Surface Defect Detection of All-dielectric Air-blown Micro Cables

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Abstract: With the development of large-scale optical network construction and transformation, optical fibre and cable transmission has gradually entered the era of miniaturization. All-dielectric air-blown micro cable technology is becoming one of the preferred solutions for communication operators to solve the shortage of duct resources. At present, industry standards have already been developed for the domestic production of air-blown micro cables. However, a series of problems in the process of the production and construction of air-blown micro cables, compared with ordinary optical cables, have not yet caused enough concern. This paper introduces the status and harm of the defects found out in the existing production and construction process of air-blown micro cables, and points out the importance of defect detection system for air-blown micro cable production.
Key words: Air-blown micro cable, bulge, micro stripping pore, defect detector

1 Introduction

With the increasing demand for information, more and more strain on the resources of communication pipe network appears. The traditional communication pipelines could not meet the requirements of the optical transmission era in terms of both construction cost and capacity requirements. Particularly on the premise of the rising of labor costs year by year and the growing scarcity of pipeline resources, the technology of cabling with the air-blown micro ducts and micro cables is becoming more and more favored by operators. According to this technology, the micro duct bundle will be laid into an existing silica core duct or an urban HDPE protection duct, and then the micro cables with the required number of cores will be laid into each micro duct through air blowing, so as to achieve duct capacity expansion and ensure that the number of optical fibres can be increased with the traffic increase. This is conducive to the use of the latest optical fibre technology for the existing line in the future, so as to save investment.

In 1997, the telecom company NKF of the Netherlands put the air blowing technology into commercial use for the first time by using the air-blowing technology and equipment of Plumettaz S.A. (Switzerland) and established a new pipeline construction mode marked by "micro ducts + micro cables + air blowing". Air-blown micro optical cables are becoming more and more favored by users in various countries because of their standardized construction, high utilization rate of pipeline space, fast laying, and many other advantages. In 2002, the technology was introduced into the Chinese market. At present, many domestic manufacturers and operators are actively promoting the technology and related products, and the localization of all products and accessories related to micro cables and micro ducts technology has been realized.

In 2007, our country issued and implemented the micro cable industry standard YD/T1460.4-2006 which specifies a series of specifications for domestic production of air-blown micro cables. Relevant operators are also formulating detailed construction specifications and technical requirements higher than the industry standard for relevant products according to their own actual conditions. Compared with ordinary

optical cables, air-blown micro optical cable has its unique requirements for structural components and air-blown laying technology; therefore, some unique problems exist in the process of its production and construction.

This paper compares the micro cable with ordinary optical cable, discusses the possible defects and harms which may exist in the production and construction of the micro cable, points out the shortcomings of the existing optical cable production defect detection system in the production of air-blown micro cables, and probes into feasible solutions.

2 Differences between Air-blown Micro Cables and Ordinary Optical Cables

2.1 Structural Differences between Air-blown Micro Cables and Ordinary Micro Cables:

1) The difference in diameter between air-blown micro cables and ordinary micro cables: The so-called micro cable, as the name implies, refers to the optical cable with relatively small size, generally with the diameter ranging from 3.0 mm to 10.5 mm. Although no special requirements are specified for the diameter of ordinary optical cable, the basic diameter of ordinary optical cable will be much larger than the diameter of the air-blown micro cable with the same number of cores.

2) The difference of sheath wall thickness between air-blown micro cable and ordinary micro cable: The sheath wall thickness of air-blown micro optical cable is specified as nominal 0.5 mm and not less than 0.3 mm in minimum, while the sheath wall thickness of ordinary optical cable will be greater than 1.0 mm. In this case, the air-blown micro optical cable will have a smaller diameter, lighter weight, and the distance of air blowing will be farther due to the lighter weight of the optical cable.

3) The difference of sheath surface friction coefficient between air-blown micro cable and ordinary micro cable: Since the micro cable with low friction coefficient will have longer air blowing distance, the dynamic friction coefficient of the sheath surface of the micro cable is required to be not more than 0.2, while no requirements for surface friction coefficient are specified for the ordinary optical cable.

2.2 The difference between the production and construction of air-blown micro cables and ordinary micro cables:

1) Production of Air-blown Micro Cables and Ordinary Micro Cables

The production of stranding air-blown micro cables is roughly the same as that of ordinary optical cables, except that, because the diameter of air-blown micro cables is small, both the tube size and the production process must be controlled very precisely. In particular, since the micro cables must be constructed in the air-blown micro ducts and one of the better laying conditions is that the duty ratio of the air-blown micro cables to the micro ducts is about 60%, the diameter of the optical cable needs to be controlled more strictly, and no defects can be escaped.

2) Construction of Air-blown Micro Cables and Ordinary Optical Cables

I) The laying method is different. For air-blown micro cables, the construction mode is different from the manual laying mode of ordinary optical fibre cables. The micro cables must be laid with machines; suitable air blowing machine needs to be selected, and the micro cables will be blown into the micro ducts with the mechanical thruster of the air blowing machine. The outer diameter of the micro ducts for cable laying through air blowing is generally about 7-16mm. At the same time, the air compressor conveys the powerful air flow into the duct through the air blowing machine, and the high-speed air flow forms a forward thrust force on the optical cable surface, which causes the micro cable to "float" forward in the micro duct.

