QUICK REPAIR OF SUBMARINE FIBRE OPTIC CABLES IN CHINA

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Abstract: A Submarine optic fiber cables are easy to be damaged by human activity or natural disasters, such as fishing, anchoring and earthquakes. As social and economic communications increasingly reply on the Internet, a damaged cable can incur system operators a significant cost and swift repair operations are required.
In China there are many un-repeatered systems which require a rapid repair operation which can restore network service. Hengtong Marine Cable Systems have developed an un-repeatered cable repair joint, which can be adapted for use with a wide variety of un-repeatered cable structures.
In this presentation, some experiences from rapid response cable repairs in domestic Chinese waters are shared when using the Hengtong Marine Jointing technology. All the repairs occurred in a water depth of less than 50 meters and in areas of intense human activity. In conclusion, some advice is offered about protecting submarine cables located in shallow water depths.

1. INTRODUCTION

Submarine cables are laid on the seabed where the environment can be extremely harsh. In addition to the natural conditions such as tides, erosion, and earthquakes, submarine cables can also be also affected by the friction of the seabed material and the erosion of harmful gases. What is more serious is the damage caused to the submarine cable by human beings in marine activities, including ship anchoring fishing and recovery. In China the length of the un-repeatered submarine cables are generally less than 100km, and they are laid in water depths of 50m or less. In areas where human activities are frequent, cable damage is common.

The quick repair of submarine cable is a very complicated task. In addition to requiring the construction ship to have certain technical capabilities and equipment, it must also have a team that enriches the experience of marine recovery and construction work. Involved in fault location, cause analysis, recovery of submarine cable, repair joint production, joints and submarine cable laying and so on, Hengtong Marine Cable Systems had participated in many quick repairs of un-repeatered submarine cables in China, designed and developed a repair joint for un-repeatered armoured submarine cable, which can be applied to various un-repeatered submarine cable structures. The mechanical parts and the armoured steel wire are pressed, and the sealing body is used to seal the casing to ensure the service life of the product for more than 25 years.

2. CAUSE ANALYSIS OF CABLE DAMAGE

Statistics show that 95% of the cable damage is caused by human activities

during fishing and shipping, mainly the following.

Damage to the submarine cable caused by fishing and marine aquaculture

Due to the scarcity of offshore fishery resources in our country, traditional fishing tools have been replaced by modern large fishing vessels and fishing tools, and the density of fishing vessels has multiplied. At present, the main ways of fishery production are: gill nets, trawls, purse nets, snake nets, fishing tackles, cages and pots, among which the overturned bars and sail nets in snake nets cause the most frequent and serious damage to the cable.

Damage to Cables by Shipping and Marine Engineering Vessels

The main cause of cable damage is that arbitrary anchoring of ships have repeatedly caused damage through impact of the anchor with the cable causing crush and external damage to the cable structure. Cargo ships are generally equipped with a hall generally used as a Hall anchor weighing of 2-10t, a holding force of 0.34-69.0t, and an in-situ depth of 1.0-2.0m. It is worth mentioning that the anchors used by the marine engineering construction ship for submarine cable construction & repair are different. These vessels have a large displacement and are simple in line type. Most of them are box-type hulls with large water resistance. In order to stably anchor the ship at sea, a large number of anchors are deployed, typically up to 10. Since the anchors of such vessels are basically without anchor chains, the mooring forces are all provided by the anchors, so the anchor weights are all 5-8 t or even larger, the anchors are all high-grip naval anchors, and the depth of penetration into the seabed can exceed 2m. For example, in 2016, the Zhoushan Telecom submarine cable failure and the 2017 Shanghai Telecom submarine cable failure were all caused by anchor damage

Natural conditions cause damage to the submarine cable

The long-term friction between the submarine cable and the exposed bedrock on the seabed may cause damage if the cable is moved or pulled over hard seabed materials; the change of the seabed topography may also damage the cable. Under the combined action of tide and wave, the submarine cables in the beach are buried from a certain depth to a shallow depth until they are exposed. Thereafter cable damage may occur due to cable flexing and fatigue or due to external damage.

3. JOINT BOX INTRODUCTION

The submarine cable joint box structure design mainly meets the following three requirements:

A) Same as the submarine cable performance index (mechanical, waterproof seal, photoelectric, anti-corrosion, etc.);
B) Matches the structural size of the submarine cable;
C) Adapts Technical conditions for existing cable laying equipment.

Therefore, in the design of the overall structure of the submarine cable connector box, it must be considered to meet the underwater cable 25 years of service life of the armoured cable anchorage, waterproof sealing insulation, fiber connection storage protection, cable bending buffer, anti-corrosion Material selection and maximum form factor, as well as compatibility with the laying and recovery equipment on the ship.

Structure and design of submarine cable joint box

The structural design of the submarine cable joint box is based on the structure and size of the armoured submarine cable to ensure the technical performance requirements of

the submarine cable. The structure of a typical double armoured submarine cable is shown in Figure 1. Figure 2 shows the structure of the Un-repeatered submarine cable repair joint box designed by Hengtong Marine.

