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Evaluation of Underwater Cable Burying ROV through Sea Trial at East Sea ⋆

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Abstract: Underwater cable burying is one of main cable protection methods in the offshore cable installation. In this paper, the performance evaluation of an underwater cable burying robot, named URI-T, through the sea trial is addressed. URI-T, the first heavy-duty underwater robot for cable burying tasks developed in South Korea, is designed to perform burying tasks and maintenance tasks for underwater cables and small-size pipes at the sea bed of 2,500m water depth. URI-T includes water-jetting systems and cable detection sensors for cable burying tasks, and employes mainpulators and tools for cable maintenance tasks. The sea trial at the East Sea having 500m water depth was focused to verify the key performance indices: operation water depth, cable burying depth, cable burying speed, and forward speed. The cable maintenance ability was also examined by carrying out the cable cutting test and the cable gripping test. Moreover, applicability of URI-T is also evaluated by two times of cable burying experiments more than 100m distance. As a result, it was verified not only that URI-T satisfies the target performance indicies, but also that URI-T is applicable for the cable burying construction.

Keywords: Underwater cable burial, heavy-duty underwater robot, sea trial, URI-T(Underwater Robotics It's Trencher), ROV(Remotely Operated Vehicle)

1. INTRODUCTION

In the ocean, a space having limitation of human accessibility, many kinds of tasks have been performed by using underwater robots(Christ and Wernli Sr (2014);Yuh (2000)). One of the tasks is installation of underwater cables, which includes HVDC(High Voltage Direct Current) cables between lands and islands, underwater communication cables, underwater cables for ocean energy development as offshore wind power. The cables installed in the seabed are easy to be exposed to risks of damage: risk induced by human like fishery actions, risk due to disaster as typhoon, etc. Thus, appropriate methods to protect the cables from the risks are required. One of mainly used protection technique is to bury the cables below the seabed. However, cable burying methods are usually performed in the deep sea where people are hard to access, and require high power. Thus, large size underwater robots for heavy-duty tasks are used for the cable burying tasks.

Recently, URI-T(Underwater Robotics It's Trencher), a heavy-duty ROV(Remotely Operated Vehicle) for cable burying tasks, is under developing in South Korea (Li et al. (2014);Li et al. (2015);Kang et al. (2019b)). URI-T is an underwater robot which can perform burying tasks and maintenance tasks of cables or small-size pipes, on the seabed having water depth of 2,500m. URI-T, 6.5m length and 21 tons weight in the air, involves high pressure water-jetting system for cable burying tasks, and manipulators and relevant tools for cable maintenance tasks.

When developing large scale underwater robots like URI-T, performance verification is very important because the performance is key index to make decision whether the robot can perform the construction or how long the construction takes, etc. If there is accident during the construction, moreover, temporal and economical loss may be substantial because the accessibility for the human or recovery equipments is limited in the underwater environment. Thus, thorough verification is required before deploying the robot into the construction. However, the performance verification is hard to be carried out because the test site is limited due to the huge size of the robot. Even large water tanks can be used only for functionality check for the robots because the motion range of the robot is limited. Therefore, full scale verification of huge size ROVs like URI-T is only possible through the sea trial.

In this research, the performance verification of URI-T through sea tial is addressed. In October 2018, the sea trial was performed at the East Sea having 500m water depth in South Korea. The purpose of the sea trial includes i) to check the functionality of URI-T, ii) to verify operation ability through the robot, winch systems, and operation systems on the vessels, iii) to evaluate the key performance indices regarding cable burying abilities: cable burying depth, cable burying speed, and forward speed in floating state, etc.

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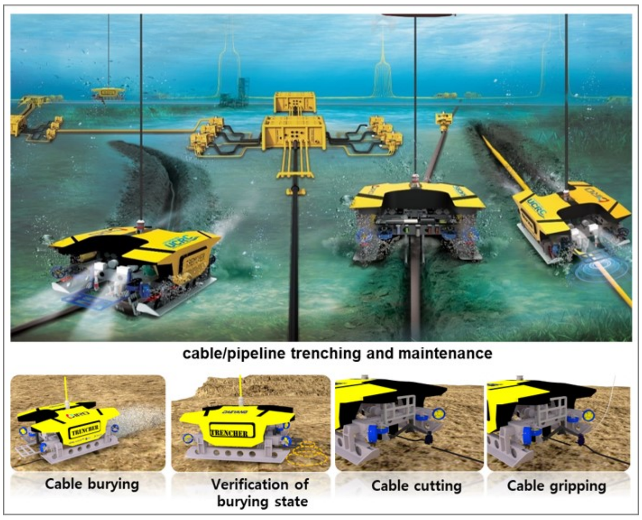