II) The force acting on the air-blown micro cable is different from that acting on the ordinary optical cable. There are two main forces acting on the micro cable. One is the air blowing machine's thrust force which pushes the cable into the micro duct. The

maximum value of the thrust force will be determined by impact test before air blowing, and the force should not let the micro cable be seriously twisted in the micro duct. The second is the driving force imposed by the high-speed air flow on the micro cable in the micro duct. This force is very uniform and small, and after being laid, the micro cable will lie loosely in the micro duct, which is beneficial for prolonging the service life of the optical cable. Ordinary optical cables need to rely on the central reinforcement core on the end or other tensile elements to provide the tensile force for cable laying, so the mechanical performance requirements for air-blown micro cables are not as high as those for ordinary optical cables.

III) Air-blown micro cables do not go through the same routing and environment as ordinary optical cables. During the process that the micro cable is blown by air, the cable needs to pass through a seal ring with a certain diameter at first. The seal ring will be only 0.5 mm larger than the optical cable in diameter, or even smaller, so as to ensure that the high-speed airflow can be conveyed into the duct without air leakage which will seriously affect the air blowing effect. Therefore, if there is large bulge on the surface of the micro cable, the cable may fail to pass through the seal ring, and cable breaking may be caused during the air blowing process. Secondly, as the distance of air blowing becomes longer, the pressure in the duct will gradually increase, and the maximum air blowing pressure can reach 12 bar. If there is micro stripping pore on the surface of the micro cable, the cable will be unable to bear the maximum air blowing pressure and crack, and the construction will not proceed smoothly. Since ordinary optical cables are routed overhead, through pipes or directly buried, the diameter of the bore passed through by ordinary optical cables will be much larger than that passed through by the micro optical cables. In addition, there will not be requirements for air blowing pressure of ordinary optical cables. Therefore, the abovementioned problems will not appear for ordinary optical cables.

IV) The laying efficiency of micro cable is different from that of ordinary optical cable. The micro cable is small in diameter, light in weight, and has the characteristics of long laying distance at one time and fast laying speed by air blowing. Sometimes the highest blowing speed can exceed 70m/min. For the defective micro cable, when problems are found out in the process of air blowing, the cable will be broken because it is too late to stop the air blowing machine. Even if the air blowing machine can be stopped in advance before the fault point, the cable laying through air blowing must be continued after the fault point is repaired and qualified. The ordinary optical cables are basically laid through manual pulling and shoulder carrying; therefore, the laying can be stopped at any time to repair the defective optical cable, and the defective optical cable can even be repaired after all optical cables are laid, and the construction progress will not be influenced basically. That is to say, for normal micro cables, the laying efficiency will be much higher than that of ordinary optical cables, but for micro cables with potential quality problems, the laying efficiency of air-blown micro cables will be greatly reduced.

3 Problems in Production and Construction of Air-blown Micro Cables

Due to the thin sheath wall (the nominal thickness of sheath is only 0.5 mm, and the minimum is only 0.3 mm) of the air-blown micro cables, for all-dielectric air-blown micro cables without metal support, the phenomenon of extremely small bulge or micro stripping pores may occur in the production process due to unexpected reasons such as the core shaking or material reasons.

The following figure shows typical cases of construction obstacles caused by bulge and micro stripping pores in actual production and laying:

Figure 1

Figure 2

Figure 3

The yellow part between two fluorescent spots in Figure 1 is a micro stripping pore, being less than 1mm in diameter and smooth in appearance. It is difficult to detect the stripping spot by hand. If the yellow cable core is not placed in the black sheath, it is difficult to find the stripping pore. Figure 3 shows the phenomenon that the sheath piles up in front of the sealing ring of the air blowing machine when the micro stripping pore passes through the air blowing machine and cable crack is caused under the action of 12BAR high-pressure air flow. Figure 2 shows the folds caused on the micro cable sheath by micro-bulge on the optical cable surface when the cable passes through the sealing ring. In this case, the construction could not be continued.

4 The non-professional detecting equipment is the main reason for the problems.

Compared with ordinary optical cables, the air-blown micro optical cable is small in diameter and light in weight; its sheath wall is thin, with the minimum thickness being only 0.3 mm. In particular, when the micro cable is blown into the micro ducts through air blowing machine, the cable needs to pass through a sealing ring with a certain diameter during the process of air blowing, and it is required that the cable must be able to withstand the air pressure of 12bar. If the micro cable has small bulge on its sheath, it may be unable to pass through the sealing ring; blocking and cable breaking will be caused. Because of the very small stripping pores on the sheath surface, the air may enter the cable core from the micro stripping pores, resulting in cracking and influencing the normal construction of the micro cables. Since any defect on the surface of the micro cable may cause an obstacle to the construction of the optical cable, the detection of the air-blown micro cable is required to be more accurate, and no defect point is allowed to be missed.

