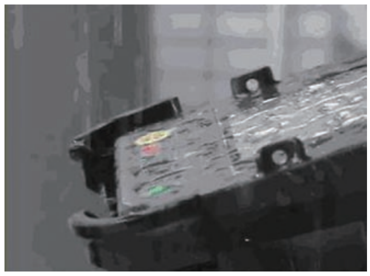

Figure 5 Conditions of the waterproof test.

4.4.3 Design for Wind Protection

In fusion splicing of optical fibers, an arc discharge is used to fuse the fiber ends, and then they are brought in contact with each other to be spliced. However, since the arc discharge is susceptible to wind, the affected arc discharge tends to show instability in intensity and directions, providing an insufficient function for splicing of optical fibers with a low loss. In the present design, a closed space for arc discharge was provided in order to secure a discharge space that can be used under a wind speed of 10 m/sec, a general standard of wind speed adopted for safe use in which for aerial work. To accomplish it, the hinge of the clamp arm mechanism for fiber holding was kept mechanically independent from the arm of the wind protecting mechanism of the arc discharge, forming a closed structure in which the canopy overlaps the top case shield. This design succeeded in protecting the arc discharge from the wind effects, allowing us to perform splicing works without adversely influencing the splicing losses even under a wind speed of 15 m/sec. Figure 6 shows in orange the overlapping portion of the canopy and top case.

Figure 6 Canopy and top case structure for wind protection.

4.5 Releasable Clamping Mechanism

Optical fiber ribbons or coated optical fibers accommodated in closures for a long time have on them a permanent bend because of their storage in the tray. Despite the presence of the clamp lifting mechanism, it sometimes poses a problem making it difficult to set the fiber on the fiber holder or V-groove at the time of fusion splicing.

Whereas, typically, the optical fiber was clamped concurrently with the opening and closing of the canopy, a clamp arm has been newly provided to enable fiber clamping independently from the canopy movement. The new function has been built while keeping the typical function. By handling a clamp of a release-lever, an operator can select one of the two operations, one couples the fiber clamping with the canopy movement, and the other uncouples the fiber clamping and canopy movement. In case the uncoupled operation is set, the operator activates the clamping arm manually and closes the canopy after visually confirming that the fiber is securely clamped.

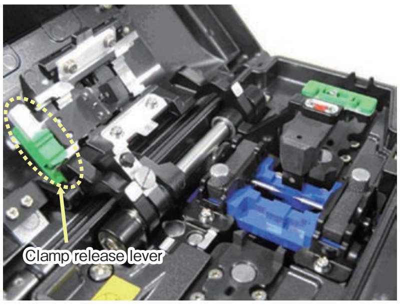

Figure 7 Independent clamping action.

4.6 Heating Reinforcement Equipment

Since a fusion spliced portion has bare glass, it needs reinforcement. The reinforcement method generally uses a heat-shrinkable tube containing a reinforcing member of glass or stainless steel to cover the portion where the glass is exposed. It subsequently heats the tube to shrink it in order to prevent the displacement of the tube. As a result, the rigidity of the reinforcing member prevents the optical fibers from breaking. This sleeve structure is called a heating reinforcing (HR) sleeve.

The HR sleeve must shrink without trapping of air bubbles, the shrinking is performed with purging the air from the center to the ends of the sleeve. And it is the heater that is required to perform the shrinking process in a shorter time. Specifically in recent years, because the splicing time has been reduced to less than 10 sec, the reduction of the heat shrinking time holds the key to the work time reduction in a series of processes from optical fiber splicing to strengthening.

4.6.1 Speeding-Up of Heating

Since, as mentioned in Section 4.6, the HR sleeve must shrink from the center to end, the temperature distribution over the whole length of the heater becomes important along with how to control the temperature distribution.

