Preventing Whip Damage in Optical Fiber Processing

Application Note

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Introduction

One of the more frequent causes of fiber breaks during the cable manufacturing process is from fiber-to-fiber contact, or "whip" damage. Whipping occurs when a loose fiber end or stray fiber impacts the fiber pack at high speed. Such a condition can develop during high speed rotation of a fiber spool, for example, during a coloring process. This issue is particularly serious since the damage introduced may not be sufficient to induce a break in the fiber immediately, and the fiber may survive until the introduction of either greater or longer term stress later in its lifetime (either downstream cable processes or, conceivably, during installation or deployment). Some straightforward precautions may be followed to exclude the most prevalent whip mechanisms that Corning has identified from over forty years of experience in supporting optical fiber cable processing.

Fiber Whip Damage Characteristics

Fiber whip occurs when the fiber is impacted and becomes damaged by a fast moving loose end of the fiber (whipping action). The high speed of the glass fiber tip cuts through the protective coating layers and can strike the cladding of the fiber. If the speed or the energy level is high enough, a flaw may be created in the cladding of the impacted fiber thereby weakening it. Whipped fiber may break at the flaw immediately, if impacted while being processed at sufficient tension; or later, if subject to higher or more sustained stress during subsequent processing, installation, or deployment. Whip-damaged fiber can also appear "brittle" as multiple whip damage sites on surface windings of a spool may cause the fiber to break easily when re-attempting to unwind fiber from the spool. In some cases, the loose end penetrates upper levels of the fiber wrap harmlessly while damaging the fiber in lower wraps. The impact damage results in characteristic features that are easily identified by inspection under microscope on either the outer surface windings or the break ends of the fiber.

The outer surface windings of a spool that has been whipped by a fiber end may present blemishes in the coating (visible at low magnification in good lighting) where the fiber end has penetrated the coating (see Figure 1).

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Figure 1. Surface layer of a spool under magnification with surface blemishes generated by fiber end whip.

When whipped fiber is inspected under high magnification, characteristic damage to the polymer coating may be observed (see Figure 2).

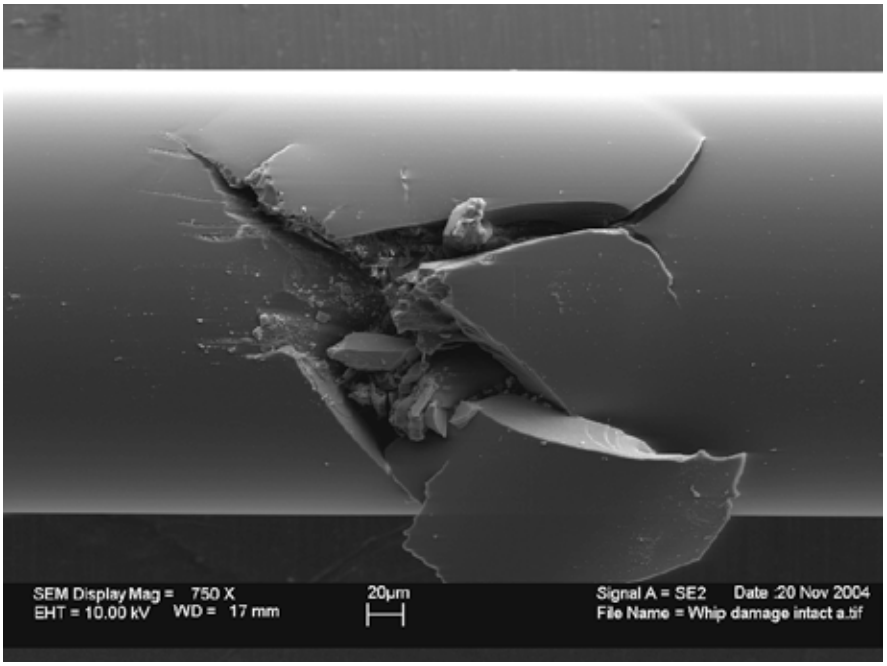

Figure 2. Coating damage introduced by fiber end whipping.

Viewed side-on with the coating chemically removed, whipping may be identified by deposition of a glass “plough” on the surface of the cladding at the impact site. The plough feature is caused by localized melting of the glass when energy is dissipated during this high speed contact event
(see Figure 3).

