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Whipping damage in Optical fiber

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Abstract
One of the frequent causes of fiber break is whip damage. This paper describes how whip damage is detected and prevented.

Keywords
Optical fiber, Fiber break, Whip damage

What is whipping in optical fiber and cable manufacturing process?

One of the most frequent causes of fiber break during optical fiber cable manufacturing process is whipping damage. Whipping occurs when the end of an unfastened or broken fiber flails and strikes another fiber. Such a situation occurs during high speed rotation of fiber reels, for example during coloring, winding and in the cable buffering process. Whipping can generate point damage and possible breaks in the struck fiber. The fiber sample can break either immediately after the whipping event or subsequently, for example, during cabling processes, cable installation/ deployment or after installation under long term static stress.

As whipping can occur after fiber proof-testing, significant care must be exercised in fiber manufacturing to achieve a zero defect rate.

How is whipping damage detected?

Whipping occurs when a glass fiber end damages the protective polymer coating layers and originates a flaw on the surface of the glass cladding. This damage can happen when glass fiber end strikes a neighboring fiber surface during high speed movement with high energy. Creating a surface flaw on the clad surface weakens the fiber significantly, even leading to fiber breaks during normal handling (e.g. rewinding by hand, fiber threading in color/ buffer machines). The depth and size of the surface flaw depends on the energy level or. how fast the fiber end strikes surface of another fiber.

Whipping damage can be detected by physical inspection of the fiber surface. The whipping damage looks like white spots to the naked eye. Figure 1 & 2 show optical micrographs of whipping damage viewed horizontally under an optical microscope. Whipping break also can easily be identified from fiber break end. Figure 1 and 2 show break end of a whipped fiber. Figure 3 and 4 show scanning electron microscope photograph of the damaged portion of the fiber. Figure 3 shows damaged fiber protective coating and Figure 4 shows a surface flaw created on the surface of the glass clad.

