Development of Animation and Simulation Module for Evaluation of Worker's Dose

H.S Park, G.H Kim, K.W Lee, C.H Jung, S.I Jin*
Korea Atomic Energy Research Institute
150 Dukjin-dong, Yuseong-gu, Daejeon, Korea, 305-353
*Dept. of Computer Science, Chungnam National University
220 Gung-dong, Yuseong-gu, Daejeon, 305-764
Korea

ABSTRACT

A study to visualize the radioactivity distribution in a dismantling facility that was contaminated by the radiation from the exposure room at KRR 2(Korean Research Reactor TRIGA MARK III) was carried out to improve worker safety and decommissioning productivity. As a basic study to minimize a radiation exposure, the worker exposure dose was calculated using the MCNP-4C(Monte Carlo N-Particle-4C). Secondly, an animation and simulation module was implemented to simulate a worker's real-time dose. The results show that various kinds of dismantling activities can be simulated while simultaneously viewing the exposure dose in a real-time according to the selected scenario for the animation.

Current work is focus on exploring the evaluation of a worker's dose in a virtual dismantling area by using computer graphics. Future work will seek an optimization of the major parameters that directly affect a personnel exposure dose rate. This will enable a worker who is engaged in a hazardous area to attain an improve safety by decreasing exposure when applied as a useful tool to dismantle nuclear facilities.

INTRODUCTION

Dismantling of KRR 1&2(Korean Research Reactor, TRIGA MARK II and III) in Seoul has been underway since June 2000[1]. To establish a dismantling schedule for an old nuclear facility, the radiation distribution through an assessment of the radioactivity inventory of the activated nuclear facility should be investigated. This is done to optimize the decommissioning schedule, worker's safety and decommissioning cost as well as estimate the amount of waste more accurately. Even though information from different kinds of data and drawings for a dismantling activity is available, it is very difficult to establish the radioactivity distribution from these data due to a lack of information about the location, the identification process and the radiological characteristics of the contamination. The motivation of this study is to visualize a detailed three dimensional radioactivity distribution for worker's dose simulations. The advantages of such a detailed radioactivity distribution are obvious. With this realistic research, worker safety and the productivity of a decommissioning can be improved.

Decommissioning is now a mature industrial process and a study of advanced technology for such a process by using computer graphics is underway in many countries. Most R&D is now focused on an optimization of the available techniques such as 3D CAD[2, 3], animation and/or virtual reality[4] although new, innovative techniques are also being developed. Of these technologies it is hard to find visualization technology[5, 6, 7] for a radioactivity distribution and worker's dose related to a decommissioning.

In the present study, the radioactivity distribution was created with a contour mapping of concrete shielding in the exposure room in the KRR 2. Secondly, an animation module was constructed to simulate dismantling activities after modeling an object by using 3D CAD. A radiation dose was calculated by using the MCNP-4C based on measured data to evaluate a worker's dose when a worker is dismantling an object. Thirdly, the radiation field of the exposure room was visualized three dimensionally by using the radiation dose that was obtained by MCNP-4C. Finally, a GUI(Graphic User Interface) module was designed to user-friendly access both the simulation and animation. The result will be used as a basis for an optimization of decommissioning activities such as a dismantling schedule, amount of waste, and dismantling cost in relation to a worker's dose.

RADIOACTIVITY INVENTORY AND DISTRIBUTION

The assessment of a radioactivity inventory is one of the most important issues as means to improve the efficiency of a dismantling by predicting a radioactivity level in advance.

Various kinds of codes[8] related to a calculation of the radioactivity inventory have limitations in evaluating it because of geometric modeling and an uncertainty that take place in a nuclear cross-section. Even if some countries have developed technology that can measure the radioactivity level on a surface by using a gamma camera, they have not described the radioactivity distribution three dimensionally and only view the location of the radioactivity.

The current evaluation method of the radioactivity inventory for dismantling the KRR 1&2 has been to ascertain a radionuclide and concentration after gathering the sample data from the object being dismantled. Based on the result of analysis of the radionuclide, dismantling wastes are classified into 3 groups for the decommissioning plan. If a measured value is higher than 0.4Bq/g, it is radioactive waste. Minimum Detectable Activity(MDA) > 0.4Bq/g is a restricted releasable waste, and a MDA < 0.4Bq/g is regarded a non-radioactive waste. The exposure room(3m x 3.7m x 2.7m) in the KRR2 is a facility with irradiated equipment for specimens with neutron and gamma ray of a high energy and shielded with a high density concrete of 3.4m-thick. Using DD 750 core-boring machine made by Hilti we measured the radioactivity inventory at 29 points (west: 8, east: 3, east/door: 6, ceiling: 5) [10] was measured as shown in Fig. 1. The radionuclides found by the measurements are ^{60}Co, ^{152}Eu, and ^{154}Eu. Of these radionuclides a visualization of the radioactivity distribution of ^{60}Co has been conducted. the radioactivity distribution of the exposure room was created by using the TECPLOT software that can plot the measurement values three dimensionally after dividing each wall into nodes of 120 and elements of 155. The result of the distribution is represented in Fig. 2. As shown in the picture, the wall where the radioactivity concentration represents the highest was in the right side of the east area and the next area was in the center of the west area.

