Consideration on the Cable Tension Increase Mechanism while Lowering Cable Ploughs in Water Deeper than 700 m

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1. Abstract

To protect the laid cable against fishing activity etc., burial methods using ploughs or ROVs up to 2000m in depth are employed. Usually, the plough is lowered in shallow water, towed offshore and recovered onboard at the planned position. The cable shape in a shallow water is considered to be vertical (up and down) while the plough is lowered and touched down on the seabed, as the moved distance of the ship and the length of cable paid out are controlled to be almost equal. While maintaining the relationship between the ship and cable, as above, the shipboard cable tension is cable weight in the water (w) × depth (h). However, when the plough was lowered in over 700 m depth, using the shallow water procedure, it was observed that the shipboard cable tension was very high and exceeded w × h near the seabed. Also when the plough touched down on the seabed, it was confirmed by an optical test that some fibres were broken. To avoid damaging the laid cable due to the increase in shipboard cable tension while lowering the plough in deep water, this paper describes the following:

a. Consideration of the mechanism of the shipboard tension increase.
b. Establishment of a plough lowering procedure for deep water.
c. Verification of the relation between failure points of the laid cable and the amount of cable slack by our simulation technology.

2. Introduction

In recent years, fishing resources in shallow water have declined, either through excessive fishing or abnormal weather. Fishing activities have therefore moved into waters over 1000 m deep. Trawl fishing presents an especially great threat to un-buried cable. To protect cables from damage in these water depths, armoured cable is used and burial is often required in water depths up to 2000 m. The seabed in deeper waters around Japan is very soft and post lay burial using trenching ROVs is often employed. If simultaneous cable lay and burial can be used into deep water, it is much more economic than post lay burial with an ROV. When making a proposal for an entire project, this economy must be worth considering.

3. Plough trial in deep water

Figure 1 shows the bottom profile by bathymetric survey for the plough deep-sea trial area.

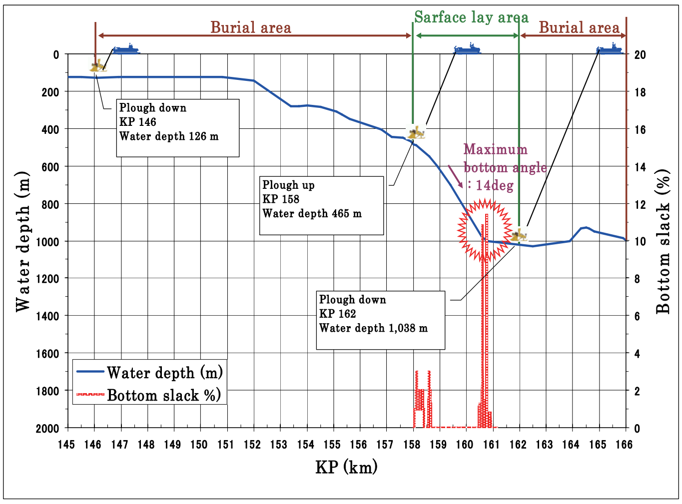

Figure1 Bottom profile for the plough trial area and simulation results of bottom slack

3.1 Ploughing plan

The plan was to plough from shallow to deep water, taking seabed slope into account.

Ploughing plan is as follows:

1) KP146 (depth 126 m): Plough down
2) KP158 (depth 465 m): Plough up
3) KP158-KP161 (depth 465-1000 m, maximum down slope angle: 14 degrees): Surface lay
4) KP162 (depth 1038 m) Plough down
5) KP168 (depth 1100 m): Plough up

3.2 Lowering the plough at KP162 (depth 1038 m)

The plough was lowered by the same procedure as that in the shallow water area. Three parameters (moved distance of the ship, the length of cable paid out and the length of tow rope paid out) were controlled to be almost equal. As a result, when plough was lowered to approximately 1000 m deep, shipboard cable tension increased to over 3 times as much as the planned shipboard cable tensions near the seabed. Measured maximum cable tension was 70kN. Figure 2 shows the planned shipboard cable tension and the measured cable tension while lowering the plough.