The production detection systems of existing optical cable production line production are all based on the through-beam detector. The implementation condition is that the object to be tested blocks the optical path and realizes the control. This detection method is simple in control, low in cost, but low in precision, and easy to cause defect missing. As for the production of ordinary optical cable, the sheath wall thickness is large (larger than 0.8 mm in minimum), and almost no stripping phenomenon occurs. If stripping phenomenon occurs, since the sheath is thick, the difference between the cable core and the outer diameter of the sheath is large, this kind of through-beam detection method is easy to be implemented. Even if no product defect is detected, for ordinary optical cables laid manually, maintenance after failure is also allowed and will not have fatal impact on the construction. For the all-dielectric stranding micro cables, spiral or parallel slot structure is adopted on the surface of optical cable in order to pursue good air blowing effect. For such thin-walled spiral or parallel slotted air-blown micro cables, if there are micro stripping pores at the bottom of the

threaded sheath surface, or if the sheath is bulging on one side due to excessive joint of yarn binding on the core or other reasons, it will be difficult for the through-beam detection system to detect such defects. Firstly, it is because the detection system has a dead space of detection; secondly, it is determined by the detecting principle of the system. Therefore, the development of or search for better detecting means is the top priority in the production of air-blown micro cables.

5 Several Innovations of YOFC in Improving the Level of Air-blown Micro Cable Detection

It is required in 5.1.3.2 of *Telecommunication Microduct Optical Fibre Cables and Fibre Units for Installation by Blowing* (YD/T1460.4-2006) that the surface of the micro cable sheath must be free of visible sand hole, bubble or crack in any cross-section, which reflects the importance of micro cable detection. However, in the sheath integrity inspection described in 5.2.5.3, only the cable with metal layer under the sheath is mentioned to be inspected electrically, while the sheath surface integrity inspection of all-dielectric micro cable is not mentioned at all. It is not because it is not important or because of insufficient understanding. It may because that since there is a certain degree of difficulty in the inspection, there is still no effective inspection means. Therefore, only the technological means and responsibility of the enterprises can be relied on to maintain a strict standard. Of course, since the standard is formulated very early, the understanding and research about micro cable were not deep enough, and the air blowing technology and its related products were still in the research stage at that time, the promotion and trial application in small batches are understandable.

applying a certain air pressure on the micro cable and checking the air tightness of the cable based on the air-blown micro duct inspection method. Firstly, it is not easy to seal the end of the micro cable; secondly, the air inflation of micro cable is different from that of the micro duct: since the micro duct is hollow inside, the air can quickly move from the head end to the tail end; however, since the micro cable has a stranded cable core in the sheath, it will take a long time for the air to move from the head end to the tail end, and the leakage phenomenon may not be found out immediately and the specific position could not be

However, the large-scale production and application in nowadays cannot be guaranteed without reliable detecting means.

YOFC, as the domestic and international leader in the production, research and promotion of micro cables, has conducted in-depth research on relevant issues and put forward a number of solutions based on actual production conditions.

1) Detection of Bulge

On the basis of the original through-beam bulge detector, the scene of passing through the sealing ring of the air blowing machine is simulated. An open-close sizing detection switch is provided on the micro cable production line. This detector is a guiding two-piece mold device with the size of corresponding sealing ring for the air-blown micro cable of the same specification. The device consists of two half-closures. When the bulging points exceeding the diameter of the two-piece mold pass through, the two-piece mold will be opened, thereby triggering the alarm meter counting device. In this case, the micro cables which can pass through the sizing mold will certainly pass through the sealing ring of the air blowing machine, thereby controlling the risk of small bulging.

2) Detection of Micro Stripping Pores

Detection of this phenomenon is much more difficult. 1) Since the diameter of air-blown micro cable sheath at the micro stripping pore is not changed basically, it is difficult to identify this defect by conventional defect detecting means. 2) Since the air-blown micro cable is all-dielectric cable, the electrical detection means will be ineffective. 3) It is impractical to judge whether micro stripping pore exists through

judged. Therefore, the operability is low.

According to the above difficulties, on the one hand, we introduce the most advanced micro cable defect detector from abroad to ensure the quality of our products; at the same time, we organize the most capable technical force to develop a new efficient and fast on-line detector with independent intellectual property rights. The detector is developed on the basis of the principle of high-speed imaging; when defect or pinhole size stripping is detected on the cable surface, the detector will give alarm immediately, and the production data will be retained on the data disk; then the production and process personnel can immediately get to know the cable surface conditions by checking the data. In case of problems, the cable can be rewound for inspection and repair. Practice proves that this method is really effective.

6 Conclusion

Generally speaking, with the continuous promotion and development of air blowing technology as well as the large-scale production and application of all-dielectric micro cables, people will gradually deepen the understanding and research about micro cables, and the corresponding detection means will be more and more perfect and reliable. It is believed that in the near future, the advantages of air-blown micro cable technology will be greatly reflected and applied.

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