RPV and Primary Circuit Inspection

Development of Underwater Vehicle System for Reactor Internals Inspection

ABSTRACT

The efficient maintenance procedure for the aging nuclear power plants has been increasing in importance. Hitachi-GE Nuclear Energy (HGNE) has developed and applied the underwater vehicle system for the reactor internals inspections in order to make them efficient. Also, to accommodate inspections of an extremely narrow area where conventional device could not access, even smaller and capable ROV has been developed. The capabilities and applications of the underwater inspection devices for the boiling water reactors (BWR) internals are introduced in this paper.

INTRODUCTION

In Japan, about 20 nuclear power plants (NPPs) have been operating for 30 years and stress corrosion cracks (SCC) in welds of reactor internals have been reported. It is necessary to improve inspection techniques for BWR reactor pressure vessels (RPV) and the internals to make procedures efficient. HGNE has been developing devices to make procedures efficient for various inspection cases.

Also, to accommodate inspections of an extremely narrow area where conventional device could not access, even smaller and capable ROV has been developed. The capabilities and applications of the Underwater Remotely Operated Vehicles (ROV) for BWR internals are introduced in this paper.

OUTLINE OF ROV’s

Inspection Area

Generally, when the internals are inspected, the device is equipped with a sensor for VT, UT, ECT depending on locations and purpose, and inserted to RPV through the top guide, shroud, jet pump, core plate and others. There are complex components and the space is narrow and congested. The devices need to be moved and repositioned to avoid interference with them during the inspections. It is time consuming to moved and replace them to prepare for the next inspection. It is desired to reduce the preparation time.

HGNE has been developing underwater remotely operated vehicles (ROV) to achieve (1) Simplify the preparation procedure, (2) Improvement of the maintainability, (3) Expansion of the inspective area.

ROV’s Line-up

There are two types of ROV. One type is that the thruster extracts water from the volume between the body of the device and the wall that makes negative pressure. It makes the body attached to the wall. Another type is submersible that is freely float and travel in the water. A water extraction type ROVs (T-type) are equipped with UT sensors and driven by precisely controlled wheels to measure the travelled distance.

The submersible type ROV(C-type,β-type) are equipped with the thrusters to move three dimensionally inside of RPV. It has the camera to VT a required location. HGNE is able to shorten the inspection time by utilizing these devices.
Figure 1 shows the applicable area of ROV. T-type ROV is used for UT of the shroud and the shroud support weld. C-type ROV is used for VT of the RPV bottom head area. β-type ROV is used for VT of narrower section.

DETAILS OF ROVs

Extraction Type ROV (T-type ROV)\(^1\)

Structure and function

SCC in welds of the core shroud has been reported, and it occurs as long continuous crack and small cracks in the dispersed area. When the SCC is confirmed with VT, measurement of the length and depth of the SCC is performed. The T-type ROV is developed to apply the efficient inspection for the dispersed SCC for which the conventional device needs to repositioned to cover dispersed area. Figure 2 shows the photograph of the T-type ROV, and table 1 shows the specification. The T-type ROV is designed to access the inside of the core shroud through top guide and the core support.

The width of the body is 110 mm, and the Lightweight ROV simplifies the carrying, installation, and handling.
T-type ROV equipped with 2 thrusters and 2 wheels in the rear of the body attach to the wall surface by the negative pressure generated by the thruster. Movements such as forward, backward, and turn are done by the remotely operated joystick controller. The scanner attached in front of body makes contact with a wall surface when body attaches to the wall by negative pressure achieved by the thrusters. The shroud surface UT is done by movement of the ROV driven by the wheels and the scanner moves along tow axis.

Figure 3 shows the inspection image of shroud. T-type ROV is designed to simplify maintenance work by making expendable components modular. This also makes planning of maintenance easier in a field. Figure 4 shows the example of modularization of the components.
Effect of the ROV application

HGNE utilized the T-type ROV for UT of shroud at TEPCO’s Fukushima daini nuclear power station. Figure 5 shows an inspection of shroud by the ROV.

The application of the T-type ROV shortened a preparation and inspection time in comparison with the conventional arm type UT device in great degree. The inspection is completed in the depth of the 20m water and high dose radiation environment.

The Top guide passage

Moving and Inspection of ROV on shroud wall

Figure 5 - Inspection of internals by the T-type ROV
Submersible Type ROV for RPV Bottom Head Area (C-type ROV) 2)

**Structure and function**

The RPV bottom head area of the BWR NPPs is a very narrow and congested that Control Rod Drive (CRD) housings and In-core Monitoring System (ICM) housings are installed in grid pattern. To inspect this area, install/uninstall the inspection equipment and also removing some of the Control Rod Guide Tube (CRGT) from vessel bottom were necessary in each inspection target. However, by using C-type ROV for RPV, reduces the work time for installing/uninstalling inspection equipment and fewer CRGT removing is required. Figure 6 shows the appearance photograph of C-type ROV, and table 2 shows the specification.

