

Mid-span Access Tool Designs and Their Impact on Fiber Reliability

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Abstract

Mid-span accessing of buffer tubes is frequently done to extract a subset of the fibers inside. The buffer tube access tools used for mid-span access have three requirements: 1) they must open the buffer tube to allow access to the optical fibers inside, 2) they must not interrupt traffic on active fibers, and 3) they must not damage the optical fibers. However, many mid-span access tools cannot meet all three of these requirements. This paper presents a detailed study of the potential for fiber damage resulting from the use of various mid-span access tools currently used in the field.

Keywords

Mid-span access tool, branch, blades, fiber damage, reliability, drop, buffer tube.

1. Introduction

This study of fiber damage resulting from the use of mid-span access tools was undertaken in response to two developments in the communications industry. The first development is the fact that mid-span access is becoming increasingly more common as networks spread closer to the end user. As this happens, small numbers of fibers (6, 4, or even 1) are dropped off of feeder lines. Since buffer tubes typically contain 12 fibers, the tube must be opened in mid-span to allow the desired fibers to be cut and spliced to a drop cable.

The second development is the emergence of unique cables especially designed to carry a large number of fibers in a small cross-section. These “high fiber density” cables are miniaturized to take advantage of unusual right-of-ways and innovative installation techniques that reduce the cost of deployment.^{1,2,3,4and 5} For example, special cables have been installed in sewers, water lines, gas lines, tiny trenches in roadways, and in miniaturized ducts^{6,7}. Instead of carrying 12 fibers in a 3mm buffer tube, some of these cables carry 24 fibers in a 2.4mm buffer tube, or 12 fibers in a 1.5mm buffer tube.

These two developments create an urgent need for a reliable and effective mid-span access tool that can address buffer tubes with higher packing density. In order to develop a reliable tool for mid-span access, several different tools, which are now commonly used in the field, were tested with the buffer tubes they were

designed to open. The purpose of this study was to benchmark the effectiveness of current tools.

2. Variables

Samples of loose tube optical fiber cable, and the corresponding recommended access tools, were procured from three major cable manufacturers. The buffer tubes were removed from the cable structure using conventional techniques, and each manufacturer’s tool was used to access the buffer tubes for which it was designed. A fourth mid-span access tool, expressly designed for mid-span access of “high fiber density” buffer tubes, designated as “tool A2”, was also tested with buffer tubes made by each of the three cable manufacturers. Three duplicate tools of each type were paired with three different buffer tubes, e.g. blue, orange, green, to achieve the variation in tools and buffer tubes that might occur in the field.

Standard buffer tubes from each manufacturer were used. Two of the cable designs used a 3mm tube containing 12 fibers, and one design used a 2.8mm tube containing 12 fibers.

Buffer Tube	Tool #1	Tool #2
Vendor A 3mm/12 fiber	Tool A1	Tool A2
Vendor B 2.8mm/12 fiber	Tool B	Tool A2
Vendor C 3mm/12 fiber	Tool C	Tool A2

Photographs of the various access tools and respective cutting channels are shown in Figures 1A-C. Tools A1 and A2 both have a blade that shaves off part of the tube with minimal intrusion into the tube interior. Tools B and C have blades that cut through the tube and penetrate substantially into the tube interior.

Tool A2 incorporates design features that makes it especially suited for mid-span access of “high fiber density” buffer tubes. Specifically, the blade is designed so that the bottom of the blade can safely contact optical fibers during access without causing

coating damage. This is achieved by positioning the cutting edge of the blade some distance above the bottom of the blade. This distance is the “blade edge height” and is illustrated in Figure 2A. Additionally, the channel of Tool A2 is integral to replaceable inserts that are precision machined. In this way, the depth of cut is carefully controlled by the “step height” illustrated in Figure 2B. These inserts are made for a specific buffer tube geometry and can be easily replaced in the tool depending on the tube that is to be accessed. Figure 3 illustrates the wide range of tube geometries that can be accessed with tool A2 and a series of inserts.

Figure 1A: Access Tools A1, B, and C.

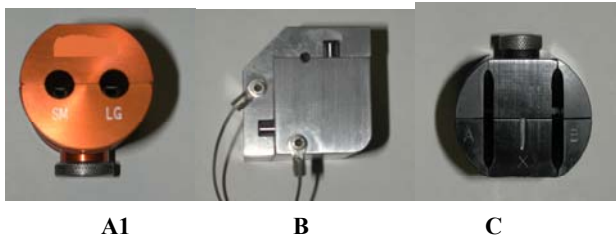


Figure 1B: Access Tool A2 in Case with 2.5mm, 2.8mm, and 3.0mm Inserts.



