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Development of Visual Inspection Robots for Reactor Vessel Upper Head and Bottom Head

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1. Introduction

On March 2002, a cavity with a surface area of approximately 20 to 30 square inches was found in the reactor pressure vessel head at the Davis-Besse Nuclear Power Station. And on April 2003, South Texas Project Unit 1 made surprising discovery of boron acid leakage from two nozzles from a bare-metal examination of the reactor vessel bottom-mounted instrument penetrations during routine refueling outage. Figure 1 shows the cavity of reactor upper head, Figure 2 shows the leakage of reactor bottom head. In both cases, the early findings are prevent an accident.

The safety and reliability of nuclear power plants become more important. Inspection and maintenance of component should be achieved continuously. The human workers are susceptible to radiation exposure and manual handling machine is hard to access because of the complexity of the path[2].

This paper describes the remote-operated robot for the visual inspection of reactor upper head and bottom head. Remote-operated robot is useful to inspect and maintain the component of nuclear power plants, which reduce the radiation exposure of human operators and improve the reliability of the operation in nuclear power plants[3].

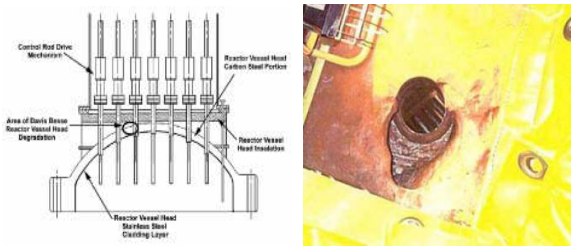

Figure 1. Sketch and photo of cavity on reactor vessel upper head

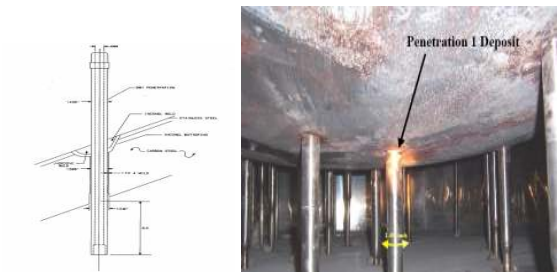

Figure 2. Sketch and photo of leakage on reactor vessel bottom head

2. Working Environments

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 complex path to access. Effective method for the inspection of the reactor head is the use of a robot system. So, we applied remote-operated robot system for the inspection of reactor upper head and bottom head.

The reactor upper head in KSNP, as shown in Figure 3, is comprised of 83 nozzles with a radius of about 12cm. The working space for robot is as follows: a minimum gap between nozzles is about 17.2cm, and a minimum gap between the head surface and thermal insulation is about 5cm. Thus a robot for the inspection of upper head should be required smaller 17.2cm in width, and 5cm in height.

The reactor bottom head in KSNP, as shown in Figure 4, is comprised of 45 nozzles with a radius of about 7.5cm. The working space for robot is as follows: a minimum gap between nozzles is about 17.2cm, and the height of the nozzle located on the center is about 6 cm and the minimum distance between the nozzles is about 20cm.. Thus a robot for the inspection of bottom head should be required smaller 17.2cm in width, and 5cm in height.

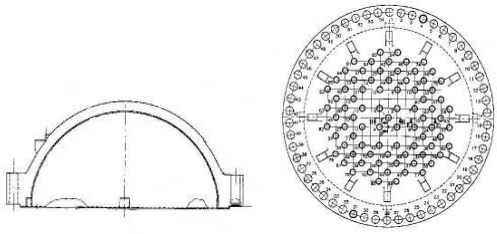

Figure 3. Upper head side view(left), top view(right)

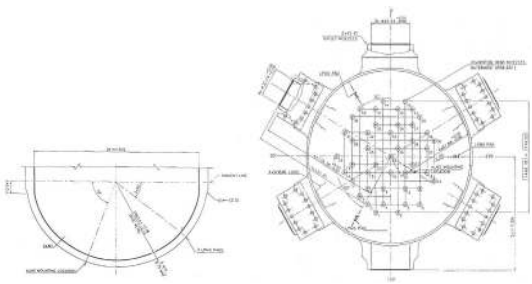

Figure 4. Sketch of bottom head side view(left), top view(right)

3. Visual Inspection Robots

The structure of the system is depicted in Figure 5.

The portable remote control and monitoring console consist of control module and a VTR and 3 LCD display. The control is operated with a joystick and a keyboard is used to on screen display. The control and monitoring console is placed in safety area and operated by human workers with no radiation exposure. The control and monitoring console is compatible with robots for the inspection of reactor upper head and bottom head.

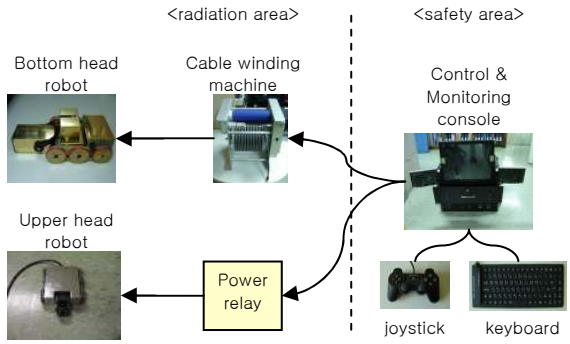

Figure 5. Structure of the visual inspection robot.

3.1 Upper head inspection robot

The robot is consists of wheel mechanism and camera roll/tilt mechanism. The inspection of upper head is achieved near the objectives, so we select a miniature camera with a fixed lens. The size of the robot is 4.5cm height, 13cm width and 18cm length.

Working on the slope of the sphere, mobile robot is adhere to the surface of the sphere. Equipped with a magnet on the lower side of robot body, we prevent robot the sliding to the downward. Figure 6 shows the upper head inspection robot.

Figure 6. Upper head visual inspection robot.

3.2 Bottom head inspection robot

The robot is consists of wheel mechanism and camera pan/tilt/lift mechanism. The distance of the objective for the inspection is near and far away. So a zoom camera is needed for the satisfaction of VT-1 code. The height of the robot is varied with 10cm~20cm for higher resolution.

Against the roughness and lots of obstacles in working surface, camera lift mechanism is used to lift the robot body. Figure 7 shows the bottom head inspection robot.

Figure 7. Bottom head visual inspection robot.

3.2 Bottom head inspection robot

The control and monitoring console consists of 3 monitors and a VTR and control module. There are 3 LCD monitors in the monitoring console: A 15” monitor for the inspection camera and two 6” monitors for the auxiliary cameras. The system is mainly operated with a handheld joystick and keyboard is used to type-in overlay texts.

Figure 8. Monitoring and control console.

3. Conclusion

Remote operated robot is useful to inspect the component of nuclear power plants, because of the limitation of radiation exposure and complexity of access. We developed remote operated robot systems for the visual inspection of the reactor upper head and bottom head leakage. Two types of mobile robots are developed: one is for the inspection of the reactor upper head and the other is for the inspection of bottom head. And a compatible control and monitoring console was developed for the upper head and bottom head robot.

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