3D Dynamic Simulation for the Dismantling Process of the KRR-2

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SUMMARY

The 3D simulations for the Rotary Specimen Rack (RSR), the shielding concrete, and the reactor core dismantling processes in the Korea Research Reactor-1&2(KRR-1&2) were carried out in the present work. The four main dismantling items, which are the RSR, reactor core, beam tube, and the thermal column and the shield concrete, were selected among the many components in the KRR-2 by consideration of the activation, worker training, difficulty of the work and so on. On the basis of these, we built 3D CAD models, selected the proper dismantling technologies, and reviewed their dismantling processes. In this study, the 3D simulation results of the shielding concrete, and the reactor core dismantling processes are also presented and discussed.

1. INTRODUCTION

As many of the world's nuclear reactors are aging, their safe decommissioning has emerged as an imminent task. As such, the world's nuclear industries have been initiating D&D (decontamination and dismantling) projects and relevant R&D programs since the mid 80's. Currently, many of the technologies have been established on a commercial basis. As revealed from experience, however, decommissioning a nuclear facility is still a costly and possibly hazardous project. Remote technology may present a safe and effective alternative. In reality, however, a proper implementation of remote technology for the dismantling project poses substantial technical challenges.

In Korea, KRR-1&2 (Korea Research Reactor 1&2), TRIGA Mark II&III, had been operated since each 1962 and 1972 respectively. However, according to the deterioration of the utility and the change to the population-massed-area by the accelerated urbanization of the surroundings, conversion to a comfortable and safe environment is inevitably required. Also HANARO, a multipurpose research reactor, which started normal operation at the new site of KAERI, the superannuated research reactors lost their value in use. Because of those reasons, the decommissioning of the KRR-1&2 was determined. Now, the researches about D&D have been progressed to a graphic simulation regarding the main dismantling process, constructing a data base, developing remote dismantling equipment, developing an automatic measurement system and so on.

Recently computer graphic simulation has been used to design and verify new equipment and also it has been expanded to virtual prototyping technology. Using an advanced simulation technique on the basis of the basic design of the real equipment, this technology has been used to verify the validation of a process and design of a machine. Namely, we can create realistic simulation after making a 3D graphic model in a computer and applying its kinematics to the equipment. Also we can analyze the working path, check the interference, and verify the validity for the design of a machine.

These technologies in the nuclear dismantling fields have been used to investigate the validation for the design of the dismantling machines and to find an optimal scenario among the several dismantling scenarios. And as for constructing the dismantling work in the virtual space, it can be used for a worker-training program.

In our project, for the purpose of preventing some errors or problems from happening in the planned dismantling scenarios and obtaining the optimized dismantling technologies and scenarios for the selected items the dynamic simulations for their processes have been created. In this paper, the main dismantling items in KRR-2 are selected and they are converted into 3D models and also the applicable dismantling technologies and the proper scenarios for them are selected. Finally the results of the simulations of the shielding concrete, the RSR, and the reactor core are presented.

2. THE PROCESS OF MAKING THE SIMULATION

To make the simulation, the process of making a simulation is required. Figure 1 shows the flow model for the dismantling items. First, the analysis of the physical properties and the radioactive properties for the dismantling objects are performed and their material properties and kinematics specifications are identified. Secondly, on the basis of the results, modeling is carried out using the appropriate functions which are the Mesh, Extrude, and Revolve functions in the ENVISION software after the 2D drawings in the AutoCAD are converted to the ENVISION software. Thirdly, the Devices are constructed by assembling each part of the models and assigning various motion attributes such as the relative assembly position, kinematics constraints, and the range of mobility. Then, the Workcell is made by arranging each Device in a computer's virtual space. And the computer programming is performed by following the dismantling scenarios.

We expect to obtain the optimized dismantling methods and scenarios after analyzing the simulation results and the merits and demerits of each dismantling technique and scenario. Finally we plan to apply the simulation results to the real dismantling field in the future.

