

High Speed Tight Buffering Process

Mr. Jari Nykänen*, Mr. Joe Lichtenwalner **

* Nextrom Oy

Ensimmäinen Savu, Vantaa, Finland

Tel: +358-9-5025 3258:jari.nykanen@nextrom.com

** CommScope,

Claremont, NC 28610 USA

Tel: +1-828-459 5107

Abstract

In this work we studied different ways to increase tight buffering process speed. We concentrated mainly in cooling process and controlling the strippability. There are several important factors to consider at high speed cooling. The most important limiting factor seems to be the line tension. The higher is the tension during production the bigger is the attenuation increase. Cooling trough plays the biggest part in line tension. In conventional, immersed cooling bath the water friction can cause remarkable tension increase at high speed. Other critical variables are adequate cooling capacity and drying the product after cooling.

According to these findings a new cooling trough was developed. It combines the low-tension increase and high cooling capacity. The new cooling concept is based on forced heat convection. The thermal energy is taken out from plastic with very thin water spray. It enables higher line speed with all major tight buffering materials. Spray cooling helps to reduce tension in the cooling trough.

Keywords: Optical fiber equipment; buffered fiber; premises cable;

1. Introduction

The tight buffer is the basic element of the indoor cable. It is more like simple half product of final cable. It consists of 250um optical fiber and colored plastic buffer. The outer diameter varies according to final application. Traditionally it is 600-900um. Usually the buffer is thermoplastic material and is made with extrusion. The most common materials are PVC, PA12 and different halogen free, flame retardant materials. It is also possible to use UV curable acrylate for tight buffering [1]. In this paper we concentrate only in extrusion process

For few years now the sales prices and margins of cables have reduced significantly. This applies also with indoor cables. On the other hand the production volume of indoor cables has stayed on the same level it was before recession started.

Before the recession the optical fiber was the biggest cost factor in tight buffer. Since the price of fiber has also come down during last couple of years the importance of productivity has increased. It is more important to cut the production time and reduce the labor cost.

There are certain ways to improve different areas of productivity. One important aspect is to reduce amount of scrap created. That can be made by fine tuning the process. The reliable and repeatable process with skilful personnel ensures that all material costs can be

minimized. That covers the control of the color change as well as the quality production during ramping up and down

In this work we concentrated in increasing the tight buffering process speed.

2. Challenges in high speed process

In standard extrusion process there are issues that might limit the line speed. All the machinery has to be designed for high speed. Extruder output has to meet the requirements.

In this paper we concentrate in following items

2.1 Cooling

High speed requires efficient cooling. The whole cross section of tight buffer should cool down before wound on the reel. Too hot plastic can easily be deformed or damaged.

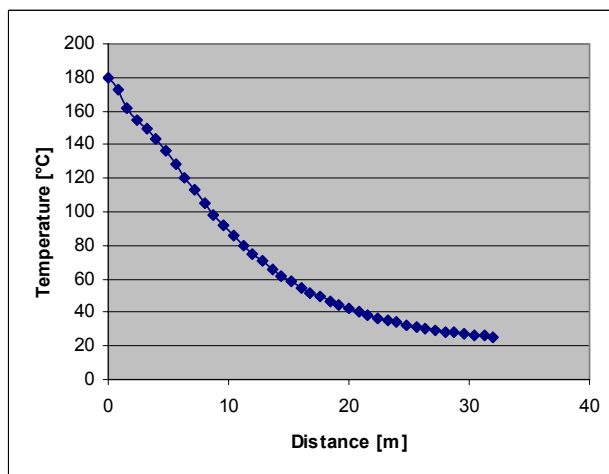


Figure 1. 900µm tight buffer cooling at 1000m/min

Usually tight buffer is cooled down in water bath. Cooling length and water temperature depend on line speed and material.

One easy way to improve cooling is to make cooling bath longer. Unfortunately in most of the factories this is not possible because of larger footprint.

Using cold water would also improve cooling. However with some materials the gradual cooling is required. Too fast cooling leaves internal stress in material and might damage optical properties of optical fiber.

