HOW TO SPEAK "FIBER GEEK"

ARTICLE 5: CRITICAL MECHANICAL PARMATERS - STRENGTH AND RELIABILITY

Welcome back, Fiber Geeks!

Article 1 in this series highlighted some bandwidth demand drivers and introductory standards information. Article 2 then focused on attenuation, while Article 3 covered dispersions. Finally, Article 4 discussed fiber geometries.

This article, the fifth in the series, will focus on fiber strength and reliability.

Light doesn't transmit very far through a broken fiber, so fiber strength and reliability are very important topics. Fiber has a reputation for excellent reliability, and that hasn't been acquired by luck. For most end users, fiber just works, and they don't give the topic much thought. However, this performance is based on a deep understanding of the mechanical performance of the glass to the molecular level. Researchers have spent entire careers acquiring this understanding and translating this knowledge to product design, manufacturing, and installation recommendations.

For starters, pristine glass optical fiber is stronger than steel, when measured diameter to diameter. Although the actual intrinsic strength of glass can vary according with sample preparation, it is often greater than 700,000 pounds/square inch (PSI), compared to 70,000-85,000 PSI for cold rolled steel.

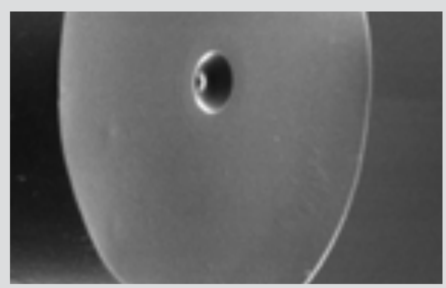
Although glass is very strong, it is brittle, so it cannot be stretched for large amounts without breaking. Like any material, fiber is only as strong as its weakest link. Impurities or other mechanical flaws in the glass, even as small as fractions of a micron, can weaken it.

For this reason, how the glass is made can give a clue as to how it will perform long term.

OFS uses synthetic silica to make our glass. Synthetic silica is made by reacting ultra-pure chemicals together to chemically form silica (SiO_2). The raw materials used to make fiber are pure to the parts per billion level, and after additional processing, the core of the finished fiber is pure to the 10 parts per trillion level. To put this in perspective, the odds of winning some lotteries are roughly 1 in 300 million. Other methods of fiber manufacturing may not provide as pure of a finished fiber.

Even though the starting glass is very pure, there are chances for flaws, such as mechanical abrasions or particulate inclusions, to be added during the manufacturing process.

FIGURE 1



Fiber made from synthetic silica

Fiber made from alternative raw material

For that reason, after the fiber is drawn, there's an additional manufacturing step called "proof testing" the fiber. It is a "go/no go" tensile test, and is used to remove flaws that are weakest links in the fiber. This test is typically performed to 100,000 pounds per square inch (100 KPSI), but may be higher for special applications, such as undersea networks. If the fiber survives the test, it is deemed strong enough to be placed into some type of cable. The test itself is simple. Fiber is typically guided around a pulley with a weight attached to it (around 2 pounds for 100 KPSI).

From above, we know that the fiber has a minimum strength after it's originally manufactured. An important question is how much tension can be applied to a fiber without causing any flaws remaining in the fiber to grow. The proof test removes the weakest flaws, but does not remove all flaws from the fiber, which is another reason why the method to produce the glass is so important. The purer the glass, the less likely problems will occur long term.

There are fundamentally two applications of fiber deployment where strength is important.

The first application is the obvious one – a fiber that's stretched in tension, either in an aerial or underground network. This application is governed by the fact that the network is only as strong as its weakest link. The proof test is designed to weed out the weakest links in the network, with the remaining strength of the glass sufficient for 40 year life (or longer), as long as the network is installed and operated per manufacturer recommendations. The weakest links in these networks are typically large flaws. Fortunately, large flaws are relatively few and far between for high quality fiber.

However, there's a second application that's less obvious, but no less important, especially for today's FTTH and FTTB networks, and tomorrow's 5G small cell networks. This is the application where fiber is bent very tightly, such as what happens in homes and apartments and sometimes drops to cell towers. In this case, reliability is often governed by the performance of the smaller flaws in the glass, which are often near the intrinsic strength of the glass.

As an industry, we approach these applications differently. For the long length application, manufacturers limit the strain applied to individual fibers. Limiting fiber strain prevents flaws in the fibers from growing, and is a main reason why fiber has achieved its stellar reputation for reliability. The way we do this is by providing a recommended maximum application tension. For many duct cables, this is 600 lbs., but some cables may have higher or lower maximum tensions, and these tension limits sometimes have different names, depending on the application.

