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Guide System for a Welding Repair Robot for a Reactor Head's CRD Nozzles

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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. Alloy 600 PWSC CRD nozzle leaks were 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 a high velocity and produce a large-break leak in a reactor vessel. A secondary concern is a head leakage from any through-wall cracks in the nozzle or J-groove weld area.

The maintenance of a reactor head is carried out in a laydown support during an overhaul period. To repair CRD nozzles, a welding repair tool and a robot were developed by Doosan heavy industry for the reactor head of a Korean standard type NPP. The robot should be delivered into the laydown support and be lifted to the height of 1.35m to reach the J-groove weld area.

This paper presents the guide system developed for the welding repair tool and robot. The guide system consists of a horizontal guide and a vertical guide. The guide system was designed to endure a full stretched robot with a 30kg tool. A control system and a monitoring system were also developed to remotely control the guide system.

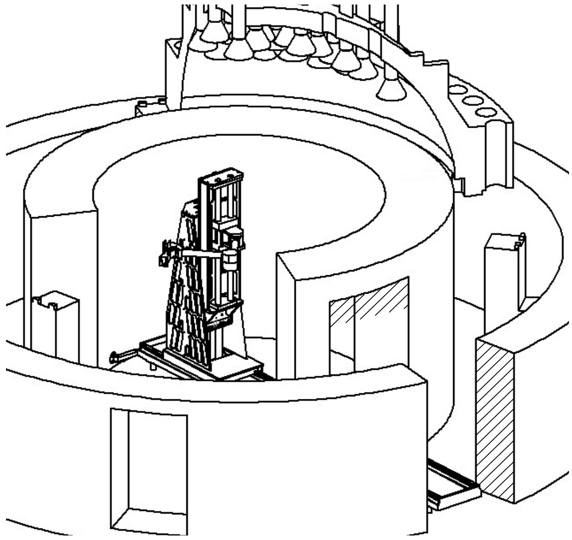


Fig.1. Reactor head's nozzle repairing system in the laydown support.

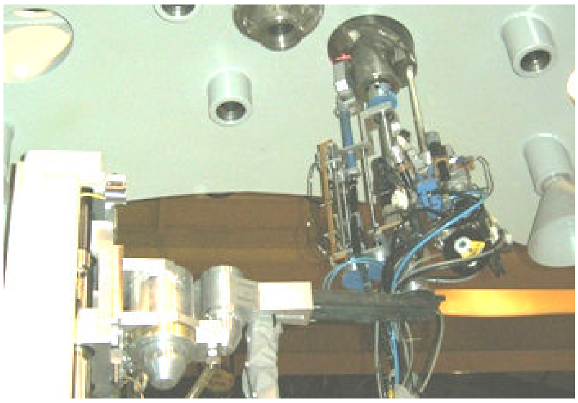


Fig.2. J-groove welding repair tool of CRD Nozzle.

2. Guide System Design

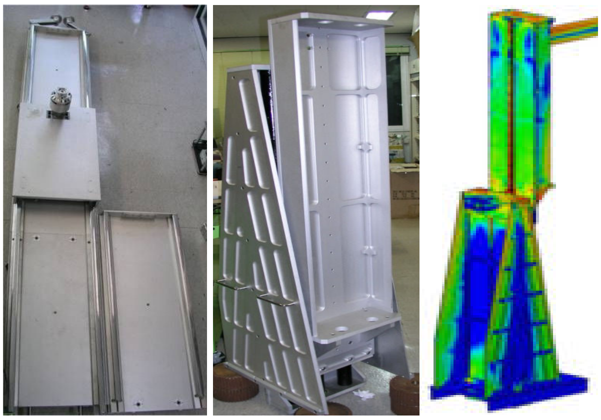
A nuclear reactor head is inspected and repaired on the laydown support which is described in Fig. 1. The laydown support needs another entrance at the outer wall to allow the repair system to go in and out. The inner entrance should be modified its height because the repair robot is higher than the inner entrance. As shown in the figure, the hatched areas need to be modified. .

Fig. 2 shows a J-groove welding repair tool developed by Doosan heavy industry. The tool consists of a TIG power supply, a 4-axis manipulator and a 3D vision sensor. The tool is positioned by the robot, GENESIS 2000 which is a remotely operated robotic fixture used in steam generators for a delivery of eddy current inspection equipment and tube repair tooling. The vertical travel of the robot is 0.889m, working radius is 1,561m and the weight of the robot itself is 70.3kg. The robot arm can carry a tool head weight of up to 34kg.

