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An Underwater Robot for the Maintenance of Nuclear Power Plants

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1. Introduction

The safety and reliability of nuclear power plants has become more important than in the past. Inspection and maintenance of a component should be achieved continuously. Two reactor types PWR (Pressurized Water Reactor) and PHWR (Pressurized Heavy Water Reactor) are normally operated in Korea. In the case of a PWR, the presence of any loose part affects the safety of a nuclear power plant. A loose part, which could be from failed components or an item inadvertently left during a construction, refueling or maintenance like as metallic parts, bolts, nuts and washers, can damage any part by frequently impacting that part in the system. Therefore, work that detects a loose part and removes it from a the nuclear reactor vessel is very important [1][2]. Moreover, the inspection of the RCS (reactor coolant system) of PWR is also important. The RCS has a role to cool down the reactor's temperature. But human workers can't access the RCS easily because of the complexity of the path and the radiation level. So a robotic system is needed to inspect the RCS closely [7].

Research on an underwater robot for an inspection of a nuclear reactor vessel began in the 1990s. Since then, many underwater robots for a nuclear power plant have been developed [3][4][5][6]. But the developed underwater robots were so heavy and also they only had one function that is to inspect the nuclear reactor vessel.

In this paper, an underwater robotic system is developed for inspecting the bottom of the nuclear reactor vessel, hot legs and cold legs of reactor coolant system and also for removing some particles in them.

2. Environments of RCS

Fig. 1 shows the figure of the RCS of a Korean standard nuclear reactor.

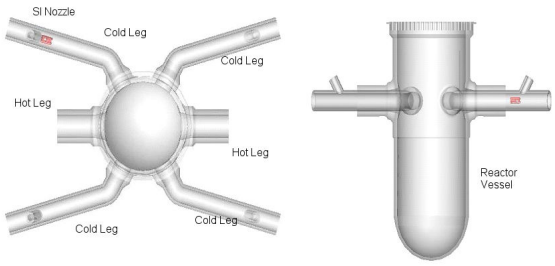

Figure 1. The RCS model of a Korean standard nuclear reactor (left : top view, right : side view)

The nuclear reactor vessel which is a 4m in diameter and is 20m in depth is a restricted area because a nuclear reactor is a high radiation area under water. The Hot Leg between the nuclear reactor vessel and steam generator and Cold Leg between the nuclear reactor vessel and the reactor coolant pump is also a high radiation area under water. Therefore, workers can't detect and remove any unexpected particles because the water and high radiation level. So a robotic system is needed.

3. Underwater Robotic System

2.1 Overall System

To perform an inspection and removal, the developed underwater robotic system is composed of an underwater vehicle, an underwater manipulator and a tele-operating control system.

2.2 Underwater vehicle

Fig. 2 shows the underwater vehicle. The underwater vehicle has 4 dof mobility with 4 thrusters; two for vertical and two for horizontal movements. Thrusters are aligned to the center of the robot body and driven by motor.

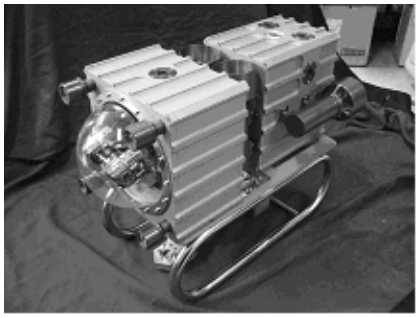

Figure 2. A picture of the underwater vehicle

In order to inspect an object, a camera module which has a stereo camera and a pan-tilt mechanism is sttached to the front of the underwater vehicle. The camera module tilts in the range of ±90 degrees and also pans in the range of ±180 degrees. The stereo camera can make it possible to measure the size of an inspected area and some particles. Operators can't control the underwater vehicle easily by only using the stereo camera. So five cameras are attached to the top, left, right, rear, under of the underwater vehicle for an operator to supply more visual information. Operator can control the underwater vehicle easily using several visual information.

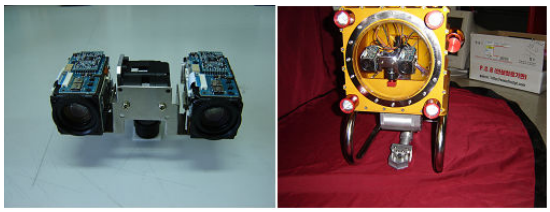

Figure 3. The picture of the stereo camera module

2.3 Underwater Manipulator

The manipulator is developed for removing some unwanted particles in the bottom of the nuclear reactor vessel.

The manipulator is composed of 4 joints and one gripper. The joints and gripper are driven by DC motors. The joints of the manipulator are waterproofed with O-rings. Each joint has a magnetic encoder to calculate the joint angle. The underwater manipulator is attached to the under of the underwater vehicle. Fig. 4 shows the developed manipulator.

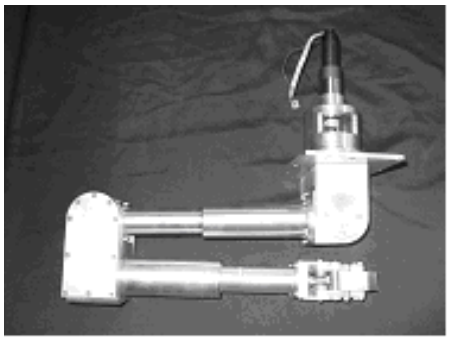

Figure 4. A picture of underwater manipulator

2.4 Tele-operating Control System

The tele-operating control system consists of a host controller and a slave controller. The Host controller receives a command from the operator and sends the command to the slave controller. The slave controller operates the operating devices attached to the underwater vehicle and the manipulator and measure the value of the sensors. After that, the slave controller transfers the information to the host controller and the operators.

The slave controller is designed particularly to work well under 100Krad in the radiation level by using radiation shield and radiation-harden chips.

3. Experiments

The tele-operated underwater robotic system should work in the nuclear reactor vessel whose depth of water is 20m. So a watertight test is needed. A watertight test is performed using a pressure vessel. After we put the tele-operated underwater robotic system into the pressure vessel, we applied 3 kgf/cm^2 of pressure to the pressure vessel. We could confirm that there is no waterproofing problem.

We also could confirm that the developed underwater robotic system is work well under 100Krad in radiation level through the radiation exposure test.

In order to evaluate the performance of the developed underwater robotic system, an experiment was performed in a small swimming pool. In the experiments, the developed robotic system can inspect the state of the tank and remove some particles successfully. Fig. 5 shows the experimental image.

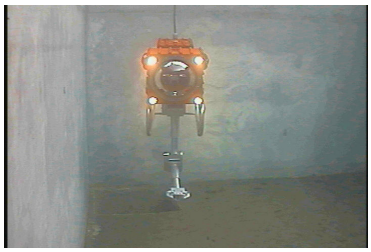

Figure 5. A picture of the underwater robotic system in the swimming pool

4. Conclusion

The limitation of a radiation exposure makes it difficult to work in nuclear power plants. Robots are useful to inspect and maintain the components of nuclear power plants because a reduction in the radiation exposure level to human operators and for improving the reliability of an operation. An underwater robotic system was developed to maintain a nuclear reactor vessel. We hope to increase the reliability for maintenance by the aid of the developed robotic system

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