RUBBLE LEVELING ROBOT IN UNDERWATER CONSTRUCTION

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ABSTRACT

In this article, the rubble leveling robot is introduced as an example of robotics in underwater works. This robot is operated remotely by operators on the support vessel to carry out rubble leveling work in the construction of breakwater foundation mounds, taking the place of manual labor of divers. This robot is 8-legged walking robot which shows the outstanding mobility and stability on uneven grounds. Due to this feature, it is applicable to a wide diversity of underwater works.

1. Introduction

Robotics in underwater works has greatly progressed in late years in the field of oil and natural-gas resource development as well as of harbor improvement and cross-channel bridge building works. Various types of underwater robots have been in operation for developing submarine oil fields in the North Sea as a typical example.

Table 1 shows a classification of underwater robots by their types.

The tethered free-swimming type is the most popular today. Making the most of three-dimensional mobility, this type of underwater structures and various kinds of underwater observation work. The bottom-reliant type, through it is lacking in mobility, is suited to underwater works requiring preciseness and large operating force. A variety of this type of robots have been proposed, namely, the crawler type, wheel type, Archimedes's screw type, and legged walking type.[1)]

We have over 20-year experience in research and development of the bottom-reliant type robots for underwater works.[2)] Lately, we have successfully developed the 8-legged walking robot, which features that it can move freely, striding over uneven sea beds which the crawler type robots would not be able to stride over, and it is very stable against tides and large reaction of working force. In this article, the rubble leveling robot is introduced as an example of the newly developed 8-legged walking robots.

2. Circumstances of Development

Rubble leveling work in the construction of breakwater foundation mounds (Fig. 1) has formerly been carried out by manual labor of divers to meet the requirements for highly accurate work. However, inefficient, dangerous, and hard manual labor causes a neck of construction work. To satisfy the requirement for executing highly productive works quickly and safely, development of mechanical methods of construction is the needs of time to take the place of manual labor of divers.

Under such a background, Komatsu started in earnest on research and development of the underwater rubble leveling robot in 1980 and brought out prototype robot system in 1982. After testing for proper function and performance of this system on land and several times of underwater experiments, Komatsu delivered the initial product of the robot system to the user in 1986.

3. Outline of System Structure and Equipment

This robot system consists of the robot body which operates underwater, the on-board equipment such as the control console, electric incoming panel, cabel winch, generator, compressor, laser geodimeter, and levels and the umbilical cables which connect the on-board equipment to the robot body. (See Fig. 2.) Performance of the robot system and specifications of individual devices are shown in Table 2., outline of the major devices is described below.

3.1 Rubble Leveling Robot Body (See Fig. 3.)

The robot body is divided into two parts, namely, the main frame and the locomotive frame. They are slided each other by the sliding mechanism to move the robot in back and forth direction and lateral direction. It is also possible to make a spot turn on the robot body by actuating either of two slide cylinders.

Each frame has four legs which are extended and retracted by the hydraulic cylinders. Two sets of four legs are landed alternately to support the weight of robot body while the two frames are slided each other, so that the robot body can walk in all directions.

Inside of the main frame is a working bogie to which the rake and roller free to lift and lower are fitted. The working bogie can be accurately slided 10 m back and forth along the robot main frame (guide rails). The working bogie has a ultra-sonic topographic-sounding measurement device on its bottom to measure the smoothness of the rubble mound surface.

In front and in the rear of the main frame are float tanks which are filled with compressed air supplied from the support vessel through the air hoses when the robot body surfaces by itself.

3.2 Control Console

The control console is in the control room on the support vessel. The console is equipped with the display panel which indicates the posture of the robot body and operating condition, the X-Y recorder which plots working traces of the rake and roller, and the condition of the leveled surface and the switch panel necessary for operating the robot.

Inside the console is a computer which is used for controlling automatic operation of the robot body and for processing transmission and display of signals.

4. Features

(1) All of underwater leveling work can be carried out safely and accurately by the remotely-controlled robot.

(2) Large-scale underwater works can be performed speedily at working efficiency of about 20 to 40 times larger than manual labor by divers.

(3) Precise adjustment of leveling height by the robot legs and strong finish-compact by the roller provide the highly accurate smoothness of the leveled surface.

(4) Computer-automated control is easy to operate.

(5) Use of the ultra-sonic topographic-sounding measurement device for automatic checking on the executed work largely contributes to labor-saving.

(6) The robot body having float tanks to submerge and surface by itself can easily be moved from a job site to another.