Figure 1C: View Through the Access Channels of the Tools.

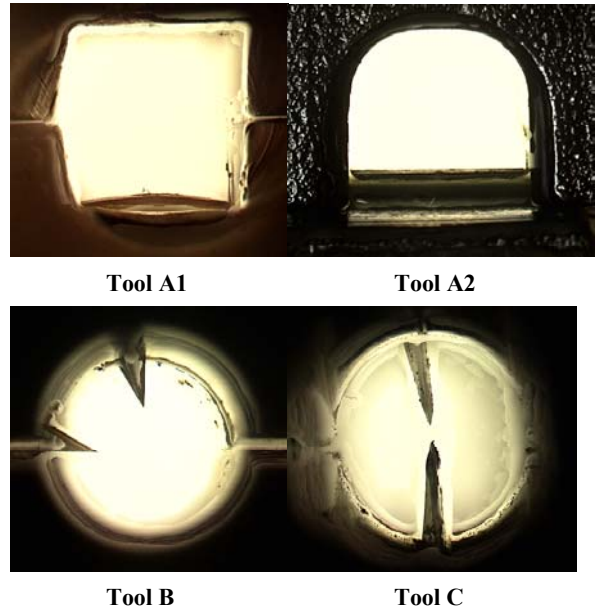


Figure 2A: Drawing of the Cutting Blade Profile of the High Fiber Density Access Tool A2.

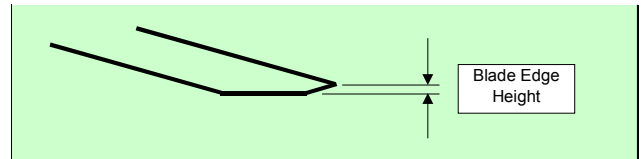


Figure 2B: Illustration of the Insert Used in the High Fiber Density Access Tool A2.

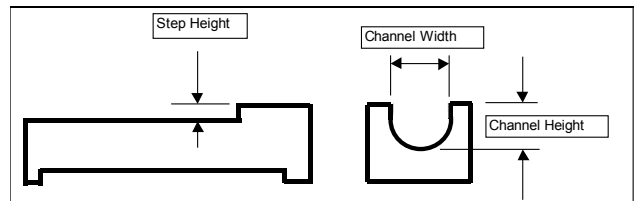
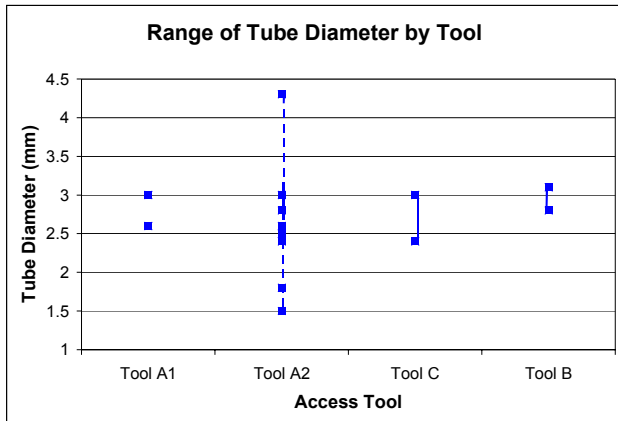


Figure 3: An Illustration of the Range of Buffer Tube Sizes that Can be Accessed with Each Tool.



3. Procedure

First, three access tools of each type were paired with three buffer tubes from the same cable. Each tool was then used to open a 2m length of buffer tube in accordance with the tool manufacturer’s instructions. The fibers were carefully removed and hung vertically to prevent contact with damaging surfaces. Thirty-six accessed fibers were obtained for each toolmaker / buffer tube maker combination. After the fibers were extracted from the opened buffer tube, they were cleaned with gel solvent and alcohol. Then, the entire length of each fiber was inspected under a microscope at 100x magnification, to look for signs of coating damage resulting from fiber contact with cutting tool blades.

The level of damage was noted for each fiber. Damage was categorized into three levels: no damage, damage to the secondary coating only, and damage to both secondary and primary coating. Note that glass damage could not be quantified with this inspection method, so some damage recorded as primary coating damage may actually have included glass damage as well.