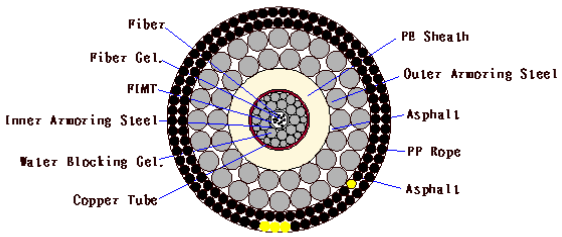

Figure 1: Structure of the double armoured submarine cable

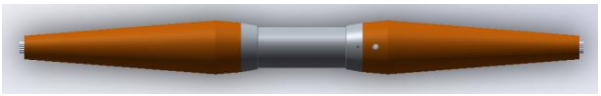

Figure 2: Hengtong Marine Un-repeatered submarine cable joint box

The connection method between joint box and cable

The external steel wire armouring is the main tension component of submarine cable. When the cable is subjected to external force, the fiber can be not damaged or pulled off. The reliable and effective connection of the armoured steel wire is the key to ensure the continuity of the mechanical performance of the submarine cable, and is also one of the keys to the structural design of the submarine cable joint box. A pressure activated tapered clamp device solves the problem of reliable connection between the joint box and the submarine cable armoured wire. According to the structural size of the submarine cable armoured wire, the armour clamping can evenly distribute the steel wire around the conical clamp body without overlapping, and the key to the wire clamping is the consistency of the taper angle. A calibrated preload force is applied in the axial direction to activate the taper clamp and ensure the armoured steel wire evenly stressed. The taper angle designed in the clamping mechanism is smaller than the friction angle, ensuring the long-term reliability of the self-locking compression clamp device. According to the commonly used connection method, by using the pressing equipment and the tooling, the armoured steel wire and the joint box fittings are matched to form a compression fit between the submarine cable and the joint box, and the process needs to maintain a typical pressure of 15 MPa for 5 min. The tapered clamp ensures that at least 90% of the cable UTS performance can be achieved.

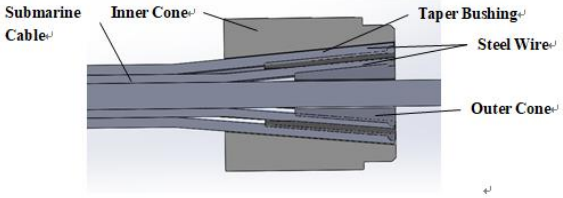

Figure 3: Armoured steel wire clamping device

Sealed and insulation

The joint box sealing method used in the non-relay submarine cable repair technology is realized by a three-layer rubber seal. The inner part of the end cap main body and the submarine cable are tightly connected by a tapered rubber ring, and the product is firstly extruded by the rubber ring. The sealing of the layer, the O-ring realizes the sealing between the joint box and the box body, and at the same time, the rubber ring is squeezed by the screw caps at both ends to seal the inside and the outside of the box body, and the internal safety performance of the product is realized by the multi-layer sealing method.

The experimental data shows that the insulation resistance between the inner conductor of the joint sealing layer of the joint box and the casing should be not less than 20 GΩ/500V (DC). Dielectric withstand voltage of the joint box sealing layer between the inner conductor and the housing should be 15 kV (DC) 2min with no breakdown. The cable repair jointing box

has been qualified to meet these key performance requirements.

Joint Box Material

The submarine cable joint box must have a normal service life of 25 years under the seabed environment, so the choice of joint box material is especially important. If the seawater corrosion resistance of the selected materials is poor, it is difficult to ensure the effective use of the submarine cable. International suppliers have used beryllium-copper alloys, coated steel or high-quality stainless steel materials for the structural material of the submarine cable housings. An analysis of various seawater resistant materials has resulted in the selection of duplex stainless steel materials with high mechanical strength and good seawater corrosion resistance. This greatly improves the overall mechanical structure and seawater corrosion resistance of the submarine cable joint box.

Assembly process of the joint box

Submarine cable joint boxes are designed in kit form to be assembled and installed at the offshore construction site; the design ensures that the assembly is successful. Due to the complicated structure of the submarine cable joint box and the high quality requirement of the assembly and splicing, the assembly of the joint box parts requires professional configuration training in addition to the complete set of special splicing process devices. Hengtong Marine has a complete set of joint box assembly operation procedures and training certification management process. The existing 11 professional joint box integration engineers have undergone complete training and assessment, and all have experience in submarine cable repair. Therefore, the quality of the joint box assembly and connection can be reliably guaranteed. At present, the repair time of the 24-core un-repeatered submarine cable is less than 8 hours. Assembly of the joint box requires assembly of workbench and support frame assemblies, hydraulic clamping devices, special assembly tool assemblies, fiber fusion splicers, OTDR, and other ancillary devices.

