International Symposium on
HYDROACOUSTICS AND ULTRASONICS
EAA Symposium (formerly 13th FASE Symposium)
Gdańsk-Jurata, 12-16 May 1997

Application of Underwater Hydroacoustic Navigation System in the Research of Submerged Cables and ROV Umbilicals

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ABSTRACT

There is several algorythms known for a computer simulation of tethers used in underwater vehicles. The results of research done for specific conditions are hardly available. Practically, there is a very limited number of data available for comparision of various calculation algorythms. The described project was directed on comparison of analytical and experimental results of the sumberged cables behaviour subjected to 3-D water flow. Experimental data were obtained in a part during tests of cable models in circular water tank. Real sea condition measurements done at full scale with ROV and underwater towed vehicles.were done to compare data from test tank with reality. Sumerged cable cooridnates were obtained using super short baseline u/w navigation system. Forces inducted in the tethers were also measured using special measurement methods. The paper describes major problems encountered during use of the ORE LXT u/w navigation system and summarises experience with real underwater systems used in the research.

INTRODUCTION

Majority of underwater vehicles operate with special tethers which are used as power supply and communication link with surface positioned control center. There are various tether configurations with a size ranging from several meters up to more than 12000 m in deep diving remotely operated systems. The diameter of tether varies from 2-3mm up to 20-30 mm and even more. Tethers are subjected to 3-D water flow which is major source of drag forces in ROV systems. Influence of water inducted phenomena in tethers is the most important limiting factor in operational footprint and total performance of the ROV system.

FULL SCALE TEST DESCRIPTION

The knowledge of tether shape and forces induced by ROV system and sea environment is crucial for estimation of performance of analytical cable simulation methods. Determination of the tether shape in a test tank is not technically difficult. Real scale tests require quite different approach for obtaining coordinates of sumerged umbilicals. Application of optical methods is limited to certain cases where cable shape could be visualised by buoys or the water transparency is very good. Also a way of looking at the total cable shape is required and this could be achieved using helicopters as observation platform. Such method was used by dr Darski during research of mine sweeping gear in late 80-ties. The use of similar methods do not lead to a valuable results in case of ROVs and their tethers. The only method which could be practically applied is hydroacoustic position measurement. Initially, the use of obstacle avoidance ROV sonar was planned by us for this purpose. We have got positive reference from fishing net sonar supplier (TRITECH) regarding line shape visalisation in the fishing gear operation. ROV tethers are smaller in diameter when compared with towed net ropes. Moreover, ROV umbilicals generally do not use additional floats as the ROV umbilicals are neutrally buoyant. However, the use of scanning sonar could lead to good results in 2-D tether shape (tow systems cable shape) it is not reliable for 3-D cable shape determination. Availability of ORE LXT super short baseline u/w navigation system in Dept. of Underwater Technology of the Technical University of Gdańsk pushed us towards the use of this system in our research of submerged cables behaviour in real sea conditions.

INSTRUMENTATION

A full set of instrumentation was not available during the project planning so a very little operational experience was available for suitable experiments planning. Finally, the instrumantation used for full scale tether configurations measurements included:

A. Measurement system
- A1 ORE LXT u/w navigation system
- A2 V-Fin for hydrophone mounting

B. Tether operated equipment
- B1 CORAL AT - Remotely Operated Vehicle
- B2 Plankton echosounder tow-fish
- B3 Guildline STD Probe

A general idea of tow-cable measurement is given in Fig.1 U/w navigation system used during tests is a small portable system with capability of tracking up to 2 transponders/responders simultaneously. There is also a possibility of tracking the additional one transponder in slightly delayed mode. This soloution was the only available at the time of the full scale tests. It proved to be working well and the recorded data provides good quality data on position of selected points.

The main limitation of LXT system used in our measurements is limited number of transponders which could be tracked at one time. This drawback we hope to overcome during the next series of tests there will be a possibility of application of more powerful ORE TRACKPOINT II with ability of tracking up to 6 transponders. Determination of approximate ROV 3-D tether shape is much easier in this case and could provide almost real time data.

A brief specification of LXT and TRACKPOINT II u/w navigation system is given in a Table 1.