Another problem with standard water bath is the thin layer of still water on the surface of plastic buffer. When extrudate moves forward in water there is thin layer of water that moves very slowly comparing the buffer surface. This water layer heats up very fast in the beginning of the trough. The heat convection is at its best when temperature difference is high. Thus the hot water layer on the hot plastic buffer limits the convection of heat energy and slows down the cooling process. The situation is the worst in still water bath. In turbulent bath the layer is thinner. This means the phenomenon can be reduced by using efficient mixing of the cooling water.

2.2 Line tension

One critical factor in high speed tight buffer extrusion is line tension. If plastic is cooled under tensile stress there are residual stresses in buffer. These stresses will release when final cable is exposed to elevated temperature. The buffer will easily shrink and cause micro bending in fiber. To avoid this it is important to minimize tensile load in cooling trough.

In normal immersed cooling bath the tension increases in square of the line speed. Also the longer is the cooling length the higher is the tension.

Another source of line tension is the extrusion crosshead. The actual increase depends on tool design. Tube tooling with land is the best. But with this design it is difficult to achieve strong bond between fiber and buffer. Compression tooling gives good adhesion but high line tension. Also the pressure stress against fiber might limit the usage of compression set up. A good compromise is semi compression (semi tube) tooling. In this design there is no cylindrical land. The plastic flow channels have tapered shape. With this set up it possible to combine acceptable line tension and adhesion between plastic and fiber.

2.3 Buffer bond control

It is important to have sufficient adhesion between fiber and plastic buffer. If the bond is too loose the optical behavior in low temperatures might get poor. This is specially the case if there is some kind of void inside the buffer. Then there is a possibility that fiber can bend when buffer shrinks in low temperature. When the bond is good there is no void and buffer support fiber and fiber takes the longitudinal compressing force without bending.

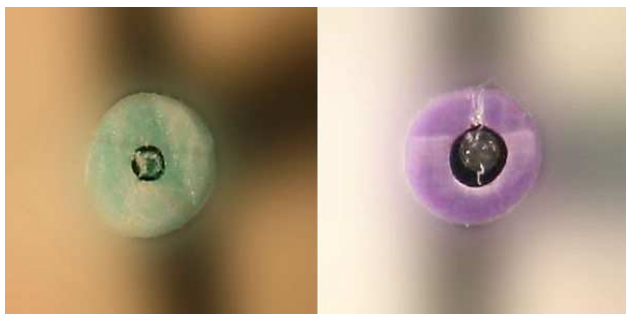


Figure 2. Good (at left) and poor buffer adhesion

Too high adhesion might also cause difficulties. When connectors are assembled or tight buffer is terminated too strong bond makes it difficult to strip the fiber. Automatic splicing machines can be very sensitive to too tight buffer.

As mentioned earlier the extrusion tool design has big influence to adhesion. Usually there is vacuum pump connected to cross head. This vacuum is used to control the bond and strippability. The fiber takes air inside the buffer and vacuum system is pumping it out. At high speed normal pumps are not strong enough. This means that the significance of tool design is pronounced at high speed.

One way to improve the bond is to change tool configuration. With semi compression tools this can be done by moving the die. When the die is move out the melt pressure against the fiber is stronger. On the other hand moving the die out increase the line tension causing potential attenuation increase. This is why it is important to carefully control the tool position, buffer adhesion and line tension.

In comprehensive tests we detect the clear correlation between these three variables. According to these findings we designed closed loop controlled mechanism to adjust the buffer strippability. The principle of the control system is shown in picture 3.

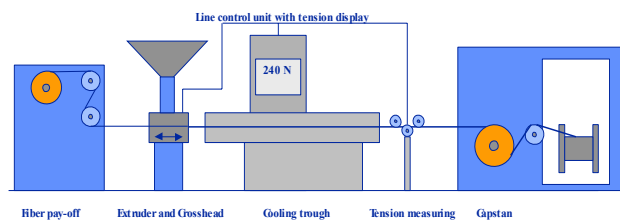


Figure 3. Buffer bond control system

The line tension is measured with load cell before the line capstan. Line control computer uses this measured value to calculate right position for extrusion die. The die is then moved with linear actuator. With this method the adhesion can be stored in line control recipe system. It eliminates the possibility of human error.