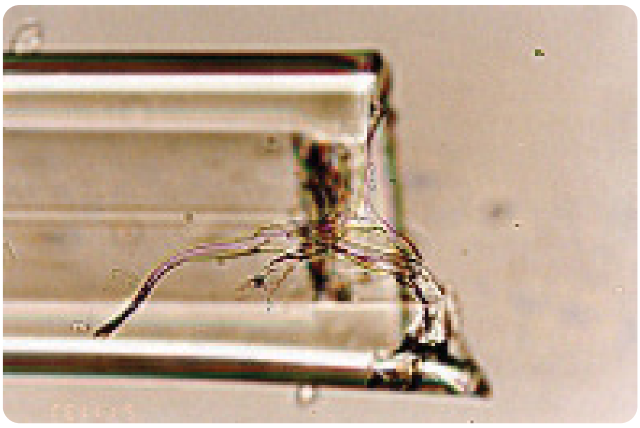

Figure 1

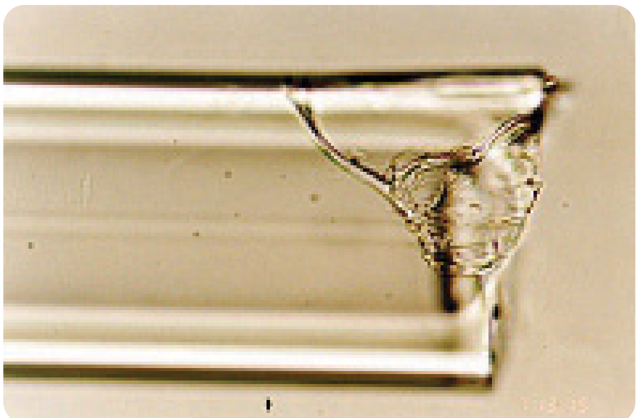

Figure 2

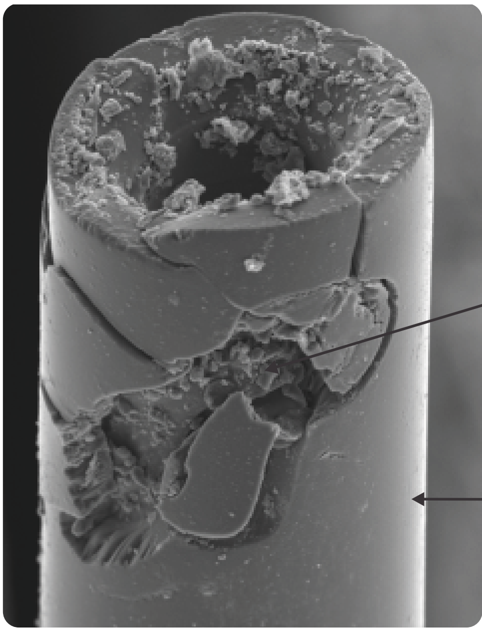

Figure 3: SEM photograph of whip break end showing outer surface coating damage

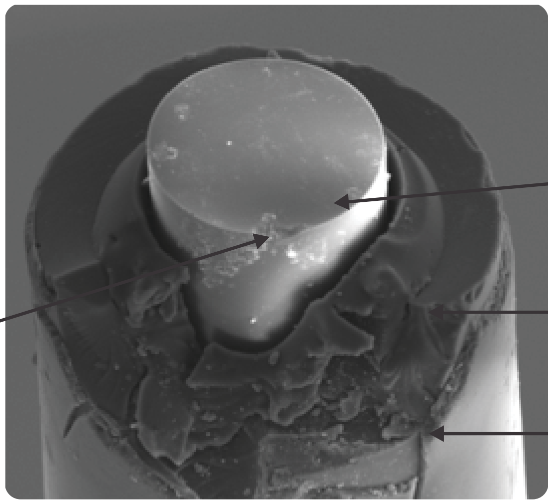

Figure 4: SEM photograph of whip break end showing surface flaw created on glass (cladding)

What are the sources of whipping?

Whipping can occur during high-speed rotation of fiber spools during fiber drawing, fiber proof testing, coloring and buffering. It is especially important to control whipping after proof-testing (e.g. during coloring) as any such event may not immediately break the fiber: breaks may occur later during cabling or installation.

There are five major sources of whipping:

1. Fiber breaks during high-speed winding: The broken end can strike the top layer of fiber on the takeup spool.

2. Unattached inner end of fiber on rotating spool: The fiber becomes unfastened and flails. The free end can come into contact with the fiber either already wound on the spool or being wound onto the spool. (Figure 5).

3. Inner end stuck to spool barrel during coloring: Inappropriate working practice during coloring. Sometimes during the coloring process the fiber inner end is stuck to the barrel of the take-up spool rather than being fed through the spool inner end window and stuck to the outside flange of the spool. This practice can cause whipping as the fiber end may become loose during high-speed rotation (Figure 6).

4. Whipping of stored spools: Spools kept close to the processing line (coloring, buffering line) can be struck by the flailing end of a fiber being processed.

5. Fiber break debris can fall and lodge in the fiber path and cause point damage.

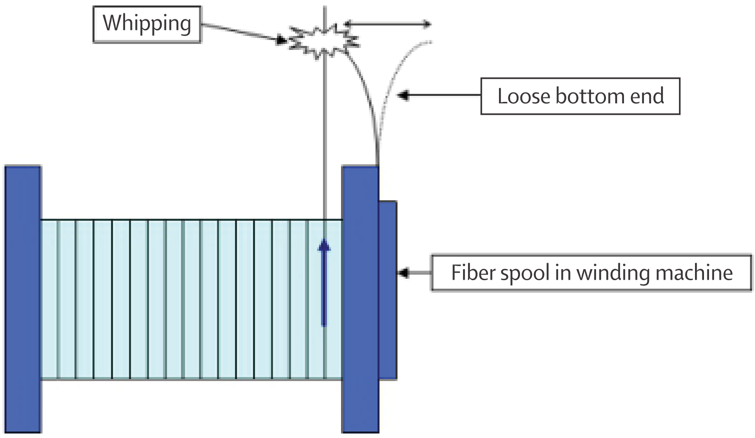

Figure 5

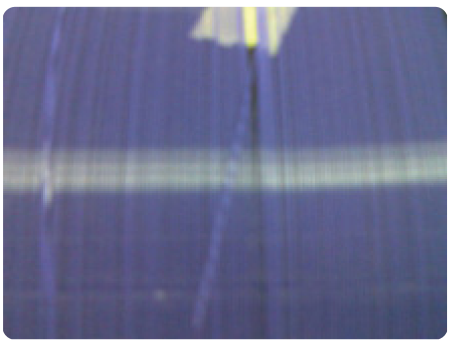

Figure 6

How is whipping damage prevented?