4. Results

A summary of the damage rates observed on fibers from the various tube access trials is shown in Figure 4. The aforementioned tool for “high fiber density” buffer tubes, tool A2, was tested on all tube types with zero fiber damage being evident. In contrast, other tools produced damage rates as high as 97%. Examples of coating damage observed through optical microscopy are shown in Figures 5 and 6.

Tools A1 and A2 did not produce observable coating damage in the tube sizes used in this study. The reduction in fiber damage rates with tools A1 and A2 is explained by the greatly reduced penetration of the cutting blade into the interior of the tube as well as by the design features described previously. An important distinction between Tool A1 and Tool A2 is that Tool

A2 is designed for use with buffer tubes having fiber densities greater than those in this study but Tool A1 is not.

With the level of coating damage observed in many of the fibers that were damaged by access tools, there is a significant reduction in the protection afforded to the glass. Since fibers within splice enclosures typically see the increased stresses due to lower bending radii and increased handling, coating damage should be avoided especially in fibers that do not have the additional protection of the cable and buffer tube.

Figure 4: Fiber Damage Observed with Various Access Tools and Buffer Tubes

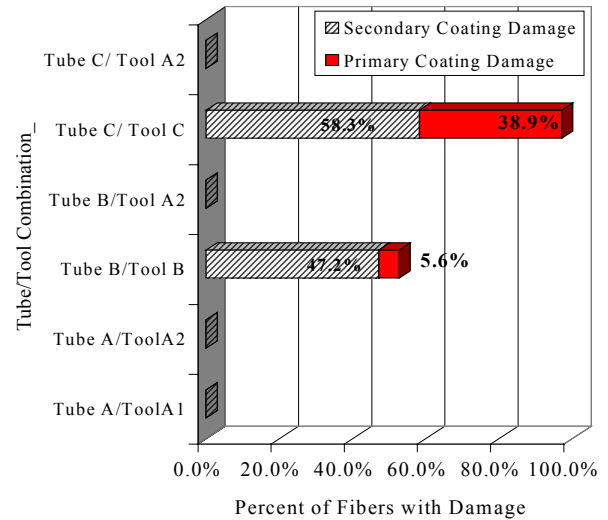


Figure 5A: Fiber Damage on a Red Fiber from Tube B Accessed with Tool B.

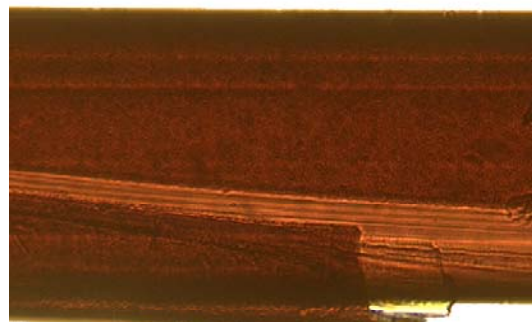


Figure 5B: Fiber Damage on a Blue Fiber from Tube B Accessed with Tool B.

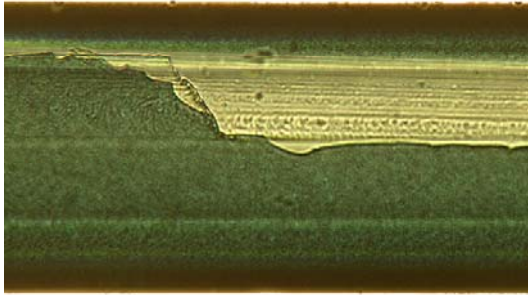


Figure 6A: Fiber Damage on an Orange Fiber from Tube C Accessed with Tool C.

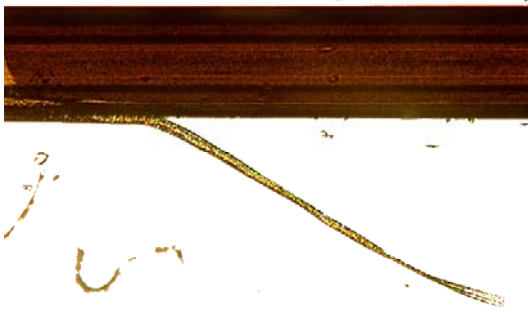


Figure 6B: Fiber Damage on a Green Fiber from Tube C Accessed with Tool C.



Figure 6C: Fiber Damage along a Substantial Length of an Orange Fiber from Tube C Accessed with Tool C.



Figure 6D: A Section of Fiber with Secondary Coating Almost Entirely Removed by Tool C.



