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Technical note

Aerial work robot for a nuclear power plant with a pressurized heavy water reactor

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ABSTRACT

This paper presents an aerial work robot for a nuclear power plant (NPP) with a pressurized heavy water reactor (PHWR). The aerial work robot provides measurements by teleoperating a fuel handling machine placed at a high location in front of the PHWR. The robot can detect a leak from pipes such as delayed neutron (DN) monitoring tubes, which are also placed at a high place. The robot is equipped with radiation-hardened controllers, radiation-hardened cameras, and a noise robust communication system.

1. Introduction

The systems and components of a nuclear power plant age with its operation. Since a fuel-handling machine, one of the major components of a PHWR NPP, also ages, at the end of the design life of the NPP, the machine may be stuck to the pressure tube in front of the PHWR Calandria. Even though the machine has a troubleshooting measure of a manual drive mechanism at its rear side and the workers make the machine operate normally by handling the manual drive mechanism, it is still a difficult problem to access the manual drive mechanism. When the machine is stuck, the NPP is being operated so that the radiation level is extremely high and the machine can be located at a high position of up to nine meters. Therefore, a human worker cannot approach the mechanism and the mechanism should be handled remotely.

When the machine is stuck to the pressure tube, the workers go down to the basement, disassemble the concrete plug which is under the manual drive mechanism from the ceiling of the basement and try to manipulate the mechanism with a long pole-shaped manually operated device. Choi made a motorized device with a telescopic mast to handle this mechanism (Choi et al., 2006). Because these devices are operated in the basement of the reactor room, the concrete plug should be removed from the ceiling of the basement and the pole or the mast should be extended up to 15 m. The pole or mast can be deformed largely due the flexibility. This flexibility makes it difficult to engage the tool attached to the end of the pole with the manual drive mechanism. To avoid any difficulties, Seo developed a mobile robot that accesses the manual drive mechanism on the ground floor (Seo et al., 2007). The mobile robot can extended to 8 m high which is too low to inspect the DN monitor tubes.

This paper shows the aerial work robot, which can raise a tool to a height of 12 m with a telescopic mast. Thus, the robot can teleoperate the fuel handling machine and inspect the DN monitor tubes. The robot equips with radiation-hardened controllers, radiation-hardened cameras, and a noise robust communication system.

2. Working environment in front of the Calandria

A PHWR should be refueled everyday while the reactor is working. For this purpose, there is a fuel exchange machine, as shown in Fig. 1. Since the fuel refueling takes place within a 9 m height, there is large space in front of the Calandria, which is a reactor room. In addition, the radiation level is so high during the on-power state that maintenance is carried out behind the shelter wall. The wall moves on the guide rail in the ditch with a width of 75 cm and depth of 25 cm, as shown in Fig. 1. It was noted that there is a service area with a passing gate with a height of 2 m and width of 1.5 m.

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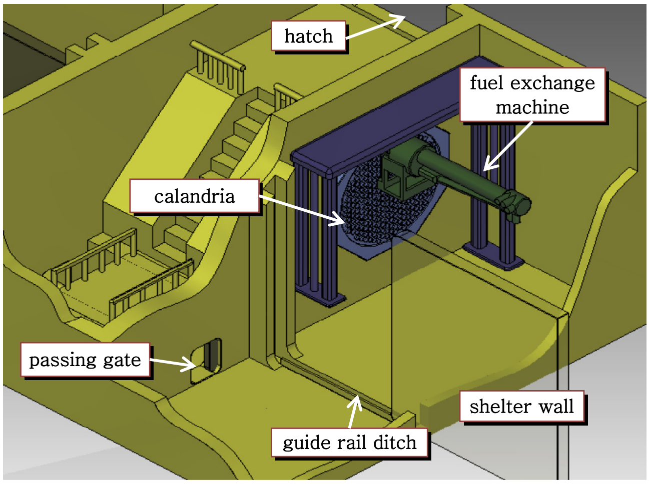

Fig. 1. Working environment in front of the Calandria.

Table 1
Design criteria of the aerial work robot.

Min height	<2 m
Max height	>9 m
Width	<1.5 m
Obstacle ditch	75 cm × 25 cm ($w \times d$)

From the investigation of the working environment, the design criteria can be determined for an aerial work robot which teleoperates the fuel handling machine and inspects the DN monitor tubes as follows (see Table 1).

3. Robot system

3.1. Mobile platform

The width of the mobile platform is designed to be 0.89 m to easily pass through the gate. To access the Calandria face area, the monitoring robot should cross over the guide rail ditch. Thus we designed a flipper and a reconfigurable mechanism for the monitoring robot. Fig. 2 shows the mobile platform with four reconfigurable flippers. The flippers have an active small wheel at the end of them.

When the aerial work robot crosses over the guide rail ditch, the robot pulls down the flippers for the small wheels to touch the ground and rolls the small and main wheels. The small wheel is driven synchronously with a main wheel by a chain. The flippers and reconfigurable mechanisms should stand the weight of the aerial work robot, which is about 500 kg. Fig. 3 shows the passage of the guide rail ditch. The robot changes the direction using the skid steering method. The robot has two omni-wheels at the rear side, which reduces the turning torque to a third that of the robot with all rubber wheels (Shin et al., 2013).

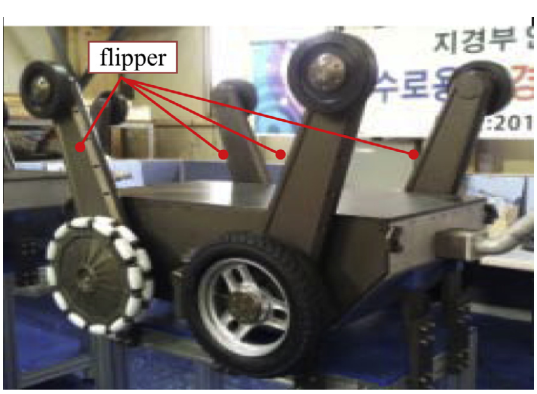

Fig. 2. Mobile platform.

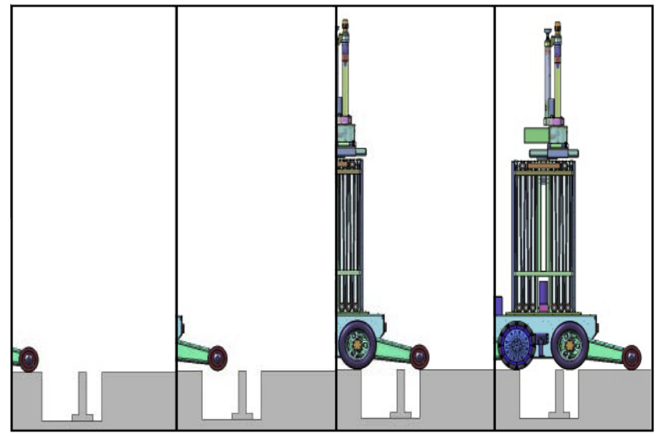

Fig. 3. Crossing the guide rail ditch.

Fig. 4. Telescopic mast.