IEICE Proceeding Series

Motion Verification of an Underwater Robot Using the Passive Posture Maintenance Mechanism for Thrusters

Fumiaki Takemura, Shota Futenma, Reyes Tatsuru Shiroku, Kuniaki Kawabata, Shinichi Sagara

Vol. 1 pp. 183-186
Publication Date: 2014/03/17
Online ISSN: 2188-5079

2012 International Symposium on Nonlinear Theory and its Applications
NOLTA2012, Palma, Majorca, Spain, October 22-26, 2012

Motion Verification of an Underwater Robot Using the Passive Posture Maintenance Mechanism for Thrusters

Fumiaki Takemura†, Shota Futenma‡, Reyes Tatsuru Shiroku‡, Kuniaki Kawabata†‡ and Shinichi Sagara‡‡

† Department of Mechanical system engineering, Okinawa National College of Technology
905 Henoko, Nago-shi, Okinawa, 905-2192, Japan
‡ Advanced Course, Okinawa National College of Technology
905 Henoko, Nago-shi, Okinawa, 905-2192, Japan
†‡ RIKEN
2-1 Hirosawa, Wako-shi, Saitama, 351-0198, Japan
‡‡ Kyushu Institute of Technology
1-1 Sensui-cho, Tobata-ku, Kitakyushu-shi, Fukuoka, 804-8550, Japan
Email: takemura@okinawa-ct.ac.jp

Abstract– Authors have been developing an underwater robot that can be used for environmental protection work in the sea near Okinawa. First, the authors are aiming at the development of an underwater robot do the work in the sea(e.g. the capture of crown-of-thorns starfish). When raising the seawater objects by an underwater robot, the conventional method to fix the thruster is difficult to raise it straight up. Therefore, we proposed “the passive posture maintenance mechanism for thrusters”. By using this mechanism, the vertical thrusters can always keep itself posture to upward and we think that an underwater robot can be relatively easy to raise to just above the object. Moreover, postural stability of the robot with a work is important in water. Hence, in this paper, we describe the postural stability of an underwater robot using by our proposed passive mechanism. We verify the usefulness of this mechanism to postural stability from the experimental results.

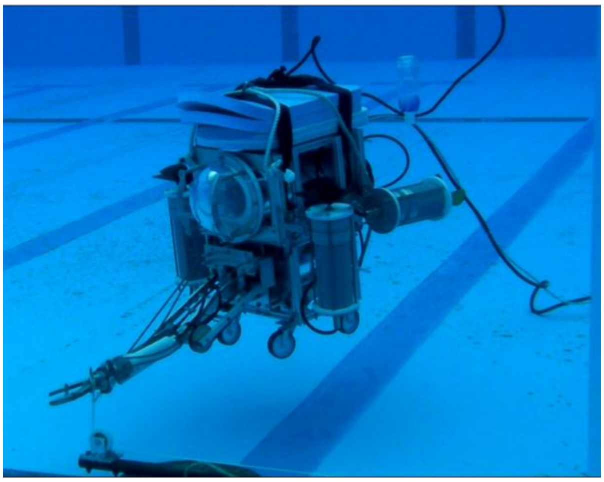


Fig. 1: The developing underwater robot

1. Introduction

In recent years, due to changes in water quality and water temperature rise caused by global warming, changing the balance of marine ecosystems has been pointed out as a matter of the marine environment. Okinawa is enclosed by the sea, and marine resources including the coral reef. Coral reef is very important for the marine ecosystem in coastal waters. Coral bleaching causes that the zooxanthellae go away from coral. In Okinawa, such as coral bleaching causes by rising ocean temperatures and coral predation by crown-of-thorns starfish outbreak[1].

For coral reef conservation activities, capture of crown-of-thorns starfish and vegetation of coral has been carried out by divers. However, considering the danger of toxic thorn crown-of-thorns starfish and physical burden of the divers, the burden or risk removal of these activities is desirable.

In the development of underwater robots to work on, research of semi-autonomous underwater vehicle equipped with the passive arm with sensor and the active arm to work[3], development of underwater robot with dual-arm for performing the work[4], development of underwater vehicle with a manipulator that aims to work in nuclear power reactor[5] etc., various studies have been carried out. However, authors do not know underwater robots to work for coral reef conservation.

Therefore, in order to achieve the capture of crown-of-thorns starfish without physical burden and risk to humans, the authors have been developing the underwater robot with the concentrated waterproof equipment type removable underwater manipulator[2](see Fig. 1).

In this paper, we propose “the passive posture maintenance mechanism for thrusters” which is a new fixing method of thrusters. It can be maintained perpendicular to the vertical thruster by using this mechanism and it can always generate a thrust to the vertical direction. Therefore, the raising of the object can be easily underwater. By measuring the change in the posture of the robot in the pool experiment, we describe the stability of the posture of the underwater robot using this mechanism.

