Suggested Guidelines For the Handling of Optical Fiber

White Paper

Optical Fiber

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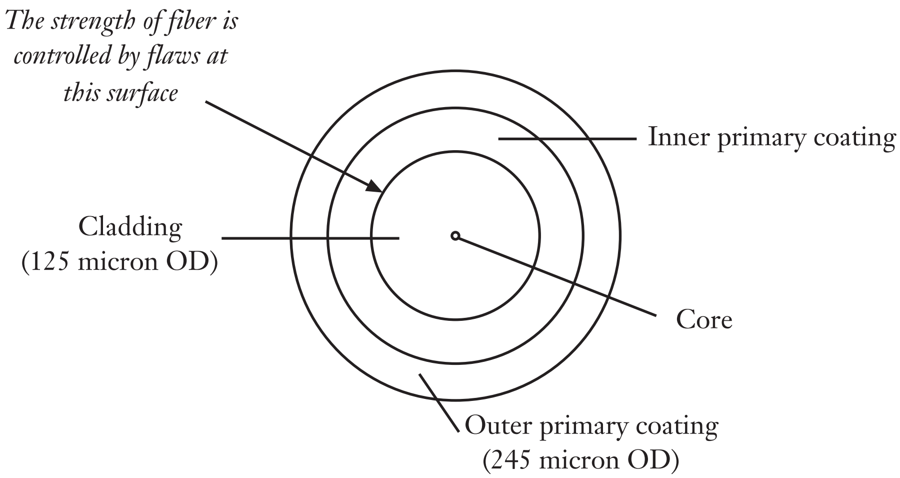
The technique with which optical fiber is handled can have a significant impact on the functionality and reliability of a manufacturer's final product, whether that be an optical cable, a photonic networking component or a fiber-optic gyroscope. The cost of rework or replacement due to improper handling can also be significant, resulting in monetary losses and increased processing times. The purpose of this paper is to outline suggested guidelines for the proper handling of optical fiber, to be considered during the design and implementation of a fiber handling program specific to a user's application and manufacturing process.

Background

Optical fiber is a composite material, typically consisting of a silica-based core and cladding surrounded by one or two layers of polymeric material. The distribution of flaws on the surface of the silica-based portion of the fiber largely controls the mechanical strength of the fiber, while the polymeric layer(s) provide mechanical protection of this glass surface. As-received fiber typically has no flaws on the surface that are weaker than the proof test level, which normally resides at 100 or 200 kpsi. However, subsequent handling or processing of the fiber can have a significant impact on its strength, either through "growing" flaws that already exist on the fiber surface, or more commonly by introducing new flaws through mechanical contact with this surface. These flaws are important, as they may play a critical role in determining the ultimate failure probability of the fiber. A graphical representation of the cross-section of a standard optical fiber can be seen in Figure 1.

Cross-section of a Standard Optical Fiber
Figure 1



Categories of Fiber "Damage"

For the purposes of this paper, four general categories of fiber "damage" will be introduced. These include (1) fatigue damage, (2) compressive damage, (3) abrasive damage and (4) particulate penetration.

Fatigue Damage

"Fatigue" is defined as the slow extension of a flaw over time due to the application of a tensile stress in the presence of moisture or humidity. The implication of fatigue is that a fiber may degrade in strength over time if placed under a considerable stress. This stress could be in the form of a pure tensile, bending, or torsional stress, or any combination thereof. Understanding of this fatigue behavior has led to the development of mechanical design rules for optical fiber, which propose limiting the applied stress levels and durations in order to limit the probability of failure during manufacture or use.[1]

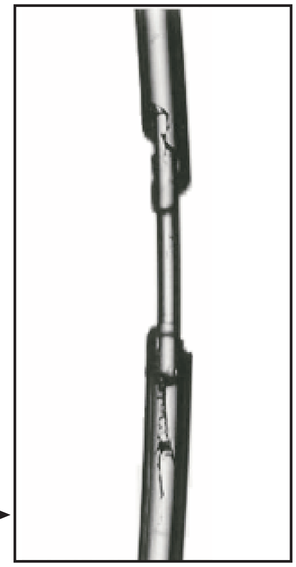
Compressive Damage

Compressive damage may occur when a fiber is pinched, clamped, or constrained to a point where the coating or glass layers become damaged. This can result in several effects depending on the severity of the compressive force, including coating delamination, coating damage (splits, cracks), and strength degradation due to the introduction of flaws onto the glass surface.

