Mechanical Fiber Splicing Gains Acceptance in Asian Markets

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Business White Paper

3M

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Background

The drop cable connection is a key component in fiber-to-the-home (FTTH), and dependable broadband service requires that subscriber drops be stable, efficiently installed, operationally flexible and affordable. These contradictory objectives call for innovative drop cable solutions that can satisfy the growing global demand for high speed services. In this paper, we will review fiber optic splicing issues, and discuss splicing practices that have developed in support of the explosion in FTTH services in Asia.

A common element of current FTTH deployment in Japan, Korea and China is the use of mechanical splicing at the drop. In the U.S., mechanical splices have traditionally been restricted to restoration and temporary service applications – primarily because of concerns over signal loss and reflectivity. While recent field performance results contradict these reservations, there has been continuing reluctance domestically to adopt mechanical splicing. Only now are several domestic operating companies beginning to deploy mechanical splicing for FTTH.

Nevertheless, millions of mechanically spliced FTTH cable drops have been installed in the past year, with users in Asia reporting the technology meets performance standards, is less complex and faster than fusion splicing, and requires substantially lower capital investment.

FTTH Solutions

FTTH Drop Cable Requirements

For a single family unit, a drop cable typically consists of a single fiber that connects a terminal at the street with an optical network terminal (ONT) installed on the outside or inside of the house. Similar to copper installation, the fiber can be connected at each end in the field using mechanical or fusion splicing or a factory terminated patch cord can be used.

Selecting the best FTTH drop installation method involves several factors, including:

1. Initial capital costs (for field splicing, equipment must be purchased for each installation crew);
2. Inventory costs (for factory terminated patch cords, many different lengths must be carried to each installation location);
3. Deployment speed/ Installation costs (FTTH installs must be completed within a defined period and in the most cost-effective manner);
4. Maintenance costs (replacement batteries for equipment and replacement of damaged plant);
5. Cable management (for field splicing, cables can be routed and cut to length, minimizing cable storage, while factory terminated cables require slack storage); and,
6. Uncontrolled environment (work conditions vary widely by job site, time of day and time of year, and drop cable work needs to proceed efficiently regardless of the changing work environment.)

Comparison

Fusion splicing has been the de facto standard for fiber feeder and distribution construction projects, so the new hand-held fusion splicers are considered to be a solution for FTTH drop splicing. However, initial capital expenditures, maintenance costs, and installation speed are key points to consider.

The initial cost of $5,000 or more for a hand-held fusion splicer, with associated preparation tools, can be burdensome when considering that each installation crew must have a set. In addition, fusion splicers require a local power source, such as a battery, and work best in low humidity environments. The battery can represent a significant maintenance cost and can result in unexpected downtime. Lastly, fusion splicers can take several minutes to set up, even if only one splice is required.

Factory terminated patch cords have gained acceptance in the U.S. because they eliminate the need for installation equipment, and they are quick and easy to install. However, there are inventory costs to stock the many different cable lengths, additional material costs associated with slack cable, and an entire pre-terminated cable must be replaced if one connector is damaged in the field. Storage of slack drop cable can also be an issue with municipalities concerned about aesthetics.

In contrast, mechanical splicing can customize the cable installation to the situation, similar to the copper drop installation. The tools for mechanical splicing have no power or environmental requirements, need no maintenance or calibration, and can be set up virtually instantly. A tool set for mechanical fiber preparation and splice actuation costs $1,000 or less, including fiber stripper and cleaver. This makes it feasible to outfit multiple crews for intensive drop cable work at modest cost compared to the fusion option.

For drop applications, mechanical splice and connector terminations can generally be completed in about one-half the time required for fusion splicing. When thousands of splices must be finished quickly with only two or three splices per location, mechanical splicing offers an efficiency advantage. Additionally, since mechanical splicing is a simpler process than fusion splicing, technicians have less chance of error or damage to sensitive components. It is for these reasons that a number of service providers in Asia have settled on mechanical splicing for FTTH drop cables.

The Mechanical Splice Concept

A typical mechanical fiber optic splice consists of a small plastic housing with an aluminum alloy element to precisely align and clamp fibers (Figure 1). An index matching gel pre-installed at the fiber connection point maintains a low-loss optical interface, which results in a median insertion loss of less than 0.1dB.

