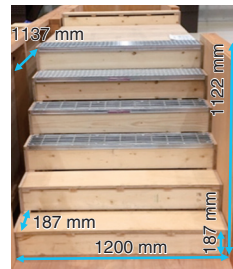
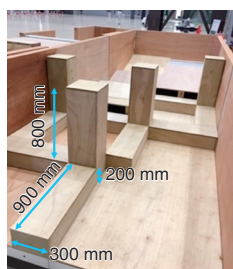


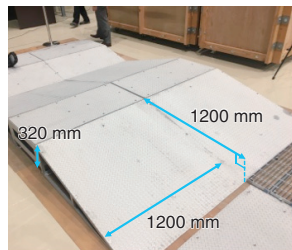
1-11 Development of a Test Method for Remotely Operated Robots for Decommissioning

— Design of Testing Fields for Robot-Performance Evaluation and Operator-Proficiency Training —

(a) Pillar-shape test field with steps (b) Staircase-type test field



(c) Checkered iron slope test field



(d) Grating floor test field

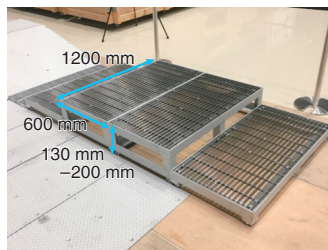


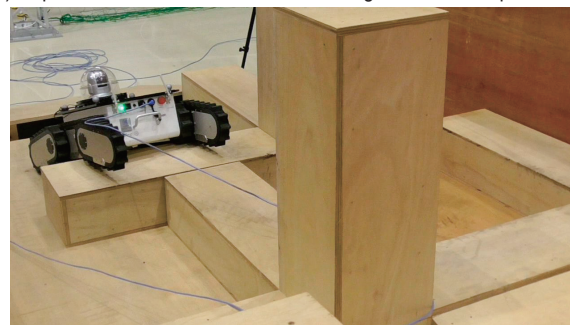
Fig.1-22 Developed test fields

Cable troubles, recognition ability of the working environment, running performance on uneven terrain, and the material properties of the floor were selected as major challenges facing remotely operated robots; to evaluate these problems, we devised four types of testing fields (a)–(d).

Inside the reactor buildings at the TEPCO's Fukushima Daiichi NPS (1F), remotely operated technologies including robots are being deployed for decommissioning tasks. However, some troubles with robot operations have occurred on account of the hazardous working environment. Therefore, it is crucial to execute prior performance evaluation of the robots and operator-proficiency training according to the mission and task. As a pioneering work by the National Institute of Standards and Technology (NIST), a series of standard test methods for response robots (STM) have been developed to measure robot mobility and operability in hazardous environments and to facilitate quantitative evaluation. It is reasonable to introduce a similar STM concept to remote operations for smooth decommissioning of 1F. Most STMs simulate ground surfaces such as rubble utilizing wood; however three-dimensional structures and metal properties that existed in the reactor building have not been prepared. The aim of this research is to develop test methods and test fields for decommissioning tasks that introduce the characteristics and properties of the working environment in the reactor building.

First, we reviewed video data related to robotic operation that is available from the TEPCO website and used a time-analysis approach to study the robot's behavior. The results revealed that traveling, traveling over steps, angular adjustment of sub-crawler tracks, and stopping account for a large percentage of the robot's time allocation. Also, classification and functional

(a) Reproduction of the effect of cable twining around developed test field



(b) Reproduction of blind region in the view by developed test field



Fig.1-23 Verification of the remotely operated robot by test runs

Test runs of the remotely operated robot showed that our testing fields reproduced the problems in remote operations.

analysis of operational troubles demonstrated that the major concerns include structures interfering with the cable connected to the robot and difficulty in recognizing the surrounding environment and the status of the robot.

Based on these results, we designed and developed a test field with three mutually perpendicular elements to reproduce cable interference and low surroundings recognition (Fig.1-22(a)). By conducting tests with a remotely operated robot, this setup is confirmed to reproduce the effect by which the cable can become entwined around a pillar-shaped part (Fig.1-23(a)). This pillar also became an obstacle, generating a blind spot in the operator's view (Fig.1-23(b)). When the robot moves in the reactor building, travel over the steps made of checkered iron and a grating is required. Therefore, we developed a staircase-type test field capable of changing the properties of the floor (Fig.1-22(b)). We also developed checkered-iron slopes and grating floors (Figs.1-22(c) and (d)). We could reproduce situations causing major trouble for remote operation and simulate the properties of the working environment. Developed fields have a size compatible with STM, as developed by NIST.

In a future study, we will design and develop a test field modeling the part accessible to the inside of the primary containment vessel (PCV) and arrange various test environments based on a combination of the test fields developed for promoting robot development and operator training to contribute to the decommissioning of 1F.

Reference

Kawabata, K. et al., Design of Test Methods for Remotely Operated Robots Utilized for Decommissioning Tasks, Proceedings of 2017 International Congress on Advances in Nuclear Power Plants (ICAPP 2017), Fukui and Kyoto, Japan, 2017, paper 17476, 4p., in DVD-ROM.