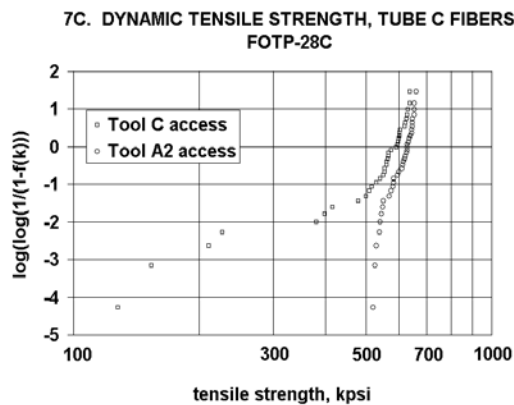
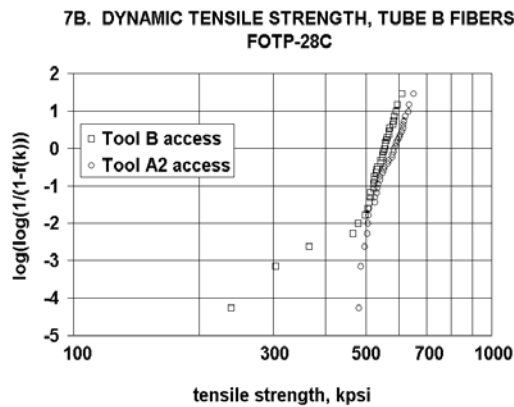
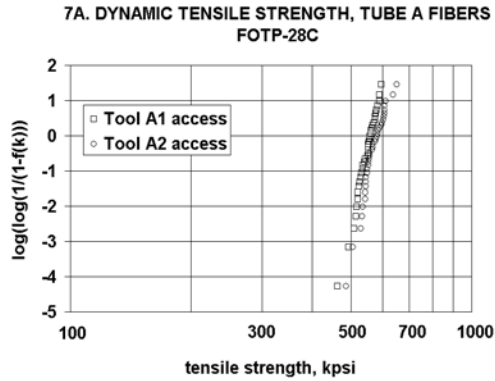
The fibers accessed with the different tools were aged for 50 days in an environmental chamber controlled at 85°C and 85% relative humidity in order to assess the effects of the coating damage on the long-term fiber reliability and strength. After aging the fibers were placed in the chamber in a stress-free state for the duration of the aging period. Following the accelerated aging, the tensile strength of the fibers was measured per the procedure of FOTP-28C for half meter tensile testing. The results are shown in Figures 7A – 7C. Note that flaws outside of the half meter gauge length would not affect strength measurements.

Tube A fibers show little difference in the strength distribution whether accessed with Tool A1 or Tool A2. The median strength of the fibers accessed with Tool A1 is somewhat lower, but there is an absence of low stress breaks that might have been a result of damage from either tool.

Tube B fibers also do not show substantial variation in median strength when accessed with either Tool A2 or Tool B. However, several large flaws in fibers accessed with Tool B were indicated by the low stress breaks in the tensile distribution as shown in Figure 7B.

Tube C fibers showed the most substantial variation in median strength as a function of access tool. Tool C resulted in the most severe effects on fiber strength, where several flaws of a strength less than 200 kpsi are seen in this 36 fiber data set, Figure 7C. Flaws this weak can lead to fiber breaks during subsequent handling of the fibers. Again, Tool A2 did not cause coating or glass damage that affected the tensile strength of the fibers from tube C even after aging.

Figures 7A-C. Tensile Strength After 50 Days Aging
85°C/85% RH.



5. Conclusions

The primary conclusions of this study are:

1. Some commonly used mid-span access tools have the potential to cause severe coating damage.
2. Substantial coating damage may go unnoticed during normal fiber access since careful inspection, sometimes requiring microscopy, is needed for detection.
3. Coating damage caused by access tools may increase the risk of fiber breaks due to static fatigue, handling, or other mechanical forces in splice closures.
4. A survey of various tool technologies available to the industry and a concurrent tool development effort has produced a buffer tube access tool that virtually eliminates the risk of coating damage. This tool is compatible with a variety of buffer tube materials and geometries.

The need for reliable mid-span access tools will grow more acute as fiber densities in buffer tubes increase. As fiber densities increase, the tolerance inside a tube for an invasive cutting tool decreases, thereby increasing the risk of coating damage. A flexible, reliable, access tool is needed to ensure that as fiber density increases, risk of fiber damage does not. This research has produced a tool that has successfully produced reliable and repeatable tube access without fiber damage with tubes of varying geometry and from various manufacturers.

6. Acknowledgments

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7. References

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