Fig. 1. Concept and main tasks of URI-T

2. URI-T, A CABLE BURYING ROV

2.1 Purpose of URI-T

URI-T is a robot for the tasks regarding uderwater cable burial. The concept and main tasks are illustrated in Fig.1. As shown in Fig.1, URI-T can bury the cables by using the water-jetting system. URI-T equips the cable detection sensors for verification of the burial state of the cables. URI-T also has manipulators and tools for the cable maintenance tasks: cutting task for damaged cables, and gripping task for recovering the cables onto the vessels.

The key performance indices of URI-T is briefly introduced in Table 1. Recently, cable burying construction is expanded rapidly to the deep sea around 2,000m; thus, URI-T is designed to be operated on the seabed with 2,500m water depth. Besides, the cable burial performance is dependent on the soil state of the seabed. The indices in Table 1 is for the case when the sea bed is sand. If the soil of sea bed is cohesive, the speed and depth for single trenching is adjusted according to the hardness of the sea bed; in the case, the trenching is carried out repeatedly until the cable is buried to the target depth. Forward speed is the speed when URI-T is on floating state, and is the index for moving to the target site under disturbances like sea currents.

Table 1. Performance specification of URI-T

Contents	Specification
Max. water depth	2,500m
Max. burying depth	3.0m
Max. burying speed	2.0km/hr @ 1m burying depth
Max. forward speed	3.0knots(5.56 km/hr)

2.2 Outlines of URI-T

The system configuration of URI-T is illustrated in Fig. 2. The system includes the ROV and the support systems on the vessels: the operation van, power vans, and the winch systems for the power transmission and communication. The shape of URI-T is depicted in Fig. 3, and the detailed specification of URI-T is arranged in Table 2. URI-T includes equipments specialized for the cable burying tasks, which are briefly introduced in the following.

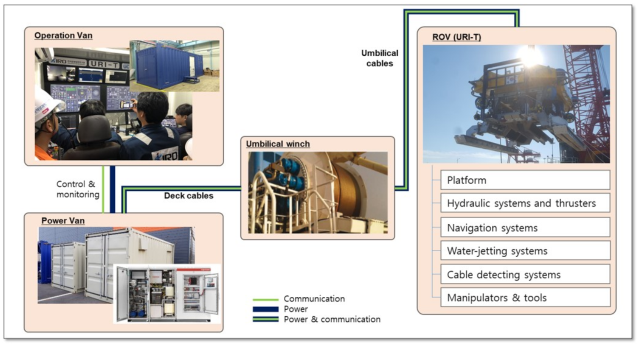

Fig. 2. System configuration

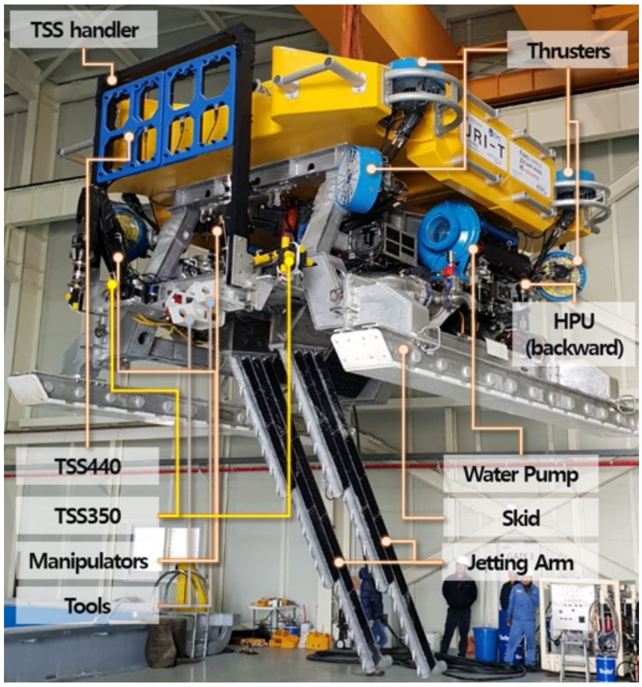

Fig. 3. URI-T, a cable burying trencher

Power and propulsion system: URI-T includes HPU (Hydraulic Power Unit) of 250kW. The HPU coverts the electric power transmitted from the umbilical cables into hydraulic power which is used for the thrusters and actuators for robot motion: motions of water-jetting arms, TSS handler, manipulators and tools, etc. URI-T also has eight hydraulic thrusters: four is for vertical motion, and the other four is for lateral motion. In URI-T, auto control function like auto heading is implemented(Cho et al. (2019)); the power distribution issues regarding motion control was also studied(Kang et al. (2019a)).