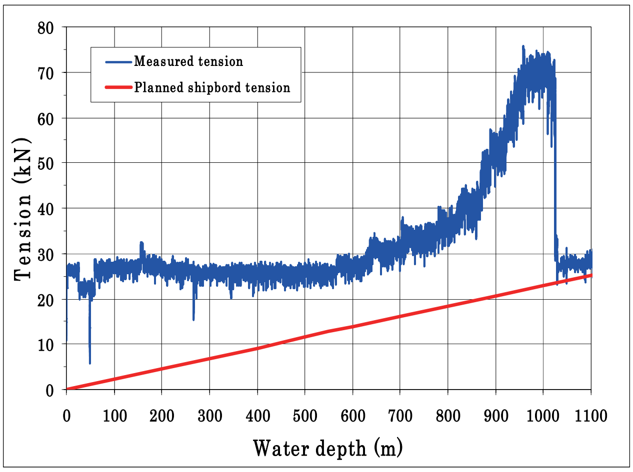

Figure 2 The planned shipboard cable tension and the measured cable tension.

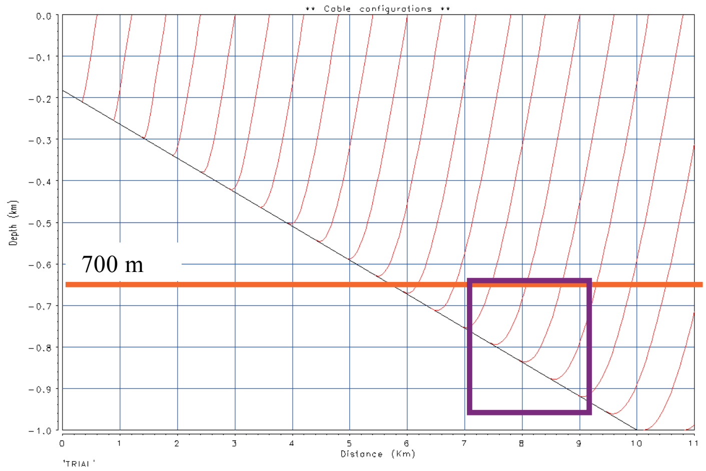

Figure 3.1 Simulation results

3.3 Analysis of changes in shipboard cable tension

This was clearly an inadequate lowering procedure for deep water (Over 700 m depth), because the shipboard tension increased over planned tension.

To understand these phenomena, a more accurate model of cable catenaries in increasing water depths was produced.

Considerations about the increasing shipboard tension

Up to 700 m deep, the approximation of the cable shape can be treated as a vertical, however, the same approximation can not be applied in deep sea areas based on the change in tension shown in Figure 2. The cause of the increasing tension in over 700 m, is presumed to be that the cable shape is changing from vertical to a catenary curve, and that a part of the plough's weight is added to the cable.

3.4 Behaviour of underwater cable

To verify the cable shape mentioned in the above section 3.3, Figure 3.1and 3.2 show the results of the simulation and behaviour of underwater cables by our developed simulation system. The cable shape is changing from vertical to catenary curve near the boundary points of 700 m depth. This result matches well with the actual results of the trial.

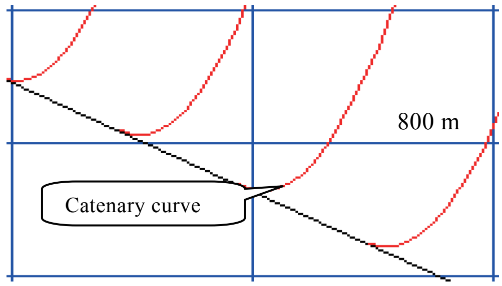

Figure 3.2 Zoom in view for over 700 m water depth

Simulation results have improved our confidence that we understand the reasons for the increased tensions at deeper depths.

4. Establishment of a plough lowering procedure for deep-sea areas

If we encountered similar situations during plough operations, it might be considered a serious accident.

Foreseeable risks are as follows:

a. Out of control for cable handling

When shipboard cable tension exceeds the specifications of the cable engine, cable laying can not be controlled. This is most likely with linear cable engines as they have lower holding capability (about 70kN).

b. Damage to the cable system laid

Cable will be damaged mechanically due to extra tension and increase chance of fibre failure.

To avoid above situations, appropriate measures corresponding to the situation should be taken.