Furukawa Electric has adopted a heating method in which the heat generated by supplying an electric current to a metal resistor is conducted to the HR sleeve. We have optimized the resistor to achieve high-speed heating, thereby reducing the time loss at an early stage of reinforcement heating. Moreover, the heat-generating part has been divided into three: the center and both end portions, enabling the precise heat control that leads to the speeding-up.

We also provide our customers who demand higher speeds with the pre-heating mode, in which the heater automatically starts heating when certain conditions are met, thus minimizing the initial time loss at heating. As a result of all these design efforts, for all the models, the single-fiber HR sleeve has achieved the world's fastest 25 sec and the multi-fiber HR sleeve 35 sec, also the world's fastest.

4.6.2 Auto-Start Heating

In ordinary heaters, after setting an HR sleeve, it is necessary to push a switch to start heating, and if one inadvertently forgets to push this switch, heating will not start even if an HR sleeve is set on the machine. The newly designed HR equipment, in contrast, is equipped with an automatic start function in which the device automatically detects whether or not an optical fiber is set on the device.

It is a characteristic of this automatic start function that it is based on the detection of an optical fiber's existence rather than the detection of opening and closing of the lid or the fiber clamp of the HR equipment. Heating begins as soon as an optical fiber is set, thereby minimizing the initial time loss at heating.

4.6.3 Permanent Bend Removing Function

As mentioned in Section 4.5, an optical fiber ribbon or optical fiber having permanent bends poses a problem in that it often causes axial misalignment, which makes it difficult to set the fiber on the fiber holder. To solve this problem, the HR equipment originally implemented for the purpose of heat shrinking the HR sleeve was modified to provide a function to remove the permanent bends on the optical fibers.

When the HR switch is pushed for a predetermined time, the temperature rises to a temperature level optimized for permanent bend removal, and discontinues the operation after a certain time to reset the permanent bend removal operation. This removes permanent bends for 70 mm (the heater length, adequately longer than 50 mm which is required for splicing of the optical fibers including the length for preprocessing).

4.7 Automatic Image Storage Function

Data on the splicing loss estimations and the cut angle at the time of fusion splicing are stored for 2,000 times of splicing, and for the latest 50 times of splicing, the images of optical fiber after splicing in the X- and Y-axis views (100 images in total) are automatically stored.

Because the fusion splicing conditions after the optical fiber splicing can be confirmed visually, this function enables us to analyze troubles and to find out splicing abnormalities at the time of fusion splicing.

4.8 Multiple Battery Slot

Multiple battery slots have been implemented in the S123M8/M12, S153 and S178 by installing two battery slots in each. Taking a fusion splicing and a heating reinforcement in one cycle, the S178 achieves 200 cycles using two full-charged batteries, which is about three times that of the S177, the conventional model (70 cycles for the S177). Compared with other fusion splicers of the same class, this is the largest cycle numbers in the world.

Figure 8 Multiple battery slot.

4.9 Semi-Automatic Mode

To reduce the process time for fusion splicing, a semi-automatic mode coupled with the opening and the closing of the canopy has been installed, with which an optical fiber is automatically transported to near the fusion splicing spot.

When the start button is pushed to start fusion splicing after the optical fiber is transported to near the fusion splicing spot, the fusion splicing is completed within 7 sec for the S178. This is the world's fastest fusion splicing time when compared with other fusion splicers of the same class.

By using the semi-automatic mode, operator can view the preprocessing situations of an optical fiber such as the cut endface and cut angle before starting fusion splicing, and after confirming the adequacy of the condition, the operator can then proceed to fusion splicing. Conventionally, it was possible for the operator to confirm such conditions only after fusion splicing began. If any problems in the cut angle and cut endface are found, the operator can restart the procedures before fusion splicing begins, and this leads to a reduction in process time. Thus, the semi-automatic mode contributes to reducing the secondary process times as well.

4.10 Splicing of G.657 Fiber

As the implementation of the FTTX advances, there arises a need for a fusion splicer capable of splicing the G.657 fiber.