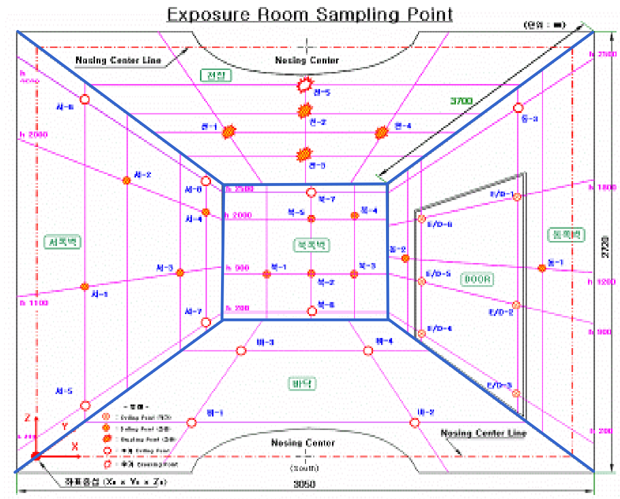

Fig 1. Location of a boring of the specimen

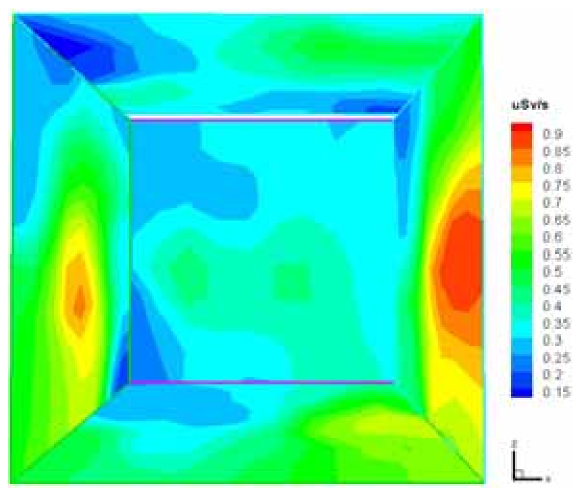

Fig 2. Visualization of the radiation distribution of the exposure room

MODELING OF WORKER'S EXTERNAL EXPOSURE

The radiation field of the exposure room divided 3m x 3.7m into a number of nodes(6 x 6) in order to classify the radiation dose in the dismantling area. To model a worker's external exposure, several items related to the exposure dose were assumed as follows;

- concrete shielding in the exposure room is ordinary heavy concrete
- it was only activated on the east wall where the radioactivity was the highest
- gamma-radiation distributes uniformly from the wall
- the radiation source emits isotropic from the gamma-radiation
- there is no shielding material inside the room
- The workers are a standard Korean who wear a protection cloth with TLD(Thermoluminescent Dosimeter)badge(equal to 150cm as height of chest)

The volume dose regarded a worker's internal organs and texture are not taken into account in this study.

ENERGY SPECTRUM AND GEOMETRIC MODELING

In order to obtain the radioactivity level of the radiation field in the exposure room, the energy spectrum of the radionuclide was calculated by using the Monte Carlo N-Particle(MCNP-4C) transport code. MCNP is a general-purpose, continuous-energy, generalized geometry, time-dependent, coupled neutron-photon-electron Monte Carlo transport code system. These applications include radiation shielding, decontamination and decommissioning, waste storage and disposal, and so on[11]. Monte Carlo simulation provides a practical way to calculate the dosimetric data by performing an accurate calculation of three-dimensional dose distribution from particle interactions in a computational phantom. This code allows a user to specify a problem as a collection of cells that are defined by means of a set of surfaces and their intersections and unions. For the point sources, Monte Carlo simulation was done for a very fine grid set of source locations(146 source locations between 3m and 3.7m from the phantom) and 2 photon energies 1.17 and 1.33 MeV in ^{60}Co and eight photon energies in ^{152}Eu and ^{154}Eu, respectively. Table I shows the energy and ratio of ^{60}Co, ^{152}Eu, and ^{154}Eu that was obtained from boring the core. The radionuclide is situated on the wall of the exposure room. The radioactivity value which was taken for each wall was assumed to be the radioactivity inventory.