Some of the best practices to be followed to prevent whipping damage during manufacturing are as follows:

1. Installation of anti-whipping guards in areas where breaks and flailing ends may occur e.g. on prooftesting machines, rewinding and coloring machines (Figure 7).

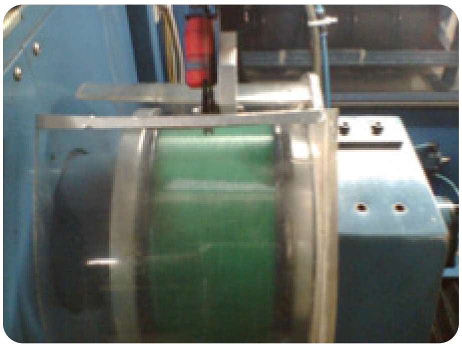

Figure 7: Anti-whipping guard installed in proof-test machine

2. Fastening the inner end of the fiber to the spool flange during coloring, ribboning, rewinding, buffering processes at both pay-out and take-up is achieved by cutting the inner end close to the inner end window and pasting & covering the inner end tightly at pay-out (Figure 8). During coloring operation, it is sometimes required to keep the inner end for testing purposes. If the inner end has to be kept in the take-up spool, it should be fastened to the inner end on the spool flange in such that it will not come loose during coloring.

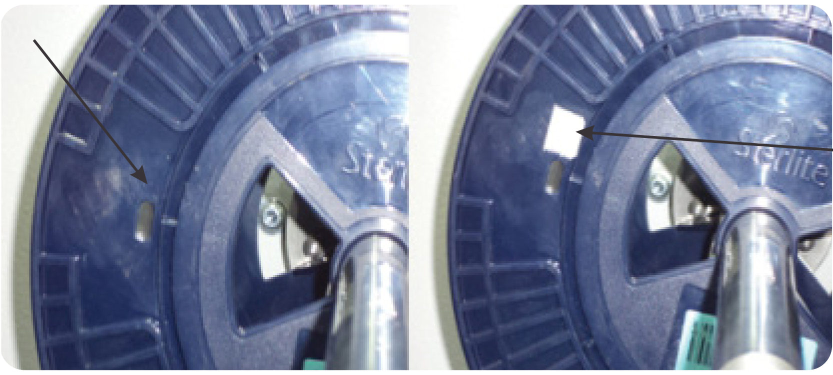

Figure 8: Cutting and fastening fiber inner end on spool flange

3. Keeping the length setting in the coloring/ winding / buffering machine to less than or equal to the physical length of the fiber in pay-off spool. If length is set higher, a ramp down event will not happen and the bottom end of the pay-off fiber spool will hit the top surface of the fiber in take-up spool at high speed creating the possibility of whip damage.

4. Storing spools with spool covers away from the process area where breaks may occur.

5. Visual inspection of fiber for whipping damage following completion of testing.

6. Checking for occurrence of whipping by analyzing proof-test and draw break ends.

7. Using identified instances of whipping damage to direct improvements in process practice.

Containment actions after suspected whip damage

Preventive actions described above are the best way to avoid whip damage in optical fiber. In case the best practices are not followed and whip damage is found, containment actions described below can prevent the damaged fiber portion from going to next stage of manufacturing, thus avoiding negative impact on fiber lifetime.

1. Proof testing the suspected fiber length again with 75% of original proof-testing load to eliminate weak portions.

2. Cutting the suspected damaged fiber length from the top. The damaged fiber length is dependent on penetration depth of whipping damage during high speed fiber winding. Penetration depth can be determined by an experiment where fiber is manually cut during high speed winding and allowing whipping to happen on fiber top surface on take-up. This is followed by Proof testing and / or long length (20 meter) tensile strength testing of the damaged top layer fibers to determine penetration depth. Typically penetration depth of whip damage can go up to 2 km from top. If the experiment cannot be carried out, a thumb rule can be adopted to cut top 2 km fiber before next processing step.

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