The S178 pre-installs the procedure, on a standard basis, the direct core monitoring program for the fusion splicing of the Bend Bright XS made by DRAKA and the EZ-Bend made by OFS. Also, the procedure that enables the fiber splicing after nulling the misalignment of the cladding center axis of the Clear Curve made by Corning, is pre-installed.

4.11 Work Belt

Work belt combines the function of a soft case for carrying a fusion splicer and that of a work table. It enables in-situ fusion splicing by wearing its accessory strap on one's shoulder and around the waist to secure the work belt on one's body, and then undoing the zipper. In case of aerial works where an aerial work vehicle can not access, the work belt makes it possible to transport a fusion splicer to the working spot safely for subsequent fusion splicing work.

Figure 9 Picture of work belt wearing.

4.12 Maintenance

4.12.1 Electrode Rod

When discharge is repeated, foreign particles progressively adhere to the tip of the electrode rod. The foreign particles can cause unstable discharge, resulting in a degraded splicing loss. Thus, the electrode rod necessitates regular cleaning.

While the electrode rod is tiny making its handling difficult, a large finger grip has been set up at the rear end of the rod to make handling easier (Figure 10). An electrode rod equipped with a non-circular finger grip is the first in the industry.

Figure 10 Easy-handling electrode.

5. PRODUCT SPECIFICATIONS

Table 3 summarizes the main specifications for three major models, the S123M4, S153A and S178A among the seven models in three series introduced here.

Table 3 Specifications for major models.

Model	S123M4	S153A	S178A
Applicable optical fiber	SM, MM, DSF, NZD, BIF/UBIF		SM, MM, DSF, NZD, EDF, BIF/UBIF
Applicable fiber numbers	1 − 4	1	
Applicable coated dia. or thickness (mm)	Single fiber: 0.25 − 0.9 Ribbon fiber: 0.28 − 0.4	Single fiber: 0.1 − 1.0	
Applicable cladding dia. (mm)	ϕ 0.125	ϕ 0.08 − 0.150	
Fusion splicing time	15 sec or less	9 sec or less	7 sec or less
Splicing loss (dB)	SM : 0.05 MM : 0.03 DSF: 0.08	SM : 0.04 MM : 0.02 DSF: 0.06	SM : 0.02 MM : 0.01 DSF: 0.04
Reinforcement time	Single fiber : 25 sec Mutti fiber : 35 sec	Single fiber: 25 sec	
Splicing program	150		
Reinforcement program	18		
Heating sleeve (mm)	20/40/60		
Storage of splicing data	1500 splicing; for the latest 50 times of splicing, the images of spliced fiber in the X- and Y-axis views are included	2000 splicing; for the latest 50 times of splicing, the images of spliced fiber in the X- and Y-axis views are included	
History of discharge test	100 data		
Fiber image acquisition	24 views		
Input-output terminal	USB 2.0		
Power supply	DC: 11 − 17 V AC: 100 − 240 V		
Outer dimensions	127 (W) × 199 (D) × 81 (H) mm, excluding shock buffer material 159 (W) × 231 (D) × 104 (H) mm, including shock buffer material	127 (W) × 199 (D) × 105 (H) mm, excluding shock buffer material 159 (W) × 231 (D) × 130 (H) mm, including shock buffer material	
Mass (excluding battery)	1.4 kg	1.7 kg	1.9 kg

6. CONCLUSION

To develop the seven models in three series in a short time, we have utilized the concept of common platform to integrate different designs among the series. As a result, a component sharing between the variations of the series has progressed, achieving a sharing ratio of 86.7% in the case of the S178.

With regard to the S153A based on a new concept, we have been successful in foreseeing the trends of the market to deliver the new product.

In terms of the fundamental specifications for the fusion splicers, we were able to provide our customers with products featuring the No. 1 specification and the first specification in the industry.

In the future, we intend to continue to be a leader company contributing to society as an equipment manufacturer supporting the optical communications and the optical industry of the world.