EXPERIMENTAL RESULTS OF THE REAL TIME SIMULATION SYSTEM (RTSS) FOR CABLE INSTALLATION EMPLOYING A KALMAN FILTER ALGORITHM

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Abstract: The most important factor in optimal laying of the submarine cable is a sense of the appropriate cable tensions and slack along the planned route. To establish of laying technology of the submarine cable without formation of kink or suspension on the seabed, several numerical simulation systems using three dimension dynamic models were developed in a software companies or ship's operators. However, the simulated results have not been evaluated to compare with the actual laid position of repeaters and the cable slack on the seabed. This paper describes the newly developed RTSS for cable installation employing "Kalman filter" to improve accuracy, stability and actual results obtained offshore.

1 INTRODUCTION

KCS have been developing the RTSS for the cable installation since 2000. The key technology of RTSS was developed by KDDI R&D Laboratories Inc. in 1988. The original RTSS could only analyze the dynamic behavior of cable in the sea based on pre-defined parameters. We tried to analyze the behavior by above system inputting the actual data measured onboard in March 2004. However the system could not continue to analyze the data according to its design because some of the measured data for RTSS were fluctuating due to ship's pitching and rolling etc. To eliminate the effects by fluctuating data, several smoothing techniques using actual measured data were evaluated and finally Kalman filtering was adopted. This resulted in smooth data which were very closer to the actual situation than those by others. In August 2004, we had a valuable opportunity to evaluate the modified system during the installation of RSCS (Real Time Seismic Cable System) offshore Japan. After laid it, we had confirmed the sensor of RSCS of actual position by HPR (LBL, SSBL) and the bottom slack condition of laid cable on the sea bed by TV camera of ROV. We compared the calculated position and bottom slack by RTSS onboard to the actual observed data. The calculated data of position by RTSS was very match up to the observed data and confirmed that the bottom slack percentage is suited to less than 4 percent at flat area.

2 AN OUTLINE OF THE RTSS

2.1 Algorithm of the RTSS

Conventional models for the cable laying and recovery of submarine cables deal with behavior of the cable in a steady state. However actual cable laying should be considered complex condition such as ship speed, current, repeaters at a same time.

Flow of RTSS (numerical simulation) is shown in Figure.1. [1]

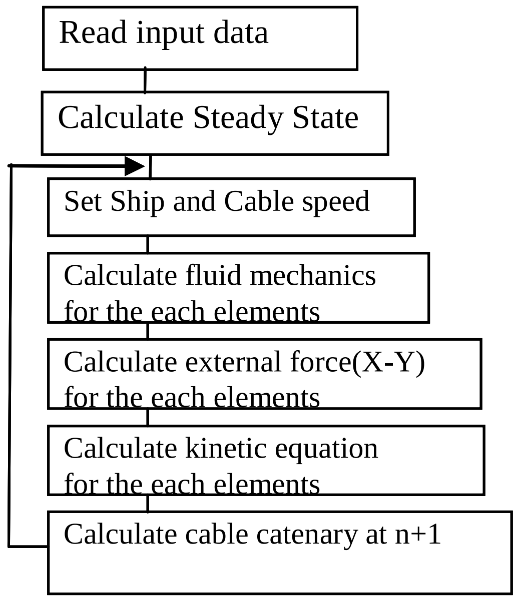

Figure 1: Flow of RTSS

The simulation system can calculate pre-defined several right parameters. Prior to configure to the ship's measurement devices, we confirmed a validity of result on the developed system based on the steady state parameters. Upon satisfied above- mentioned result, we decided to configure the RTSS to the ship's measurement devices.

2.2 The configuration of the rtss and result of filtering

The configuration of our developed system is shown Figure 2[2].

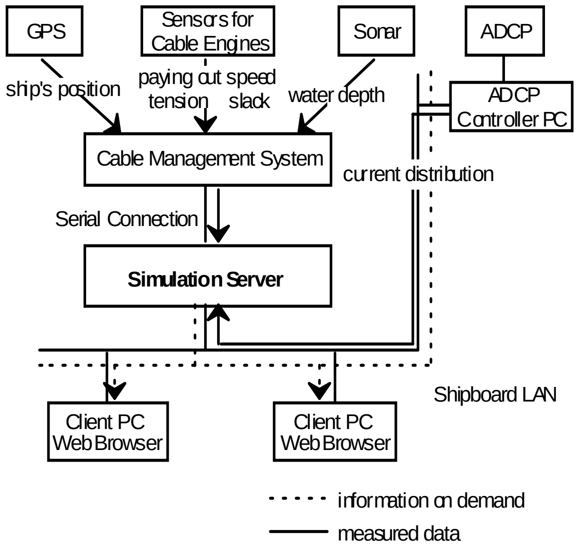

Figure 2: System Configuration

To avoid malfunction of the system due to fluctuating data, we applied "Kalman Filter" for all ship's measurement devices in the RTSS.