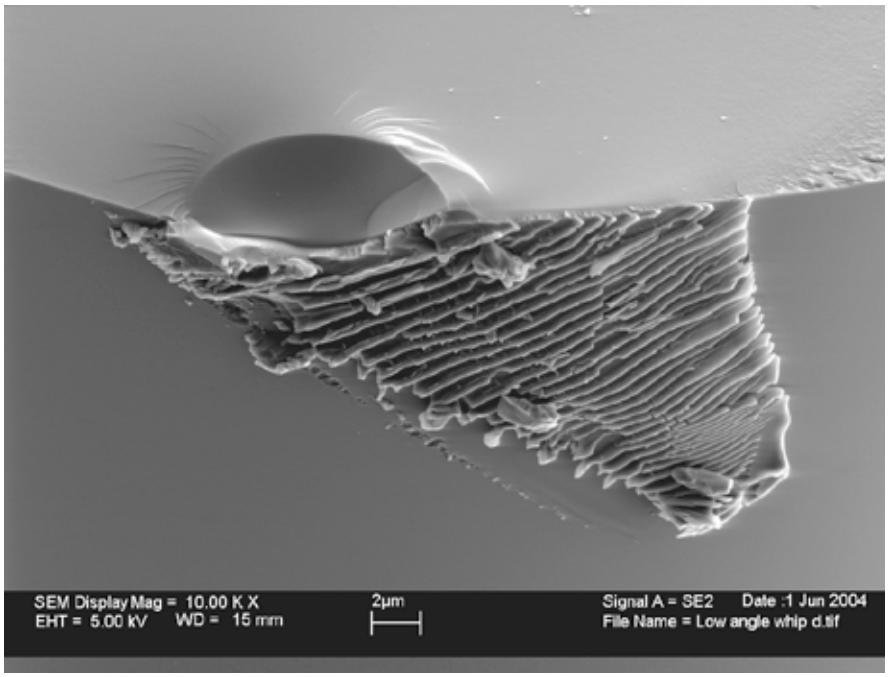

Figure 3. Glass deposition on the cladding surface following a whip impact which caused this fiber to break.

These fracture features are unique to whip damage and relatively easy to identify using a microscope. Identifying the particular aspect of fiber processing that created the whipping event can be more challenging and may require a detailed investigation of the process, including upstream processes from where the fiber break occurred.

Common Sources of Fiber Whip Damage

A common cause of whip during high speed processing of optical fibers has been identified when the inner end of the fiber is not properly fastened to the spool prior to coloring or tubing. The coloring process is particularly susceptible due to the high rotation speed of the spools and because the fiber spool at both pay-off and take up is susceptible to the same mechanism.

A schematic of the manner in which the inner end may induce whip damage is presented (see Illustration 4). If the inside end of the fiber is free during the rotational pay-out of fiber, the length straightens along the spool radius under the influence of centrifugal force. Although the pay-out fiber path is typically away from the nearest flange, turbulence or contact with part of the processing equipment machinery during traversing motion, may be sufficient to cause the fiber end to swing around and deflect back into the fiber path, generating whip damage as fiber is paid off. It is also conceivable that, if the inner end is unsecured and sufficiently long, the fiber end could swing back into the outer surface of the fiber spool and induce the type of damage indicated in Figure 1.

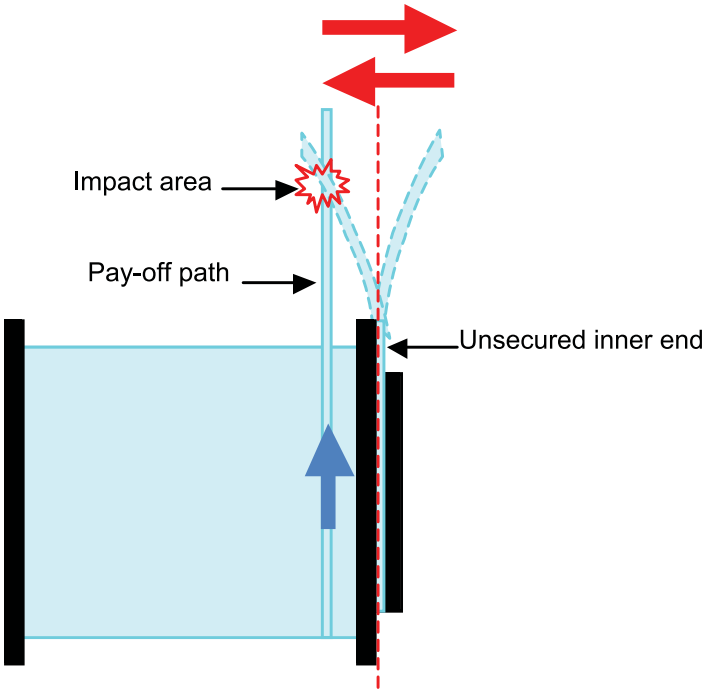

Figure 4. Turbulence causes the unsecured inner end to strike fiber in the pay-off path.

