



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 making process is from “whip” damage. Whipping occurs when a loose fiber end impacts the fiber pack at high speed. Such a condition can develop during high speed rotation of a fiber reel, 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 thirty years of experience in supporting optical fiber cable processing.

Fiber Whip 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 strikes 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. Fiber having suffered whip damage 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 end of the fiber.

The outer surface windings of a reel 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 Illustration 1).



Illustration 1. Surface of a reel with surface blemishes generated by fiber end whip

When the break end of a whipped fiber is inspected under magnification, characteristic damage to the polymer coating may be observed (see Illustration 2).

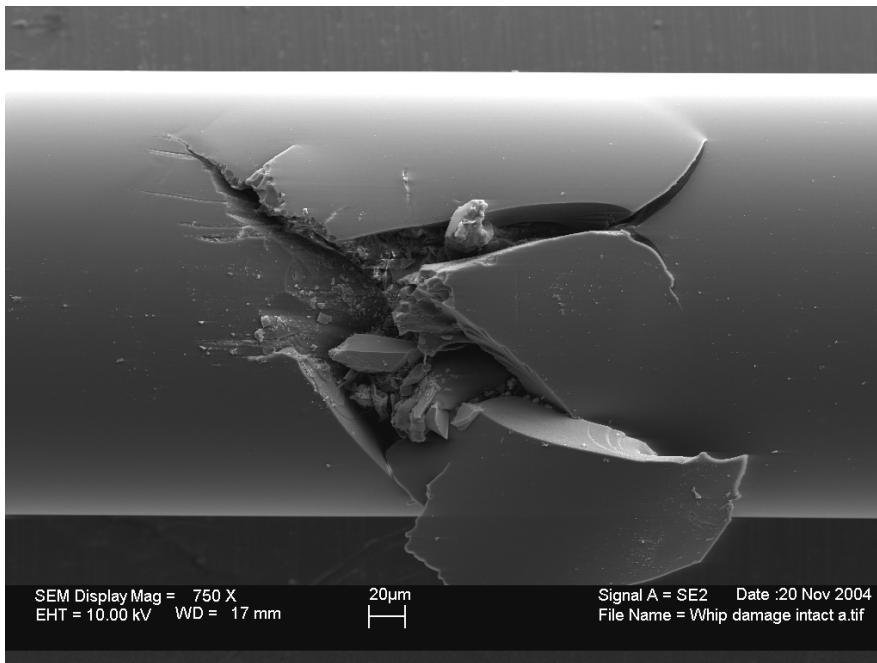


Illustration 2. Coating cracks introduced by fiber end whipping

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

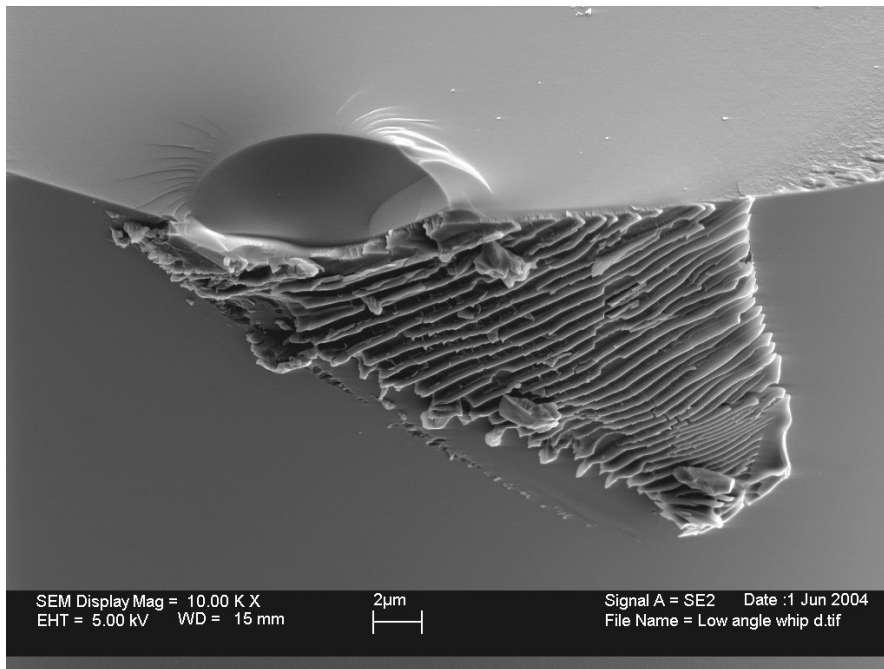


Illustration 3. Glass deposition on the cladding surface following a whip impact which caused this fiber to break.

