Unmanned Surface Vehicle for Nuclear Spent Fuel Inspection

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1. Introduction

One of the roles of the International Atomic Energy Agency (IAEA) is to deter the proliferation of nuclear weapons. To do so, the IAEA applies various technical measures referred to as 'safeguards' to verify the correctness and the completeness of the declarations made by the Member States about their nuclear material and activities. The IAEA safeguards are an essential component of the international security system. Conducting in-field inspections forms the core of the IAEA's nuclear verification activities and equipping inspectors with the appropriate tools is the key to effective nuclear safeguards. Over hundred types of equipment are used by the IAEA inspectors to verify the form, isotopic composition and quantity of nuclear material.

Some of the most common tasks undertaken by the IAEA inspectors involve making repetitive measurements in areas that can be difficult to access, or with elevated radiation levels. This is a domain where robotic could play a role, not only to improve the working conditions of the inspectors but also to enhance the consistency of the IAEA measurements.

2. Unmanned Surface Vehicle

Inspectors frequently use a small handheld optical instrument called the Improved Cerenkov Viewing Device (ICVD) to confirm the presence of spent fuel stored underwater. The IAEA would like to mount this device inside a small robotized floating platform, which would autonomously propel itself across the surface of the pond, while stabilizing the ICVD in a vertical position.

2.1 USV requirements for spent fuel inspection

Unmanned surface vehicle is the most appropriate type of robot to perform inspection in the spent fuel pond with ICVD. The followings are requirements of the USV.

- USV with a tele-lens and camera pointing down, mounted on tripod collar inside the robot
- An underwater observation window allowing the camera to record videos of the bottom of the pond.
- The system always remains buoyant, no part can fall in the pond and the camera system remains protected from water.
- The camera remains stable and vertical
- The system can be carried in a plane, unpacked and prepared by a single user.
- The system can be easily and thoroughly cleaned up and any trace of contaminated water can be eliminated.
- The positioning system should autonomously guide the system within a few centimeters accuracy, and propel itself across the whole pond without any user input.

2.2 Hardware features

To meet the requirements of the USV, we built a Spent fuel Check Vehicle, SCV as shown in Fig.1.

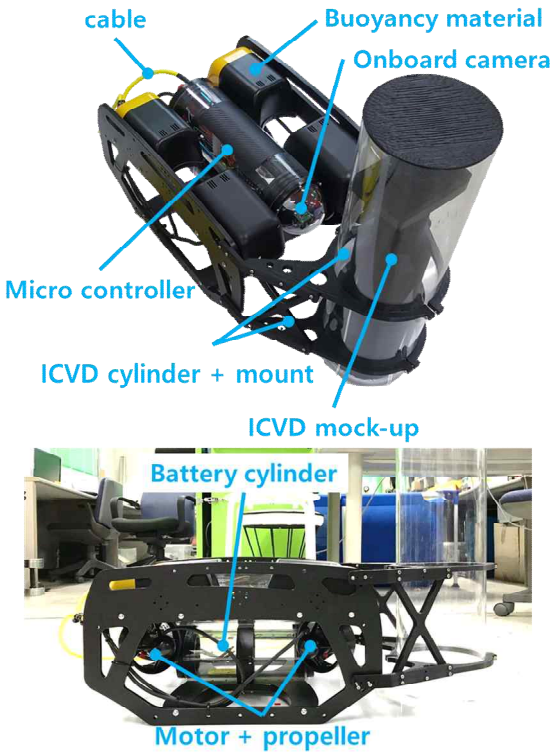

Fig. 1. Hardware features of SCV

SCV has four buoyant materials on top, and ICVD mount and cylinder are located in front of the vehicle. There are two cylindrical enclosures for the control computer in the upper one and battery in the lower one. SCV is completely waterproof to prevent both the vehicle and the spent fuel pond. It weighs only 11.1 kg, so can be easily handled by one person and delivered by an airplane.

Four propellers for maneuvering the USV forward/backward, left/right and CW/CCW rotations and an onboard camera is for recognizing surrounding environment and spent fuel assemblies. SCV utilizes a lithium polymer battery of 14.8 V/18000mAh. The power and control signal tether is currently 50 meters and can be extended considering the spent fuel pond size. The maximum operation speed is over 20 cm/sec and the system can last more than 5 hours.

2.3 Control environment

SCV can be fully controlled by a laptop computer. Because, there are no wireless communication network in the spent fuel pond and not allowed to install additional device for the wired communication, the control laptop and SCV are connected by a wire communication through 50-meter cable. Therefore, SCV can operate stably in the spent fuel pond environment.

Fig. 2. Control environment

2.4 Control program

The main control program consists of three subprograms (image processing program, position control program and navigation/inspection program).

Image processing program detects the surrounding environment and recognizes spent fuel assemblies in the pond.

Position control program keeps SCV at the target position with an accuracy of less than 1 cm and aligns the posture of SCV to spent fuel array for accurate positioning against small waves and disturbances.

Navigation/inspection program has the two modes, which are manual and automatic. Manual mode is used when the user wants to move the vehicle to the desired position or to examine the spent fuel of interest. In the automatic mode, the SCV searches the first row and column fuel assembly by itself. Then, the SCV autonomously navigates and inspects the rest of the fuel assemblies

3. Conclusions

In this paper, we presented an unmanned surface vehicle, SCV for spent fuel inspection. System requirements were mentioned and hardware, control environment and program were discussed in detail. The SCV's final evaluation will take place inside an actual nuclear power plant. The dry run is expected within this year. Once it passes the technological test, the SCV can be expected be prepared for production and export, with numbers in accordance with the IAEA's request in near future.

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