Table 1 **General technical specification of ORE LXT and TRACKPOINT II system used for tether shape determination**

	LXT USBL	TRACKPOINT II USBL
Accuracy	5.0 °	0.3 °
No of tracked targets	2	6 (Parameters for 9 targets stored in memory)
Tracking targets	transponders, responders	transponders, responders, pingers
Power output	400 W	100W or 500 W selectable
Working frequency	Selection of channels	Step 500 Hz
Receivers	22-30 kHz	7-14; 22-30; 28-40; 35-45 kHz
Transmitters	5-30 kHz	4.5-40kHz in500 HZ steps
Audio	Std	Std
Display	LCD	RGB, 7 colours
Displayed information	Range, bearing for 2 targets	Slant range, bearing, horizontal distance, XYZ coordinates
Target Alarms	Not available	Slant range, Bearing, Depth Elapsed Time & Telemetry for each target
Weight	11.4 kg	26 kg
Pitch & Roll Compensation	Not available	Std

TESTING AT BALTIC SEA

To obtain comparison data for tether behaviour analysis a number of tests was conducted at Baltic waters from a deck of research vessel s/y OCEANIA. The following objectives were planned for testing:

1. Accuracy and repeatability of measurements in stationary conditions
2. Accuracy and repeatability of measurements in dynamic conditions
3. The influence of the hydrophone mounting on the quality of measurements and possibility of improvement of accuracy.

For the first time it was planned to carry out tests during the motion of the ship. Bearing this in mind, we were concerned about suitable fitting of LXT receiving/transmitting hydrophone. The LXT hydrophone ought to be placed in the point optimal for hydroacoustic transmission. This was found to be quite difficult as this required stiff pole mounted to the ship hull with ability of the hydrophone removal for callibration and servicing purposes. Also the mounting should not pose any problems during ship maneuvring operations. As a result two other ideas were planned for testing:

1. Mounting of the hydrophone with a ballast weight and additional vertical stabilising plane by tensioned lines
2. Mounting of the hydrophone to the V-Fin tail

The first solution was totally arranged on the deck during the cruise and was found to be easy for handling particularly during ship motion. The second was initially prepared in the lab but was modified during the cruise.

The conducted tests included

1. The system callibration - lowering hydrophone and transponders in the known position and position data recording in the agreed schedule
2. Tracking of the towed STD/CTD sensor with known cable length, depth and LXT transponder

3. Tracking of the CORAL AT ROV using u/w hydroacoustic navigation during controlled submergence along the tested cable.

Sample results of determination of STD probe tow-cable shape is given in Fig. 2. As it was expected a very good repeatability of distance measurements was observed. On the other hand angle measurements were much more dispersed. A potential reason for such behaviour were small rotations of the LXT hydrophone induced by water flaw around the ship hull. The small angle oscillations resulted from „flexible" mounting of the hydrophone and this was almost impossible to be eliminated duing this tests. The use of ballasted and stabilised hydrophone by small vertical plane and suspended on 3 lines appeared to be easy and reliable solution in the speed range of up to 3-3.5 m/s. To avoid shadowing of the transponder by a ship hull the hydrophone was operated from oceanographic davit. Using this device we were able set a hydrophone submergence depth into position calculation.

Operation of the hydrophone from a V-Fin which was towed along the ship side was an exciting experience. V-Fin is a very stable platform for the hydrophone placement but some precautions must always be taken into account to avoid operational problems. First of all, the 10m hydrophone cable was to short for operation at see. Longer 30m cable appeared to be sufficient in length but required much more care during handling. We experienced almost cable cut in the davit sheave during V-Fin lifting up as the hydrophone cable had to be taped to the winch steel lifting rope. Towing V-Fin along the ship hull must be done at depth greater that ships draft to avoid shadowing of the hydrophone. Also potential sucking of the towed vehicle in the direction of the ship hull could occur. Moreover, with greater ship speed the available cable length was to small as the towed vehicle decresed his cruising depth and this worsened the hydrophone operation conditions. The fish which can be used for operation of the underwater navigation system must have greater weight or be able to generate the greater down lifting force. In operation of the tow fish the horizontal trajectory of the towed body is a problem. Any oscillations resulting from wave action and movement transfered from the vessel into the tow fish decrease the quality of the position measurements.

An analysis of such influence is impossible without additional equipment which should include rate gyro and presision flux gate compass. Motion sensor would also be a solution for correction of the hydrophone measurements but this is far beyond our actual financial abilities.

The transponder locations were assumed with repeatability of 0.1 m of the slant range and of 1-5° in angle measurements. The mean accuracesobtained for X,Y,Z are within 3-6m are not sufficient for a computer simulation calculations.

CONLUSIONS

It was proved in a real tests that space configuration of tethers and umbilicals could be measured using hydraacoustic SSBL system. Real time data could be obtained for towed and ROV tether system using different hydrophone placement methods.

A critical for data collection is callibration procedure for hydracoustic instruments. This task is quite complicated when we operate in a real, noisy and multipath environment. A clear evidence of worsening of the registered data with the increased ship speed and sea state was also indicated in both methods path environment.