These fracture features are unique to whip damage and relatively easy to identify. 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 break occurred.

Common Sources of Fiber Whip

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 reel 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 flap 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 flap back into the outer surface of the fiber reel and induce the type of damage indicated in Illustration 1.

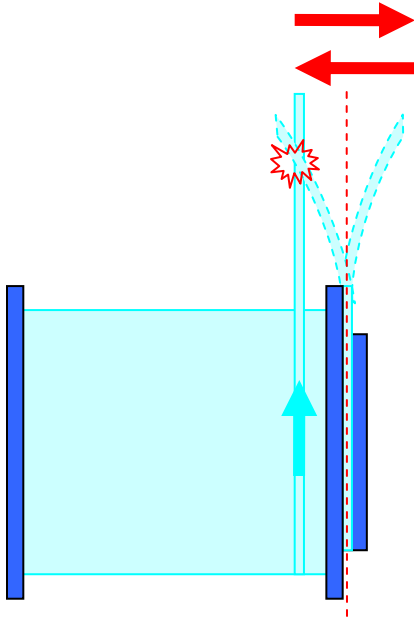


Illustration 4. Turbulence causes the unsecured inner end to strike fiber in the pay-off path.

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 encountered situations where the inside end is attached to the barrel of the take-up spool (rather than the flange) with tape or a sticker to cover the end. This arrangement is not recommended due to the fact that tape and stickers can release from the barrel during reel rotation and allow the fiber end to protrude from the fiber pack as shown in Illustration 5. This fiber end is now free to cause whip damage. The fiber should be attached to the flange rather than the barrel.

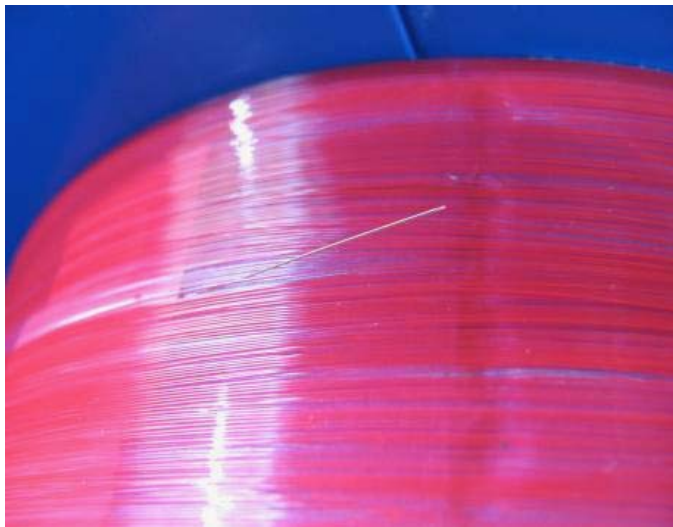


Illustration 5. An example of fiber-end whip source caused by insufficient adhesion of the fiber end to the barrel using a sticker.

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. Corning does not recommend this approach as poor placement of the sticker or poor sticker adhesion might also create sources of fiber damage to the take-up reel. 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 once only for coloring take-up wherever possible.

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 identified on fibers that are sat on trolleys that are close to operating cable processing lines. This can occur if the fiber breaks on the processing line and the trolley is sufficiently close to the line that the break-end can snap back and fly into the reels on the trolley at high speed. Reels 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 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. Illustration 6 shows a coloring surface from which debris from previous breaks has not been removed, leading to the probability of further breaks on the line.



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

Recommendations

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

1. At the pay-out reel (particularly in coloring where the rotational velocity of the reel 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/docs/opticalfiber/AN3683.pdf>.

2. At the take-up reel, 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. When securing fiber ends with stickers or tape, 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 reels.
4. Between process steps, fibers (colored or natural) that are left unattended in the plant, should be kept with the spool covers in place and stored on a suitable rack or portable trolley until the reels are loaded onto the next processing line. Spools should never be placed on the floor or be placed where there is a risk of contamination from dust or debris.
5. Immediately following a 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 applying an alcohol soaked cloth to wipe down the pulleys, capstans and dies of the fiber path. A sharps bin should be conveniently 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 reel 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.

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