The RTSS receives the necessary data from the ship's measurement devices and provides a simulation based on filtered data. For example of filtering, the onboard tension and it's filtered data is shown in Figure 3.

The onboard tension is very fluctuating approximately from 3 to -0.5 tons in a few seconds due to rough sea (Sea state 6). An obvious fact, the filtered tension shows accurately tracing of predicting real value and it is improving on fluctuations in the difference. Simulated onboard tension is calculated by the RTSS based on pre-defined physical parameter. Therefore it is not affected by ship's dynamic factor. Obviously, filtered tension is matched up to simulated onboard tension and both results are corresponding very well. The RTSS uses the following data.

a) Ship's position, b) Ship's speed and distance, c) Gyro, d) Cable speed and distance, e) Current by ADCP (Acoustic Doppler Current Profiler)

Each filtered data were very stable same as above-mentioned filtered tension and we confirmed that the RTSS can maintain calculation without divergence due to ship's motion.

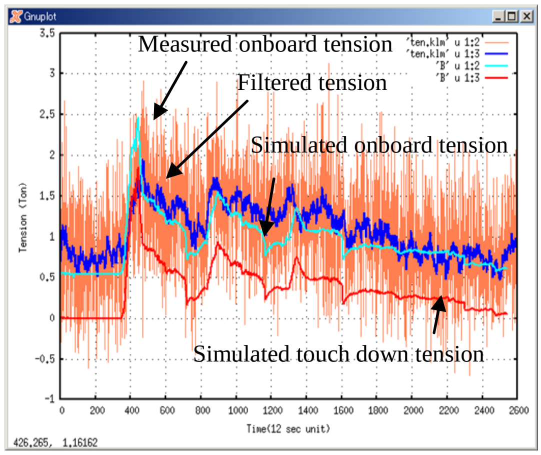

Figure 3:. Filtered result of on board tension

3 VERIFICATION OF THE SYSTEM ACCURACY ON THE FIELD TEST

3.1 Desk study of laid position and cable condition on the seabed

We tried to apply the developed system for the seismic survey near off east of Japan where water depth was 1,200 to 2,000m in 2002. The seismic system was configured 17 sensors and each sensor was connected by 3km of OS-LW type cable.The configuration of seismic survey is shown in Figure 4.

To be function the seismic system in good condition on the bottom after laid, we had to consider following points.

a) To be touched down all seismic sensor to the sea bed surely. Therefore we made up a laying plan as 4% target of bottom cable slack percentage in flat area basically. After that, simulated on 2 dimensions several times based on the modified laying plan and finalized it as desk study. Simulated graphs are shown Figure 5. Result of this simulation, we are assured that the finalized laying plan have validity of this project.

b) To be laid a seismic sensor to the planned bottom position. Also we checked estimated touch down position of each sensors using same simulation program as planned position.

3.2 Result of laid position and cable condition on the seabed

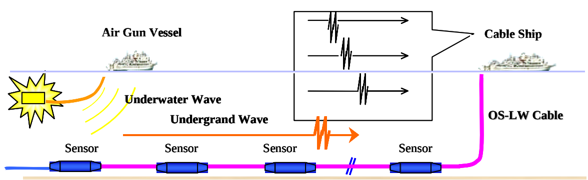

Figure 4: Configuration of the seismic survey

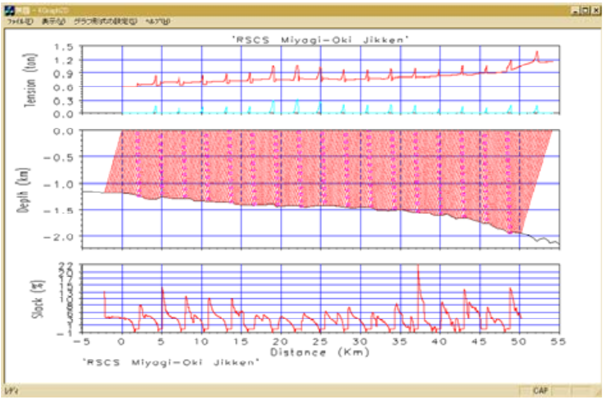

Figure5: Desk study of simulation

We laid approximately 50km in total length and 17 seismic sensors. One transponder was attached near the seismic sensors No.17. To establish placement accuracy, the transponder position was measured by the air gun vessel using LBL (Long Base Line Acoustic System) navigation systems and tried to confirm the laid sensor and cable condition on the seabed by swimming ROV camera. The placement accuracy is shown in Table 1 (see Section 6).