3. Spray cooling

According to experience in tight buffering process we designed new cooling method for tight buffered fiber. Instead of water bath it uses very fine water spray. The surface of spray drops is very big comparing the heat convection surface in standard water bath. This improves the heat convection from hot plastic to the water. There is no solid water layer on the buffer when using the spray. Instead of that the new fresh water comes in all the time.



Figure 4. Spray cooling trough

In spray cooling trough we use special nozzles to create the water mist. The drop size is only 50µm. By shaping the inner trough and placing the nozzles we can optimize the drop density in the cooling chamber.

Even if the cooling capacity is better with water spray we need some cooling length at high speeds. We equipped the spray chamber with wheel set for multiple loops. In spray cooling the length expanding is easy because spray does not increase the tension in trough. Additional tension created by water spray and bearing friction grows linear.

4. Test arrangements

Tight buffer process tests were carried out with Nextrom's tight buffering line in Vantaa, Finland. Cables were ran and tested in CommScope, Claremont, NC, USA.

The tight buffering line is equipped and geared up for 1000m/min as maximum speed. The main components are:

- Fiber pay-off
- Fiber pre-heater
- Extruder and crosshead
- spray cooling system
- take-up with integrated capstan

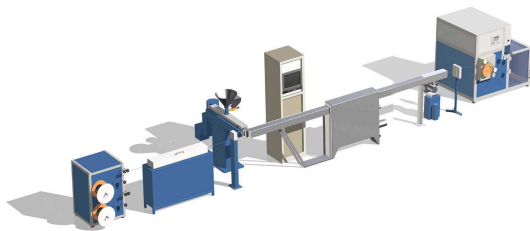


Figure 5. Tight buffer extrusion line with spray cooling

We divide the tests in two parts:

1. Testing the equipment
2. Testing the tight buffered fiber and cable

4.1 Testing the equipment

4.1.1 Cooling at high speed

We tested the cooling capacity of spray cooling trough. We measured the surface temperature on plastic melt when exiting the crosshead. Then the buffered fiber was ran through the spray chamber and the temperature was measured again in three points. This shows the residual heat inside the buffer. The heat transfer coefficient was determined by fitting measured values to cooling curve (Fig. 5). This curve shows rapid cooling in the beginning of trough. After the trough the surface temperature of the buffer increase again if inner temperature is higher than surface. Temperatures in these points were measured with heat sensitive infrared cameras.

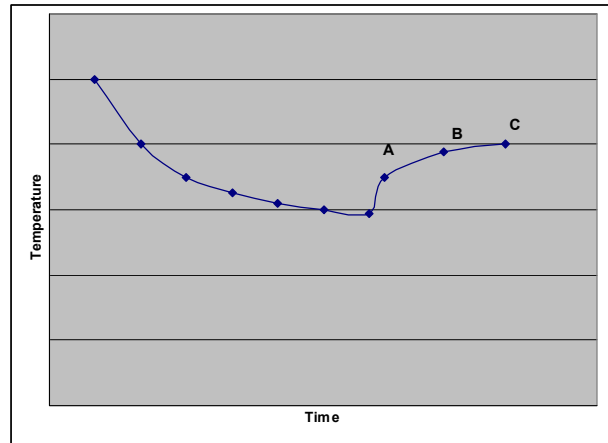


Figure 6 Tight buffer cooling curve

The first test (Table 1.) was made running tight buffer straight through the spray chamber. After that we add cooling length by using multi pass loops inside the trough. It can be clearly seen thermal coefficient dropping when using multiple loops. In the beginning of cooling process the surface of the buffer is hot, almost 200°C. At the temperature higher than 100°C the cooling is very rapid because water evaporates from the surface. When temperature decreases under boiling temperature the cooling speed declines. According to theory the thermal coefficient in the case of boiling convection can be as high as 100000 W/m²K. Value we get with our testing method shows average over the whole cooling process. That is why we get smaller values when using longer cooling length.

