A MULTIFUNCTIONAL CABLE TERMINATION MODULE (CTM) FOR USE IN UNDERWATER OBSERVATION NETWORK CABLE SYSTEMS

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Abstract: This paper describes the challenges in the design and development of a multifunctional Cable Termination Module (CTM), which has been supplied for use in an underwater observation network cable system. The CTM design enables the quick and reliable connection between an optical-electric composite cable and the Scientific Instrument Interface Module (SIIM). The CTM discussed here, comprises a composite cable mechanical termination, with pressure resistant housing containing in line cable connections, electronic components such as voltage conversion modules & photoelectric conversion modules, and up to three dry-mate connectors. The main function of the CTM is to protect and separate the optical fibers and power conductors, and to convert optical signals into electrical signals which will be sent to the SIIM. Some lessons learnt during the project are shared.

1. INTRODUCTION

At present, in the fields of marine scientific research and seabed resource development, the demand for long-term real-time remote observation of the seabed environment is becoming more and more intense [1]. Since traditional cable with electrical signal communication systems are difficult to realize long-distance with large-capacity data transmission, it is necessary to adopt an optical-electric composite communication submarine cable. The cable utilises an optical fiber as the signal transmission medium.

The traditional submarine cable communication system is used for communication between lands to across oceans, and adopts standard optical-electric composite communication submarine cable, which includes communication optical fiber, a single power supply conductor and armour structure for tensile strength and mechanical protection, etc.

In the fields of scientific ocean research and seabed resource development, real-time data transmission between land and subsea equipment and submarine equipment is required. To enable this, the communication fiber and the power supply conductor in the optic-electric composite cable must be separated on the seabed at the submarine cable terminal device.

Among the technologies available, the submarine cable terminal devices are passive, and the communication fiber and the power supply conductor only can be separated physically inside the termination device. A connection to the under-water junction box, or other equipment can be made by wet-mate optical connectors and wet-mate power connectors respectively. These connections enable data transfer and continuous power supply between land and subsea equipment.

To increase the flexibility of deployment and maintenance operations, and to reduce the cost of deployment and maintenance work, these watertight connectors sometimes use wet-mate connectors which will be operated

by underwater Remote Operated Vehicle (ROV). But the shortcoming of the existing solution is that, due to the maturity of the water-tight connection technology, whether it is dry-mate water-tight optical connector or wet-mate water-tight optical connector, the connection reliability is much lower than that of dry-mate water-tight electrical connector and wet-mate water-tight electrical connector. This will reduce the stability of long-term data transmission between land and subsea equipment. In addition the cost of water-tight optical connectors are much higher than water-tight electrical connector, thus limiting such sea-link communication systems in marine scientific research and Seabed resource development, etc.
The CTM developed by Hengtong Marine and described in this paper is applicable to the twin-conductors optical-electrical cable system typically used in the underwater observation network cable system industry.

2. DESIGN ENGINEERING PROCESS

Normally, when new market order requirements are received, the engineering design process followed is as shown below:

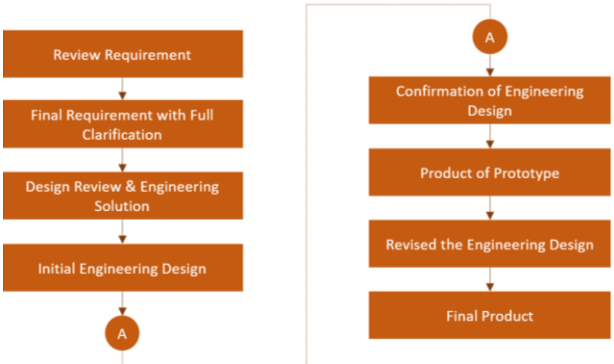

Figure 1. Design engineering process

3. FINAL REQUIREMENT WITH FULL CLARIFICATION

Based on the initial functional requirements of a low cost, shallow water, observation network system additional clarification meeting with clients are required to detail the full system specification. Following several meetings the following system requirements were defined & agreed:

