Development of 3D Visualization Technology for Medium-and Large-sized Radioactive Metal Wastes from Decommissioning Nuclear Facilities - 14159

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ABSTRACT

In the field of decommissioning nuclear power plant, the total amount of nuclear decommissioning market reaches about 1800 million USD. Recently, there is an increase in the number of nuclear power plants, which is ended of operating life. Furthermore, according to the report on radioactive wastes from Decommissioning Nuclear power plant written by Korea Power Engineering Co., Inc., it is expected that the nuclear decommissioning market size will rapidly increase from 2030 to 2050. The large amount of radioactive metal wastes will be generated during the operating period as well as decommissioning nuclear facilities including nuclear power plants. In order to make less radioactive metal wastes, the self-disposal technology of radioactive metal wastes should be developed.

The purpose of this study is to develop 3D visualization technology for large radioactive metal wastes from decommissioning nuclear power plants. The 3D-SCAN data files from 3D scanner are saved as text files, which consist of each lattice's Cartesian coordinates (x, y, z). The data of this text files that consist of dots should be converted into the other type of data file having line and surface data because this is text file, which is created from 3D scanner, cannot be utilized for MCNP code (Monte Carlo N-Particle code) directly. After following some step, we can create the input texts for MCNP about the data from 3D-SCAN. This technology is expected to be applied with other technologies and this interlocking system can help with developing licensing materials or the radioactive wastes handling, disposal during the decommissioning process.

INTRODUCTION

After the Fukushima Daiichi nuclear power plant accident, there are some change on national nuclear policy and the increased interest in decommissioning nuclear power plants around the world.

Moreover, there is the increase in the number of operating nuclear power plants and old nuclear power plants. With the increased number of nuclear power plants, the amount of radioactive metal wastes generated from the old components replacement process and decommissioning process is also gradually increased. For one 1,100 M We PWR (Pressurized Light Water Reactor) nuclear power plant, It is reported that the radioactive metal wastes from decontamination and decommissioning nuclear facilities amount to 0.50 billion ton. Additionally, the amount of radioactive metal wastes is 3 drums on 1981, 159 drums on 1990, 428 drums on 2000, 784 drums on 2009.

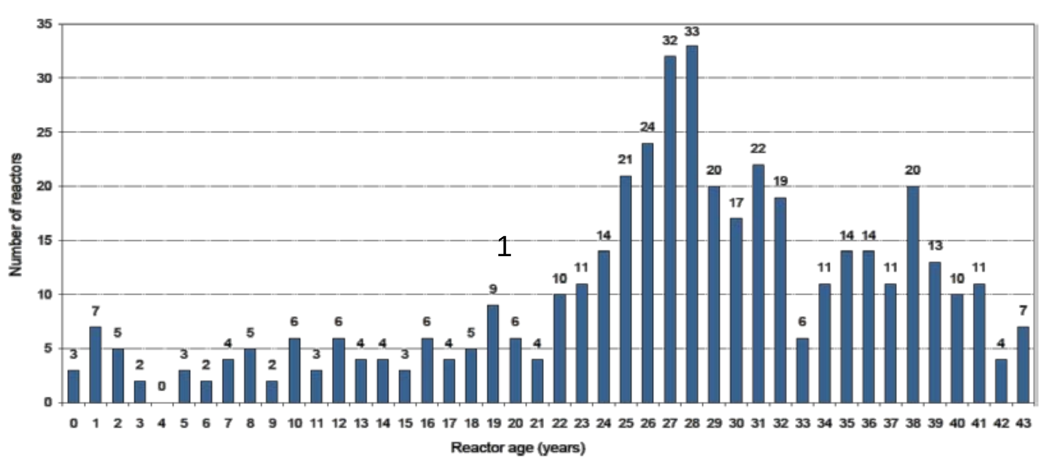

Fig.1. Number of Reactors in Operation by age (as of 31 Dec. 2012).

Status of the large-sized radioactive metal wastes

There are mainly three representative components of the large-sized of radioactive metal wastes; a steam generator, a nuclear reactor head, and a component cooling water system (CCW Hx).

The radioactive metal wastes are generated in the case of the replacement of Atmosphere Cleanup System (ACS) or Cooling Water Pipe in Nuclear power plant. Additionally, during improving the work environment of the radiation control area process and mending the old facilities, the radioactive metal wastes can also be created. Totally, 26 numbers of the radioactive metal wastes from decommissioning nuclear power plants are decided to be created; 16 numbers of steam generators, 4 nuclear reactor heads, and 6 CCW Hxs. In addition, there are 20 numbers of steam generators under the consideration to be decommissioned. Therefore, the total 199 numbers of large radioactive metal wastes are decided, planned, decommissioned to be replaced.

