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Development of Guide System for a Reactor Head Maintenance Robot

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1. Introduction

The Control Rod Drive(CRD) nozzles for PWR nuclear power plants(NPP) house the control rod drives. The number of nozzle penetrations range from the mid-30's to over 100 in each reactor head. The integrity of CRD nozzles is very important, because the primary pressure boundary is established with the J-groove weld joining the nozzle to the head clad surface. The Alloy 600 PWSC CRD nozzle leaks discovered in the fall of 2000 and spring of 2001 in several US plants. Therefore the NRC has recommended a more pro-active effort by US utilities to inspect similarly susceptible nozzles in all US plants. The primary safety concern is circumferential cracks that can permit the nozzles to separate from the head at high velocity and produce a large-break leak in the reactor vessel. A secondary concern is head leakage from any through-wall cracks in the nozzle or J-groove weld area.

Numerous inspection and repair tools have been developed to address CRD nozzle inspection and repair issues. For example, Framatome-ANP has been developed several inspection and repair tools: bare-head visual inspection crawler, blade eddy current probes and rotating eddy current proves, ultrasonic volumetric test(UT) blade proves, rotating UT prove, remote dye-penetrant test(PT) tool and remote weld tool. And they developed tool delivering systems such as ARAMIS, ROCKY and SUMO ROCKY. KPS and Westing House also developed inspection tool and delivering system. In this paper, a guide system delivering a welding repair tool and robot was developed. The welding repair tool and robot is being developed by Doosan heavy industry.

The guide system was designed to apply for the reactor head of Korean standard type NPP. The reactor head is placed on the laydown support during overhaul period. The maintenance of reactor head is carried out in the laydown support. First, work conditions of the job site were investigated to consider the entering and leaving convenience of the reactor head repair robot. The guide system which consists of horizontal guide and vertical guide is developed. A control system is developed to remotely control the guide system, and a monitoring system is also developed

2. Reactor Head Laydown Support and Robot

A nuclear reactor head is inspected and repaired on the laydwon support which is described in Fig. 1. There is no other appropriate area in the containment building. A inspection/maintenance robot and a guide system are delivered into containment building through air lock. The robot and guide system must be designed to be handled by 2 men.

After analyzing the work conditions of job site, a modification of outer wall and inner entrance to allow easy entrance of the maintenance robot was suggested.

A welding tool is being developed by Doosan heavy industry. The tool is positioned by GENESIS 2000

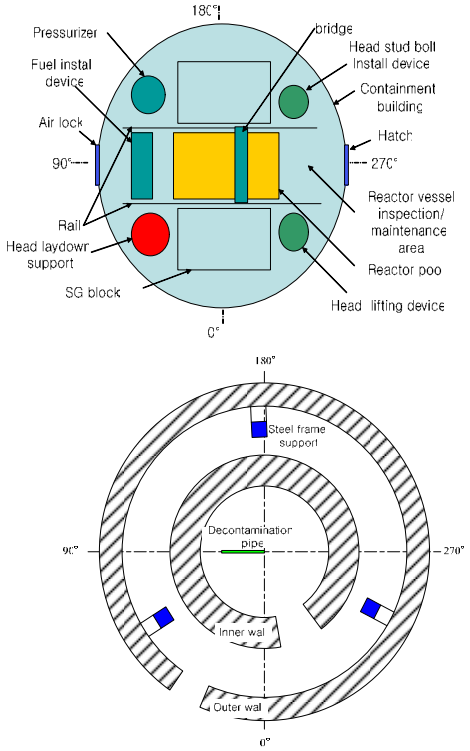

Fig.1. Reactor head laydown support.

Fig.2. Genesis 2000.

which is a remotely operated robotic fixture used in steam generators for delivery of eddy current inspection

equipment and tube repair tooling. Fig. 2 shows Genesis 2000 in a steam generator water-chamber. The weight of Genesis arm and Leg are 29.5kg and 41kg, respectively. The arm can carry a tool head weight of up to 34kg.

3. Guide System

The guide system consists of two parts: horizontal guide, vertical guide. To deliver the repair robot system in to the reactor head laydown support, it is needed at least a 3.8m long horizontal guide. The horizontal guide is designed to support more than 250kg load and to be divided into four parts to be able to be carried by 2 men. The driving system of the cart adopts rolling friction. The speed of the cart is 0.1m/sec

The height from the floor of the head laydown support to the first CRD nozzle is 3.7m. The vertical guide is designed to lift 130kg with a stroke, 1.35m. The stress analysis of the guide system with full length of genesis arm was carried out for structure safety

Fig.3. Guide system.

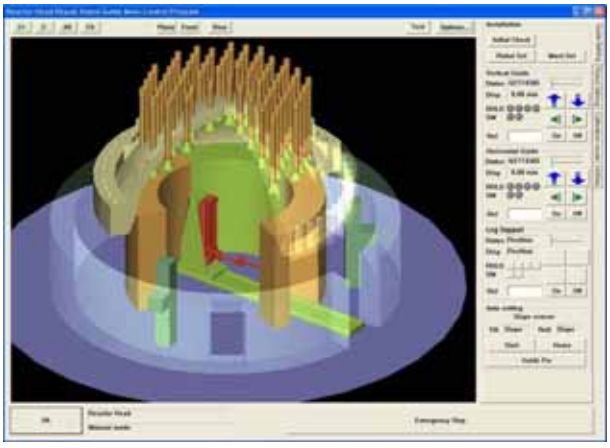

Fig.4. GUI program.

verification and weight reducing. Fig. 3 shows a guide system and a motion controller.

4. Control System

A motion controller in Fig. 3 and a control software program in Fig. 4 was developed to remotely control the guide system. The control program communicates with the motion controller through Ethernet. The program also provides a real time 3D graphic function which offers a remote reality.

The monitoring system supports the guide system by providing various video signals from the reactor head laydown support. The monitoring system has the capability to control one or two pan/tilt/zoom cameras. The monitoring system consists of a video monitor, quad view, joystick controller and pan/tilt/zoom cameras.

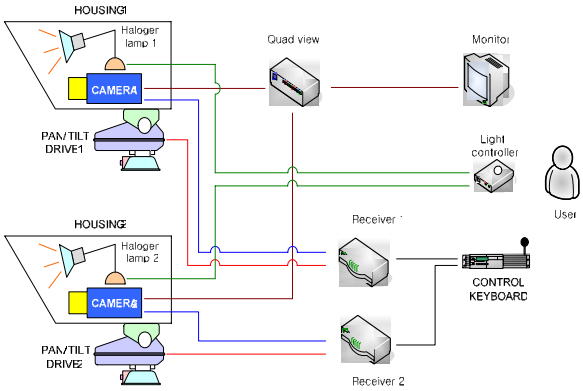

Fig.5. Monitoring system.

5. Conclusion

A remotely operated guide system delivering a welding repair tool and robot into the reactor head laydown support was developed. The guide system is designed to be divided into several parts for easy carriage and installation. A software program to control and manage the guide system was developed. The control program provides a real time 3D graphic function which offers a remote reality. The actual scene of repair site is monitored by a monitoring system. The monitoring system consists of a video monitor, quad view, joystick controller and pan/tilt/zoom cameras. The guide system will be tested in the reactor head mockup of KSNP

Acknowledgement

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REFERENCES

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