- The CTM is utilised to separate the electrical power and optical fibers of backbone submarine cable.
- System location in fresh water with the maximum water depth of 10 m.
- Redundant optical-electric convertor modules with 48 of VDC input voltage to be housed in the CTM (100 Mb/s of communication rate).
- Redundant power convertor modules with 400V~48 VDC to be housed in the CTM.
- Connection to underwater SIIM facility with electric dry-mate connector.
- CTM has excellent mechanical performance to terminate the backbone cable and bear the hydrostatic pressure.
- Design a light weight CTM to simplify the installation.
- Design a low cost CTM, to assist with the economic cost of whole system.

Notes: The information of the system cable entering the CTM is as following:
The twin-conductor optical-electrical cable is a cost effective cable design [2] which uses two wires to form an electrical loop, to transmit a high-power feed and is applicable for different water depths of sea water or fresh water in underwater observation network system industry.
When applied to shallow sea areas, double armored (DA) or single armoured (SA) cable is required. However when applied to shallow fresh water areas such as rivers and lakes, a non-armored cable may be appropriate, depending on the level of risk from external cable damage. The non-armoured cable option was selected by the client due to the low risk environment and cost. The design of a suitable termination anchorage for the non-armoured was identified as one of the project challenges at an early stage.
Two types of typical twin-conductor optical-electrical cable are as following:

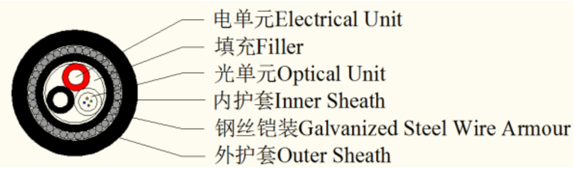

Figure 2. The armored twin-conductor optical-electrical cable

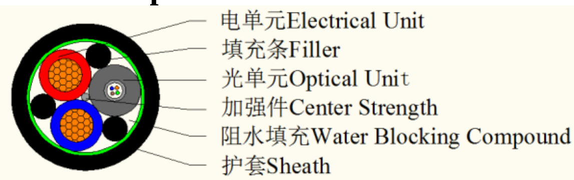

Figure 3. The non-armored twin-conductor optical-electrical cable

4. DESIGN REVIEW & ENGINEERING SOLUTION

4.1 CTM functional topology design

The CTM described here not only separates the optical signal and electrical power but also realizes the bidirectional conversion between the optical signal and electrical signal for data transmission. Thereby improving the reliability and lower the cost of such underwater observation network cable systems.