2. Passive Posture Maintenance Mechanism for Thrusters

At the conventional underwater robot, when to raise the heavy underwater object, it uses the thrust of the robot's vertical thrusters. However, when an attempt to raise it straight up, at a conventional fixed-thruster(the fixed thruster) to bolt the robot body, it is difficult to control for pulling it straight up as the robot tilts.

Hence, to solve this problem, we propose "the passive posture maintenance mechanism for thrusters"(the passive thruster). This mechanism has the following characteristics:

1. Thruster is connected by a free joint.
2. The distance of the center of gravity of thruster and the rotating part of a free joint will be long as much as possible.

By such a mechanism, using the influence of gravity, the vertical thrusters are always self-righting to the vertical direction at changes in the pitch angle of the main body(see Fig. 2(b)).

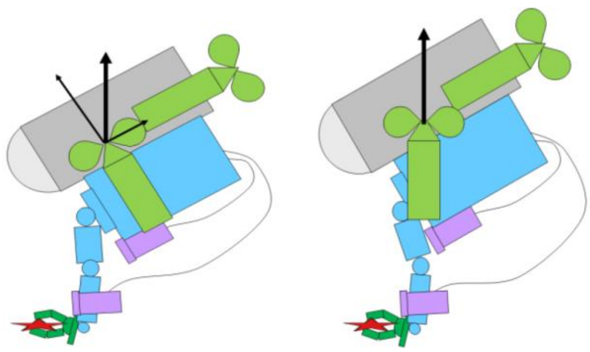
In the case that the attitude of a thruster is changed by using the active action of an actuator(e.g. electric motor), leading to larger weight of the robot. In addition, since the energy consumption increases, that is not valid. Hence, we propose the mechanism by using the influence of gravity, always able to maintain the direction of a thruster.

Fig. 3 shows the parts of a free joint. Consisting of parts is mainly the following three points:

- Aluminum block: this part is fixed to the frame of the main body
- Stainless shaft: dia. 25[mm], the axis of rotation of the thruster
- Resin bush: Bearing of the stainless shaft

Fig. 4 shows that the robot was attached to using this mechanism. The vertical thruster is fixed to the shaft tip. Resin bush is fitted in an aluminum block, the stainless shaft become a free joint. Therefore, due to the weight of the thruster which is fixed to the shaft tip, the vertical thruster can be always pointing to the vertical direction.

By this mechanism, since the thrust direction of the thruster is always vertical direction and the thrust of vertical direction is not affected by the inclination of the main body, we expect to obtain easy operability of the underwater robot.



(a) The fixed thruster (b) The passive thruster

Fig. 2: Differences in the way

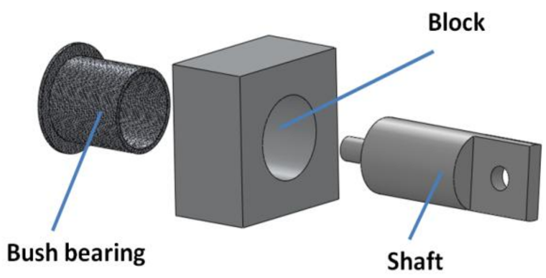


Fig. 3: Parts of the passive posture maintenance mechanism for thrusters

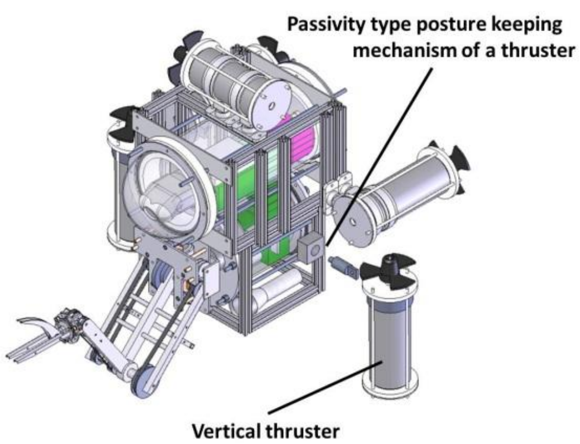


Fig. 4: ROV with the proposed mechanism

3. Measurement Experimental of Attitude Change of the Underwater Robot when Raising Operation in the Pool

To verify the effectiveness of the passive posture maintenance mechanism for thrusters, raising the submerged object by the underwater robot, it measures the attitude change of the robot at that time. We experiment in the 2 case of the fixed thruster and the passive thruster in the pool.

