A new structural totally dry optical fiber cable via co-extrusion technology for double-layer loose tube

Wu Di, Liu Peidong, Wu Junxiong, Yin Jicheng, Ju Zhigang, Wu Jian, Yuan Jian

Hengtong Optic-electric Co., Ltd

Suzhou, Jiangsu, P.R.China

Wud@htgd.com.cn

Abstract

A fully dry optical fiber cable can make the cable manufacturing processes more environmental friendly; and can connect to facility easily installation. In this paper, a new fully dry optical fiber cable was introduced, which used co-extrusion technology for double-layer loose tube. The soft polypropylene (PP) material was used as the loose tube. The inner layer of loose tube was made up of PP to protect the optical fiber, for its soft characteristic. The outer layer consisted of a mixture of PP and low density linear polyethylene (PE-LLD) with a certain ratio. The production condition was optimized by analyzing the properties of the PP (or mixture of PP and PE), the processed parameters and the different type of color master batch. It found that the double-layer composite loose tube possess better stability for excess fiber length and physical, mechanical properties, comparing with ordinary one.

We have completely tested the performances of the final products. The analytical test results showed that it could match the relevant international and Chinese quality standards. At the same time, the technology can also reduce energy and material consumption enhances production efficiency. We believe this new product can meet the taste of market and business prospect.

Keywords: loose tube; double-layer co-extrusion; analytical test; excess fiber length; fully dry optical fiber cable.

1. Introduction

Co-extrusion is an innovative material forming method which can combine various materials with different properties and utilize their inherent characteristics well. It is widely used in the production of plastic products with different purposes. Co-extrusion products have specific appearance and performance such as having excellent thermal stability, being waterproof and refractory, and having mechanical properties, etc. Moreover, compared to the conventional extrusion processing, this new technology has numerous advantages, including lower production cost and energy level, simple technological process, high productivity and high-quality. We introduced a new double-layer co-extrusion, which belongs to co-extrusion, into the loose tube manufacturing and succeeded in manufacturing a new polypropylene (PP) double-layer composite loose tube .The basic theory is as follows: the melts of two materials from two different extruders are simultaneously delivered to the same extruder head and continuously extruded.

The soft polypropylene (PP) material was used as the loose tube. The inner layer of loose tube was made up of PP to protect the optical fiber for its soft characteristic and the outer layer consisted of the mixture of PP and low density linear polyethylene (PE-LLD) with a certain ratio. The production condition was optimized by analyzing the properties of the PP or mixture of PP and PE, processed parameters and different type of color master batch.

In order to explore the influences of the inherent characteristic of each material on the properties of the loose tube, we ompletely tested the materials and final products by using a variety of testing methods and instruments. These analytical test results can provide important theoretical basis which not only improving the quality of the composite loose tube but also guiding the engineering application.

2. Materials test and analysis

Material: Natural PP resin, PP/PE blends: Natural PP resin blended with 2% mass fraction PE color master-batch, PP/PP blends: Natural PP resin blended with 2% mass fraction PP color master-batch. The colors of two color master-batch are the same.

Preparation of the samples

1. The samples were prepared through melt blending in a mixer.

2. PP resin mixed with 2% mass fraction PE color master-batch and PP color master-batch respectively and melted at 195℃ for 10 min at a stirring rate of 60 rpm till a homogenous blend appeared. The natural PP resin was processed in the same way.

3. The obtained three types of melt were cast, after cooling, the samples were cut into different dimensions and geometric shapes for different tests.

2.1 Color master batch

The good dispersion of pigments in the product as well as excellent compatibility between color master-batch and matrix resin are not only essential standards of eligible color master-batch but also critical guarantee for loose tube to obtain good appearance. Generally, if the dispersion and compatibility are better, the tinting strength and hiding power will be higher. And the appearance of colored product will look even, There will be fewer color spots and smaller color deviation. In the meantime, performances of the loose tube should not suffer unacceptable degradation due to the addition of various color master batch.

In order to evaluate the dispersion and compatibility, differential scanning calorimeter (DSC) and torque rheometer were used to investigate the natural PP resin and colored blends. The test results of DSC showed that there was only one glass-transition temperature (Tg) in each material and the numerical values were very close. It showed there was wonderful compatibility between color master-batch and matrix resin. The balance torque and maximum torque of PP resin which obtained from torque remoter were 24N·m and 47N·m respectively. The balance torque and maximum torque of PP/PE blends were close to them, which revealing the relatively good pigment dispersion, flow properties and plasticization performance. Unlike PP/PE blends, the balance torque and maximum torque of PP/PP blends were both slightly higher, which indicating the relatively poorer pigment dispersion, flow properties and plasticization performance. According to those results we can state that the two color master-batch both had ideal coloring effect and PP/PE blends had better coloring effect than PP/PP blends. These results were displayed in table1.