5. Working Procedure

Rubble leveling work is carried out by repeating the working procedure shown in Fig. 4. The following describes each step of work.

(1) Submerged setting

After the towed robot body reaches the surface above the job site, the air vent valve is opened on each float tank to let the robot submerge and land on the rubble foundation mound.

(2) Walking

The position and direction of the robot body is measured with the laser geodimeter and then the robot body is guided to walk to the leveling point. This is performed automatically under the control of the computer.

(3) Level adjustment

The underwater depth of the robot body is measured with the level and the length of landing legs are adjusted until the leveling height agrees with the projected height of finished mound.

(4) Precise horizontal posture

Prior to leveling work, the robot body must be automatically adjusted to a precise horizontal posture (within ±0.14 deg.) adjusting each leg.

(5) Topographical measurement

The working bogie is run along the guide rails with the rake and roller left lifted to measure the topographical conditions with the topographic-sounding measurement device mounted on the bogie. The result of measurement is plotted on the X-Y recorder.

(6) Raking

The rake is lowered to the projected height and the working bogie is run to push out to level the rubble.

(7) Compaction by roller

After raking the surface, the compaction roller presses down any rubble above the projected level, finishing the mound surface uniform.

(8) Topographical measurement

After completion of leveling work, smoothness of the finished topographical condition is measured using the same method as described in (5) to get the finish-inspection data. Since the data of actual configuration can be obtained without being subjected to influence of waves and tides, highly accurate, fine-measurement data, which would never been attained by conventional methods, can be obtained quickly.

(9) Surfacing

The float tanks on the robot body are charged with compressed air supplied from the support vessel through the air hoses, and the robot body surfaces by itself.

6. Actual Working Records

This robot system has borne ample fruits (see Table 3.), successfully exhibitting the planned performance both in accuracy and productivity of work, and has enjoyed a good reputation as the easy-to-operate, highly reliable robot system.

7. Features of 8-legged Walking Type Underwater Robot and Application to Other Underwater Works

The above-mentioned rubble leveling robot is an example of the 8-legged walking type underwater robot which has the features described below.

(1) Since the robot body walk by adjusting the length of each grouping leg, it can stride over uneven sea bottom which the crawler type robots would not be able to stride over.

(2) The robot body always supported by four legs is very stable against tides and large reaction of working force.

(3) Since the robot can easily be maintained in horizontal posture, it is easy to catch the existing condition of the object of works and to finish the surfaces in high degree of accuracy in the case of leveling work.

(4) Robot movement by a fixed pitch of walking is suited to accurate, continuous work.

The 8-legged walking type underwater robots having the above-mentioned features can be used as the base machine for a wide variety of applications. The seabed surveying robot equipped with TV camera, photograph camera, etc. has already been put to practical use to observe the seabed ground conditions and configurations accurately.[4] Other possible applications of the 8-legged walking type underwater robots are as follows:

(1) Underwater digging robot

The robot, equipped with a drum cutter, will be able to dig and level the seabed ground accurately and safely without causing pollution (no dynamite is used.)

(2) Pipeline laying robot

The robot, equipped with a cutter and pump dredger, will be able to dig a V-groove in the seabed along the laid-down pipeline to bury it in the groove.

(3) Underwater dredging robot

The robot, equipped with a cutter and dredging pump, with dredge a harbor to remove mud accumulated on seabed.

(4) Mineral resources mining robot

The robot, equipped with a cutter and mining machine, will be able to extract mineral resources such as manganese nodule, cobalt cluster, etc.

(5) Underwater handling robot

The robot, equipped with manipulators, will be useful for maintenance of underwater structures.

8. Conclusion

Underwater works involves many unfavorable conditions which prevent application of automated work. A variety of underwater robots have been developed only lately with application of remarkably progressed electronics to robotics. There will be a great demands for underwater robots in future with further increase of underwater works under severer conditions. Also, need for underwater robots will develop from the surveying robots used for the observation and measurement purposes to the working robots which actually carry out construction works. Komatsu will make every effort to meet such need of underwater robots by making the best use of 8-legged walking type robot featuring high working accuracy and large productivity.

In this development project, we were favored with the kind guidance and co-operation of Penta-Ocean Construction Co., Ltd.