3.1. Experimental Method

The weight of the 4kg(air weight) fixes to the tip of the manipulator of underwater robot in the pool and it generates the thrust of the vertical thruster. After this, the underwater robot performs the action of pulling up the submerged object. It measures the attitude change of the robot at the time of pulling behavior by a 3D motion sensor(3-axis geomagnetic sensor & 3-axis acceleration sensor, TruePoint, Silicon Sensing Systems Japan, Ltd.) mounted in the robot. Experimental time raising operation is about 10 seconds. This experiment is carried out by the 2 case of the fixed thruster and the passive thruster. Command value to the vertical thruster is a constant value (sog. Step input). Maximum depth of the pool is 1.4 [m].

3.2. Experimental results

Fig. 5 shows the state of the experiment at the fixed thruster. Fig. 6 shows the state of the experiment at the passive thruster. Fig. 5 and 6 are photos when the robot was performing the raising operation of the submerged object by using the vertical thruster. In the case of the fixed thruster, you find that the vertical thruster also tilt due to the inclination of the robot body. On the other hand, in the case of the passive thruster, it is seen that the vertical thruster maintains the vertical direction regardless of the inclination of the robot body.

Fig. 7 shows that the roll angle of the robot body was measured from the 3D motion sensor and Fig. 8 shows

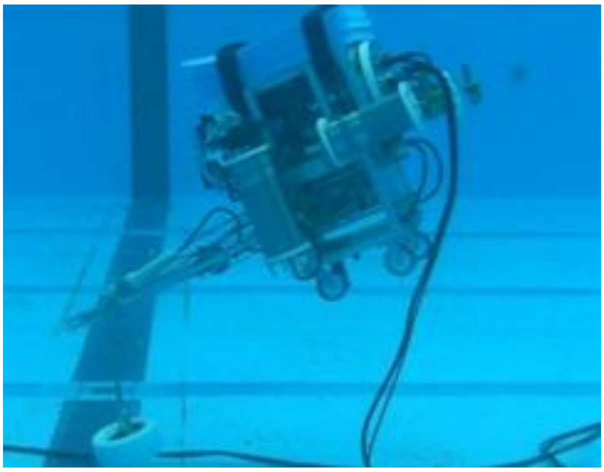


Fig. 5: The state of experiment –the fixed thruster-

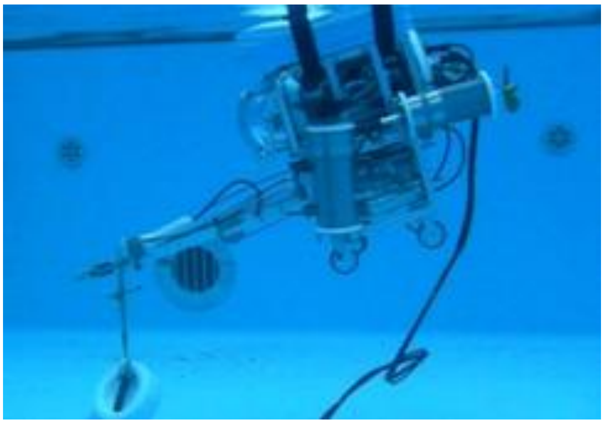


Fig. 6: The state of experiment –the passive thruster-

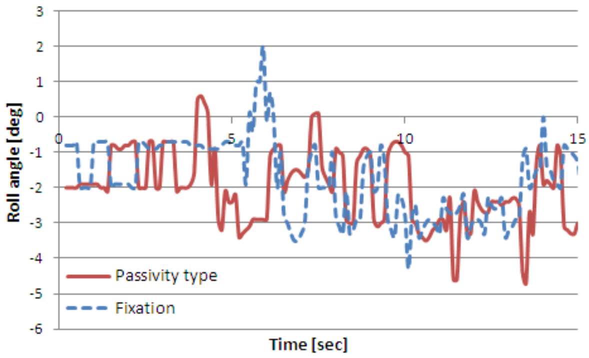


Fig. 7: Experimental result: Roll angle

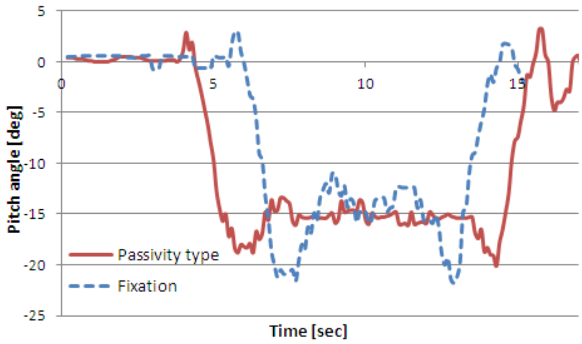


Fig. 8: Experimental result: Pitch angle

that the pitch angle of the robot body was measured from the 3D motion sensor, too. Attitude change of the roll angle, the big difference is not seen between the two. On the other hand, the pitch angle of the two is converged to about -15 [deg] after pulling an object from the initial attitude 0 [deg]. However, the maximum displacement can be seen that the fixed thruster is greater than the passive thruster.

