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Application of an Underwater Robot in Reactor Coolant System

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1. Introduction

Nuclear energy is a major source of electric energy consumed in Korea. It has the advantage of other energy sources, nuclear energy is cost effective and little pollution. But the fearfulness of an accident and/or failure has scared us the utilization of nuclear energy extensively. So, the safety and reliability of nuclear power plants become more important. Inspection and maintenance of component should be achieved continuously. The RCS(reactor coolant system) of PWR(pressurized water reactor) has a role to cool down the reactor's temperature. Cooling water is injected through the SI(safety injection) nozzle into the cold leg of the primary loop. Thermal sleeves are attached inside the cylindrical SI nozzle to reduce the thermal shock of the cooling water to the weld zone of the safety injection nozzle[1]. Figure 1 shows the RCS model of nuclear reactor, the access to the SI nozzle is not simple. The human workers are susceptible to radiation exposure and manual handling machine is hard to access because of the complexity of the path[2]. So, we developed and applied free running, tele-operated underwater vehicle to inspect SI nozzle close to the place. Tele-operated robot is useful to inspect and maintain the component of nuclear power plants to reduce the radiation exposure of human operators and improve the reliability of the operation in nuclear power plants[3]. Underwater robot is comprised of two parts; one is robot vehicle and the other is remote control module. Underwater robot vehicle has 4 DOF(degree of freedom) of mobility and 1 DOF of camera observation. The task to inspect the internal of RCS in nuclear power plant is achieved successfully. And the reliability for the maintenance is increased by the aid of tele-operated robot[4].

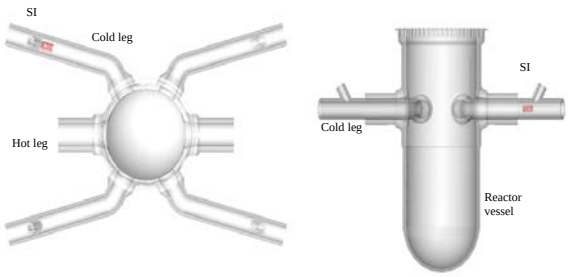

Figure 1. RCS model of Korea standard nuclear reactor, top view(left), side view(right)

2. Underwater robot in RCS

2.1 Environments

The RCS of PWR has a role to cool down the reactor's temperature. The RCS system is comprised of 4 cold leg and 2 hot leg in Korea standard nuclear power plant. Cooling water is injected through the SI(safety injection) nozzle into the cold leg of the primary loop, and hot water is pumped out through hot leg. The size of cold leg is 69.8 cm and hot leg is 73.7 cm. The shape of cold leg is cylindrical, and the boundary of the entrance from reactor vessel is curved 45. SI nozzle is located about 6m far from the entrance of the reactor vessel, and positioned upper side of the cold leg, which angle is 60° with respect to the axis of cold leg. The diameter of SI nozzle is about 31cm.

The environment of the objective place is hard to work by human or manual handling machine because of the radiation exposure and difficulties in the complexity of the access path. Effective method for the inspection of the SI nozzle in the cold leg is the use of free running unmanned robot system. So, we applied tele-operated underwater robot system for the inspection of RCS.

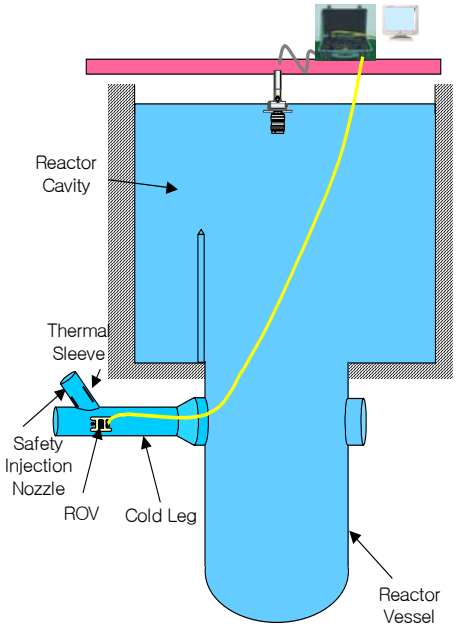

Figure 2. Inspection of the SI nozzle using underwater robot.

2.2 Composition of the underwater robot system

The underwater robot we developed is comprised of two parts mainly: robot vehicle and control unit. Robot vehicle has a robust body, contrast to human body, equipped with inspection camera module. And it has an advantage of flexibility with a mobile mechanism, superior to manual handling machine. Robot vehicle has mobility of 4 DOF with 4 thrusters, two for vertical and two for horizontal movement. Thrusters are aligned the center of the robot body and driven by electric motor. The buoyant force is adjusted to zero for the effective movement of robot body. In order to inspect an object anywhere in the RCS area, a zoom camera with a tilt mechanism is applied. The camera module, with a high magnification lens, tilted ±90° vertically. The size of robot is 66cm in length, 35cm in width, and 30cm in height and the weight is 25kg in air.

The functions of the control unit are the followings. : robot movement, camera tilt, zoom/focus of the camera, light control, and monitoring the object and robot. Between the control unit and the robot body, umbilical cable is connected for the transmission/reception of the control signal and acquired data. Fig 3 shows the composition of the underwater robot system.

Figure 3. Underwater robot vehicle and control system.

2.3 Application of the underwater robot in RCS

During overhaul of nuclear power plants, we applied underwater robot system to inspect the states of SI nozzle and RCS. The underwater robot was remote controlled by the operator in safety zone. The operator could control easily the underwater robot by means of cameras for robot observation and objective inspection. Figure 4 shows the scene, underwater robot working in the reactor vessel, acquired from the observation camera for robot monitoring. And, Figure 5 shows the image of the SI nozzle, acquired from the inspection camera attached in underwater robot.

From the result, the state of the component was verified clearly, and then the safety and reliability of nuclear power plant could be confirmed.

Figure 4. Underwater Robot working in the reactor vessel.

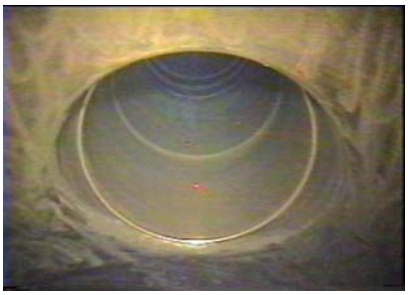

Figure 5. Captured image of the SI nozzle.

3. Conclusion

Occasionally, the limitation of radiation exposure and/or complexity of access, makes it difficult to work in nuclear power plants. Tele-operated robot is useful to inspect and maintain the component of nuclear power plants to reduce the radiation exposure of human operators and improve the reliability of the operation in nuclear power plants. We developed and applied free running, tele-operated underwater vehicle to inspect SI nozzle close to the place. The task to inspect the internal of RCS in nuclear power plant is achieved successfully. And the reliability for the maintenance is increased by the aid of tele-operated robot.

Acknowledgements

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