FIGURE 2

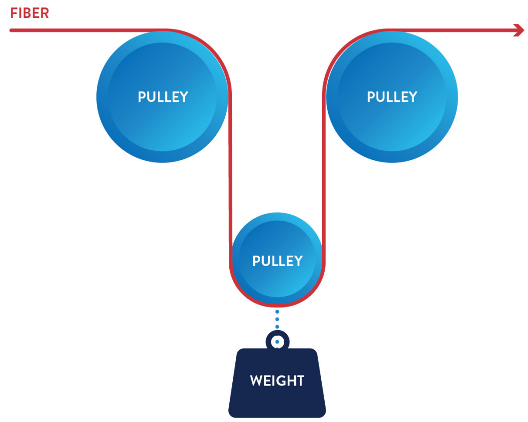
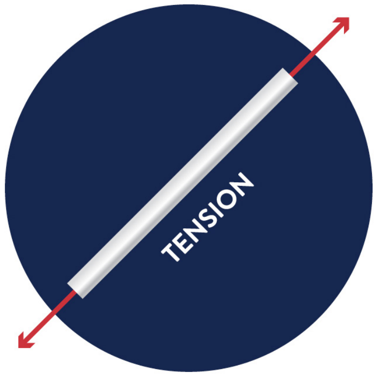
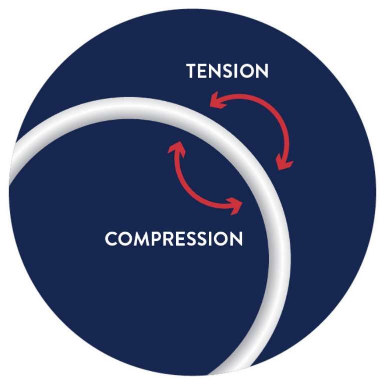


FIGURE 3



Tension Applications: Tension is a concern for long length applications.

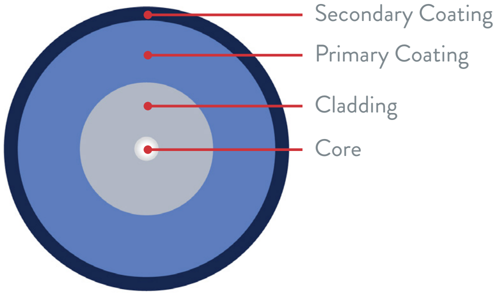
FIGURE 4



Bending Applications: Mechanical bending strain is a concern for drop applications.

For bending applications, manufacturers often provide recommendations for minimum bend diameters. It's notable that bend diameters for fiber in splice trays are typically provided due to potential bend loss issues rather than reliability issues. For some indoor drop applications to individual customers, such as the very tight bends around door frames in homes, there can be a very small probability of mechanical failure, on the order of a few parts per million, over a 20 year life. For this reason, manufacturers typically don't recommend having these types of bends in applications in the core of the network.

FIGURE 5



Not exactly to scale.

Fiber coatings affect the long-term reliability of the fiber.

The fiber coating is also a very important component of the fiber. In most fibers, there are actually two layers of coating – a softer inner "primary" layer of coating closest to the glass to provide cushioning, and a tougher outer layer. The coating is an integral part of the fiber, and significantly contributes to the overall reliability of the fiber. The primary coating needs to have some "Goldilocks" qualities – soft enough that it cushions against stresses that can cause attenuation, but also tough enough not to separate or delaminate from the glass. The coating also needs to be free of bubbles and other inclusions that could cause uneven stresses on the glass.

An additional test for mechanical reliability is the dynamic fatigue test. This test measures how flaws grow in the presence of tension. If flaws never grew when exposed to tension, fiber cables could be pulled very tightly with no consequences. Likewise, if flaws grew significantly with tension, we may need to reduce the tension that can be applied to the fiber. The dynamic fatigue coefficient of a fiber is called the "n" value. It's used by fiber and cable manufacturers to determine how much strain can be applied to a fiber both during installation and over its lifetime.

In general, the principles above apply to both single-mode and multimode fibers. The performance of today's fiber networks have given fiber a well-earned reputation for reliability. This is not by accident. Every step of the manufacturing and installation processes have implications for reliability for networks that need to operate 24/7/365 for decades at a time. Keep that in mind the next time you use any of your devices.

Fiber geekdom is a journey, not a destination, and there's always more to learn. OFS has multiple decades of experience with fiber optic networks. Please contact your local OFS representative if you would like additional information regarding any of the items in this article.