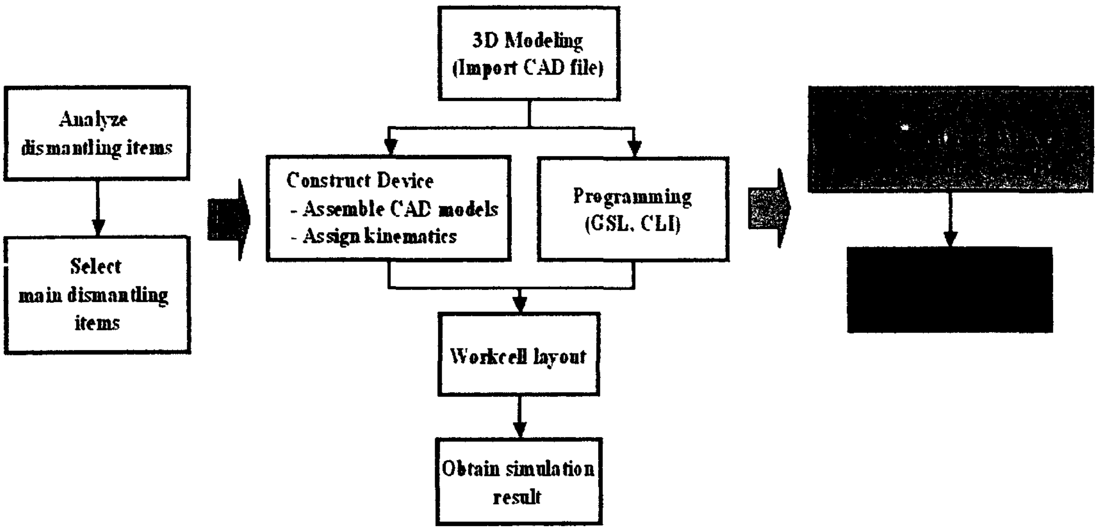


Figure 1: The simulation process

3. SELECTION OF THE MAIN DISMANTLING ITEMS

As seen in Figure 2, the KRR-2 is composed of many items such as components and laboratory equipment etc. Due to its operation and the experiments undertaken in it for a few decades, a portion of them has been activated. So the dismantling work should be carefully carried out for the worker's safe. The main items among the many items are selected as follows.

- ☐ Work with the treatment of the high radioactivity materials
- ☐ Work with a difficult approach or access
- ☐ Work with the relatively large expectation dose for the workers
- ☐ Work with the possibility of risk in terms of the safety
- ☐ Work with the difficulty of the work due to under-water and remote control
- ☐ Work with the requirements of the precise and detailed work procedure
- ☐ Work with the requirement of special training

Taking into account these criteria, four dismantling processes are chosen to simulate the virtual space and the dismantling of the main items can be selected as follows. Table 1 shows the selected processes according to the criteria.