In principle, the same damage mechanism can be introduced at the coloring take-up if the inside end of the colored fiber is similarly unsecured at the take-up spool.

Corning has observed situations where the inside end is attached to the barrel of the take-up spool (rather than the outer flange) with tape or a sticker to cover the end. This arrangement is not recommended as the tape or stickers can release from the barrel during spool rotation and allow the fiber end to protrude from the fiber pack (see Figure 5). This loose fiber end can potentially cause whip damage. The fiber end should always be attached to the outer flange rather than the barrel.

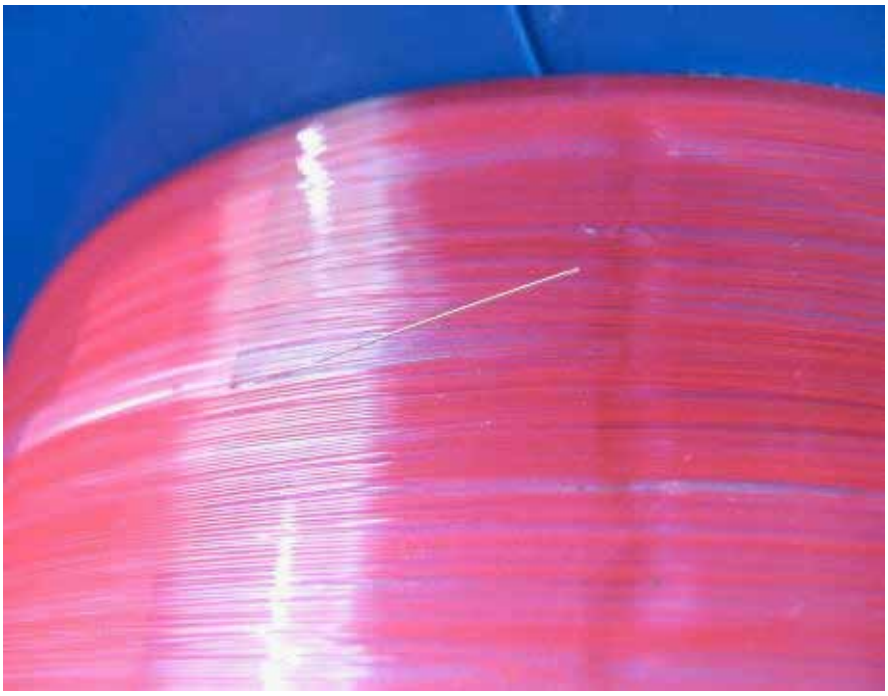

Figure 5. An example of fiber-end whip source caused by insufficient adhesion of the fiber end to the barrel using a sticker.

Corning has also observed the practice of re-cycling take-up spools and using stickers to cover the multiple ends of fibers previously secured to the barrel of the spool. This is not recommended as poor sticker placement or adhesion might create sources of fiber damage to the take-up spool. Furthermore, the barrel surface of a re-used spool may be contaminated by fiber ends not efficiently removed prior to re-use. Since most coloring operations generate a new empty spool (where the full fiber length is colored in a single operation), Corning recommends that each spool be used only once for coloring take-up wherever possible. At a minimum, all fiber should be removed from a spool prior to being used to take up fiber.

Fibers that are work-in-progress in a cable factory are typically stored and transported around the factory on trolleys. Whip damage has also been found on fibers sitting on trolleys that are close to operating cable processing lines. This can occur if the fiber breaks on the processing line and the break-end snaps back and flies at high speed into the spools on the trolley that is near the line. Spools can be protected against this damage mechanism by storing them in shipping spool covers in either the natural or colored state until processed into a tube or ribbon.

Finally, it needs to be recognized that when whip damage leads to a break event, the shattering of the fiber may lead to the generation of multiple fiber shards in the region of the processing equipment. If not efficiently removed from the area, these shards may become mobile in the circulating air, lodge in the fiber path, and propagate more breaks through penetration by the shard of the coating to damage the glass. Figure 6 shows a cable processing surface from which debris from previous breaks has not been removed, increasing the probability of further breaks on the line.