Our corrective measure is as follows:

Lowering speed of plough is slower than the ship moving speed in over 700 m depth. This means that the plough weight is held only on the tow rope.

Results

The operational results of the above measure in the trial showed there were no cable tension rises and measured shipboard cable tensions over 700 m depth were as expected. There were no mechanical, electrical or optical defects in the un-buried cable section, plough was touched down on the seabed as in the original procedure.

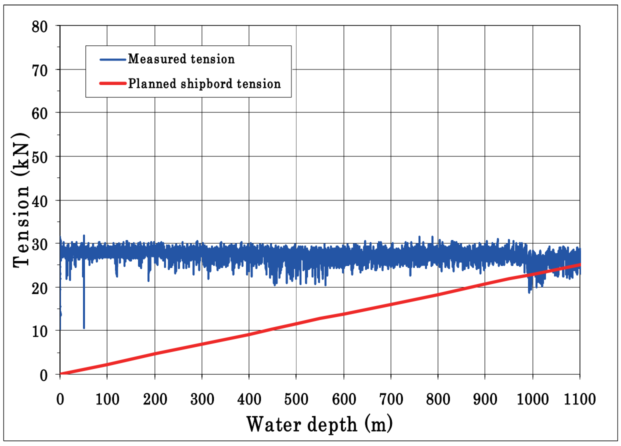

Figure 4 Shipboard cable tension using modified plough lowering procedure

5. The relationship between increasing shipboard tension and location of broken fibres.

Several fibres were broken around un-buried area (KP158-161), where was not suitable for ploughing due to the steep down slope.

Our view of the reason for the fibre broken:

a. Laying plan of the bottom angle for this area was designed as 15 degrees.
b. Bottom angle less than 15 degrees was partially observed by sounding during surface lay.
c. Bottom slack was exceeded over 10% correspond to less than 15 degrees area and lazy turn or loop was formed to the laid cable.
d. When lowering the plough using the original procedure in shallow water, shipboard cable tension increased and extra force was added to the laid un-buried cable.
e. Applying tension to the lazy turn or loop formed a kink and fibres were broken.

Figure.5 shows the recovered damaged portion of fibres.

Figure.5 The recovered un-buried cable of damaged fibres

Verification of the bottom slack percentage in the down slope area by our simulation system

Right side of vertical axis of Figure 1 shows the bottom slack percentages and highlighted mark is shown the peak of the bottom slack in the steep down slope area. Our simulation system calculated over 10% bottom slack in several locations shown in Figure1. Actual fibre break locations correspond well with calculated locations. From these results, function for calculating bottom slack by our simulation system was verified as appropriate.

6. To ensure reliability of cable laying

6.1 Design technique

In order to ensure the reliability of laid cable, bottom slack must be maintained at 2-3%. There is great risk in using simulations to produce slack plans unless they have been validated with real data. Recent trials have given KCS confidence that the simulations are suitable as the results have closely agreed with the observed data.

6.2 Laying work

The slack plan described in above section 6.1 was created by laying simulations. During cable laying, it is necessary to constantly monitor the amount of bottom slack laid. This can be controlled manually or automatically.

Simulations should be conducted in the following situations at the laying design stage of the desk top study:

a. When sudden changing in seabed slope of more than 5 degree.
b. When laying repeaters, junction boxes or cable transitions.
c. When altering course in greater than 10 degrees.

7. Postscript

During this plough trial, a procedure was established for lowering the plough in deep-sea areas. Also, our simulation system was verified when an inaccuracy in the seabed survey resulted in cable damage. When using better survey data, the simulation system accurately showed the areas of bottom slack that resulted in cable failures.

KCS believe firmly that it is most economic to use simultaneous lay and plough burial, without using an ROV on another vessel.

Submarine cable technology is also being applied to marine seismic observation system in Japan and is being developed around a wide observation network.

These submarine systems have the same external risk factors as the communication cables. The observation system has made a large contribution to our daily life to reduce the risk of disaster, therefore its worth protecting against fishing activity. In most soil types, ploughing provides effective protection to submarine cables with good economic efficiency.

8. Acknowledgement

We would like to extend sincere appreciation to Mr.Sakaguchi of KCS for his great contributions to this paper.