2.2 Materials properties test

Table1. Color master batch test

Material	PP	PP/PE blends	PP/PP blends
Tg [℃]	165.5	164.9	165.9
△Hm [J/g]	121.7	121.1	121.6
Balance torque[N·m]	24	24.1	25.2
Maximum torque[N·m]	47	46.9	48.3

In recent years, polypropylene (PP), which obtained from propylene polymerization, has been one of the thermoplastic with fastest-growing popularity. It is widely used for different applications due to excellent comprehensive property and high net profit. We tested the properties of natural PP matrix and the colored blends. These results were displayed in table 2.

As be seen from table 2，there is little difference in all indexes of matrix resin and blends, which reveals that the using of 2% mass fraction color master-batch does not have harmful influence on the properties of natural PP resin. The melt flow rate (MFR) of PP resin is about 2.5 $g\cdot(10min)^{-1}$, which can not only guarantee good extrusion process ability, but also provide enough viscidity for maintaining melt strength and meet the requirement of higher delivery speed in production. The density of PP resin is low and it implies that the product with the same size has lighter weight. The total aberration (△E) is less than 2. which indicates the color stability of blends is very good. The numerical values of thermal deformation temperature and oxidative induction time (OIT) are relatively high, showing that the blends possesses good thermal and processing stability. Tensile yield strength, nominal tensile strain at breaking point and charpy notched impact strength are all ideal. It means the materials have excellent mechanical properties and meet the requirement of loose tube fabrication as well as flexibility requirement when in use. The higher crystallization temperature of the plastic materials contribute to shortening molding cycle times, decreasing post shrinkage, reducing performance discrepancies of the inner and outer wall of loose tube and also improving yields. After comparing and analyzing the experimental data, we got the conclusion which will be benefit for the improvement of product's advanced performance.

Table2. Materials properties test

Material	PP	PP/PE blends	PP/PP blends
MFR/$g\cdot(10min)^{-1}$	2.53	2. 57	2.46
Density / $g\cdot cm^{-3}$	0.907	0.911	0.909
Total aberrations △E		≤ 2	≤ 2
OIT / min	45	48	43
Tensile yield strength Mpa	32	31	32
Thermal deformation temperature℃	98	92	96
Nominal tensile strain at break%	≥ 500	≥ 540	≥ 510
Charpy notched impact strength / (KJ·M2)	48	48	48
Vicat softening point℃	150	140	150
Crystallization temperature℃	126	123	131

3. Production equipments and process

The production line of double-layer composite loose tube is composed of pay-off system, plastic extrusion equipment, die head forming system, cooling and sizing system, extrusion processing controlling system, haul-off units and take-up system. The integrated equipment drawing is as shown in the figure 1. The key issue related to the line is designing a well-constructed extrusion die with ingenious flow channel. For years, most researches focused on this field including die structure design and fluid flow condition, particularly the stability of interface complexes. In order to meet the requirement of frequently-used polymer materials extrusion processing, our company expanded technical cooperation with manufacturing equipment provider and jointly developed a new kind of complex co-extrusion die. I've shown part of its contents in Figure 2.

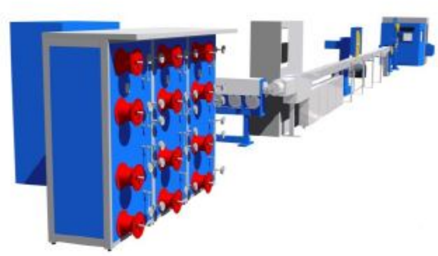


Figure 1 Second coating Line

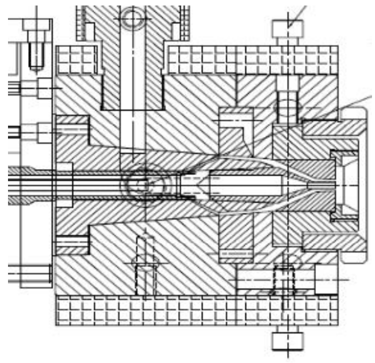


Figure 2 Co-extrusion die

For producing use-proved product, we should ensure favorable interface bonding strength between two materials，the same fluid flow rate between two polymer melts and homogeneous material allocation, which are challenges for both equipments and process. There are different processes control corresponding to different materials combination, sometimes even auxiliaries or solely design parts are needed. The forming of co-extrusion interface is the emphasis and difficulty during the debugging of production Molds and loose tube performances had all reached the anticipate requirement by optimizing the parameters of co-extrusion die and continuously adjusting productive technology. Some process parameters were shown in table 3.

