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Technical note

A methodology to simulate the cutting process for a nuclear dismantling simulation based on a digital manufacturing platform

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ABSTRACT

This study proposes a methodology to simulate the cutting process in a digital manufacturing platform for the flexible planning of nuclear facility decommissioning. During the planning phase of decommissioning, visualization and verification using process simulation can be powerful tools for the flexible planning of the dismantling process of highly radioactive, large and complex nuclear facilities. However, existing research and commercial solutions are not sufficient for such a situation because complete segmented digital models for the dismantling objects such as the reactor vessel, internal assembly, and closure head must be prepared before the process simulation. The preparation work has significantly impeded the broad application of process simulation due to the complexity and workload. The methodology of process simulation proposed in this paper can flexibly handle various dismantling processes including repetitive object cuttings over heavy and complex structures using a digital manufacturing platform. The proposed methodology, which is applied to dismantling scenarios of a Korean nuclear power plant in this paper, is expected to reduce the complexity and workload of nuclear dismantling simulations.

1. Introduction

The dismantling of major components of a nuclear power plant is one of the most difficult activities during nuclear facility decommissioning, which includes facility characterization, decontamination, dismantlement, waste management, and site remediation for these high-radiation, large, and complex structures. In the planning phase, the organization of the dismantling process and the selection of dismantling equipment have a significant effect on the cost and safety of the decommissioning (Radioactive Waste Management Committee, 2011). Therefore, the visualization and verification of the dismantling process and equipment via process simulation are very useful for the flexible planning of nuclear facility decommissioning. Various dismantling scenarios and equipment can be effectively verified in a virtual environment at a low cost, and the visualization of the dismantling process can enable various experts to consider the situation more concretely. The optimization of the process and equipment via trials over various scenarios is an important part of the process simulation, as well.

In recent years, the manufacturing industry has aggressively adopted digital manufacturing systems to design assembly lines with enhanced productivity. Maropoulos and Ceglarek reviewed the standard definitions of verification and validation in the context of engineering design and progresses, and presented industrial requirements and research trends related to the technology (Maropoulos and Ceglarek, 2010). A simulation-based approach was proposed to support engineers in the process of designing cooperating robot cells related to automotive assembly lines (Papakostas et al., 2011).

In the area of nuclear facility decommissioning, process simulation has various research and industrial applications. A simple implementation of a commercial tool was applied to the dismantling process of the rotary specimen rack (RSR) in the Korea Research Reactor-1&2 (KRR-1&2) (Kim et al., 2003). Engineers of San Onofre Nuclear Generating Station (SONGS) were the first to apply the technology to the nuclear industry to replace steam generators on time and on budget (Stephens, 2006), and the digital mock-up (DMU) system was developed to realize an effective work process (Kim et al., 2006).

Software capable of estimating the dose rate and optimizing costs has been developed using process simulation because radiation protection for workers entails extensive financial and safety

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Fig. 1. Example segmentation plan of RPV.

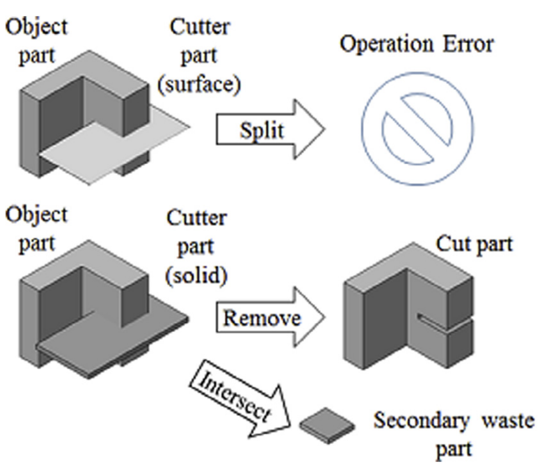

Fig. 2. Object-cutting operations of CAD system.

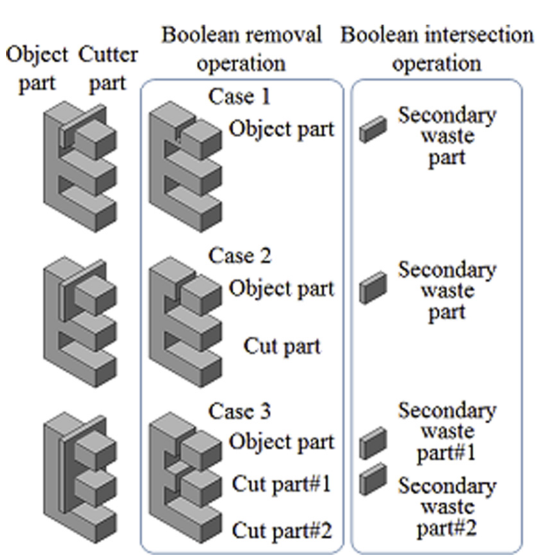

Fig. 3. Classification of object-cutting cases.

Table 1
Object-cutting algorithm with Boolean remove command.

Algorithm ObjectCutting (object-part, cutter-part)	
GET	object-part
GET	cutter-part
INIT	temporary-part
COPY	object-part into temporary-part
COPY	cutter-part into temporary-part
INTERSECTION	object-part with cutter-part to intersect-part
IF nVOLUME(intersect-part) = 0	
RETURN	null
ENDIF	
weight_2ndWaste = fVOLUME(intersect-part) * density	
REMOVE	object-part with cutter-part to remove-part
IF nVOLUME(remove-part) = 1	
COPY	remove-part into object-part with overwrite
RETURN	object-part
ELSE	
INIT	list-parts
CREATE	BREP solid from 1st cut-volume
COPY	BREP solid into object-part with overwrite
APPEND	object-part to list-parts
FOR i = 1 to nVOLUME(remove-part) – 1	
INIT	cut-part_i
CREATE	BREP solid from (i+1)th cut-volume
COPY	BREP solid into cut-part_i
APPEND	cut-part_i to list-parts
ENDFOR	
ENDIF	
RETURN	list-parts

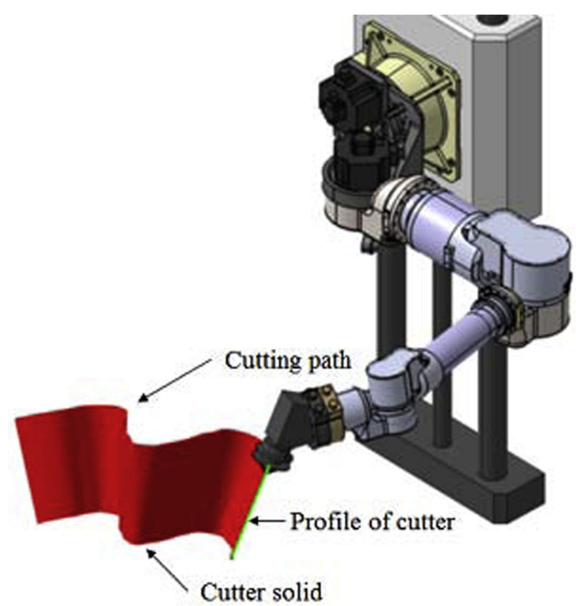

Fig. 4. Creation of cutter solid.

costs. A decommissioning engineering support system (DEXUS) was developed to create a dismantling plan using the quantification of radioactive waste, the visualization of the radioactive inventory, the simulation of the dismantling plan, and the evaluation of the workload in radiation environments (Iguchi et al., 2004). NARVEOS, an industrial product developed by EURIWARE, provides various functions such as geometric kernel functions, dose rate