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Guide System for a Robot Repairing 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 the reactor vessel. A secondary concern is a head leakage from any through-wall cracks in the nozzle or J-groove weld area.

The welding repair tool and robot is being developed by Doosan heavy industry to apply to the reactor head of a Korean standard type NPP. This paper presents the guide system being developed for the welding repair tool and robot. The reactor head is placed on the laydown support during a overhaul period. The maintenance of a reactor head is carried out in the laydown support. The guide system which consists of a horizontal guide and a vertical guide is developed. The guide system was designed to endure the full stretched robot with the 30kg tool. A control system and a monitoring system is also developed are developed to remotely control the guide system.

2. Guide System Design

A nuclear reactor head is inspected and repaired on the laydown support which is described in Fig. 1.

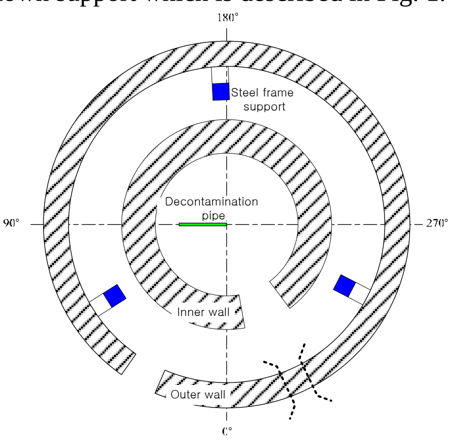


Fig.1. Reactor head laydown support.

To apply the repair robot, the outer wall and inner entrance of the laydown support have to be modified as dotted line in the Fig. 1.

Fig. 2 shows a welding tool being developed by Doosan heavy industry. 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 robot arm can carry a tool head weight of up to 34kg.

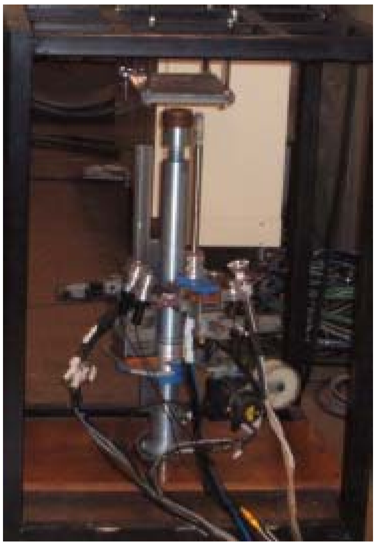
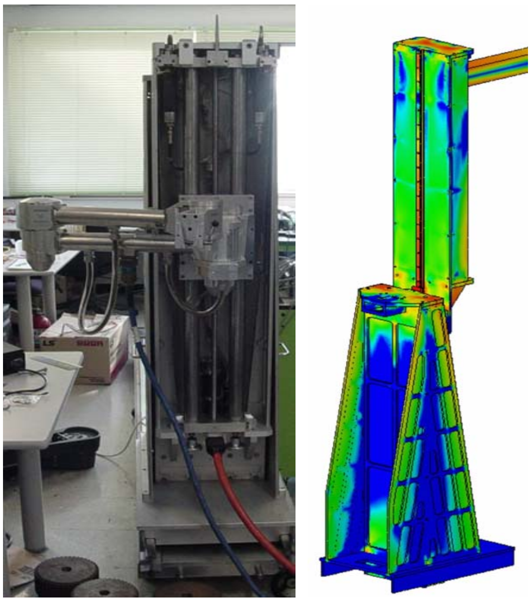


Fig.2. The Welding Equipment for CRD Nozzle Welds.

The guide system consists of two sections: horizontal guide, vertical guide. To deliver the repair robot system in to 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 driving system of the cart adopts a rolling friction. The speed of the cart is 0.1m/sec

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, robot adapter. Fig. 3(a) shows a guide system with the repair robot. The repair robot is installed on the robot adapter of the vertical guide. The robot can be detached easily. Fig 3(b) shows stress. The stress analysis was carried out with the full stretched genesis arm with 30kg tip load for structure safety verification and weight reducing.



(a) (b)

Fig.3. Guide system with the repair robot.

4. Control System

A motion control box in Fig. 4 was developed to remotely control the guide system. The motion control box is placed near the reactor head laydwon support and it is connected with main control computer by a Ethernet cable.

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

Fig.4. Motion control Box.

The software program was developed to control and manage the guide system. Its important functions are the real time 3D graphic function which offers a remote reality, communication function with the 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, quad view, joystick controller and pan/tilt/zoom cameras.

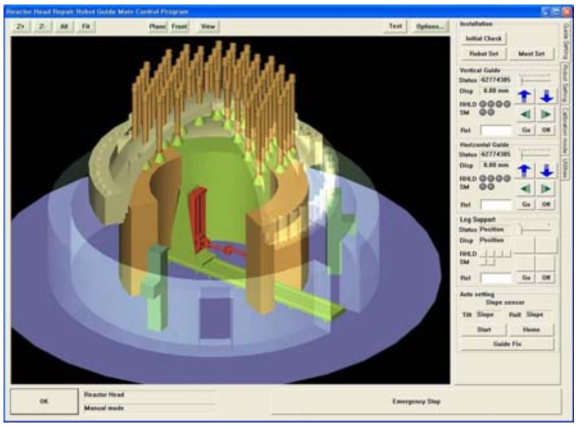


Fig.5. GUI of control program.

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 was designed to endure the full stretched robot with the 30kg tool and to be divided into several parts for an easy carriage and installation. A motion control box providing 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. The control program provides a real time 3D graphic function which offers a remote reality. The actual scene of the 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 a KSNP

Acknowledgement

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