TABLE I. The status of the large-sized of radioactive metal wastes decided to be replaced

	Steam generator	Nuclear reactor head	CCW Hx	Total
Decided	16	4	6	26
Planned	20			20
Decommissioned	54	20	79	153
Total	90	24	85	199

TABLE II shows how many the large-sized of radioactive metal wastes will be generated from decommissioning nuclear power plant in Korea and when they are occurred. From decommissioning Wolsong #1 on 2013 to Hanul #6 on 2065 after decommissioning of nuclear facilities, the total number of steam generators, Nuclear reactors and CCW Hxs generated from the decommissioning process is expected as 54, 20 and 79. To be specific, in the case of Wolsong nuclear power plant, 16 steam generators, 4 nuclear reactor heads, 16 CCW Hxs will be generated.

TABLE II. The large-sized of radioactive metal wastes generated from decommissioning

component	Quantity	Occurred
Steam generator	54(16)	2013 (Wolsong #1) ~ 2065 (Hanul #6)
Nuclear power reactor	20(4)	
CCW Hx	79(16)	

The large-sized of radioactive metal wastes are stored in temporary storage facilities and Comprehensive treatment building. TABLE III can describe the status of the radioactive metal wastes such as the type of component and quantity of wastes.

Most of the large-sized of radioactive metal wastes are stored in temporary storage facilities today. In addition, because the constructing the Nuclear Waste Disposal Sites are delayed, most of the radioactive metal wastes generated from nuclear power plants are temporarily stored in AR storage facility (temporary storage facility).

It is expected that the wastes are put into appropriate disposal container after the appropriate processing such as cutting procedure and then go through some procedures such as characterization and drum packaging to meet the takeover provisions of the disposal site for further final disposal of radioactive wastes.

TABLE III. The status of the large-sized of radioactive metal wastes decided to be replaced

Nuclear power plant	Component	Quantity	Occurred	Status (storage facility)
Kori #1	Steam Generator	2	1998	temporary storage facility (storage # 4)
Kori #2	CCW Hx	4	2005~2006	temporary storage facility (controlled area)
Yeongkwang #1	CCW Hx	2	2007	temporary storage facility (controlled area)
Wolsong #1	Pressure Tube	2	2009	temporary storage facility (SF storage)
Hanul #2	Steam Generator	3	2011	temporary storage facility (separated storage)
Hanul #1	Steam Generator	3	2012	temporary storage facility (separated storage)
Kori #1	Nuclear reactor head	1	2013	Comprehensive treatment building
Hanul #3,4	Steam Generator	4	2013~2014	temporary storage facility
Kori #2	Nuclear reactor head	1	2016 (planned)	temporary storage facility
Yeongkwang #3,4	Nuclear reactor head	2	2015 (planned)	temporary storage facility
Yeongkwang #3,4	Steam Generator	4	2016~2017 (planned)	temporary storage facility

Characteristics of the large-sized radioactive metal wastes

The radioactive metal wastes in Korea, only the surface contamination of wastes are estimated and the result of the estimation is that not only the radioactive density of corrosion radionuclide such as Co-60, Ni-59 and Ni-63 but also that of tritium are high.

In addition, those who implement the cutting process can make decisions on the shape of radioactive metal wastes without any formal cutting procedures and the shapes of radioactive metal wastes are changed during the cutting process. Therefore, the radioactive wastes from decommissioning nuclear power plants have some certain shapes. The 70 percent of radioactive metal wastes mostly are in the form of rectangular or cylinder form. Therefore, the radioactive metal wastes that will be created from decommissioning nuclear power plants will be disposed in the form of plane or cylinder as cutting shapes.

In the case of Korea, Some of domestic nuclear power plant such as Wolsong #1(PHWR: Pressurized Heavy Water Reactor) and Kori #1(PWR: Pressurized Water Reactor) should be decontaminated and decommissioned after their design life. But the domestic technologies of decommissioning nuclear power plants are evaluated 70% of that of other nuclear advanced nations so the development of domestic self-disposal technology is highlighted. According to the Nuclear Safety Act, Self-disposal is defined that Operators of nuclear reactors dispose radioactive wastes that have less than the classification level determined by Nuclear Safety and Security Commission in the way of incineration, landfill or recycling them. There is the characterization method depending on source and the densities of radio-nuclides in a drum are determined with the use of one program. But this is only used as a reference because this method has limitation such as high uncertainty. Therefore, it is needed to development of the self-disposal technology and 3D scanning technology for large-sized radioactive metal wastes from nuclear power plants