Table I. Energy and ratio of each radionuclide

Radionuclide	Energy(MeV)	ratio(%)	Energy(MeV)	ratio(%)
^{60}Co	1.170	100	1.330	100
^{152}Eu	0.122	37	0.965	15
	0.245	8	1.087	12
	0.344	27	1.113	14
	0.799	14	1.408	22
^{154}Eu	0.123	38	0.759	5
	0.248	7	0.876	12
	0.593	6	1.000	31
	0.724	21	1.278	37

The dose conversion factor of ICRP Publication 74 is employed to calculate the effective dose rates in order to calculate the dose rate from a particle fluence. The input value used the MCNP is shown in Table II. To obtain the density of the concrete, reference chemical compositions such as O, Al, Si, Ca, and Fe were used. A density value of 2.347 g/cm^3 was obtained from the neutron and gamma quantum attenuation parameters.

CALCULATION OF THE RADIATION FIELD

For an error of lower than 0.01, the history of the simulation was selected as 5,000,000. In addition, a power detector tally("F5 type" estimates in MCNP) was applied to the calculation. The result of calculation from the MCNP is shown in Table III.

As the data presented in Table III is the radiation dose, a worker's dose in the radiation field that consists of nodes of 6 x 6 is calculated based on these data.

Table II. Conversion coefficient for the air kerma per unit fluence

Photon Energy(MeV)	Ka/φ(pGy cm^2)	Photon Energy(MeV)	Ka/φ(pGy cm^2)

0.010	7.43	0.500	2.380
0.015	3.12	0.600	2.840
0.020	1.68	0.800	3.690
0.030	0.721	1.000	4.470
0.040	0.429	1.500	6.140
0.050	0.323	2.000	7.550
0.060	0.289	3.000	9.960
0.080	0.307	4.000	12.10
0.100	0.371	5.000	14.10
0.150	0.599	6.000	16.10
0.200	0.856	8.000	20.10
0.300	1.380	10.00	24.10
0.400	1.890		

Table III. Result of the calculation from MCNP

1.44E+02	1.26E+02	1.14E+02	1.46E+02	1.77E+02	2.16E+02
1.65E+02	1.27E+02	1.07E+02	1.26E+02	1.61E+02	2.25E+02
1.88E+02	1.42E+02	1.28E+02	1.63E+02	1.92E+02	2.22E+02
2.74E+02	1.96E+02	1.74E+02	2.19E+02	2.51E+02	3.07E+02
2.26E+02	1.63E+02	1.46E+02	1.87E+02	2.17E+02	2.53E+02
1.53E+02	1.26E+02	1.02E+02	1.23E+02	1.87E+02	2.07E+02

ANIMATION AND VISUALIZATION OF A WORKER'S DOSE

To evaluate the exposure dose in a real-time while the worker dismantles the concrete shielding of the exposure room, an animation and simulation module was constructed. Many of the components that are needed to design the animation were established by using AutoCAD, 3D MAX, and EON software. Under the circumstance of the animation, a simulation module enables estimation of personnel dose during a dismantling of the objects inside a room. Fig 3 illustrates that a worker is dismantling the concrete shielding according to the decommissioning scenario through an animation and it also represents simultaneously the dose rate that the worker will be exposed to. This picture shows dose rate a worker is exposed to is 0.187 mSv/sec during 4 minutes.