Compressive Damage of an Optical Fiber, Resulting in Splitting of the Polymeric Coating
Figure 2

Abrasive Damage

Abrasive damage may occur when a fiber comes into sliding contact with a sharp object such that it is "scratched" or "scraped." This may result in damage or removal of the polymeric coating from the fiber. There is also a high likelihood that the contact event may damage the glass surface of the fiber, creating flaws that reduce the fiber's strength. It is also possible that the glass portion of the fiber is left exposed (due to the damage or removal of coating), which can then become easily damaged through subsequent processing or handling steps.



Abrasive damage of an optical fiber, resulting in the removal of the fiber coating and exposure of the cladding surface.
Figure 3

Particulate Penetration

Particulate penetration occurs when a hard particle, such as glass or ceramic, penetrates the coating layer(s) of a fiber. This can often be initiated due to poor process cleanliness, and exacerbated by static electricity and/or subsequent processing. For example, a particle may first become attracted to the outside coating surface of a fiber due to static electricity, which in itself would not create a strength degradation. However, if this fiber is later placed around a pulley under some tensile stress, or clamped under a compressive force, the particle may be forced through the fiber coating and against the glass surface. This can in turn introduce flaws onto the cladding surface, weakening the fiber and possibly causing immediate or delayed failure.

Suggested Practices

Fatigue Resistance

- Always follow the recommended applied stress design guidelines for optical fiber.[1] In general, these rules dictate that a fiber should not be subjected to a stress higher than one-half the proof stress for a time on the order of one second, and to no more than one-third the proof stress for a time on the order of four hours. Long-term stresses (tens of years) should not exceed one fifth the proof stress. It is important to note that this includes limiting the bend radius to which a fiber is exposed (typically to no tighter than a 13-30 mm bend radius for 100 kpsi proof-tested fiber, and to no tighter than a 6.5-15 mm bend radius for 200 kpsi proof-tested fiber, depending on the duration of the event).

Compressive Damage Resistance

- Never place tools, fixtures, components, etc. on top of an optical fiber
- Do not over-tighten wire ties, tie wraps, or other objects used to constrain optical fiber
- Avoid the use of tweezers or other such tools to handle optical fiber. If fiber must be manipulated using such devices, ensure that the device's gripping ends are smooth and made of a soft, pliable material (e.g., rubber)
- If fiber is clamped during processing, ensure that the clamping pressure is limited so that damage is not induced. Any clamping materials that physically contact the fiber should be smooth, pliable and nonabrasive
- Never allow a fiber to contact an uncontrolled surface (floor, etc.) where it may be stepped upon, rolled over with a chair castor, etc.
- Take care with fingernails and jewelry when handling optical fiber. Gloves or finger cots may prevent such damage, but also limit the ability to detect damage using tactile senses

Abrasive Damage Resistance

- Do not allow an optical fiber to come into contact with a sharp or jagged edge or work surface. Non-anodized metal surfaces may be especially susceptible to forming sharp burrs that can abrade the fiber
- Regularly check any pulleys or other hardware that the fiber may contact for nicks, burrs, corrosion, etc. All surfaces should be smooth and free of any debris or defect
- Never wipe an optical fiber with an abrasive material or with organic solvents such as acetone
- Take care with fingernails and jewelry when handling optical fiber. Gloves or finger cots may prevent such damage, but also limit the ability to detect damage using tactile senses
- Never allow a fiber to contact an uncontrolled surface (floor, etc.) where it may become snagged or otherwise abraded
- Design new processes and equipment with good fiber handling practices in mind

Particulate Penetration Resistance

- Clean all surfaces that contact the fiber (work surfaces, pulleys, hands, etc.) regularly
- Do not cut or break fibers directly over work surfaces. This creates a high stress fracture and may release numerous microscopic shards of glass over the work surface. If a fiber does break over a work surface, wipe or vacuum the surface before continuing with production
- Never allow a fiber to contact an uncontrolled or dirty surface (floor, etc.) where it may contact particulate material
- Check pulleys, work surfaces and other hardware regularly for the presence of corrosion or other contamination
- Dispose of cleaves and stripped coating scraps regularly
- Control static electricity. This may reduce fiber tangles, as well as attraction of particulate to the fiber
- Ensure that any bins or receptacles used to hold or contain fiber are free of debris (including fiber scraps, etc.)

Process Auditing

Process auditing is an important tool in controlling and reducing losses attributed to improper fiber handling. Such audits should focus equally on both operator technique and process robustness, including the physical condition of equipment and work surfaces. The following page contains a sample checklist of items that may be covered during such an audit. The frequency with which such an audit should be performed depends on the specific application and manufacturing process, but typically ranges from a per-shift (e.g., pulley condition) to a weekly or monthly (e.g., work surface condition) basis.