Equipments for cable burying tasks: For the cable burying tasks and verification of cable burial state, the position of the underwater cables needs to be measured. To identify the cable position, URI-T includes the cable detection sensors: TSS350 and TSS440. TSS350 detects the cable position by utilizing the tone signal which is supplied intentionally into the cables; TSS440 detects steel materials under sea bed for the small-size pipe detection. As shown in Fig. 3, TSS440 is installed on the TSS

Table 2. HW specification of URI-T

Contents	Items	Specification
Size		6.5 × 4.5 × 3.5 m(LWH)
Weight		21,280kg(air) / 540kg(water)
Hydraulic system	HPU power	250kW
	Thrusters	Max. 10.5kN×8EA
Navigation system	IMU	GH1700, Honeywell
	DVL	WHN600K3, Teledyne
	Depth sensor	Series8000, Paroscientific
	Multibeam sonar	M900-250, Blueview
	USBL	WMT,Sonardyne
Cable burying system	Water pump	986m^3/hr(@9bar, 224kW) ×2EA
	Vertical motion	-0.96 ∼ 3.03m(@endtip of jetting arms)
	Lateral motion	0.2 ∼ 0.7m(gap between the two jetting arms)
	Cable detection	TSS350 & TSS440, Teledyne
Cable maintenance system	Manipulator	7 function & 5 function, KNR systems
	cutting tool	690bar cutting pressure
	gripping tool	25tonf gripping force

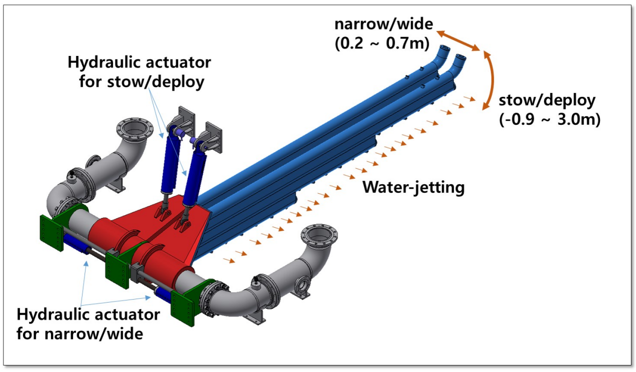

Fig. 4. Motion of water-jetting system

handler, which can fold and unfold the TSS440 sensor. URI-T employs water-jetting system for cable burying tasks. As shown in Fig. 3, on the below of URI-T, there are two jetting arms, each of which can inject the water of 986m^3/hr at 9 bar. The positions of the jetting arms are adjustable as illustrated in Fig. 4.

Equipements for cable maintenance: For the cable maintenance, URI-T includes manipulators and tools as shown in Fig. 5. If there is any problem at the cables on the seabed, the cable needs to be cut and to be recovered to the deck of the vessel. Appropriate repairment for the cable would be performed on the deck, and then, the cable would be re-installed on the seabed. There are two tools included in URI-T: cutting tool is for cable cutting tasks, and the gripping tool is for cable recovery by pulling the towing line which is connected to the gripping tool. For the efficiency of the manipulation, the assistance technique using touch screen have been studied, of which detailed results can be refered to Cho et al. (2017), Cho et al. (2018).

2.3 Development status of URI-T

From January 2014 to March 2019, URI-T system was developed. The development includes two times of shallow sea tests and the sea trial at 500m water depth. During the shallow sea tests, the performance indices in Table 1 except for operation water depth was verified(Kang et al. (2019b)). During the sea trial, the performance indices including operation water depth of 500m was verified, and the usuability for cable burying construction