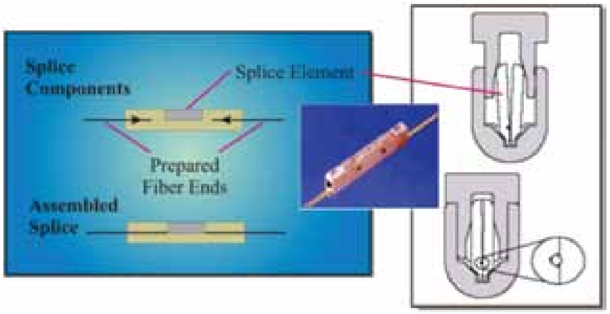


Figure 1 – On activation, the metal element in this mechanical splice grips prepared fiber ends to hold them in permanent alignment and contact, immersed in an optical gel.

The mechanical splice process involves four steps: stripping the fiber coating from the glass, cleaning the glass, cleaving the fiber with a flat end face, inserting the fibers in the mechanical splice and activating the splicing tool. This tool (such as shown in Figure 2) holds the mechanical splice and retains the fibers so their ends are in contact.

Figure 2 – A mechanical splice activation tool holds the fiber ends in contact and presses the metal element over fiber ends to complete the splice. No power source is required.

A splice is completed by pulling down the tool handle to force a plastic cap down, which presses the sides of the metal element together and clamps the fiber ends. This hand-operated mechanical splicing tool can be used on any flat surface and requires only a small work area. Field assembled, mechanical splice connectors use the same metal element concept and the same assembly and actuation sequence.

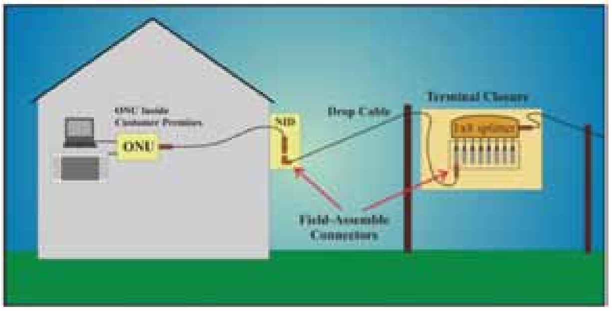
Optimum mechanical splice performance depends on careful and consistent fiber cleaves accomplished with appropriate tools as well as optimized product design and constant attention to cleanliness. These are the same requirements that fusion splicing has to make a good splice.

Drop Cable Practice - Japan

Japan service providers are the leaders in FTTH deployment with more than 10 million homes connected. FTTH construction activity is currently underway at a rapid pace with more than 100,000 drops connected every month by the incumbent service provider and the CLECs. Quite simply, they probably have more experience deploying FTTH than almost anyone else in the world.

In the past few years, Japanese service providers completed laboratory and field analyses that affirmed mechanical splicing as a viable long-term answer to outside plant fiber optic requirements. Mechanical splicing reduced initial tool capital expenditures by 90%, doubled splicing speed, and decreased installed costs by 50% relative to fusion splicing. Subsequently, the providers abandoned fusion splicing in favor of full scale mechanical splicing deployment of the FTTH drop (Figure 3). Millions of splices and field-assembled no-polish connectors using mechanical splice technology have now been completed in Japan, with more being installed daily, making Japan the leader to date in implementing mechanical fiber optic splicing. Field performance has been excellent with one supplier’s products having reliability of greater than 99% percent.

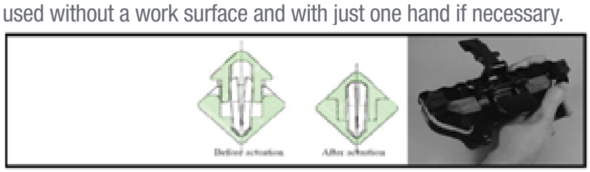
Figure 3 – In Japan the drop cable is attached to the on-premise



optical network unit (ONU) through a pluggable FA connector.

For the transition from fusion to mechanical splicing, service providers in Japan recognized the need for a 250µm fiber splice that could be used in existing fusion splice trays for FTTH drop splices. A compact splice component (Figure 4) was developed to meet this need, using the same splice element design as a conventional mechanical splice. For the past seven years, this smaller device has been used in Japan under widely varying environmental conditions and with very high reliability. This smaller splice and its associated tool have improved usability because the compact tool can be hand-held and used even while on a ladder or standing at the side of a house. No work surface is necessary.