References

(1) "Investigative report for trend of new underwater technology" Japan Marine Science and Technology Center (May 1984)

(2) T. Naruse and T. Sawano: "Bottom-reliant type robot" WORK VESSEL No. 175 (Jan. 1988)

(3) T. Naruse and others: "Development of rubble leveling robot": pp 35-40, KENSETSU NO KIKAIKA No. 444 (Feb. 1987)

(4) Y. Ishino and others: "Walking robot for underwater construction" Proceedings of '83 International Conference on Advanced Robotics: pp 107-114, (Sept. 1983)

Table 1 Classification of Underwater Robots

Underwater robot	Tethered type	Free-swimming type
		Bottom-reliant type
		Towed type
	Untethered type	Free-swimming type

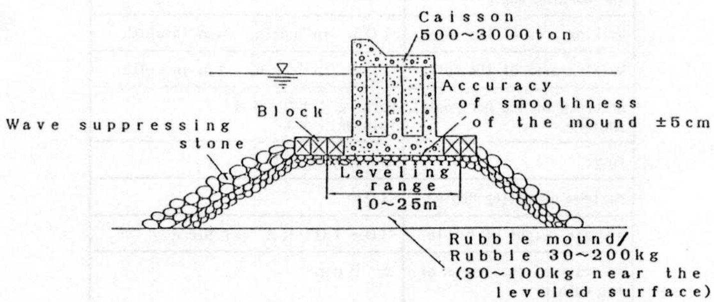

Fig-1 Typical cross Section of the Breakwater

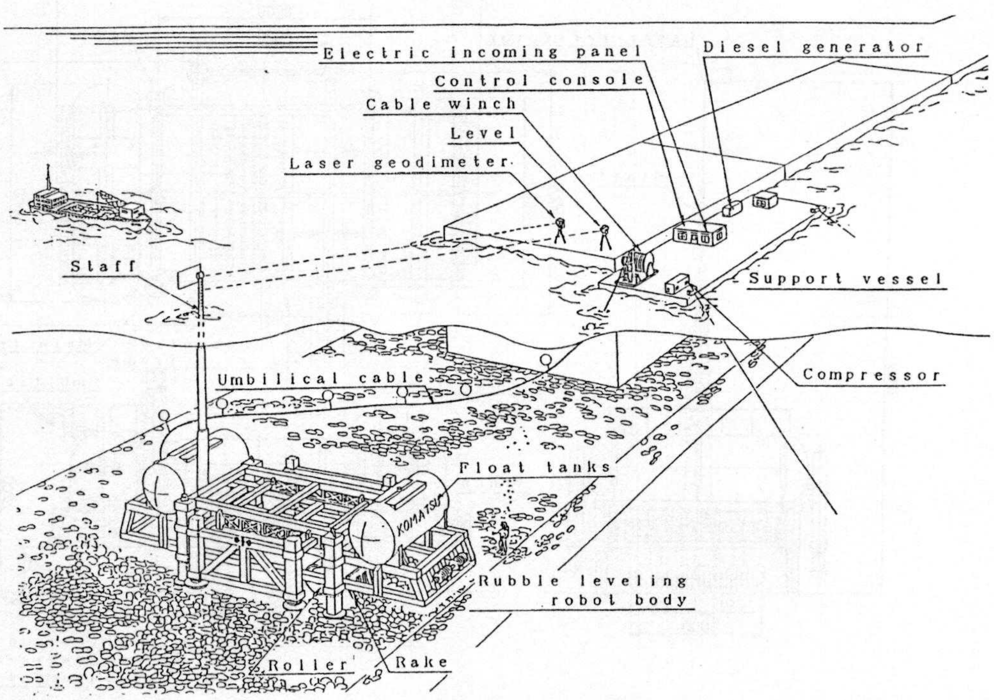

Fig-2 A Scheme of Rubble Leveling Robot System

Table-2 Specifications

Body weight	77tons in air -10~62tons in water
Machine dimensions	Length: 17m Width : 10m Height: 6.2m (except for staff)
Walking stroke in back and forth direction and lateral direction	1.25m
Walking speeds	25m/h
Leg cylinder stroke	2.0m
Maximum pulling force of the working bogie	20tons
Walking area of the rake	10m in length, 5m in width
Walking area of the roller	10m in length, 4m in width
Accuracy of the horizontal posture	Working : ±0.14° Walking : ±1°
Power	55kw/440V
Maximum operating depth	30m
Average weight of rubble	30~100kg per piece
Accuracy of smoothness of the rubble	± 5cm
Efficiency of the work	40m²/h