To reach the J-groove weld area of CRD nozzles, the robot arm and tool are delivered into the laydown support and lifted to the height of 1.35m by a guide system

The guide system consists of two sections: horizontal guide, vertical guide. To deliver the repair robot system into the reactor head laydown support, it needs at least a 3.8m long horizontal guide. The horizontal guide is designed to support more than a 250kg load and to be divided into four parts to be able to be carried by 2 men.

The vertical guide is designed to lift 130kg with a stroke, 1.35m so that the repair tool reaches the first CRD nozzle which height from the floor is 3.7m. The vertical guide is divided into 3 parts: a cart, a lifting part, a robot adapter. The driving system of the cart adopts a rolling friction wheel. The speed of the cart is 0.1m/sec. Fig. 3(a) shows a horizontal guide and Fig. 3(b) shows a vertical guide. The repair robot is installed on the robot adapter without any modification. The stress analysis was carried out with a full stretched genesis arm with a 30kg tip load for structure safety verification and weight reduction. The result of the stress analysis is shown in Fig. 3(c).



(a) (b) (c)

Fig.3. Guide system and stress analysis.

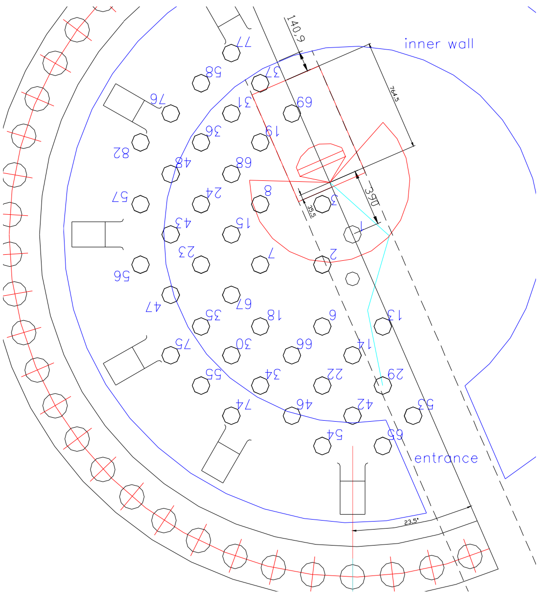


Fig.4. Entering direction and Working pose

To repair the J-groove weld area, four tools are developed: EDM tool, welding tool, UT tool and PT tool. Tool changes should be performed out of the laydown support due to a radiation exposure. Therefore vertical guide is designed to go into the laydown support at the rear side and out at the robot side. The tool approaches to nozzle in the radial direction to set a reference point easily.

4. Control System

Fig. 5 shows a control system of the guide system. The control system consists of the guide system, a motion control box, an industrial computer on which a main control program runs, a monitoring camera with a pan/tilt and a monitoring camera controller.

The motion control box is placed near the reactor head laydown support and it is connected to the main control computer by an Ethernet cable.

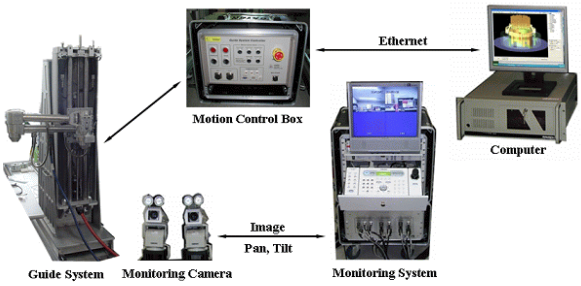


Fig.5. Control system of the guide system.

The guide system can be operated manually with the motion control box in the case of a emergency such as a shutdown of a main control computer. The manual operating function is implemented by the switches in the middle of the front panel of the motion control box.

The software program was developed to control and manage the guide system. Its important functions are a real time 3D graphic function which offers a remote reality, a communication function with a local motion control box to control the guide system, and so on.

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, a quad view, a joystick controller and two pan/tilt/zoom cameras.

5. Conclusion

A remotely operated guide system for delivering a welding repair tool and a robot into a reactor head laydown support was developed. The guide system was designed to endure a full stretched robot with a 30kg tool and to be divided into several parts for a easy carriage and installation. A motion control box providing a manual operating function was developed. The motion control box communicates with a main control computer through Ethernet. A software program to control and manage the guide system was developed, which provides a real time 3D graphic function for offering a remote reality. The actual scene of the repair site is monitored by a monitoring system. The guide system was tested in the reactor head mockup of a KSNP

Acknowledgement

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