Table 1. Test no 1.

Line speed m/min	Melt temperature [°C]	Measuring point A [°C]	Measuring point B [°C]	Measuring point C [°C]	W/m ² K
300	183	59	65	67	2700
500	185	67	71	74	2900
700	186	72	77	84	2600
900	188	72	77	85	3200

With this method we can determine coefficient between plastic surface and water mist. The heat transfer inside the plastic buffer is material property. It cannot be accelerate by cooling.

According to measured data there are big differences between materials (Table 2.). We tested two different PVC grades: riser and plenum. To achieve flame retardancy the plenum PVC is heavily filled. These additives increase heat conductivity. That is why plenum rated PVC is easier to cool down. According to measured results we calculated required cooling length for both materials. The target is that plastic buffer cools down so that the temperature in whole cross section is below 30°C. Additional cooling length is easily achieved by adding loops in cooling chamber.

Table 2. Test no 2.

Material	Line speed [m/min]	Required cooling length [m]
Plenum PVC	300	7
	500	11
	700	16
	900	21
Riser PVC	300	12
	500	21
	700	29
	900	36

4.1.2 Line tension at high speed

Line tension was measured between the spray cooling and capstan.

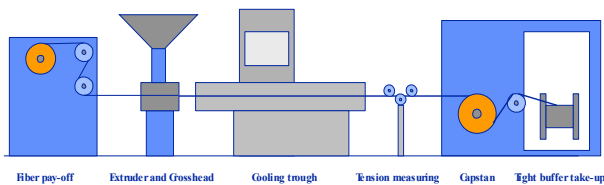


Figure 7 Tension measuring arrangement

We measured the tension with two different cooling lengths in spray cooling trough. First the tension was measured with using two loops (cooling length 13m). After that with 5 loops (cooling length 30m). We ran also test with standard cooling bath to compare tension.

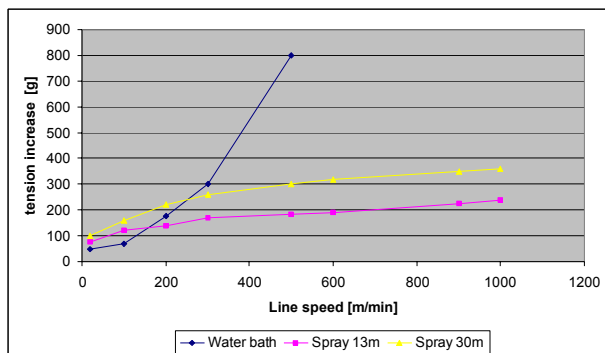


Figure 8 Tension measuring results with different cooling set up

The results in picture 8 show that there is small increase in tension because of additional loops. But when comparing to tension in standard cooling the different is clearly seen. When using spray cooling the tension increase is linear according to line speed. With conventional water bath the flow resistance of water plays bigger role. Thus tension increases in square of line speed.

4.1.3 Buffer bond control

The adhesion between fiber and buffer was measured with different line speeds and with different configurations of extrusion tooling. The result show that different die position is needed at different line speeds to achieve the targeted stripping force

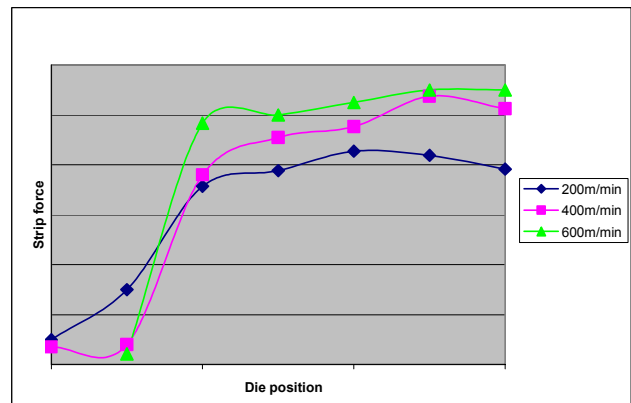


Figure 9 Stripping force with different line speeds and die position

The test was carried out by pulling the buffer off with slow constant speed. The peeling length was 15mm

4.2 Testing the Tight buffer and cable

Different fibers and plastic materials were tested. We tested standard single mode fibers as well as 50µm multimode fiber from different suppliers.