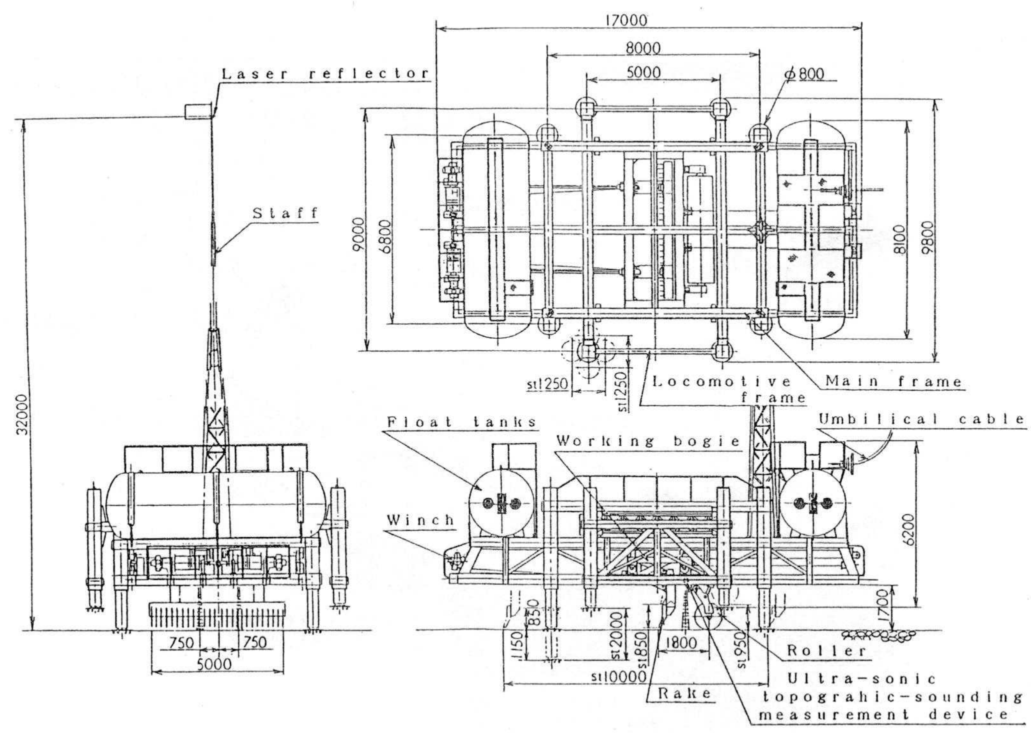

Fig-3 Rubble Leveling Robot Body

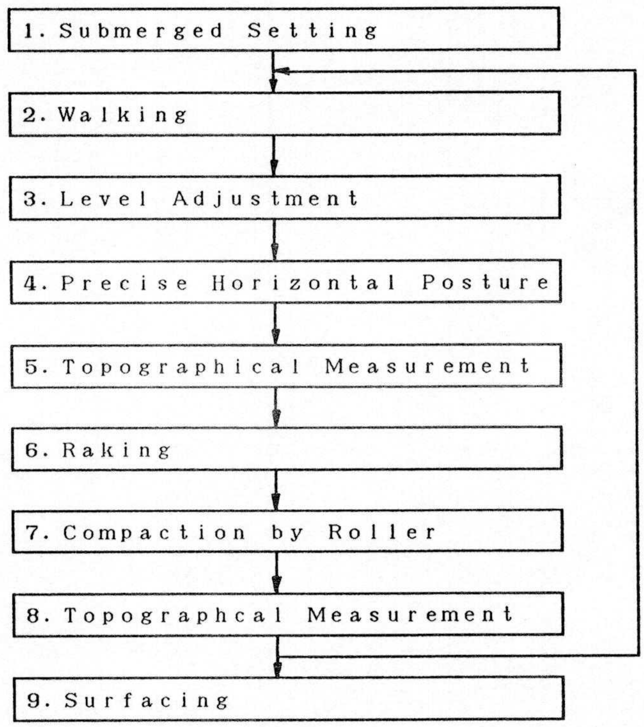

Fig. -4 Work Sequences

Table-3 Past records of execution of works

Time	1983 Mar.	1983 Aug.			1984 Nov.	1985 Sep.
Areas	1, 100㎡	8,930 ㎡	480 ㎡	760 ㎡	3, 000㎡	8, 500㎡
Rubble weight	20～200kg	5 ～50kg	10～100 kg	200 ～400 kg	20～90kg	100～200kg
Soft of rubble	Granite	Andesite			Andesite	Hard sandstone
Depth	-11. 42m	-7. 0m			-4. 0m, -3. 5m -0. 44m, +0. 2m	-3. 4m