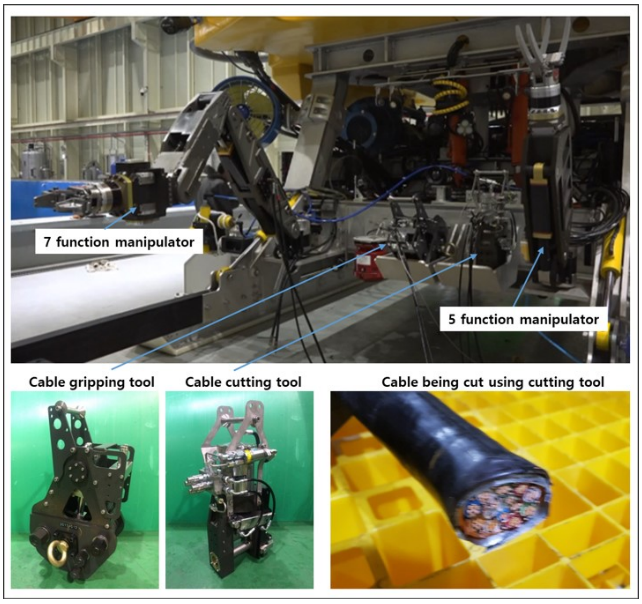

Fig. 5. Equipments for cable maintenance

is examined. Nowadays, 2nd phase of developement for URI-T is undergoing to make field demonstration and to obtain track-records of construction. Regarding the trend for expanding offshore energy development, we expect that URI-T, the first cable burying ROV in South Korea, can be used widely in near future.

This paper focuses on the results of the sea trial, which are introduced in details in the following section.

3. SEA TRIAL OF URI-T AT 500M WATER DEPTH

3.1 Purpose and scenario

In October 2018, we performed the sea trial of URI-T. The main purpose of the sea trial is to evaluate the performance of URI-T which are introduced in Table 1. Besides, the functionality of URI-T and the manipulation for cable maintenance are also examined. In the Table 1, the target performance of maximum water depth for this sea trial is adjusted to 500m due to the limitation of umbilical cables: Until now, umbilical cable for 500m depth is prepared, and, during 2nd phase development, umbillical for 2,500m

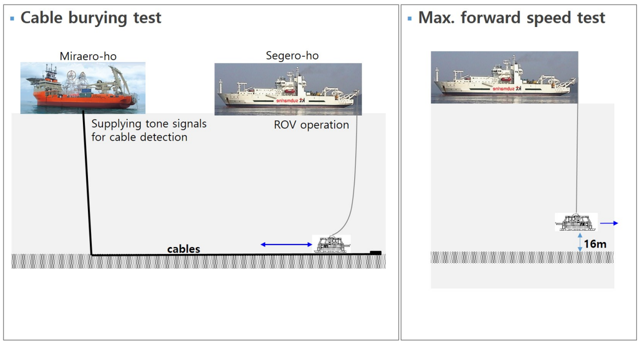

Fig. 6. Scenarios for the sea trial

Fig. 7. Launching of URI-T from Segero-ho

depth will be developed. The test site is located at the East Sea where is about 40 km far from the East coast of Pohang city, South Korea. The waterdepth of the test site is about 490m $\sim$ 520m.

There are two main scenarios for the sea trial as illustrated in Fig. 6. The first one is for the cable burying test. Two ships having dynamic positioning function are used for the test: One is for the operation of URI-T, and the other is for supplying tone signal to the cables for detection using TSS350 cable sensor. The first scenario is used for the testing the cable burying depth and burying speed. The second scenario is for the forward speed. In the scenario, URI-T is floated about 16m from the seabed, and URI-T is fully actuated with the thrusters.

For the operation of URI-T during the sea trial, Segero-ho, a cable laying vessel of KT submarine, was mobilized. Segero-ho is a specialized ship for cable laying and burying, and employs equipments for cable installation tasks: a A-frame for launch and recovery of cable burying ROV, cable tank and transporters for cable laying, dynamic positioning function, etc. Fig. 7 shows the URI-T launched from Segero-ho. Besides, another ship, Mirero-ho, was mobilized to supply the tone signal for the detection of underwater cables.

3.2 Verification for operation waterdepth

The operation warterdepth was verifyed by performing all experiments at 500 waterdepth, including water-jetting functional test, cable burying and survey test, cable cutting and gripping test. Fig. 8 shows the scenes and waterdepths of every experiments under performing. Over the 20 hours totally, the experiments on the seabed around

