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Technical note

Seamless remote dismantling system for heavy and highly radioactive components of Korean nuclear power plants

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ABSTRACT

A seamless remote system for dismantling heavy and highly radioactive components during the decommissioning of a nuclear power plant is proposed. The originality of the dismantling system is in its ability to handle all the processes involved in the dismantling of major components of a nuclear power plant without external intervention. Previous types of dismantling equipment were designed for specific components or a particular process, which required time consuming and risky equipment replacement tasks between different processes. The proposed dismantling system was designed and verified by simulation of all the processes for dismantling the major components of a Korean nuclear power plant. Several challenges such as working in confined spaces and with complex movement lines as well as interference between components were overcome. The proposed system is capable of handling all the dismantling processes without equipment replacement tasks or the need to drain the reactor pool. The system is expected to considerably reduce the time and cost of the entire decommissioning process while also improving safety.

1. Introduction

Since the commissioning of the first nuclear power plant (NPP) in Korea in 1978, 22 others have commenced operation. Although their termination licences may be revised according to government policies, the first NPP is expected to be dismantled in 10 years, and approximately 10 more would follow suit over the next 20 years. The international market of NPP decommissioning is also expected to expand dramatically. However, only a few advanced countries are presently experienced in nuclear decommissioning and have developed related technologies (Radioactive Waste Management Committee, 2011). The effective handling of the expected upsurge in the decommissioning of nuclear facilities thus requires the further development of various related technologies. The major components of an NPP, which include the reactor pressure vessel, steam generator, reactor coolant pump, and pressuriser, are very heavy and highly radioactive, and their dismantling processes are the most difficult and dangerous during decommissioning. High-level radiation restricts access by human workers, and this makes manual cutting of the heavy and thick structures – often made of carbon steel – very impractical. Remote dismantling technologies thus play an important role in NPP decommissioning.

The determination of the concept of a remote dismantling system is a very important preparatory step in NPP decommissioning because a well-designed remote dismantling system would considerably reduce the total decommissioning cost and time as wells as improve the safety of the entire task. Process simulation is necessary for the design process to avoid potential problems and risks and to select an effective mechanism or equipment for managing various dismantling scenarios. A 3D graphical simulation of the dismantling process of the Korea Research Reactors 1 and 2 was performed by Kim et al. (2003), and a digital mock-up system for selecting a proper decommissioning scenario for the two reactors was also developed (Kim et al., 2006). A process simulation technology that utilises haptic rendering was used to verify the maintenance task in a PyRoprocess Integrated Inactive DEmonstration (PRIDE) digital mock-up (Park et al., 2011). The Commissariat à l'énergie atomique et aux énergies (CEA) conducted an R&D program to develop a simulation tool that can be used to understand constraints, test different alternatives, and train workers (Chabal et al., 2011).

This paper proposes a seamless remote dismantling system as a novel solution to the time consuming, costly, and risky interruptions that occur between the different dismantling processes

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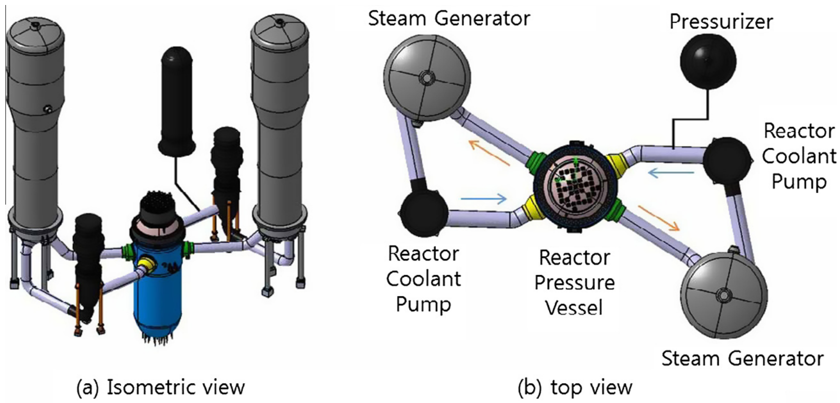

Fig. 1. Primary system of Korean NPP.

involved in the decommissioning of an NPP. Because conventional remote dismantling systems are designed to handle a single process such as cutting of pipes or segmenting of cylindrical parts, interruptions are required to replace equipment between different processes. The replacement operations often involve human workers, are time intensive, and sometimes require the drainage and supply of substantial amounts of water to the reactor pool for protection against radiation.