Figure 4 – The compact 250µm splice and its actuation tool can be used without a work surface and with just one hand if necessary.



A field assembled, mechanical fiber optic connector was developed and produced especially for the Japanese market. The service providers needed to install drop cables easily with fiber connectors that plug in at the terminal, for quick adds, drops, and changes. These mechanical connectors make it possible to customize drop cable lengths and minimize slack storage.

Both connector and socket have precisely aligned and factory-polished ferrule assemblies that are connected to internal stub fibers. These fibers and internal metal elements are used to make fiber drop cable connections in the same manner as the basic mechanical splice.

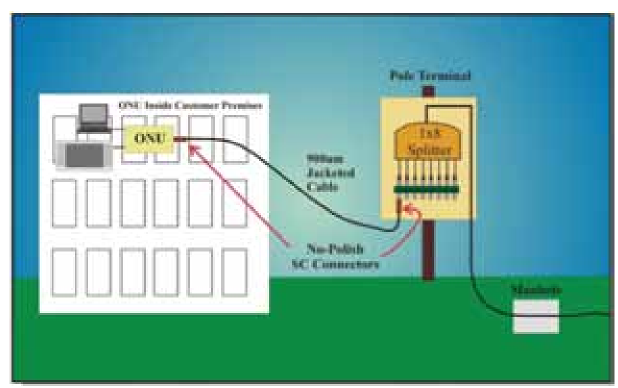
No polishing or other special preparation is required for a complete, low-loss pluggable connection, and a hand-held mechanical fiber splicing tool can be used with field-assembled mechanical connectors where a suitable work surface is not available. This custom plug and socket connector pair is used in Japan with bend insensitive fiber which handles a 15mm radius with low-loss at long wavelengths, instead of the 25 or 30 mm bend radius of standard fibers. This fiber is encased in a unique, strippable jacket that enables the connector to be mounted directly on the cable. This fiber is easier to store, less likely to break, and allows for more compact packaging than standard FTTH drop cables.

Drop Cable Practice – South Korea

In the mid-1990s regulators in Korea established aggressive targets for broadband service to both business and residential customers. At present, the nation of Korea is a world leader in internet service with >70% of households having broadband connections. Since 2006, they have deployed FTTH with several million homes connected.

In 2005, a major Korean service provider conducted a FTTH field trial, installing fiber-optic service to thousands of homes with mechanical splicing technology. Results were positive, and the concept is now used in full scale deployment. This involves placing drop cables that can be plugged directly into the customer's ONU. This reportedly results in use of fewer parts, simpler installation, lower light loss and greater dependability (Figure 5). However, it sacrifices cabling flexibility and the drop cable must be replaced if the end user breaks a fiber in the home.

Figure 5 –Drop cables in the Korea FTTH have two mechanical splice points – one at the pole-mounted splitter and the other at the customer's ONU inside the apartment.



Both ends of the drop cable are terminated in field assembled, fiber optic connectors, with a standard SC interface. One end plugs into the cross-connect field on the neighborhood pole-mount fiber optic terminal and the other into the customer's ONU. The drop cable length is customized for each FTTH drop installation and has the benefits of minimum slack and test access in either direction.

Mechanical splice products for this FTTH deployment were subjected to testing in Korean laboratories, and the selected field assembled, SC no-polish mechanical connector was modified for use with the jacketed cable used in Korea. The fiber itself is R15 bend insensitive single mode in a 900um buffer, surrounded by yarn, which acts as the strength member. To simplify assembly, this product does not require any special tools for installation. It has the advantage of a standard SC interface, which can mate to other standard SC connectors, but it is designed for only the 3mm jacketed cable.

Because of the advantages of mechanical splice technology and its performance, the service provider is now approving mechanical splices for the rest of the optical network.