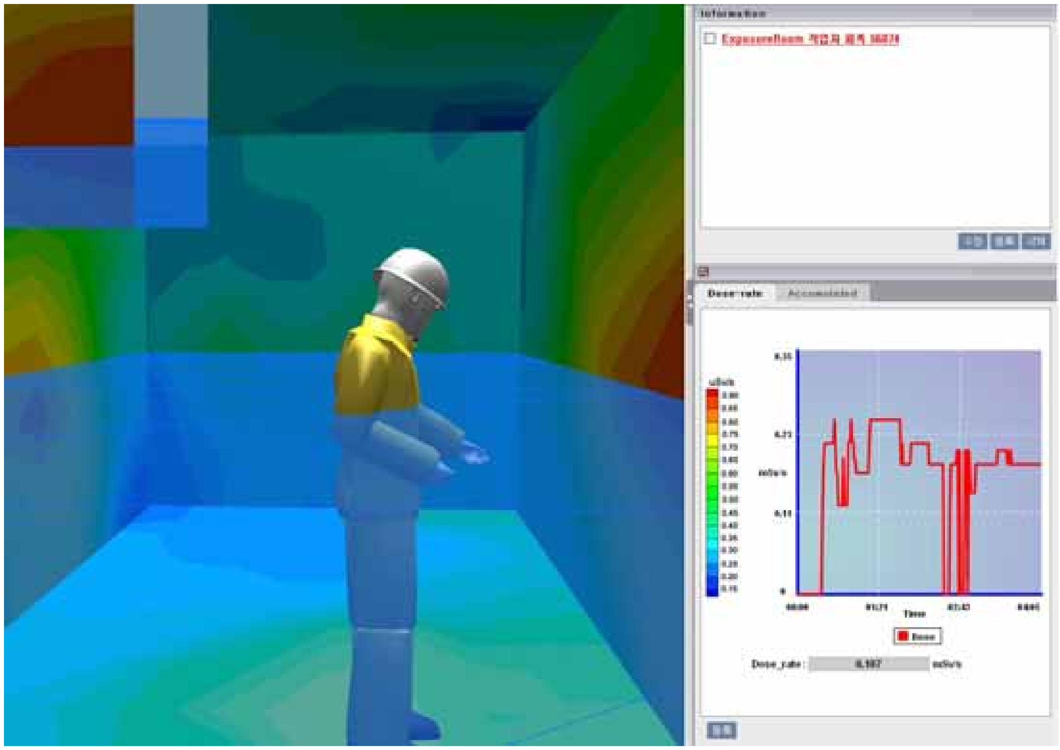

Fig 3. Scene of dismantling concrete shielding on the animation (left) and personnel dose rate(right)

CONCLUSION

The visualization of the radioactivity distribution and a simulation of a worker's dose in a real-time of the exposure room in KRR 2 has been completed. Even although a lot of data has been obtained from the dismantling activities, it is difficult to ascertain how the object being dismantled was activated. But the result of a visualization of a radioactivity distribution enables us to establishing which locations are contaminated the most through a 3D contour plot. The animation module was designed to simulate the exposure dose when a worker is dismantling the concrete shielding in an exposure room in a virtual environment. The radiation dose was calculated by MCNP to model the dose rate three dimensionally. Based on this data, the radiation field was visualized with graphics and a simulation was established the dose rate that a worker is exposed to during a dismantling. This simulated dose rate can correctly illustrate a worker's dose rate in a real-time.

This study was conducted to establish basic technology for a visualization and evaluation of a worker's dose based on information that was collected from a core sampling. Future work will develop a system that can optimize the exposure dose and simulate a dismantling scenario such as a schedule, amount of waste, and cost in relation to a personnel dose. The results can be utilized for D&D research in relation to harzadous areas such as a hotcell and Post Irradiation facilities and can be applied as a useful tool to dismantle nuclear facilities.

REFERENCE

1. K. J. Jung, et al., "Decommissioning of TRIGA Mark 1&2", KAERI-TR-1654, 2000.
2. Charles E, et al., "Computer Mapping and Visualization of Facilities for Planning of D&D Operations", International Conference on Radioactive Waste Management and Environment Remediation, ICEM, Vol 2, pp 1749-1753, 1995.
3. Jacques Pot et al., "Techniques for CAD reconstruction of 'as-built' environments and application to preparing for dismantling of plants", Nuclear Engineering and design 178, 135-143, 1997.
4. D J Lee, et al., "Virtual reality for Inspection, Maintenance, Operation and Repair of Nuclear Power Plant(VRIMOR).
5. Yukiharu OHGA, et al., "A System for Calculation and Visualization of Radiation Field for Maintenance Support in Nuclear Power Plants", ICRS 10, Madeira, 9-14 May, 2004
6. Yukiharu IGUCHI, et al., "Development of Decommissioning Engineering Support System(DEXUS) of the Fugen Nuclear Power Station", Journal of Nuclear Science and technology, Vol. 41, No. 3, p. 367-375, 2004
7. F. Vermeersch, et al., "Development of the VISIPLAN ALARA planning tool", Proceeding of the International Conference on Topicalissues in Nuclear Radiation and Radioactive Waste Safety, Vienna Austria, 31-August to September 1999.
8. R. J. Morford, "Source Term and Shielding Calculations to Support Decommissioning of Shippingport Reactor," WHC-SA-0206, Westinghouse Hanford Company, 1988.
9. Le Goaller C., et al., "On Site Nuclear Video Imaging", Waste Management 1998
10. J. H. Park, et al., "Decontamination and Decommissioning Project for the Nuclear Facilities", KAERI/RR-2625/2005
11. G. W. Mckinney., et al., "MCNP Application for the 21st Century ", Form SNA 2000 Conference, Tokyo, Japan, Sept. 4-7, 2000