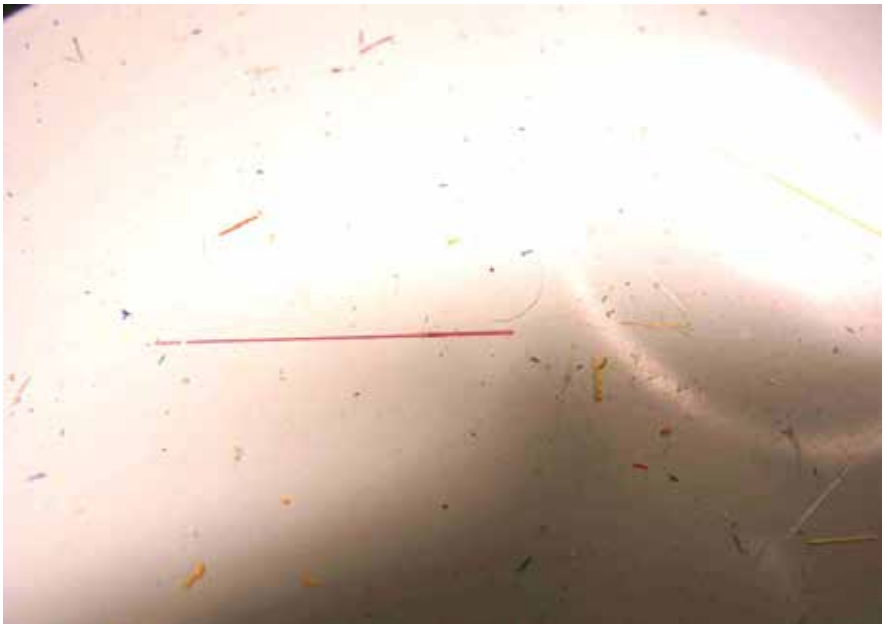

Figure 6. A coloring surface contaminated by shards from previous break events.

Recommendations

The following recommendations are suggested to address the most obvious sources of whip damage in processing optical fibers.

1. At the pay-out spool (particularly in coloring where the rotational velocity of the spool is greatest) ensure that a long inner end is not allowed to become detached from the outside of the flange. This may be achieved by cutting the inner end close to the slot and operating with the slot plug in position. Alternatively the inner end may be cut close to the slot and secured by a sufficiently well adhered sticker. See Corning Application Note 3683 for recommendations on cutting the inner end before processing. This document is available on the Corning Optical Fiber website at http://www.corning.com/media/worldwide/coc/documents/Fiber/RC-Application Notes/AN3683_06-09.pdf.
2. At the take-up spool, secure the fiber from the pay-out spool (after threading up through the machine) by passing it through the slot and securing to the lead-meter side flange. Carefully rotate the take-up spool by hand to remove any slack in the fiber path. Do not attach fibers to the spool barrel.
3. While Corning discourages the use of stickers, if doing so, ensure that the sticker is properly applied to cover the fiber end and the adhesion is sufficiently strong so as to remain in place when the spool begins to rotate. Use stickers only once - do not attempt to re-use stickers for multiple spools.
4. Between process steps, fibers (colored or natural) that are left unattended in the plant, should be protected with spool covers in place and stored on a suitable rack or portable trolley until the spools are loaded onto the next processing line. Spools should never be placed on the floor or be placed were there is a risk of contamination from dust or debris.
5. Immediately after a fiber break event, ensure a thorough clean-down procedure is followed to eliminate glass shards from the area of the processing equipment. Appropriate cleaning following a break can include vacuuming of the processing surfaces and using an alcohol soaked cloth to wipe down the pulleys, capstans and dies of the fiber path. A disposal bin should be located close to the processing equipment to dispose of any shards or fiber ends generated in operating the equipment. If a break is suspected to have induced whip damage in the outer surface windings, remove sufficient fiber from the outside of the spool to ensure the damaged section is eliminated. This prevents more breaks being propagated in further processing. Removal of up to 2 km of fiber may be required for this purpose.

Corning Incorporated
www.corning.com/opticalfiber

One Riverfront Plaza
Corning, New York
USA

Phone: (607)248-2000
Email: cofic@corning.com