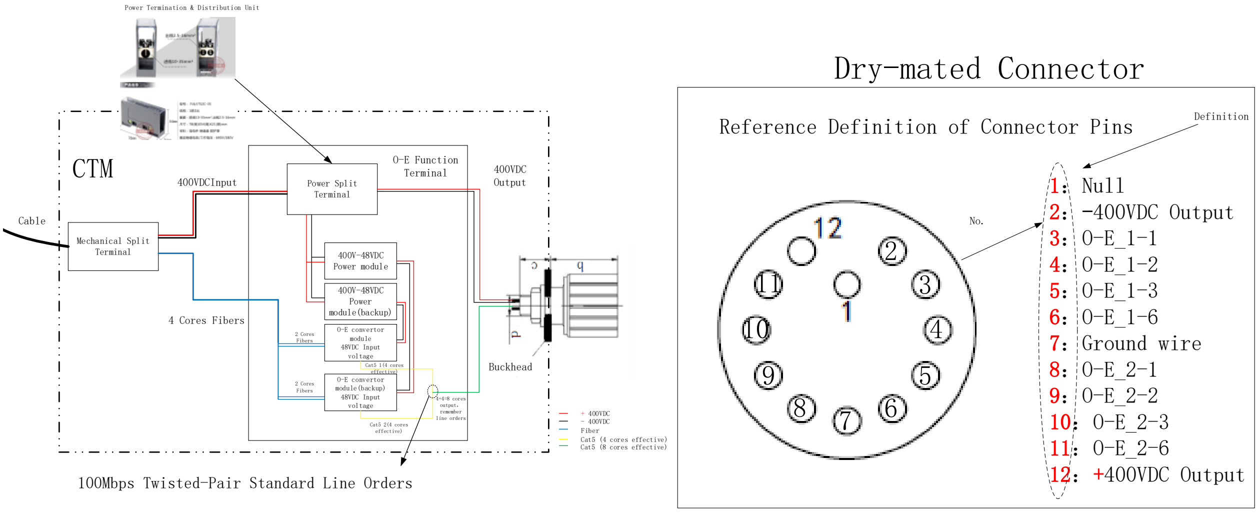

Figure 4. Functional topology of CTM

4.2 Design the termination anchorage for an non-armoured cable

In order to achieve economical efficiency of whole underwater observation network system, client selected an unarmoured cable with no strength member as the backbone cable. It was necessary to design a new anchorage design for this special cable. Based on a sheath fiction clamp as following:

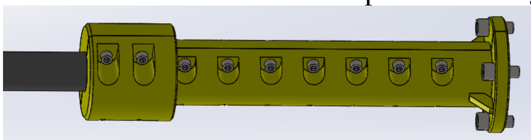

Figure 5. Termination anchorage design for non-armoured cable

4.3 Design an economic bend restrictor sleeve

Based on the project budget & time limitation, The design of a cable bend restrictor using high stiffness hoses was progressed. Stiffness hoses are extremely cost effective for small batch production projects and are readily available. The hose selected for use incorporated three layers of high-tensile steel wire stranded in hose body to increase the stiffness of hose, and subsequently limit the bend of cable. By combining hoses of different diameters (slipping one hose inside another), fillers and other parts to attach the CTM cable bend restrictor could be tailored to meet project requirements.

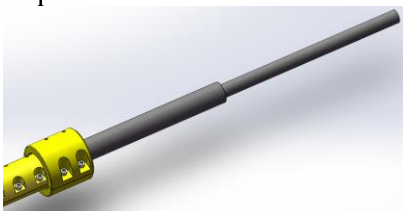


Figure 6. Economic bend restrictor sleeve design

4.4 Design cable sealing system

The CTM sealing design incorporated a conical compression seal for cable sheath sealing and utilized standard O-rings seals to seal the mechanical parts to achieve the required sealing performance.

4.5 Design thermal absorption heat sink

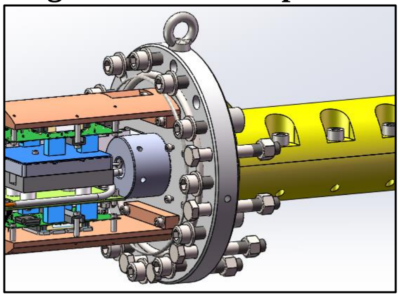

Figure 7. Thermal absorption heat-sink

To control the temperature of the electrical devices which dissipate power & generate heat within the CTM, it was necessary to mount these components on a heat-sink attached to the main CTM bulkhead. This proved to be an effective method of controlling the device temperature and the thermal management within the CTM.

5. DESIGN CONFIRMATION

5.1 Clamp performance verification

5.1.1. Building test system environment

To verify the gripping performance of various clamp designs, two clamps were applied to a length of non-armoured cable and a tensile force applied via the clamps in steps of 5kN until slippage of the clamp occurs. Clamps using different liner material were tested for holding capability.

Test 1: The tensile test will start from 5kN and hold the load for 5 mins to check no slippage and increase the tensile load each time for 5kN until 20 kN.

Test 2: Tensile load is increased until the clamp slippage is observed over the test cable.