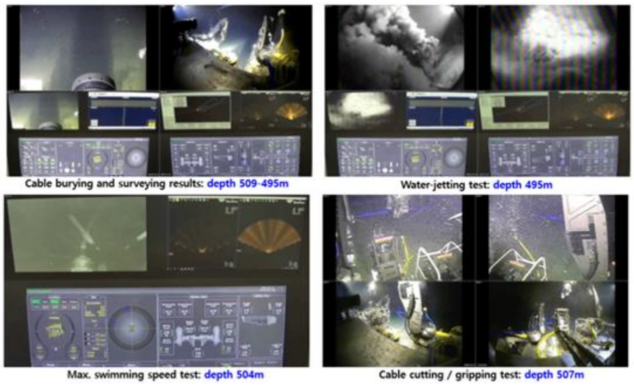

Fig. 8. Verification for operation waterdepth

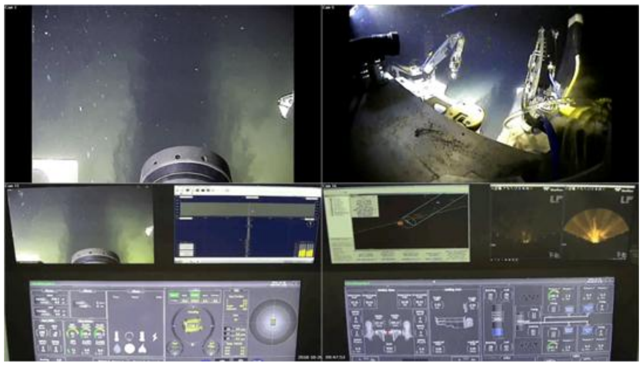

Fig. 9. Survey for results of cable burying depth test

500m waterdepth were carried out, verifying fully that the URI-T is utilizable at waterdepth of 500m.

3.3 Verification for cable burying depth

For the trenching ability test, we tried to trench 3m depth at once for more than the minimum valid distance, 5m. The experiments was performed on the seabed at 509m waterdepth where have never been trenched before. The jetting-arms are fully deployed(3.03m treching depth), and trenches about 7m, verifying the trenching performance of URI-T.

For the operation ability test, we tried to bury the underwater cables by trenching 3m depth for more than 100m distance. The test was performed on the seabed with 495$\sim$ 499m waterdepth, where the underwater cables for trenching test is pre-installed on the seabed. The target trenching depth, 3m, is reached by three times of trenching: 1.2m depth, 2.2m depth, and finally 3.03m depth. The cable burying results are also surveyed by using URI-T: while URI-T moves along the cable path, the status of treching and cable burial are checked by cameras and cable detection sensors. Fig. 9 shows the survey results. In the camera images of Fig. 9, one can find deep and uniform ditch which is created by the trenching. Cable burial depth is also checked using the cable detection sensor, TSS 350, which indicated that the underwater cable was buried about 2.4m below the seabed.

3.4 Verification for cable burying speed

The performance regarding cable burying speed is examined by two steps. At first, we checked the functionality of

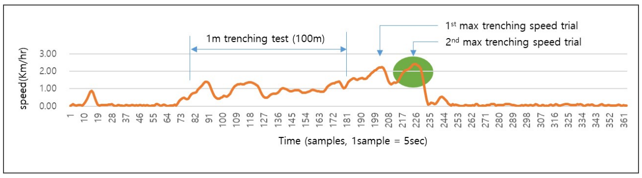

Fig. 10. Speed during cable burying with 1m depth

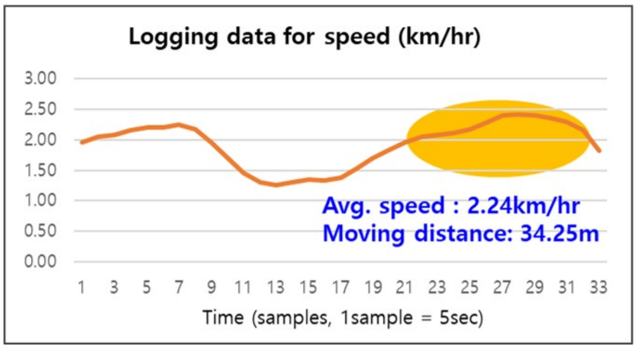

Fig. 11. Speed during cable burying speed test

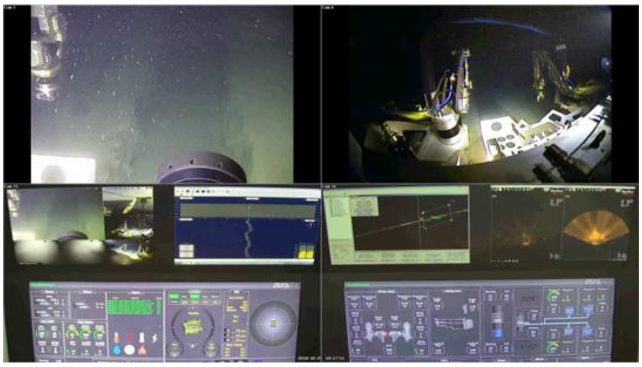

Fig. 12. Survey for results of cable burying speed test

URI-T by treching on the underwater cables with about 1m depth for more than 100m distance. Then, we tried to propulse URI-T with maximum speed while maintaining trenching. The test was performed on the seabed having 499∼502m waterdepth.