The following section presents an overview of the first Korean NPP, which is very likely to be the first to be decommissioned in the country and was the subject of the dismantling process simulated in this study. Section 3 describes how the proposed seamless remote dismantling system effectively handles the tasks of dismantling the major components of the NPP without external intervention, such as the removal of existing equipment, installation of additional equipment, and operations usually performed by human workers. The conclusion section summaries the study and states the potential contributions of the proposed system.

2. Overview of Korean NPP

The primary system of the first Korean NPP is a Westinghouse two-loop pressurized water reactor that consists of a reactor pressure vessel (RPV), two steam generators (SG), two reactor coolant pumps (RCP), and a pressurizer (PZR) (see Fig. 1). The RPV composed of the reactor vessel (RV), the vessel head and reactor internals is approximately 3.4 m in diameter and 12 m in height. The RV weighs approximately 180 tons and has carbon steel walls with a stainless steel cladding of which thickness is 1.7 m in the cylindrical part, 1.2 m in the bottom hemispheric part, and 0.53 m in the flange.

The containment building is a reinforced steel structure with a can-like shape, with the RPV at its centre (see Fig. 2). The polar crane, hand rail, and reactor pool in Fig. 2 are used to provide the proposed dismantling system with utilities because the use of existing equipment reduces the overall decommissioning cost. The polar crane is primarily used to transport heavy components within the containment building, whereas the hand rail is used to deploy the equipment and transport relatively small objects within the reactor pool.

The reactor pool is situated above the RPV at a floor elevation of between +44 ft and +70 ft, and is temporarily filled with water for protection against radiation during re-fuelling. At a floor elevation of +70 ft in the containment building, the reactor pool is located at the centre and is 7.0 m long and 16.5 m wide, and includes a reactor internals storage area that is 5.5 m long and 7.2 m wide (see Fig. 3). Although the reactor internals storage area is very small for the installation of a large number of equipment, it affords the best dismantling workshop with radiation protection and isolation from contamination.

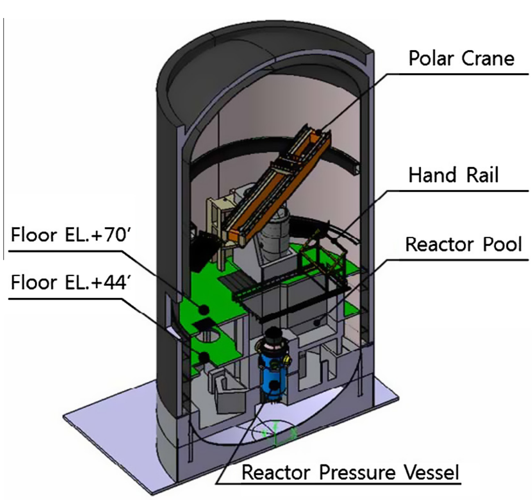

Fig. 2. Containment building.

3. Seamless remote dismantling system

The proposed seamless remote dismantling system has a conceptual design with specifications and operation mechanisms for components that closely interact with each other. The components of the system are yet to be developed, and only a digital mock-up designed with reasonable considerations based on existing equipment and common engineering practise is presented here. The system was designed and demonstrated using the process simulation software developed by the Korea Atomic Energy Research Institute (KAERI), which is based on DELMIA developed by Dassault Systemes. The process simulation software provides graphical tools for solving spatial problems and a unique function that can be used to flexibly simulate cutting processes.

The seamless remote dismantling system consists of a circular saw, gantry manipulator, waste container, band saw, and turn table, and can be used for both dry and wet operations (see Fig. 4). The layout of the components was determined by delicate considerations such as the movement lines of heavy components from the reactor cavity area to the workshop, movement lines of segmented wastes from the cutting equipment to the waste container, and cutting of large and long cylindrical components involving slicing using a circular saw and segmenting using a band saw.