According to the results obtained, transponders fixed to the tether has little influence on its shape. Their influence on tether shape could be estimated by introduction of a locally induced forces

Literature

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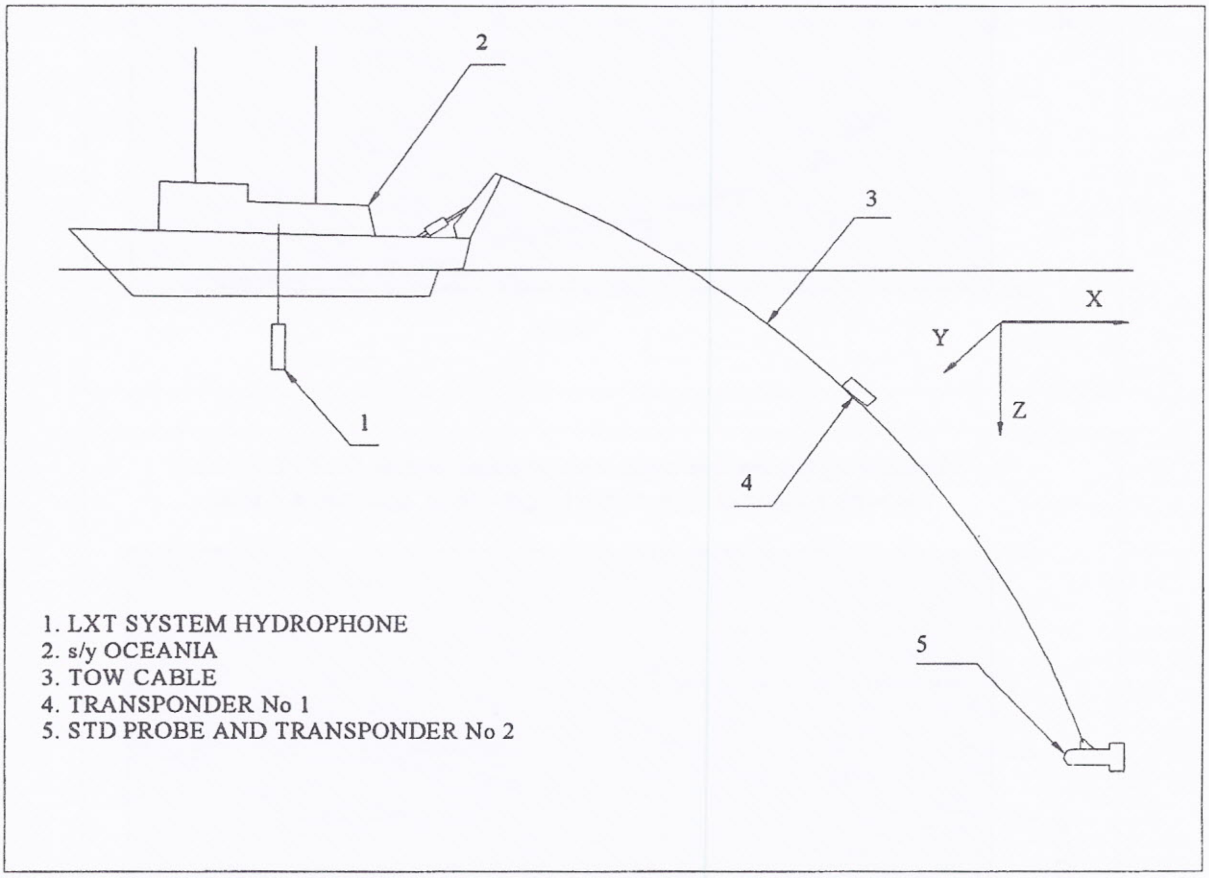
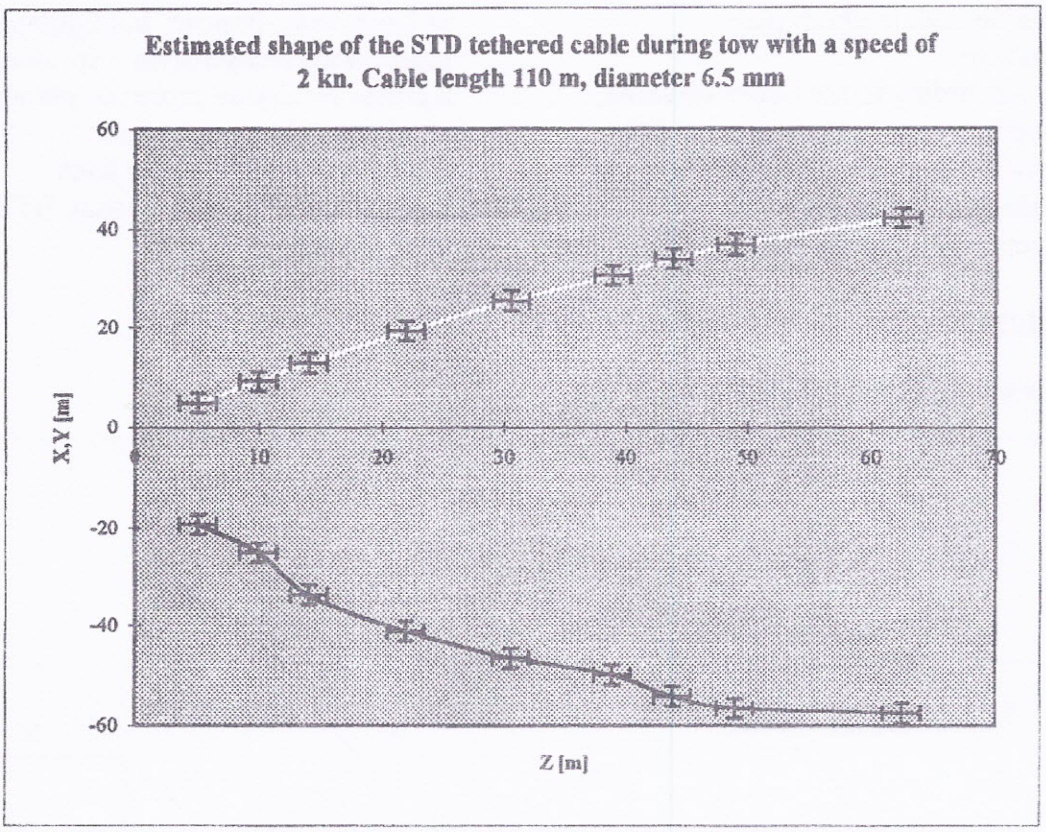