Fig. 10 shows the forward speed of URI-T which is measured from Segero-ho, the vessel for operation of URI-T. As indicated in Fig. 10, we tried two times for the maximum burying speed test. Fig. 11 shows the forward speed during the second trial. In the second trial, URI-T moves for 34.25m with averaged speed of 2.24km/hr, which fulfills the target performance(2km/hr).

As shown in Fig. 12, the cable burying results were surveyed using URI-T. One can find the ditch which was trenched by URI-T in the camera images of Fig. 12. The cable burial status also measured by using cable detection sensors, which indicates that the underwater cables are located at 0.8 depth below the seabed.

3.5 Verification for forward speed

The performance regarding forward speed was examined. URI-T was floated in the middle of water having 504m water depth and 16 m altitude from the seabed; then, URI-T was fully thrusted. Fig. 13 shows the forward speed

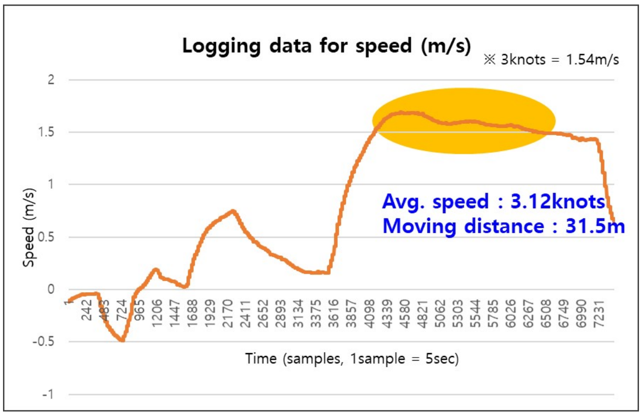

Fig. 13. Speed during forward speed test

of URI-T measured from the operation vessel. As shown in Fig. 13, URI-T swimmed along 31.5m distance with averaged speed of 3.12knots(5.78km/hr), satisfying the target performance of 3knots.

3.6 Verification for cable maintenance

As shown in Fig. 5, the cable gripping and cable cutting tasks are carried out successfully on the seabed having 507m waterdepth. Using the manipulator, gripping tools is took out from the bucket of URI-T, and is installed to the cable. Then, the cable is gripped and the gripping state is checked by pulling up the gripping tool. Similarily, cable cutting test is performed by intalling the cutting tool to the cable and cutting the cable using the tool. Fig. 15 shows the test cables for the maintenance experiments, which is cut by using the cutting tool on the seabed.

3.7 Summary on sea trial results

The quantative results of the sea trial is arranged in Table 3. The results fulfills the target performance of URI-T. During the experiments over 20 hours on the seabed, the key performance indices were verified; the applicability of URI-T also examined by long distance trenching test over 100m; fuctionalities for the cable maintenance are also tested by performing the cable gripping tasks and the cable cutting tasks.

Table 3. Goal and Results of sea trial

Contents	Goal	Results
Max. water depth(m)	500(design spec.: 2,500)	509.4
Max. burying depth(m)	3.0	3.03
Max. burying speed(km/hr)	2.0	2.24
Max. forward speed(knots)	3.0	3.12

4. CONCLUSION

In this paper, the sea trial results of URI-T is addressed. URI-T is an underwater ROV for burying tasks and maintenance tasks of underwater cables and small-size pipes. URI-T includes water-jetting systems and cable detection sensors for cable burying tasks, and employs manipulators and tools for cable maintenance tasks. The sea trial at the East Sea having 500m water depth was focused to verify the key performance indices: operation

Fig. 14. Test for cable maintenance

Fig. 15. Cable cut by cutting tool

water depth, cable burying depth, cable burying speed, and forward speed. The cable maintenance ability was also examined by carrying out the cable cutting test and the cable gripping test. Moreover, applicability for cable burying construction is also evaluated by two times of cable burying experiments more than 100m distance.

Nowadays, we are trying to obtain track-record for field construnction. We are preparing the underwater construction of water supplying pipes for the island in the South Sea of the Korean Peninsula. We expect that we can find supplement points of URI-T for the commercialized service during the construction.

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