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Underwater Robot System for Reactor Vessel

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1. Introduction

It is dangerous to work inside reactor vessel because of high radio activity. So robot system is necessary to work inside reactor vessel instead of workers. And robot also has advantage of mobility over conventional equipment which has limitation of the range of accessibility. In this paper, we describe design consideration and criteria of robot system for reactor vessel, and component of developed system. Reliability, usability and convenience of robot system were considered to design and fabrication.

2. Design

In this section the consideration and requirement of the underwater robot system is described.

For the design of robot system, the environment of reactor vessel and function of robot system have to be investigated. Environments of reactor vessel are high radiation, underwater condition and size of nozzle is restricted to robot. Considering reliability, usability and convenience of robot system, we produce design requirement and design specification. For the reliability of robot system, the components of the robot system are designed to withstand irradiation and leakage of water. And the usability of robot system, the size of the robot system is designed to move through reactor coolant nozzle. For the convenience of operating the robot, detection of robot position is carried out using multi camera.

Deciding for the system requirement, radiation level and size of reactor vessel was investigated. Gamma dose rate of reactor core is several tens or several hundreds of Gy/hr during shutdown. We supposed robot operating time up to one hundred hours, and we targeted total dose up to several tens of kGy. The component was selected to minimize radiation damage on the basis of radiation effect database and reference.

Operators control underwater robot at a remote station by handling joystick which connected to the control computer with observing the situation of vehicle movement shown as Fig. 1. With the aid of camera on the vehicle and on the flange of the reactor, operators easily control the vehicle remotely. The underwater robot system is comprised of three parts: remotely operated vehicle, controller and robot positioning module. Robot vehicle is equipped with inspection camera and thruster module. Remote control unit is comprised of control computer and robot position detection computer. Considering radiation damage on electronic devices, electronic processors are not lied on the vehicle but control unit, Umbilical cable is connected between underwater robot and control unit, power and signal cables are connected directly each module.

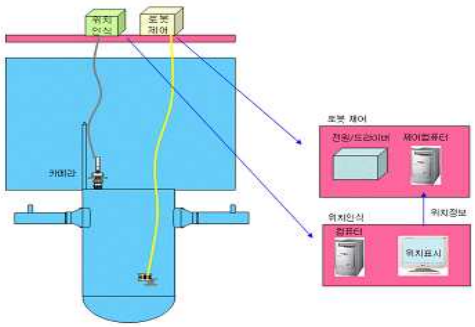

Fig. 1. Conceptual drawing of robot system.

3. Embodiment of robot system

The robot system is comprised of robot vehicle, remote control unit and robot positioning module. The vehicle has 4 thrusters, tilt, camera, light and depth sensor, etc. Considering radiation damage, processors are not equipped on the vehicle. Control signals and sensing signals are transferred through umbilical cable. Remote control unit is composed of electric driving module and two computers which one is for the control and the other is for the detection of robot position. Control computer has a joystick user input and video/signal input, and transmit motor control signal and lens control signal via CAN/RS485 communication. And the other computers transmit information of vehicle position to the control computer via serial communication. Information of vehicle position is obtained through image processing algorithm. The acquiring camera of vehicle is on the flange of reactor vessel.

3.1 Robot vehicle

Remotely operated vehicle has a role to perform task at the hazardous area instead of human workers. Therefore, underwater robot must have functions of movement, sensing, etc. Robot vehicle is comprised of buoyant, thrusters, camera and depth sensor shown as Fig.3. Thrusters have 4 DOF(degree of freedom) mobility with 4 propellers, 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 neutral for the effective movement of robot body. In order to inspect an object in the RV area, a zoom camera with a tilt mechanism is applied. The camera module, with a high magnification lens, tilted +90 degrees and -90° degrees vertically. The size of robot is 60cm in length, 41cm in width, and 38cm in height and the weight is 28kg in air.

Fig. 3. Underwater robot.

Table I: Specification of robot

Item	Spec.
Robot size	600(L)X410(W)X375(H) mm
weight	27.5 kg
Cable length	30m
Cable weight	11.4kg
Console weight	11.9kg

3.2 Remote control unit

The functions of the control unit are as follows: robot movement control, camera tilt control, zoom/focus control, 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. 4 shows the control computer, input devices and control screen. Thruster motor and camera tilt is driven by motor driver which controlled by control computer via CAN communication. Camera lens is controlled by RS-485 communication. Sampling time for the input of joystick is set to 30ms, and dead zone margin is set about ±15% of acquired value of joystick considering hardware characteristics. Virtual joystick is showed on the computer screen for the operation.

Fig. 4. Robot controller and control screen

3.3 Detection of robot position

To detect robot position in the reactor, we proposed an image processing algorithm using multi camera on the flange of the reactor vessel. Proposed tracking algorithm is composed of 4 camera module and visual tracking algorithm. The algorithm is as follows : First, camera position and image plane is decided through camera calibration. Second, robot silhouette is acquired and center point of robot is extracted using ellipse fitting. And then robot position is calculated crossing line through 4 camera center line. Simulations are performed at the reactor vessel mockup and verified to use in the control of robot by visual tracking. Fig. 5 shows the result of detection of vehicle on the mockup.

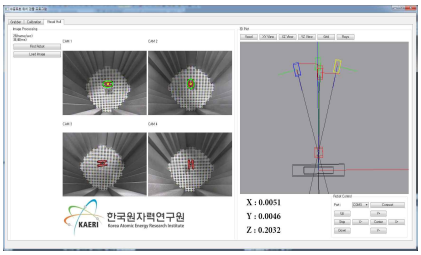

Fig. 5. Result of robot positioning.

4. Conclusions

The limitation of radiation exposure to human workers and complexity of access for conventional equipment make it difficult to work in reactor vessel. Remotely operated robot is useful to search and retrieval of foreign object in reactor vessel for reducing the radiation exposure of human operators and improvement of the reliability of the operation. We developed free running, remotely operated underwater vehicle to search and retrieve foreign object in the bottom of the reactor vessel. Furthermore we are planning to experiment the functional test at the mockup and apply to on-site FOSAR. Using the underwater robot system on the reactor vessel, the reliability for the maintenance will be increased by the aid of remotely operated robot.

REFERENCES

[1] Y. S. Choi et al., "Development of an Underwater Robot for the Maintenance of Nuclear Reactor," ICROS2007, 2007.
[2] C. H. Choi, et al., "The Robots for Nuclear Power Plants," Conference on Korean Nuclear Society 2005, Spring, 2005.
[3] S. H. Kim, "Development of Radiation Hardened Robot for Nuclear Facilities," KAERI/RR-953/98, KOREA, 1998.
[4] J. K. Kim, et al., "Implementation of Reliable Robot Control System for Nuclear Power Plant Manipulation," Proc. of the 32nd ISR, 19-21 April 2001.