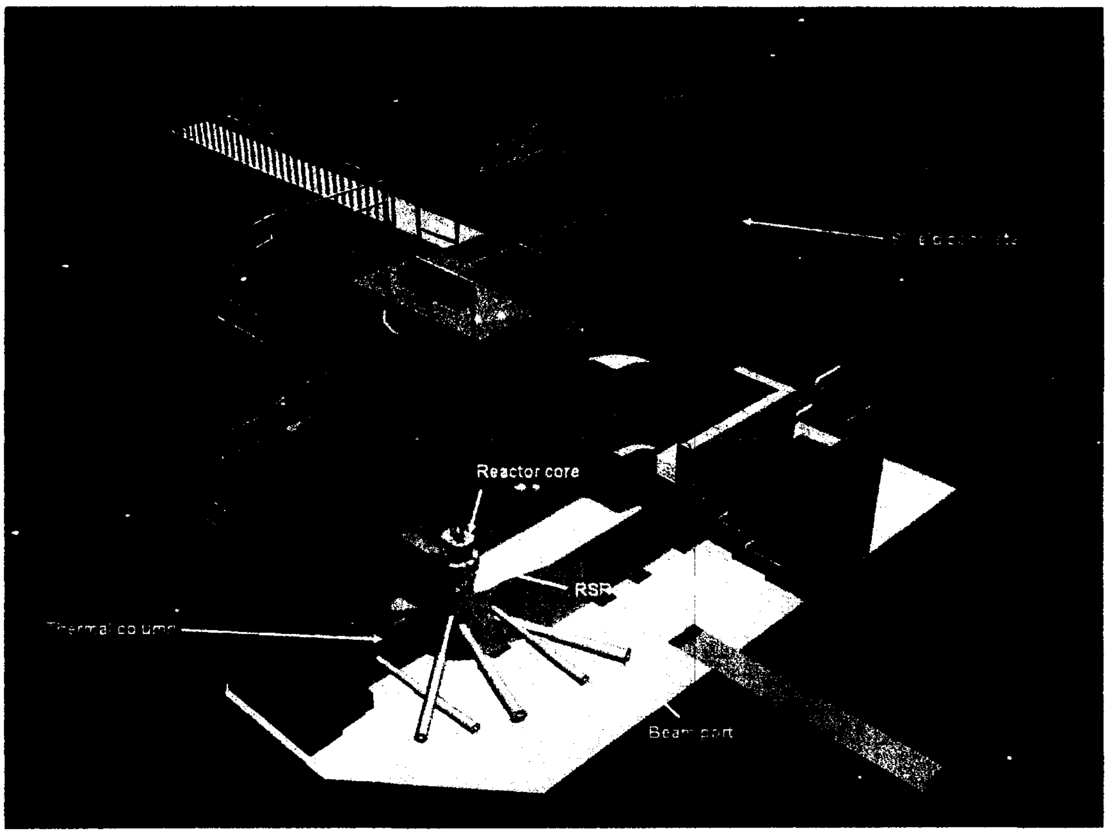


Figure 2: The cutting view of the KRR-2

- Rotary Specimen Rack
- Reactor Core
- Thermal Column and Beam Ports
- Shielding Concrete

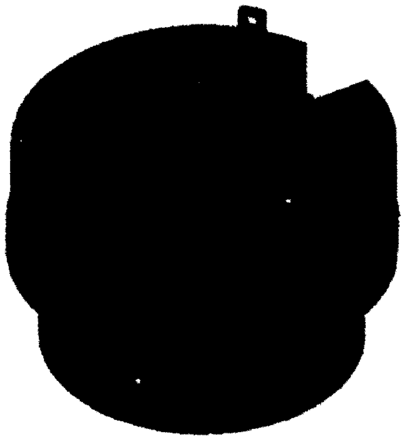
Table 1 The Selection of the dismantling items for graphic simulation

Selection Criteria / Dismantling process	Expected dose (man-mSV)	Risk	Work difficulty of the work	Detail procedure	Special training
Internal component and pipes	1.56	M	L	×	×
RSR	3.84	H	H	O	O
Reactor core	718.00	H	H	O	O
Drain the reactor water	0.08	L	L	×	×
Thermal column	4.80	H	H	O	O
Cooling system	0.50	L	M	O	×
Core bridge	0.86	M	M	×	×
Activated concrete and beam tube	105.83	H	H	O	O
Pit and distilled water tank	2.51	M	H	O	×
Room wall and floor	3.02	L	M	×	×