Development of 3D scanning technology for the radioactive metal wastes using the 3D-scanner

1. The information on 3D Scanner and data from 3D Scanner

In order to get 3D image from the radioactive metal wastes, it is required that a noncontact 3D scanner are used, considering the radioactive nuclides in objects, and also the 3D-SCAN data from 3D scanner are saved as text files via exclusive converting program. Scanned 3D images are divided as small lattice form and saved. This text file is a data file, which is composed of each lattice's Cartesian coordinates (x, y, z). Fig.2. shows the formation of 3D-SCAN output file. This file has three component; x, y, z, and they can make coordinates, like dot (x, y, z). It can contain 1.5 milions-1.8milions of dots in the range of 10*10*10cm. Inside of the surface is void and located on the visualized surface as Cartesian coordinates. As this type of data cannot be used with MCNP code directly, the data with dots should be converted into line and plane type of data.

```
solid box.stl
facet normal 0.7178968453 0.4359717430 -0.5427271495
outer loop
vertex 18.625431 58.218906 -1043.966919
vertex 18.426994 58.906116 -1043.677368
vertex 19.045918 58.324154 -1043.326172
endloop
endfacet
facet normal 0.6881743409 0.4413527590 -0.5758678830
outer loop
vertex 18.050632 58.539536 -1044.408081
vertex 18.426994 58.906116 -1043.677368
vertex 18.625431 58.218906 -1043.966919
endloop
endfacet
```

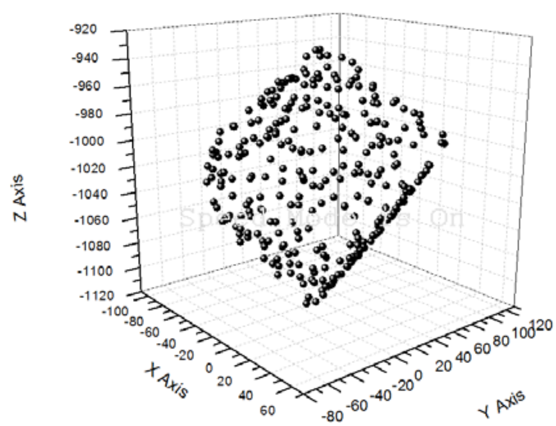

Fig.2. ANSI Text and the Graph of Scan Data from 3D Scanner.

2. The method of converting 3D Scanner data into MCNP input text

The Geometry of MCNP code is made up of surface and cells constructed with the surface. Additionally, each cell has certain materials with certain density and code user can calculate the reaction between sources and other elements of the cell in quantity as well as in quality. In this study, we want 3D-SCAN data of a simple figure to be changed into the surface and cell data of MCNP code input texts. Each coordinates(x, y, z) should be parallel with Cartesian coordinates, among many type of basic structures, we chose the Box-shaped structure, which can be formed by 4～5 numbers of dots, and try to convert.

The first thing we should do is to save the 3D-SCAN data as an appropriate form of file extensions. We convert this kind of data into a text file according to ANSI criteria, Global standard encoding method and analyzed it. The 3D-SCAN data file has more than1.5 million numbers of dots and is not vertical or horizontal for axis so we found the maximum and minimum value of each dot component and then figure out each vertex with the use of values.

The MCNP input texts file can be created by the steps below. In order to transform the input texts for MCNP about the data from 3D-SCAN for simple diagram, there are some step; Create the file in each axis components, Check 3D-SCAN file, Save the each axis components files, Check the Maximum and Minimum values of the each three axis, Save the each components axis file, Change string variables into the real number, Assort the Maximum and Minimum values and save into the different files, Save the Maximum and Minimum values separately, Determine the Maximum and Minimum values of each axis, Calculate the length of x, y, z- axis using two dots, and Create the input texts for MCNP.