4. REPAIR OF SUBMARINE CABLE

Compared with the submarine cable laying project, the recovery and repair of the submarine cable is an arduous and complicated task. It involves many disciplines such as ocean navigation, photoelectric performance testing, recovery from the deep sea, long length and deep burial conditions, where the implementation difficulty and requirements are higher. In addition to requiring the construction unit to have certain technical capabilities and equipment, it must also have a team that enriches the experience of construction work at sea.

Domestic cable repair process

The submarine cable repair process is mainly:

A) Confirmation of the location of the submarine cable fault point;
B) Confirmation of the position of the submarine cable and its fault point in the water;
C) Recovery of the submarine cable;
D) Removal of the faulty cable and re-testing to ensure good cable remains;
E) Joint box production;
F) The laying of the joint box and the spare submarine cable;
G) The burial of the repaired submarine cable.

Confirmation of the fault point of the submarine cable

The confirmation of the location of the fault point of the submarine cable is the key process of the whole repair work. It is directly related to the smooth progress of the work and the accuracy of the measurement. It is directly related to whether the recovery and repair work can be carried out as scheduled. Therefore, the

work must be taken seriously and scientifically.

The confirmation of the location of the fault point of the submarine cable is divided into two steps: first confirm the distance (m) from the fault point to the end of the submarine cable. The distance indicates the position of the fault point on the submarine cable. For the optical cable, the OTDR is generally used for test, and the insulation value of the submarine cable can be measured by an Insulation Resistance Tester to confirm if external damage of the cable. Then according to the measured fault point distance (m), on the submarine cable construction original record table, the cable laying length column on the "cable report", the geographical location of the fault point corresponding to the sea is obtained. That is the location of the cable that needs to be recovered. According to the cable report, the construction parameters such as cable laying time, water depth and depth of the cable can be conveniently accessed. Secondly, by consulting the completion data of the submarine cable, it is possible to initially understand the natural conditions of the sea area where the fault is located, and the various situations that occurred during the installation of the facility, and tentatively infer the cause of the fault.

Recovery of faulty submarine cable

The recovery vessel is anchored in the "DGPS" position; with the help of “submarine cable tracking” equipment and positioned above the fault point of the submarine cable. The diver or ROV with cable detection equipment searches for and initially locates the seabed, and then uses a high-pressure water gun to align the lateral mud in the upper part of the submarine cable until the submarine cable is found. Then the ROV or diver equipped with a high-pressure water gun, supplemented by an air lifting device, to wash mud along the cable longitudinally, and remove the mud using the air lifting device and then discharges it into the sea, so that the buried cable of a certain depth is exposed in an open trench.

After removing power from the cable, the exposed cable can be cut and recovered to the deck of the construction vessel.

The 4-point mooring repair vessel / cable recovery method is generally limited by water depth to typically 40 m depth. The vessel is normally equipped with grapnels which can be used to recover the cable where visibility is poor and in areas where divers cannot be used. For the shallow depth of the submarine cable, the conventional shackle or four-claw can be used. For deep-buried submarine cables, must be recovered with a specialised cable de-burial equipment.

Fault point cutting and joint box assembly

The cable that has been recovered is cut for testing, and after confirming that the fault point has been removed, the connection between the submarine cable and the spare submarine cable can be commenced and a joint box can be made. Generally, two joint boxes are required for each repair work.

Laying of joint box and spare cable

After the first joint box is completed, the joint box and one section of spare cable are deployed and the cable laid to the position required to make the 2nd repair joint box. The final splice (2nd) joint box is lowered to the seabed by winch or crane. In order to prevent the cable in the final splice bight from twisting, a good spread is maintained on the two cables and the repair ship maintains a low tension on the submarine cable, until the bight is finally laid flat on the seabed.

Burial after submarine cable repair

The joint box and the spare submarine cable are generally buried by divers with a high-pressure water gun and an air lifting device, to a maximum burial depth of 1.5m. At the

end of the repair work, timely records are created detailing the location of the repair, cause of the cable damage, test results before & after the repair, submerged joint box and spare submarine cable used and related test reports.

5. CONCLUSION

The importance of submarine cable is self-evident. At present, China has gradually strengthened the protection of submarine cables, and has repeatedly appealed to all sectors of society, especially offshore fishing vessels, to pay attention to the protection of submarine communication cables. As a research and development manufacturer of submarine cables and accessories, Hengtong Marine has strengthened the performance improvement of submarine cables and developed new submarine cable repair technology. Qualified cable repair joints for different types of submarine cables have been designed to minimize repair time using trained & certified offshore technicians, which can save valuable time for submarine cable repair works.

6. REFERENCES

[1]Jaap Griep, Arnie Berkers, “Factory Splicing Fibers in Metal Tubes (FIMT)”, IWCS 2008

[2]Vincenzo V.Rondinella, M.John Matthewson, “Effect of Loading Mode and Coating on Dynamic Fatigue of Optical Fiber in Two-Point Bending”, J.Am.Ceram.Soc, 76(1)139-44(1993)

[3] Zhiyuan Pan, “Experiment on the fatigue behavior of bare optical fiber”, Advanced Materials Research, p1995-2000(2014)