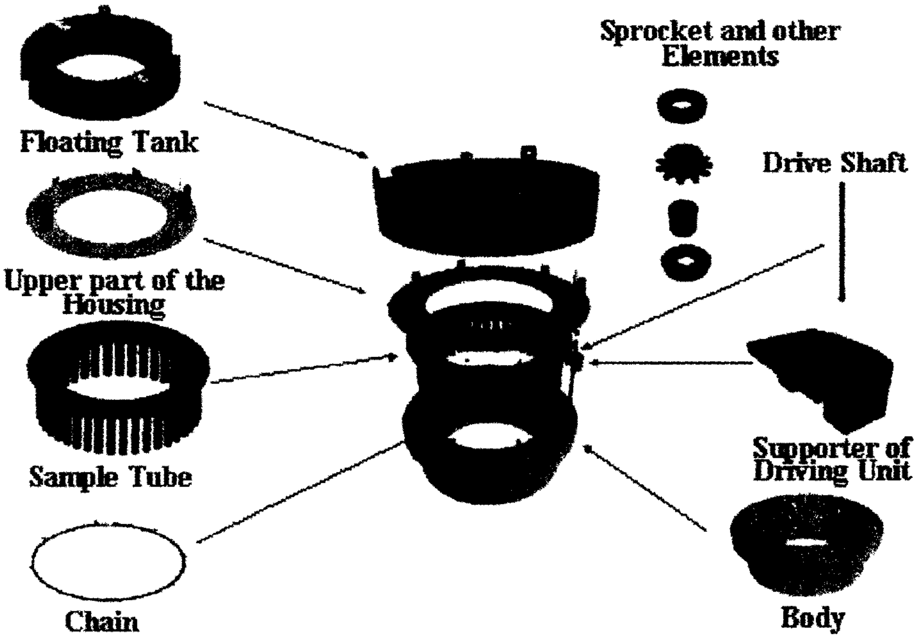
4. 3D CAD modeling for selected items

Rotary Specimen Rack

As shown in Figure 3 the RSR is composed of a flotation tank, housing cover, specimen rack, drive chin, drive shaft, bearing, strip, bolt, nut and so on. As a result of the radiation and modeling, the high-level radiation parts are mostly stainless steel such as the bolts, nuts, bearings, and chains. After analysis of the modeling we found that they were distributed between the flotation tank and the housing cover. Therefore we decided that the dismantling procedure of the RSR should be progressed from the upper parts of the flotation tank t lower parts of the housing.



(a) The assembly of the RSR



(b) The components of the RSR

Figure 3: RSR CAD modeling

Thermal column and beam ports

Figures 4 and 5 show the results of the modeling for the thermal column and the beam ports. As a result of the modeling we found that the beam ports adjacent to the thermal columns, the two beam ports were connected to the sides of the thermal columns, and the 4 thermal column access ports constituted of a symmetric structure. Since the beam ports are included in the shield concrete, we concluded that the beam ports should be worked on after finishing the shielding concrete.