Sample Fiber Handling Audit Checklist

Operator Technique

- √ Are operators taking care not to place tools, fixtures, etc. on top of fiber?
- √ Are operators cleaning hands, tools and work surfaces regularly?
- √ Are operators taking care not to break or cut fibers over the work surface? If a fiber does break over a work surface, is the surface wiped down or vacuumed immediately?
- √ Are operators avoiding the use of tweezers or other tools with sharp or hard gripping surfaces?
- √ Are operators limiting the magnitude and duration of stresses that are placed on the fiber during processing (including bend stresses)?
- √ Are operators taking care so that the fiber does not contact uncontrolled surfaces such as the floor?
- √ Are operators cleaning fiber scraps, cleaves and coating from the work surface(s) regularly?
- √ Are wire ties, tie clamps, and other such devices placed on the fiber loosely?
- √ Are operators avoiding wiping the fiber with abrasive materials or solvents such as acetone?

Process and Equipment

- √ Are equipment and work surfaces free of sharp edges and pinch or snag points that may damage the fiber (these sites can typically be detected using the naked eye and/or running fingers/hands over the work surface)?
- √ Are pulleys and other hardware free of corrosion, nicks and burrs? Are pulleys checked and cleaned on a regular basis?
- √ Are equipment and surfaces designed so that the fiber cannot easily contact the floor or other uncontrolled surfaces?
- √ Do equipment and work surfaces contain designated and easily accessible locations for the storage of tools, fixtures, etc.?
- √ Are clamping pressures limited and appropriately controlled so that compressive damage is not induced? Are clamping surface materials clean, smooth and pliable?
- √ Is equipment designed so that stresses do not exceed the recommended stress design guidelines?
- √ Is static electricity controlled appropriately (through ESD controls, ionization, etc.)?

Special Considerations During Stripping, Cleaving and Splicing/Connectorization

In addition to the above recommendations, special considerations must be given to fiber handling during the operations of stripping, cleaving and splicing or connectorization. Suggested practices during such operations are outlined below.

Stripping

- If possible, mechanical stripping tools should not be shared between users. Strippers may wear in a distinct pattern depending on the user's technique, making them less efficient or "fiber-friendly" for alternate users
- Do not use mechanical strippers that have been dropped or otherwise damaged until it can be demonstrated that they can provide satisfactory strip strengths
- Users should strip the least amount of coating necessary to facilitate proper cleaving and/or splicing of the fiber. Removing less coating exposes less bare glass, and therefore limits the potential for inducing flaws
- The bare glass exposed after stripping should not be contacted by tools, fingers, etc. The glass should only be contacted by an appropriate lint-free clean cloth, which may be soaked in high-purity isopropyl alcohol. The number of passes over the fiber should be limited (optimally one pass), and the cloth should be discarded and replaced with a new cloth regularly
- The work area and stripping tool should be kept clean of any dust or debris, which can degrade the fiber strength if brought into contact with the cladding surface
- The fiber should be cleaned and cleaved immediately after stripping to reduce the effect of any airborne contaminants

Cleaving

- The fiber must be placed carefully into the cleaving tool, taking care not to abrade or otherwise contact the exposed bare glass
- The work area and cleaving tool should be kept clean of any dirt or dust, which can degrade the fiber strength and cause increased splice losses
- As mentioned above, remnants of stripped coating and cleaved fibers should be cleaned from the work surface regularly

Splicing/Connectorization

- The fiber must be placed carefully into the splicing equipment, taking care not to abrade or otherwise contact the exposed bare glass
- Care should be taken when placing the fiber into equipment not to exceed the recommended stresses as outlined in the stress design guidelines[1]
- Splices must be protected by either splice protectors or recoating of the exposed glass area. These processes should be performed in an area with minimal particulate contamination, and should completely cover the areas of exposed glass fiber
- Splices should be proof tested upon completion and protection/recoating to ensure that they meet the minimum strength requirements of the application. Optimally, splices should be deployed in a non-bent state and under minimal tensile stresses
- Polished end faces of connectorized fibers should be protected at all times from contamination (debris, finger oils) and mechanical contact

Summary

Suggested guidelines have been presented for the proper handling of optical fiber. These guidelines are intended to reduce the occurrences of fiber damage or breakage and are applicable to a wide range of processes and applications. Following these guidelines is an important step in creating a functional and reliable product utilizing optical fiber, as handling and processing procedures may have a significant impact on the strength and reliability of a final product.

References

1. "Mechanical Reliability: Applied Stress Design Guidelines," Corning White Paper WP5053.

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