Result of the placement accuracy of the water depth for inline and lateral direction is as follows.

a) Inline direction

Simulation accuracy was approximately less than 1.8% and accuracy based on onboard tension was less than 2.7%.

b) Lateral direction

Simulation accuracy was approximately less than7.6%

Observed laying condition on the bottom:

a) Sensor was touched down on the sea bed and the lower part of cylinder was sunk to the sea bed.

Observed laid condition of a sensor is shown Figure 6.

b) Cable was touched down on the seabed in straight condition.

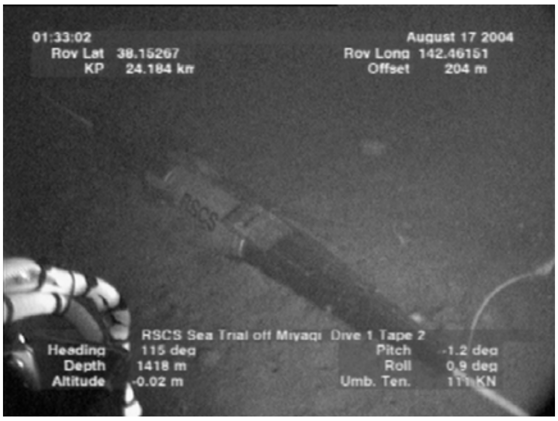

Figure 6: Laid condition of the RSCS

3.3 Bottom slack

We confirmed a proper bottom slack is 4% or less in flat area without marked meanderer or loop, however if the bottom slack percentage exceed over 4%, the meanderer will be occurred on the laid cable and make a formation of loop in an approximately 10%. The meanderer of laid cable in the bottom slack percentage approximately 6 percent is shown Figure 7.

Figure 7: The meanderer of laid cable

4 CONCLUSION

We could not calculate bottom slack and touchdown position for lateral direction automatically before developing the RTSS in real time. Similar tools have been developed in the world and they are applying cable project based on their verification. Our engineering of the real time monitoring during cable lay was reached approximately 5 years behind for other developed tools. However we got various valuable experiences in a developing process and this valuable technology will be taken over our next generation continuously to maintain one of the cable engineering technique. Developed the RTSS will contribute to maintain reliability for long run cable security. Also we have been developed the GIS (Geographic Information System) –MAPS in parallel. In future, both systems will collaborate and laying installation process will improve in the planning and installation process.

5 REFERENCES

[1] J.Kojima, M.Nasu “Numerical simulation of laying and recovery of optical submarine cable and branching unit” Proc. of Suboptic ‘94, pp.480-481, 1994.

[2] K.Ogaki , Y.Ogasawara “The development of real-time numerical simulation system for laying and recovery of cable” Proc. of Suboptic ‘00, pp.579-580,2000.

6 TABLE

Sensor No.	Touchdown KP on inline direction						(D) Depth [km]	Difference of lateral direction		
	(A) KP estimated by onboard tension[km]	(B) Simulation result [km]	(C) Measured by HPR [km]		Error (B)-(A) / (D) [%]	Error (B)-(C) / (D) [%]		(E) Simulation result [m]	(F) Measured by HPR [m]	Error (E)-(F) / (D) [%]
17	6.867	6.888	Transponder	6.901	1.7	-1.0	1.243	195.85	287	-7.3
16	9.735	9.788	-	-	4.2	-	1.266	172.98	-	-
15	12.611	12.630	-	-	1.5	-	1.295	155.42	-	-
14	15.443	15.467	-	-	1.8	-	1.346	154.04	-	-
13	18.387	18.362	-	-	-1.8	-	1.370	146.30	-	-
12	21.310	21.310	-	-	0.0	-	1.412	106.95	-	-
11	24.203	24.212	ROV	24.190	0.6	1.5	1.439	92.45	202	-7.6
10	27.135	27.139	ROV	27.113	0.3	1.8	1.427	68.54	162	-6.5
9	30.062	30.084	-	-	1.6	-	1.415	36.82	-	-
8	33.001	33.004	-	-	0.2	-	1.455	-50.32	-	-
7	35.932	35.950	-	-	1.2	-	1.458	-84.92	-	-
6	38.847	38.882	-	-	2.3	-	1.508	-92.88	-	-
5	41.780	41.817	-	-	2.4	-	1.553	-98.41	-	-
4	44.732	44.755	-	-	1.4	-	1.606	-102.96	-	-
3	47.625	47.635	-	-	0.6	-	1.667	-114.14	-	-
2	50.572	50.556	-	-	-0.9	-	1.762	-91.79	-	-
1	53.442	53.437	-	-	-0.3	-	1.933	-88.54	-	-

Table 1