Figure 8. Clamp gripping force test

5.1.2. Judgement method and test result

Figure 9. Load vs Time of gripper liner

The gripper liners with three different material were tested. Under the same conditions, the gripper liner with material C showed a best load performance in figure 9. So we selected it in our final products.

5.2 Verification of economic bend restrictor sleeve

To check the additional bending stiffness offered by the CTM bend stiffener, one side of the sample was fixed to form a cantilever. An applied load of 10 kg force was used to deflect the cable, allowing the measurement of the degree of deflection as the following pictures shown:

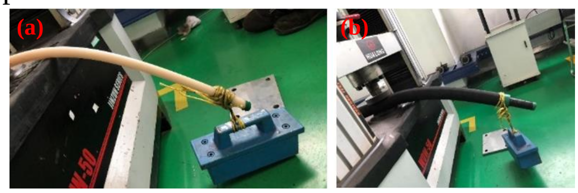

Figure 10. Bending test on the high stiffness hose

(a) Test on non-amoured cable; (b)Test on non-amoured cable with stiffness hose

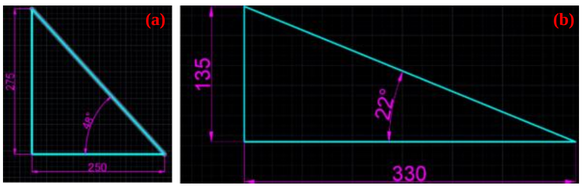

Figure 11. Results of bending test

(a) Result of non-armored cable; (b) Result of non-armored cable with stiffness hose

Figure 11 shows that the non-armoured cable without any bending protection has a noticeable distortion with a deflection of 48 degrees. Under the same conditions the non-armoured cable fitted with bend protection using two layers of stiffness hose is deflected to 22 degrees with no permanent distortion. Hence by applying two layers of stiffness hose, an excellent bend performance is created to limit the deflection of the cable.

5.3 Hydrostatic sealing performance verification

5.3.1. Building the test system

The sealing performance of the cable cone seal design was tested using three seal material.

The sealing structure was tested at DWP (30MPa) for seven days to simulate long period submersion in water. Furthermore a proof load test pressure test at 1.5×DWP (45MPa) for 4 hours and a pressure cycle test at DWP for 10 cycles (60 minutes per cycle) were also performed. The central seal assembly was installed in the test pressure as shown in Figure 12.

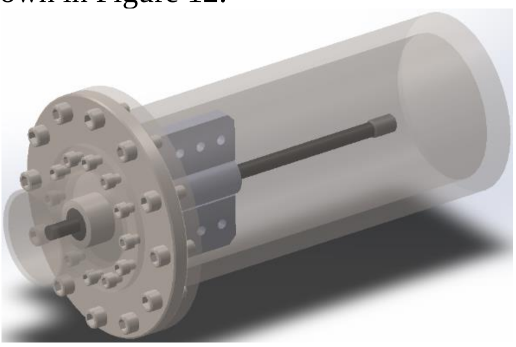

Figure 12. Hydrostatic sealing performance test

5.3.2. Judgement method and test results

(1)Hydrostatic sealing performance test at DWP for 7 days.

(2)Hydrostatic sealing performance test at 1.5 × DWP for 4 hours.

(3)Hydrostatic sealing performance test at DWP for 10 cycles.

After qualification of the long duration DWP pressure test of 30 MPa, the pressure cycle test of sealing structure was continued for the pressure cycle test.

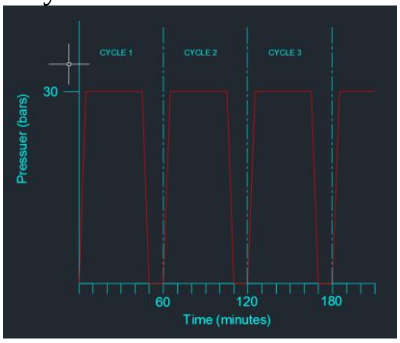

Figure 13. Guideline of repeated 10 cycle tests

Figure 14. Hydrostatic sealing performance test

From the figure 14, there was no evidence of any water leak (red dye used to colour the water) anywhere around the seal area during the test. All the pressure tests were successfully passed.

