Mechanical Reliability: Applied Stress Design Guidelines
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Mechanical reliability models are used to predict the expected lifetime or failure rates for optical fibers under given service stress conditions. Typically, strength distributions are measured to determine a flaw size distribution; the model then predicts how these flaws will grow over time. If the stress is sufficiently high, a flaw will grow to a large enough size to cause catastrophic failure. This classic flaw growth behavior and the models used to estimate failure rates are summarized in another Corning publication.[1]

Corning has developed a multi-region power law model for reliability predictions in optical fiber.[2] This model can account for the differences in crack growth behavior between high speed events such as proof testing and fiber processing, and slower events like installation and in-service life. Corning also measures the distribution of flaws near the proof stress level.[3] This, coupled with the multi-region crack growth model, allows Corning to determine safe tensile and bending stress guidelines for a wide variety of fiber applications.

The applied stress design guidelines below define the safe allowable applied stress that can be applied to optical fiber in various conditions. These guidelines apply to the Corning optical fibers listed in Table I. The guidelines are based on the assumption that no fiber damage occurs after proof testing. Failure is defined as > 1% crack growth in the designated time-frame.[4] As shown in Table II, the proof test stress level (σ_p) is a part of the equation which defines the allowable stress level.

Table I: Shows a list of products for which the applied stress guidelines pertain.
Table II: Defines the maximum allowable stresses for any fiber length for zero failures.
Table III: Shows the maximum allowable stresses for medium fiber lengths (≤ 300 m) when some risk of failure is allowable.
Table IV: Shows the minimum bend radii calculated for long and short lengths.

Each table differentiates the length of time that the fiber is exposed to the given stress level. Forty years is considered a fiber life, and the stress level reported is the maximum stress or bending from the sum of the stresses induced by the cable design and service environment. Four hours is assumed as typical for the time period of cable installation, and 1 second is assumed as typical for the time period that the fiber could be exposed to an extreme condition such as in cable processing (i.e. going around a pulley). Note that the minimum bend radius values calculated in Table IV assume zero additional tension on the fiber in the bent configuration.

One particular short-term bending scenario involves LID (Local Injection and Detection) splicers. These splicers place a very small bend on the fiber (3 to 4 mm bend radius) for up to 1 minute. In these situations, it is highly unlikely that a critical flaw will be located in the bent configuration and fail during the splicing operation (see last line in Table IV). Further-more, if no failure occurs, this section will not be a reliability risk in the future.

It is understood that there are numerous scenarios involving tension and bending for different lengths or durations, which are not listed in the tables. For specific scenarios involving Corning Optical Fiber reliability, please contact the Corning Optical Fiber Information Center at *info@corningfiber.com*.

Corning Optical Fiber products which fall under the applied stress guidelines
Table 1

Product Type
LEAF® Optical Fiber
Corning Submarine Fibers
MetroCor™ Optical Fiber
SMF-28™ Optical Fiber
SMF-28e™ Optical Fiber
Corning Multimode Fibers

Total allowable stress design guidelines for any length, resulting in zero failures
Table 2

Duration of Applied Stress	Allowable Safe Stress in Relation to σ_p	Allowable Safe Stress (kpsi) when σ_p = 100 kpsi
40 years	1/5 σ_p	20 kpsi
4 hours	1/3 σ_p	33 kpsi
1 second	1/2 σ_p	50 kpsi

σ_p = proof stress

Allowable stress design guidelines for medium lengths, (≤ 300 m) in tension, resulting in < 1 ppm failures
Table 3

Duration of Applied Stress	Allowable Medium Length Safe Stress (kpsi) when σ_p = 100 kpsi
40 years	21 kpsi
4 hours	35 kpsi
1 second	57 kpsi

Allowable stress design guidelines for long and short lengths in bending
Table 4

Length of Fiber	Length of Time	Risk of Failure	Minimum Bend Radius (σ_p = 100 kpsi)
>1 km	40 years	0	30 mm
>1 km	4 hours	0	20 mm
>1 km	1 second	0	13 mm
≤5 m	40 years	<1 ppm	25 mm
1/2 Turn	1 minute	<0.5 ppm	3 mm*

*Typical LID splicing application

Use of these guidelines is not a guarantee that the fiber will not fail. They are based on the knowledge of the strength distribution of Corning fiber as it leaves our manufacturing facilities, and does not include any change to the strength distribution from subsequent handling. These guidelines also do not include any information on optical performance: they are limited to mechanical failures only. For more papers on mechanical reliability, please visit www.corning.com/opticalfiber.

Summary

A two-region power law model is used to predict the mechanical reliability of Corning optical fiber and gives stress guidelines for its usage. For the greatest reliability, short-term stresses for silica-clad fiber should not exceed one-third to one-half the proof stress, depending upon the duration of the stressing event; long-term stresses should not exceed one-fifth the proof stress. For bending scenarios, a number of different minimum bend radii have been provided depending on the length and duration under stress and the level of risk one is willing to take.

References

1. “Comparison of Mechanical Reliability Models”, Corning White Paper WP5049.

2. T.A. Hanson, G.S. Glaesemann, “Incorporating multi-region crack growth into mechanical reliability predictions for optical fibres,” J. Mater. Science, **32**, 5305-5311, (1997).

3. R. J. Castilone, G. S. Glaesemann, T. A. Hanson, “Extrinsic Strength Measurements and Associated Mechanical Reliability Modeling of Optical Fiber,”Proceedings from the 16th National Fiber Optics Engineers Conference – Denver, CO, 1-9, (2000).

4. G.S. Glaesemann, S.T. Gulati, “Design methodology for the mechanical reliability of optical fiber,” Optical Engineering, **30**, 709-715, (1991).

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