Table 3 process parameters

Item	Process parameters
Extruder barrel temperature /℃	195/210/230/230/230
Extruder temperature /℃	230/230/230/220
Extrusion mould size /mm	3.5/4.5/6.5
Screw rotational speed /RPM	60
Line speed/ m•min-1	200

4. Product performance and testing

Indicated by the small scale trial production, the product line has stable capability. Four kinds of loose tube are chose for testing: two single-layer loose tubes used PP and PE respectively, two double-layer loose tubes used the nature PP for inner layer, PP and PE used for the outer layer. The double-layer loose tube is as shown in the Figure 3.

Figure 3 Double-layer loose tube

The product performances have reached the anticipate requirement. The main test items and results are listed in table 4.

Table 4 Loose tube test

Material	PP/PP color master batch	PP/PE color master batch	PP+ PP/PP color master batch	PP+ PP/PE color master batch
Yield strength/Mpa	28.5	25.3	33.0	28.1
Yield strength elongation/%	18.5	18.8	20.1	21.3
Lateral pressure/N	582.3	576.6	593.5	585.2
Bending / 10*D	Pass	Pass	Pass	Pass
Bending / 8*D	Pass	Pass	Pass	Pass
Bending / 5*D	Fail	Pass	Pass	Pass
Nominal tensile strain at break/%	530	560	580	600
Excess fiber length/%	0.04	0.05	0.03	0.03

The thermal shrinkage of the blue tube, orange tube, black tube and aqua tube were measured. In the Figure 4, it showed that the thermal shrinkage of the aqua tube changed more than 0.2%. Therefore, we focus on tracking aqua tube, when we measured excess fiber length and after excess fiber length.

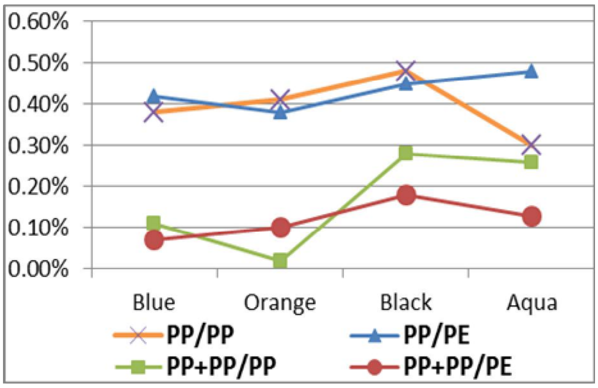


Figure 4 Thermal postshrinkage test

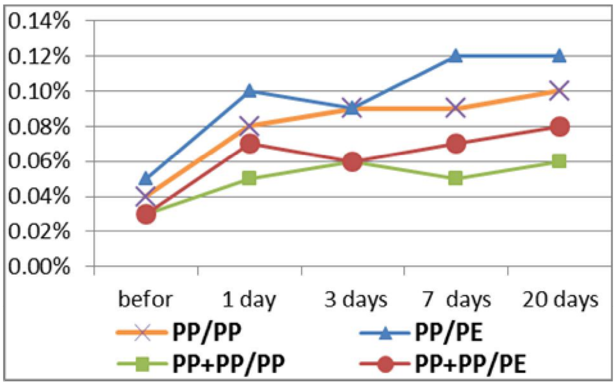


Figure 5 Excess fiber length of aqua tube

In Figure 4 and Figure 5, the double-layer loose tube have lower heat shrinkage rate, excess fiber length (EFL) and after EFL than single-layer loose. PE color master batch have greater shrinkage rate than PP color master batch.

For the loose tube made of PP color master batch, color of optical fiber can be seen through the PP layer. This phenomenon does not occur in the PE color master batch. It also proves that the PE color master batch has better color adhesion.

With the double-layer loose tubes, we design and manufacture a single jacket structure. The cable structure is shown in Figure 6. The cable parameters are listed in Table 5.