5.4 Evaluation of the heat sink design

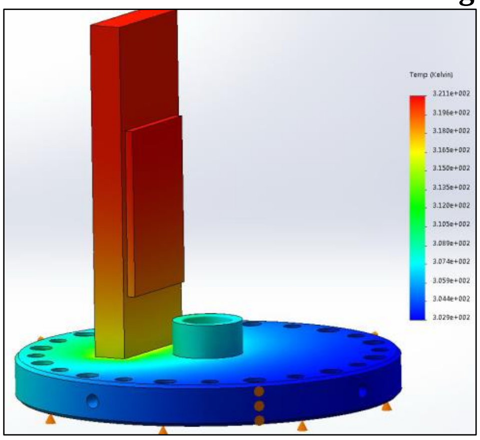

Figure 15. Analysis for heat sink performance

To avoid the heat accumulation dissipated by electrical modules housed in the CTM, a heat sink mounting was designed and analysed as shown in Figure 15. The results show that the design efficient at transferring thermal energy to the external bulkhead and limiting the temperature increase observed on the mounting plate.

5.5 Evaluation of hydrostatic pressure performance

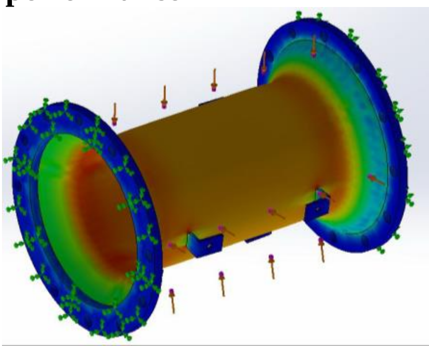

Figure 16. Analysis for hydrostatic pressure performance

The hydrostatic pressure performance of the pressure sleeve design was analysed by engineering calculation according to ISO standard. The result is shown in Figure 16, where a steel housing with a 4 mm wall thickness is capable to resist the DWP hydrostatic pressure of 30 MPa.

5.6 Integrated functional alignment test

5.6.1. Building test system

To check the functional performance after assembling the functional modules housed in the CTM, a testing system was built as shown in Figure 17. It was possible to test the electrical connectivity performance and data transmission performance simultaneously. The electrical connectivity performance is shown on the 400 VDC Power Supply Equipment. The data rate /data transmission performance is shown in the computer running the software of “LAN Speed Test”.

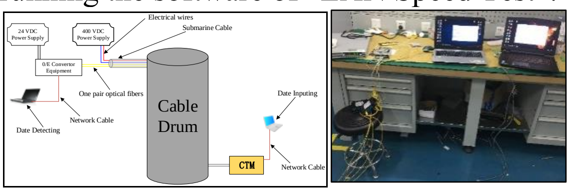

Figure 17. Integrated Functional Alignment Test for CTM

5.6.2. Building test system

(1) Electrical Connectivity Performance

A power feed of 375 VDC was applied to the system through the submarine cable at the start of the integrated functional alignment test. Current values shown on the 400 VDC Power Supply Equipment should be in the range of 0.030A to 0.040A (Based on the theoretical calculation when design), Thus the electrical connectivity performance test can be evaluated.

Figure 18. Result of electrical connectivity performance

Figure 18, shows that the current value is 0.036A with an applied power feed of 375 VDC to the system, indicating that the test has been successful.

(2) Data transmission performance

A 100 Mbps analogue data stream was input to the system at CTM and the data detected at the submarine cable end. The data rate (including writing and reading) should be greater than 90 Mbps, for the data transmission performance test to be successful.