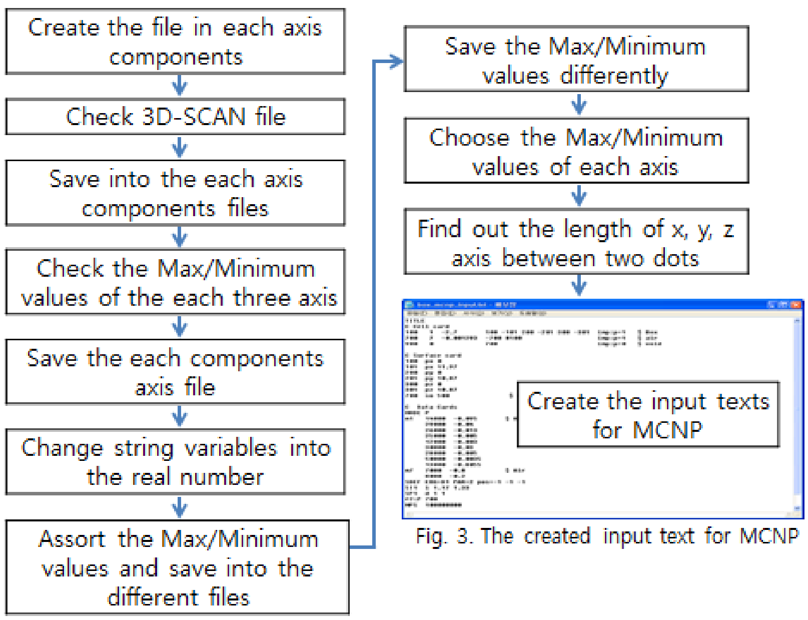

Fig.3. The Created Input Text for MCNP.

3. The result of converting into MCNP input text

In order to converting, C is used and it is implemented on the command window. When displaying the executable file, the input text [file name.stl] is used for converting and the input text [filename]-mcnp-input.txt are created. Created MCNP input text can reform figure from components of each axis from the 3D Scanner data. The result of converting and created MCNP input text is below.

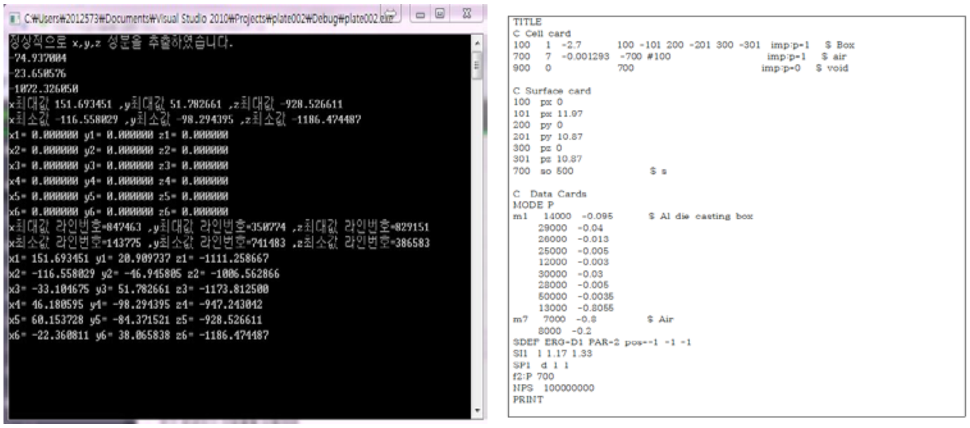

Fig.3. The Result of Converting and Created MCNP Input Text.

This simple shape is box-shaped figure with the length of 10×10×10 and 3D-SCAN data and MCNP input file created by converting have a margin error of approximately 5~10 percent.

$$\sqrt{\frac{10}{11.97} \times 100\%} = 4.43\%, \quad \sqrt{\frac{10}{10.87} \times 100\%} = 9.59\% \qquad \text{(Eq.1)}$$

CONCLUSIONS

A lot of radioactive metal wastes having complex geometries are continually generated from nuclear power plants in Korea and it is expected that the amount of the radioactive metal wastes is gradually increased. In addition, further decommissioning nuclear power plants, lots of radioactive metal wastes will be generated so base concept of domestic technology will be expected to be developed and to accomplish technological independence via developing this technology and source term characterization for the radioactive metal wastes

The self-disposal technology can disposal many radioactive metal wastes generated during the operating period or decommissioning nuclear facilities including nuclear power plants and can make less radioactive metal wastes and can spend less money. With the advanced level of technology development of self-disposal technology of radioactive metal wastes, the feasibility of technology can be improved.

This analysis of large-sized radioactive metal wastes and this 3D visualization technology can be applied with other technologies; such as 3D visualized technology using laser, gamma detecting method, Radiological evaluation system for the low level radioactive metal wastes and so on.

In addition, with the use of 3D data, quantification of radioactive waste, source term data base and radiation impact assessment tool as an interlocking system, we can use this for development the licensing materials. This technology is planned to be used to construct the data base, which is expected to be used as a basic technology for decommissioning nuclear power plants, moreover, expected to be useful for the large amount of the radioactive wastes handling, disposal during the decommissioning step.

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