3.3. Discussion

From Fig. 5, at the raising operation of the fixed thruster, the direction of the vertical thruster tilts because the pitch angle of the robot tilts. And the raising operation is performed only in the thrust of the vertical thruster. We has been confirmed in the video that the robot is moved to the forward direction as the thrust to the forward direction occurs. After capture the object, the robot is raised to just above and the operator can easily identify the location of the robot. However, in order to move the robot to just above in the fixed thruster, the motion control of the robot must takes into account the resultant vector by using the thrust of the horizontal thruster. Therefore, the robot operation becomes complicated.

On the other hand, the passive thruster in Fig. 6, regardless of the change of pitch angle of the robot, the vertical thruster is still upward. Because it is always to maintain the thrust direction to the vertical direction, the robot operation to the vertical direction becomes possible only in the vertical thruster operation. Therefore, the underwater robot with the passive thruster does not require complex operations.

From Fig. 7, this mechanism would not impact on the roll angle of the robot.

From Fig. 8, the change in pitch angle of the robot is a difference between the two is seen, the fixed thruster is the maximum displacement is greater than the passive thruster. And, both the pitch angle is approximately the same angle -15 [deg] as in the steady state. Consider the cause of this. In both, the rotational moment occurs around the manipulator tip. Because the vertical thruster of the passive thruster always upturns, the thrust in tangential direction to the manipulator tip at the fixed thruster is larger than the passive thruster. Therefore, the rotational moment at the fixed thruster is also large. Since the rotational moment in the fixed thruster is large, the maximum displacement of the pitch angle of the fixed thruster is larger than that of the passive thruster in the transient state. In the steady state, drag only works in the vertical direction at the passive thruster. But drag work the horizontal and vertical direction in the steady state of the fixed thruster. Therefore, it is considered that the pitch angle of the fixed thruster is the same as that of the passive thruster in the steady state.

We have been confirmed in the video that the underwater robot with the fixed thruster proceeds to the forward direction. On the other hand, the robot with the passive thruster will rise just above. This characteristic is desirable for the operator.

4. Conclusion

In this paper, we described the postural stability of the underwater robot with our proposed “the passive posture maintenance mechanism for thrusters”. This mechanism is applied to the underwater robot for operation such as pulling heavy objects in seawater.

We have carried out experiments to verify the attitude change of the robot with this mechanism. In each case of the conventional fixed thruster and the new passive thruster, raising operation of the 4 [kg](air weight) object was performed by the robot, the attitude change of the robot was measured by the 3D motion sensor at this time. Consequently, our proposed “the passive posture maintenance mechanism for thrusters” was confirmed to have the following characteristics.

- If you raise the submerged objet to the vertical direction, the underwater robot operation is facilitated.
- If you raise the submerged objet to the vertical direction, the pitch angle change is suppressed in the transient state. Stable operability can be obtained.

In the future, we verify the operation of the underwater robot with this mechanism in actual seas, are planning the implementation of the hovering control of the robot.

Acknowledgments

A part of this work was supported by Grant-in-Aid for Scientific Research (B), MEXT (No. 23300074).

References

[1] T. Motokawa, “Story of coral and coral reef”, CHUOKORON-SHINSHA, pp. 228 – 246, 2008 (in Japanese).

[2] F. Takemura and R. T. Shiroku, “Development of the Actuator Concentration Type Removable Underwater Manipulator”, The 11th International Conference on Control, Automation, Robotics and Vision (ICARCV2010), pp. 2124 - 2128, 2010

[3] J. Yuh, S. K. Choi, C. Ikehara, G. H. Kim, G. McMurty, M. Ghasemi-Nejhad, N. Sarkar, K. Sugihara, "Design of a semi-autonomous underwater vehicle for intervention missions (SAUVIM)", Proceedings of the 1998 International Symposium on Underwater Technology, pp. 63 - 68, 1998.

[4] N. Sakagami, M. Shibata, H. Hashizume, Y. Hagiwara, K. Ishimaru, T. Ueda, T. Saitou, K. Fujita, S. Kawamura, T. Inoue, H. Onishi and S. Murakami, "Development of a Human-Sized ROV with Dual-Arm", Proceedings of MTS/IEEE International Conference on OCEANS, DVD, 2010.

[5] S. Lee, Y. Choi, K. Jeong and S. Jung, “Development of an Underwater Manipulator for Maintaining Nuclear Power Reactor”, International Conference on Control, Automation and Systems, pp. 1006 - 1010, 2007.