China

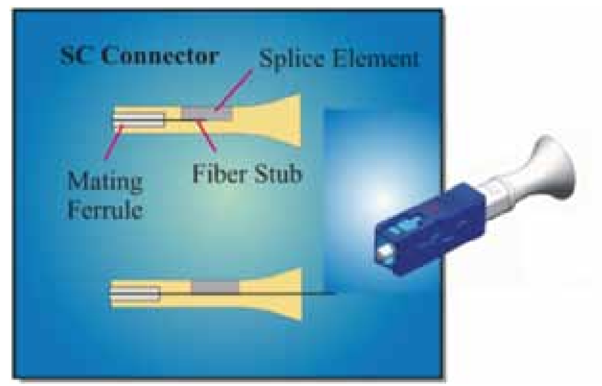
All of China's telecom services are growing at a rapid pace. The country boasts the world's largest user base at 457 million customers, but that figure accounts for only 30% of China's population. Fiber optics would provide those users with speeds of up to 100 Mbps, at prices cheaper than standard DSL connections. When completed, China will have the largest fiber optic network in the world. The company plans to put the superior bandwidth to use by introducing high-definition IPTV, 3D media and encouraging device manufacturers to rely more on cloud computing.

As part of a new FTTH initiative, China service providers are currently deploying FTTH high-rise buildings, delivering broadband to each apartment. Cable runs are made from a basement optical distribution frame (ODF) to fiber distribution units (FDUs) in closets with splitters. FTTH drop cables are connected to fiber stubs at the splitter using mechanical connectors and to a pluggable patch cord at the customer's ONU with another mechanical connector. In China it is a common practice to use a similar drop cable construction as Japan with the standard interface connector used in Korea.

U.S.

Another product, which is offered in the U.S., is a field-assembled, no-polish mechanical connector with a standard SC interface (Figure 6). Similar to the connector used in Korea and China, this component allows for plug-to-plug compatibility with other standard connectors on ONUs and factory-made patch cords. However, this no-polish connector accommodates standard 250µm and 900µm fiber sizes interchangeably, instead of 3mm Korean cable jacket. It can offer APC interfaces with angle splices for excellent reflection performance as required in some analog transmission situations.

Figure 6 – This no-polish mechanical SC connector can be used with 250µm or 900µm fibers and mates with other SC standard connectors.



Laboratory Testing

The optical index gel used for the referenced drop cable applications in Asia and for mechanical splice products in the U.S. has been subjected to a range of tests to confirm its immediate and long-term performance. For example, gel samples were aged in bulk at elevated temperatures: 85ºC (185ºF) for seven months (5,100+ hrs); and then compared to non-aged gel for changes in refraction index from -40ºC to 80ºC (-40ºF to 176ºF). No significant difference was detected between aged and non-aged samples.

In another test, the optical gel was heat-aged at 80ºC for 17.5 months (12,700+ hours). Thirty optical splices were manufactured using this aged gel, and insertion loss was then measured. The highest loss noted was less than 0.1dB. Gel samples have also been aged at 115ºC (239ºF) for 7 months with similar test performance results.

Mechanical splice performance tests substantiating the reported field experience in Asia include a sequence where 30 pairs of optical fibers were joined with mechanical splices at room temperature and then heat aged for 2000 hours at 85ºC (185ºF). After cooling to room temperature, insertion loss values were recorded. In both initial and final data, measured losses were <0.2dB.

Insertion loss results for 30 mechanical splices immersed in distilled water for 30 months showed splice loss values of <0.2dB both before and after the test. The laboratory results for these and other immersion and high humidity tests of mechanical splice components can be obtained from the author.

Conclusion

As fiber deployment accelerates in North America, Asia and Europe, there is a need for field-installed drop cable connectivity solutions that are simple, low in cost, and meet high service standards. Mechanical splicing is being used successfully for FTTH drops in multiple countries representing a range of labor rates and skill levels, and this demonstrates the general applicability of this splice method. It is serving as one of the base technologies for divergent drop cable approaches and broadband delivery methods.

In the case of Japan, where mechanical splicing for drop cables has one of the longest records of use, users report that the process has reduced tool cost by 90%, improved productivity by 50%, and resulted in a 50% overall reduction in the installed cost of each mechanical splice.

The experience of users in Japan, Korea and China confirms that with proper tools and components, mechanical FTTP drop splices and connections may meet both budget restraints - such as cost-per splice and time-per-splice - and long-term performance standards. These standards include environmental resistance, pull-out strength and signal integrity. The benefits of mechanical splicing apply to aerial, buried, underground and pedestal fiber-joining requirements in the field, for both indoor and outside applications.

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