Fig.1. General idea of measurement of the tow cable shape.


Estimated shape of the STD tethered cable during tow with a speed of 2 kn. Cable length 110 m, diameter 6.5 mm
X,Y [m]
Z [m]

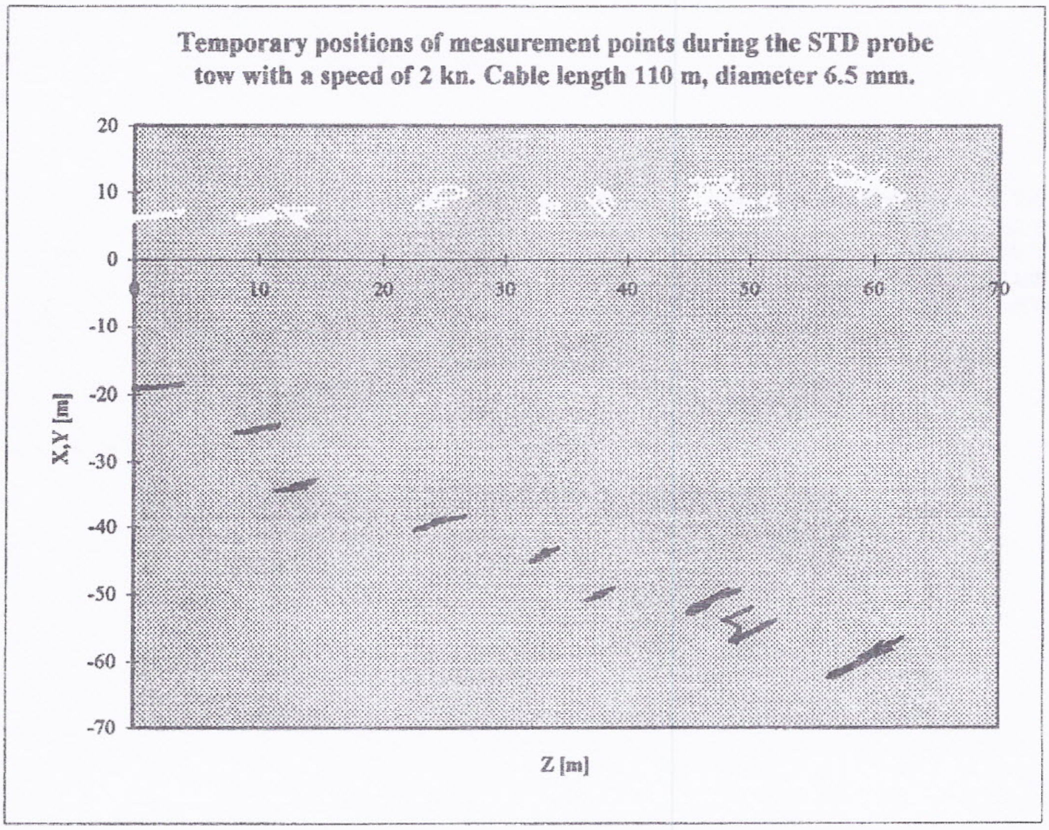

Temporary positions of measurement points during the STD probe tow with a speed of 2 kn. Cable length 110 m, diameter 6.5 mm.
X,Y [m]
Z [m]

Fig. 2