



Determining Appropriate Proof Test Level for G.657 Fiber (Designed for Tight Bending)

Application Note

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Summary

- Where fiber is exposed to elevated stress that is highly localized, increasing the proof stress to 200kpsi imparts negligible improvement in mechanical reliability. This is true of FTTH applications where regions of a few mm are typically exposed to bend radii down to 5 mm while the great majority of fiber is essentially straight.
- This is because very few of the flaws susceptible to failure through fatigue during the lifetime of the deployment are actually eliminated by 200kpsi proof testing.
- The probability of failure in bends to 5 mm is low (3ppm per full turn) because failure demands the exact coincidence of a susceptible flaw in the region under tight bend.
- Increased proof stress to 200kpsi is an appropriate method to enable higher stress deployment only where all or most of the fiber is exposed to elevated stress. This is true of submarine applications (where elevated tensile stress is encountered during cable installation and deployment) and some photonic applications (where elevated bending stress is created by deployment in multiple small radius coils).

Introduction

ITU Recommendation G.657 defines two classes of bend resistant fibers that are increasingly being used in fiber to the home (FTTH) applications. Optical performance in bending is defined as low as 10 mm radius for Class G.657.A and 7.5 mm radius for Class G.657.B. Some exceptionally bend insensitive fibers are defined as low as 5 mm radius, leading to industry proposals for a Class G.657.C within the published standard.

Proof testing is the process where the full fiber length is stressed (typically 100kpsi tensile stress for terrestrial fiber applications) to assure a lower limit on the strength of the fiber prior to cable processing, installation and deployment. Divergent opinion has been expressed as to whether G.657 fibers should be proof tested to 100kpsi (as required in the standard) or whether the elevated stress imparted to the fiber in the tightest allowed bends demands an increase in the proof test to 200kpsi. This application note explains why Corning has determined that 100kpsi proof testing remains appropriate even for bend insensitive products that are deployed to 5 mm bend.

Explanation

200kpsi proof stress is sometimes defined to allow application of higher tensile stress during the processing, installation or long-term deployment of optical fiber cable. This is particularly true of submarine cables in which any non-zero failure rate is considered unacceptable due to the high density of traffic carried, the large number of subscribers that may be supported by a single fiber and the high cost associated with cable recovery and repair. Safe (i.e. zero failure probability) stress limits are defined around the weakest flaw that might be present in the fiber after proof testing (the flaw that just survives the proof stress). If safe stress levels are adhered to the strength of the weakest flaw will never fatigue to below the applied stress so the lowest strength flaw (and therefore the full fiber length) will survive

throughout the deployment lifetime. Similarly Photonic fiber, when used for component manufacture in which most of the length is permanently deployed in multiple tight coils, can benefit from increasing the proof test level to 200kpsi to enable tighter zero failure bending deployments.

Corning has determined that the safe deployment stress level is one fifth of the applied proof test level¹. The weakest surviving flaw of a 200kpsi proof tested fiber is twice as strong as a 100kpsi proof tested fiber. A 200kpsi proof tested fiber consequently has a safe stress limit that is twice that of a 100kpsi fiber for long length, tensile stress conditions and is therefore more resilient to higher stress events.

While it is tempting to follow the same logic in specifying G.657 fiber and require 200kpsi proof testing for fibers designed to operate to 5 mm bend radii (which imparts bending stress at ~130kpsi) in FTTH applications, this would be misguided. Unlike fiber which is uniformly subject to increased tensile stress in cable, G.657 fibers are exposed to elevated bending stress only in the isolated regions actually under bend (i.e. a quarter turn of 5 mm radius consists of < 8 mm of fiber actually under stress). As with all G.657 fibers, these regions under bend have both a deterministic and very low failure probability. Knowing the distribution of low strength flaws in the fiber (through extensive mechanical reliability testing using Continuous Rotating Capstan Fiber Tester, CRCFT²) Corning has determined the probability that a flaw with initial strength below a particular critical value coincides with a region of fiber under tight bend. The critical value is the initial flaw strength that can fatigue to failure under the bending stress imparted. At 5 mm bend radius an initial flaw of up to 662kpsi is susceptible to fatigue to failure over a 40 year installed lifetime.

According to Corning's fiber reliability model, for 100kpsi proof tested fiber, the likelihood of coincidence of such a flaw in a full turn of 5 mm radius results in failure probability of 3ppm. If the proof test is increased from 100kpsi to 200kpsi, very few further flaws in the susceptible region are removed and the modeled probability of failure only reduces to 2.5ppm.

Further Reading

A more detailed discussion of this subject can be found in Corning's White Paper "The Mechanical Reliability of Corning Optical Fiber in Small Bend Scenarios".

References

1. Corning White Paper 5030 – Mechanical Reliability: Applied Stress Design Guidelines
2. Corning White Paper 5050- Optical Fiber Mechanical Testing Techniques

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