![Figure 6 - The appearance photograph of C-type ROV](image)

<table>
<thead>
<tr>
<th>Size</th>
<th>W 120 mm × H 352 mm × L 250 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Approx. 6 kg (in air)</td>
</tr>
<tr>
<td>Driving function</td>
<td>Driving Thrusters (for cruise forward or backward)</td>
</tr>
<tr>
<td></td>
<td>Vertical Thrusters (for left/right circling, left/right moving, up/down)</td>
</tr>
<tr>
<td>Camera</td>
<td>CCD Camera, LED lights</td>
</tr>
<tr>
<td></td>
<td>Pan: 360 degrees</td>
</tr>
<tr>
<td></td>
<td>Tilt: 0 to 90 degrees</td>
</tr>
<tr>
<td>Environment Resistance</td>
<td>Radiation Resistance</td>
</tr>
<tr>
<td></td>
<td>Water Pressure Resistance</td>
</tr>
</tbody>
</table>

Table 2 - Specification of C-type ROV

The C-type ROV is box-shaped vehicle with 120 mm in width in order to move between the CRD housings which are approximately 150 mm apart. The ROV is small and lightweight enough to be carried around by one man/woman on the operating floor and inserted it into the RPV.
The ROV is equipped with the thrusters in back, above and below of the body. The thrusters in back are for cruising forward and backward, and these are designed to gain enough thrust force in order to drag cable along between the CRD housings. The thrusters at the above and below of the body make the vehicle to move to left or right, up or down, and rotate. This ROV has much longer life than existing ROV because use of the seals for movable parts such as the axis of thrusters and axis of the camera were avoided. This contributes to reduce the time of inspection.

There is a CCD camera and LED lights on the bottom of vehicle to meet the requirements of VT-3 \( ^{A} \) and MVT-1 \( ^{B} \). The camera pans 360 degrees and tilt 90 degrees, this ROV can perform VT inspection in various directions without change of position in the narrow vessel bottom head area. Figure 7 shows image of inspection by the C-type ROV in the RPV bottom head area.

**Effect of the ROV application**

HGNE utilized C-type ROV for VT in the RPV bottom head area at TEPCO’s Kashiwazaki Kariwa nuclear power station. Figure 8 shows an inspection video still image by this ROV in RPV bottom head area. The application of C-type ROV shortened a preparation time, such as the fewer removes of CRGT, in comparison with the conventional suspended camera type. Inspection is completed in the depth of 30 meters water and high dose radiation environment.

Figure 7 - Image of inspection by the C-type ROV in the RPV bottom head area

Figure 8 - Inspection video picture shot by the C-type ROV in the RPV bottom head area
SUBMERSIBLE TYPE ROV FOR NARROW SECTION (β-type ROV)\(^2\)

HGNE is developing ROV to achieve the visual inspection of the narrow area in the nuclear reactor that is difficult to access with the underwater camera. Figure 9 shows the β-type ROV, and table 3 shows the specification.

This ROV is designed by cylindrical shape (φ60mm and L:165mm), and the size of this ROV is for a smoothly movement inside the piping of 100mm diameter, 200mm bending radius.

The ROV is equipped with thrusters to drive forward, backward, right turn and left turn. In addition, this ROV include with tilt position adjustment mechanism so that ROV can cruise in the arbitrary direction of three dimensions. The CCD camera and LED lights unit at the front of ROV is possible the visual inspection (VT-1\(^A\) or MVT-1\(^B\)) in the arbitrary direction.

The basic piping mock-up test is completed. With this smaller ROV, HGNE hopes to expand area to be inspected.

![Image of β-type ROV](image_url)

**Figure 9 - The appearance photograph of β-type**

<table>
<thead>
<tr>
<th>Size</th>
<th>φ60mm×L165 mm</th>
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<tbody>
<tr>
<td>Weight</td>
<td>Approx. 0.4 kg (in air)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Driving function</th>
<th>Thruster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circling (for left/right circling)</td>
<td>Screw</td>
</tr>
<tr>
<td>Balance (pitch control)</td>
<td>Weight</td>
</tr>
</tbody>
</table>

| Camera                  | CCD Camera, LED lights |

**Table 3 - Specification of β-type ROV**

CONCLUSION

In this report, we described the function and the effect of underwater ROV developed. With the water extraction type ROV (T-type) and submersible type ROV (C-type), we reduced the preparation work, improved maintainancability, established the UT, VT inspection technique by remote control, and applied to the nuclear reactor. The submersible type ROV (β-type) is developing, and we hope to expand the inspection area.

Hitachi-GE Nuclear Energy will improve inspection technology continuously and consistently in the future and would like to contribute for the safe and efficient BWR operation.
REFERENCES


ANNOTATION

A) Visual Testing to detect abnormalities of transformation of equipment, damage of parts provided for by “Codes for Nuclear Power Generation Facilities – Rules on Fitness-for-Service for Nuclear Power Plants -”.

B) Minute Visual Testing to detect abnormalities such as wear-out, crack, corrosion, and erosion of surface of reactor core internal structure provided for by “Codes for Nuclear Power Generation Facilities – Rules on Fitness-for-Service for Nuclear Power Plants -”.