Development of ROV System for FOSAR in Reactor Vessel

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1. Introduction

Foreign object in the reactor vessel is susceptible to damage the fuel. Prior to reloading fuel assemblies into the core, FOSAR(Foreign Object Search And Retrieval) activities were performed on and beneath the lower core plate with conventional equipment. However, the reactor vessel is limited to humans who are susceptible to radiation exposure, and conventional equipment is hard to access because of the complexity of the structure. To improve the convenience of use and retrieval ability in the under-core plate region, we are developing a FOSAR system carried by ROV (Remotely Operated Vehicle). In this paper, we describe a ROV system developed. The ROV system is composed of robot vehicle and remote control unit. 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.

Simulations on the detection of vehicle position are performed at the reactor vessel mockup which scaled down by 6 and verified to use in the control of robot by visual tracking. And functional test has been performed on the air condition. In the future, performance test will be carried out real sized mockup and underwater condition.

2. Methods and Results

In this section the configuration of the ROV system is described. The system is composed of remotely operated vehicle and controller.

2.1 System configuration

Operators work ROV 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.

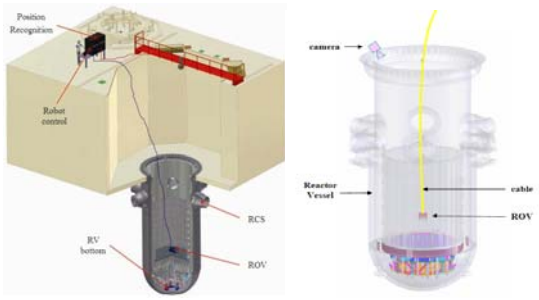

Fig. 1. Concept of working with ROV system

The ROV system is comprised of two parts: remotely operated vehicle and controller. Robot vehicle is equipped with inspection camera and thruster module. Remote control unit is composed 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 ROV and control unit, power and signal cables are connected directly each module shown as Fig. 2.

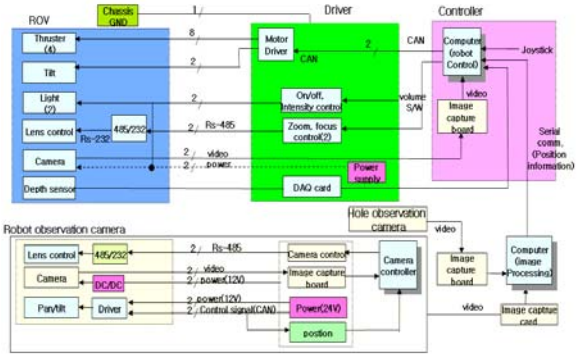

Fig. 2. Configuration of the ROV system.

2.2 ROV

Remotely operated vehicle has a role to perform task at the hazardous area instead of human workers. Therefore, ROV 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 +30 degrees and -90° degrees vertically. The size of robot is 60cm in length, 35cm in width, and 32cm in height and the weight is 15kg in air.

Fig. 3. Remotely operated vehicle.

2.3 Controller

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 and input devices. 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. 5 shows the screen of control computer.

Fig. 4. ROV controller

Fig. 5. ROV control program.

2.4 Detection of vehicle position

To detect vehicle position in the reactor, we proposed an image processing algorithm using camera on the flange of the reactor vessel. Proposed algorithm is composed of Modified SURF(Speeded Up Robust Feature) based on Mean-Shift and CAMSHIFT (Continuously Adaptive Mean Shift Algorithm) based on color tracking algorithm. Noise filtering using luminosity blend method and color clipping are preprocessed. Initial tracking area for the CAMSHIFT is determined by using modified SURF. And then extracting the contour and corner points in the area of target tracked by CAMSHIFT method. Simulations are performed at the reactor vessel mockup and verified to use in the control of robot by visual tracking. Fig. 6 shows the result of detection of vehicle on the mockup.

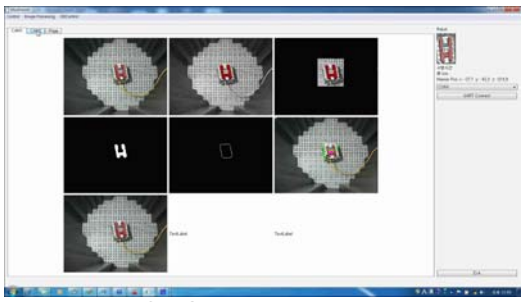

Fig. 6. ROV image processing.

3. 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 ROV system on the reactor vessel, the reliability for the maintenance will be increased by the aid of remotely operated robot.

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