With single mode fiber we tested four different plastics: plenum PVC, Riser PVC, PA12 and LSOH. After the tight buffering the attenuation was measured. We also performed temperature cycling test to the samples.

Both PVC grades tested from 100 to 900m/min. LSOH from 100 to 600m/min. PA12 from 100 to 500m/min. Max attenuation increase with both wave lengths was 0.04db/km.

Table 3. Attenuation with 50µm fiber

Line speed	Attenuation	
	850nm	1300nm
200	2.35	0.54
300	2.33	0.56
400	2.46	0.63

With multimode fiber the most interesting finding is that there are big differences between fiber suppliers. The biggest reason seems to be the different quality and curing rate in acrylate coating. Especially with 50um fiber the attenuation value varies a lot. With some fibers the attenuation measuring is within the limit right after buffering process. With some other fibers the attenuation was elevated in the beginning but came down to acceptable value in few hours. Eventually the result with all fibers was acceptable. Winding tension is also critical. The higher is the tension the bigger is the optical loss in the fiber. Running with low tension helps with attenuation but the reel might get difficult to handle. The plastic material used in MM fiber test is LSOH.

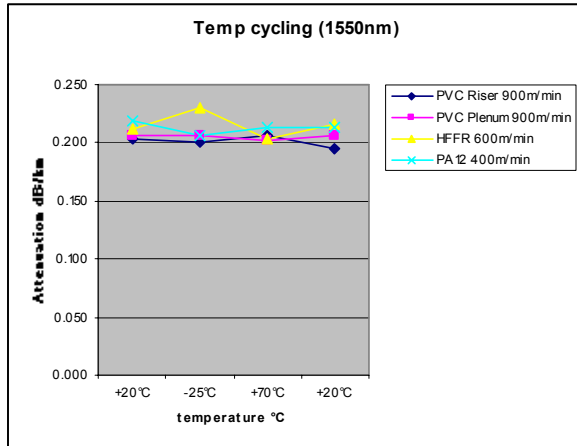


Figure 10 Temperature cycling with SM-fiber samples

5. Conclusion

Increasing tight buffering process speed is possible. It requires careful planning and testing. The critical parts in extrusion process are cooling and controlling the line tension. When cooling is made with water spray instead of immersed water the tension can be controlled. Water spray enables efficient cooling and makes it possible to reduce line length.

The most efficient line speed increase is with single mode fiber. It is quite robust and usually delivered in long lengths. More challenging is the high speed with multi mode fiber. Optically it is sensitive to tensile stress. This makes it even more important to reduce the line tension. For MM fiber it is important to fine tune the process for fibers from different suppliers. The acrylate finishing and curing rate plays big part in optical performance of tight buffer.

6. References

- [1] Dougherty, Turunen, Nykänen, "Buffered Optical Fiber Manufacturing Developments" Proceedings of *IWCS 2003*.

Authors



Jari Nykänen received the degree of M.Sc. in Mechanical Engineering in 1996. Since then he has been working at Nextrom. He started as a process engineer working with extrusion lines. Today he is Product Manager of fiber optic indoor cable machinery.



Joe Lichtenwalner is currently a Senior Process Engineer at CommScope, with focus on Premises Fiber Optic Cable manufacturing. He holds a Bachelor of Materials Engineering degree from Georgia Institute of Technology. Joining CommScope in 1994, he held positions in Product Development and Plant Management before moving into his current position. Prior to CommScope, Mr. Lichtenwalner worked for Oxford Superconducting Technology as a Product Development Engineer responsible for NbTi-based superconducting wire and cable.