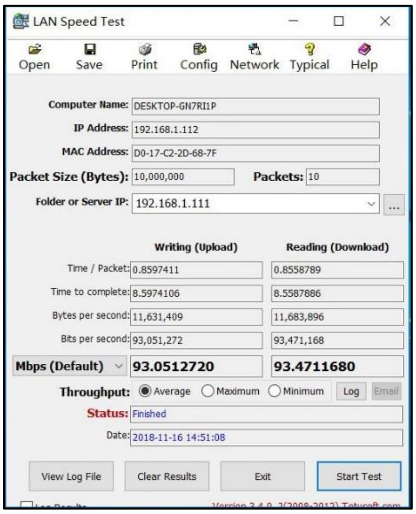

Figure 19. Result of data rate

Figure 19, shows that the writing rate is 93.05 Mbps and the reading rate is 93.47 Mbps after an input 100 Mbps data stream to the test system. As both the Writing and Reading rate are above 90 Mbps, the test was successfully.

Tests during integration have shown that the data transmission has achieved an excellent performance after assembly of the CTM and can convert the optical signal and electrical signal in both directions between shore station and subsea equipment.

6. TRIAL ASSEMBLY

An initial assembly of the prototype CTM was performed to detect all interface detail of the sub-components and ensure no major issue with final CTM assembly.

7. REVISED DESIGN

All feed-back from the assembly activities were used as input to a CTM design review. Only small assembly issues were noted and modified in the engineering documents to improve the assembly operation. No major issues were detected, which would have required an engineering design review and a new engineering solution with the revision of all associated engineering documents to cover the issues.

8. FINAL PRODUCT

8.1 Main structure

Figure 20. CTM main structure

8.2 Key specifications

- Key function: Terminate the cable and separate electrical power with optical fibers of backbone submarine cable in the CTM, then output electrical signal and electrical power.
- Redundant: Both O/E convertor modules and power voltage convertor modules are redundant with double units.
- External Interface: Connect to other underwater facilities with electric dry-mate connector.
- Maximum depth: 200m
- Operating temperature range: -5°C to +45°C (Limited by connectors)
- Corrosion protection: Duplex stainless steel with high resistance to erosion corrosion, corrosion fatigue and very high mechanical strength.

8.3 Main functions and advantageous

The CTM shall have the following main functions:

- It shall form a fixed structure for an armoured composite cable.
- Its weight and mechanical stability shall be compatible with forces arising from cable laying currents and installation.
- It shall contain at least one connectorized jumper cable to detach and mate with a connector to the SIIM or other permanent sub-sea equipment.

Main advantageous of the CTM are as following:

The hydrostatic pressure sealing structure is very compact and reliable. The use of water-tight optical connectors is avoided and only water-tight electrical connector are used in the long-distance communication between the shore station and underwater equipment or between different underwater equipment. Thereby improving the reliability of long-term operations on the seabed, and greatly reducing the construction cost of underwater observation network system of cable communication.

9. CONCLUSION

The objective of this paper was to share some of the challenges, experience of “Design Engineering Process” when a new CTM products was designed for a client’s underwater observation network system. In this process, Hengtong Marine has

developed and qualified a Cable Termination Module (CTM) which enables the rapid and reliable connection between a subsea composite cable and permanent subsea Scientific Instrument Interface Module equipment with dry-mate connectors.
Seven CTM's have already been delivered to the client, all of which have been integrated with system cable, onsite system assembly, cable integration and FAT testing. The sea bed installation of the CTM components are currently in progress.

10. REFERENCES

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[2] Jerry Brown, Rendong Xu, Qi Xin, Hongdong Wu, Zhengwei Wu (Hengtong Marine & Hengtong Subsea Technologies), "Cost Effective Cable Designs & Sensor Interface Platforms for Deep Water Scientific Applications", Ocean Sciences Meeting 2018, 11th – 16th February 2018, Portland Oregeon, USA.