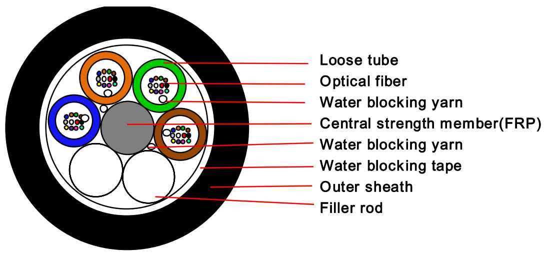


Figure 6 Single jacket cable

Table 5. Single jacket cable parameters

Number	Items	Parameters (mm)
1	Tube diameter	2.5
2	Stranding pitch	95

3	FRP diameter	2.6
4	Outer sheath thickness	1.8

The mechanical properties are listed in Table 6 according to IEC 60794-1-2.

Table 6. Mechanical test results

Items	Test method	Test condition	Test results
Tensile strength	IEC 60794-1-2 E1	1000N	Fiber strain:0.003%
			Fiber attenuation change:0.015dB
		3000N	Fiber strain:0.14%
			Fiber attenuation change:0.028dB
Crush	IEC 60794-1-2 E3	Pressure:2000N 10 min	Residual increase in attenuation:0.012dB
Impact	IEC 60794-1-2 E4	4.5N． m, 5 points, 3 times per point	Residual increase in attenuation:0.005dB
Repeated bending	IEC 60794-1-2 E6	Load: 150N Bending radius:20 cable OD, ±90° Number of cycles: 30	Residual increase in attenuation:0.003dB
Torsion	IEC 60794-1-2 E7	Load: 150N Bending radius:20 cable OD, ±180° Number of cycles: 10	Residual increase in attenuation:0.006dB

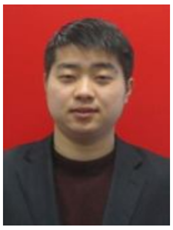
5. Conclusion

This paper expounds the PP and PE - LLD mixed extruding is feasible, from the materials test and analysis. The two color master-batch both had ideal coloring effect while PP/PE blends had better coloring effect than PP/PP blends. The double-layer loose tube had better mechanical properties, stable EFL and thermal shrinkage than the single-layer loose tube. The results of loose tube and cable could match the relevant international and Chinese quality standards.

6. Acknowledgments

Thanks to our R&D, Engineering and Quality teams for designing, tracking and testing the samples.

7. Pictures of Authors



Wu Di

Mr. Di wu was born in Jiangsu Province, China, in 1988. After he graduated from Jiangnan University, he joined Hengtong Optic-Electric Co., Ltd. in 2009. Since then, he has been working in the technology research and development department.

Liu Peidong

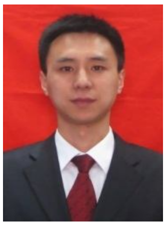
Mr. Liu received his M.S degree in Material Science from Henan University of Science and Technology in 2004. Since then, he has been working in optical fiber cable technology area. Now he is a R&D deputy manager of R&D Department of Jiangsu Hengtong Optic-electric Co., Ltd, engaged in research and development of optical fiber cable and new material development.

Wu Junxiong

Mr. Wu was born in 1963. He received Ph.D. degree in optic-electric science from National Central University in 1994. He now works as chief engineer in Jiangsu Hengtong Optic-Electric Co.,LTD. He is in charge of technical research and production.

Yin Jicheng

Mr. Yin Jicheng joined Jiangsu Hengtong Optic-electric Co., Ltd in 1992 after Graduation from Wuhan Research Institute of Posts and Telecommunications, and has been engaged in optical fiber and cable industry for about 20 years. Now he is the General Manager of Jiangsu Hengtong Optic-electric Co., Ltd and in charge of enterprise.



Ju Zhigang

Mr. Ju Zhigang joined Jiangsu Hengtong Optic-electric Co., Ltd in 2002 after Graduation from the Southwest University of Science and Technology, and has been engaged in process research of optical fiber cables. Now he is a process supervisor of Outdoor Optical Cable Technique Department.

Wu Jian

Mr. Wu Jian, with 20 years of experience in telecommunication, Mr. Wu Jian has been standard composer of optical fiber cable for Ministry of Industry of Information Technology of the People's Republic of China (MIIT)

Yuan Jian

Mr.Yuan Jian, born in 1964, M.E.E, EMBA, Senior Engineer. He has experiences of decades years in optical fiber manufacturing, engineering, marketing, R/D and operation management. He has hold and published patents and articles related optical fiber field.