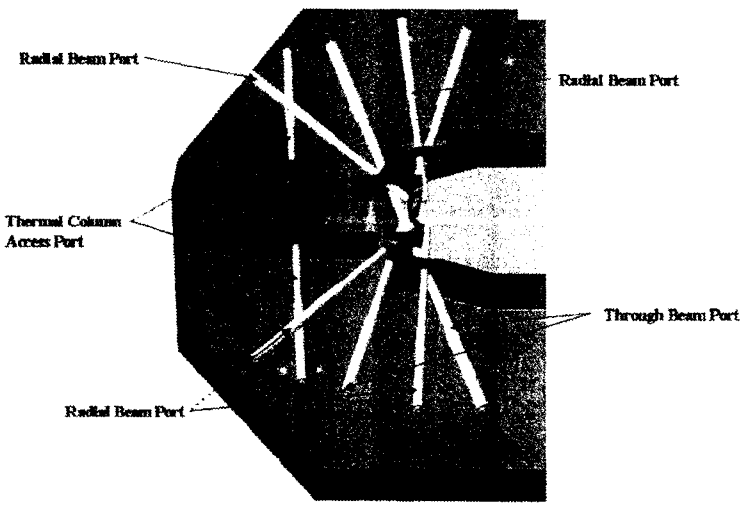


Figure 4: The beam ports CAD modeling

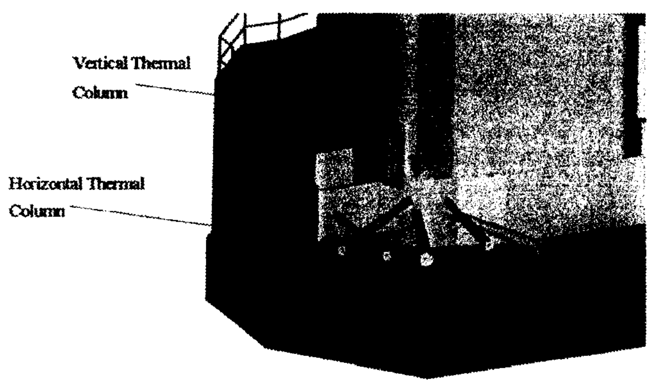


Figure 5: The thermal column CAD modeling

Core

The core is composed of two parts the upper shroud and the lower shroud. The upper shroud has a stainless steel cylindrical shape and the thickness is 6.4 mm. The two grid plates support the central thimble and the water diffuser pipe. They are connected to the upper support plate. As a result of the modeling the other two pipes were the simulation fuel rods in the core. Therefore, we decided that after they had been removed by the fuel withdrawal equipment, the pipes should be cut by a hydraulic cutter and the others contained in a container.

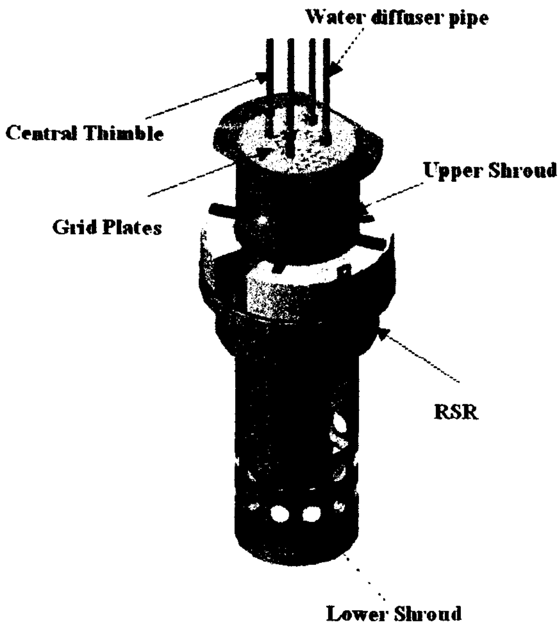


Figure 6: The core CAD modeling

Shield concrete

We decided to dismantle the shielding concrete by a size of 1m × 1m × 1m considering the weight that a crane is capable of moving of a maximum speed. Figure 7 shows the results of the modeling. The shield concrete is divided into 9 floors and then each floor is cut by a size of 1m × 1m × 1m. The dismantling work will be progressed from the top 9th floor to the ground floor. And as in the following scenario and working sequence, each concrete mass will be given a number. After the dismantling work starts for the non-activated concrete, the activated concrete will be worked on.

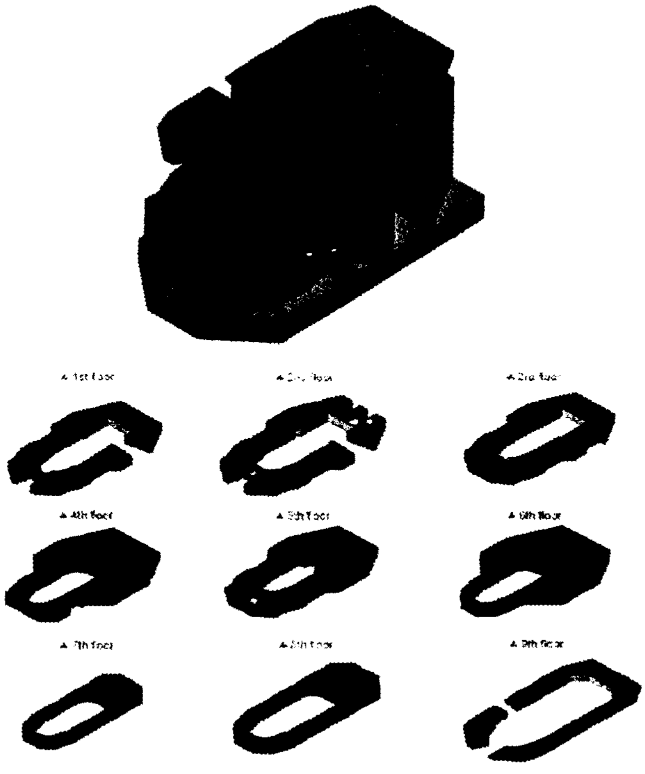
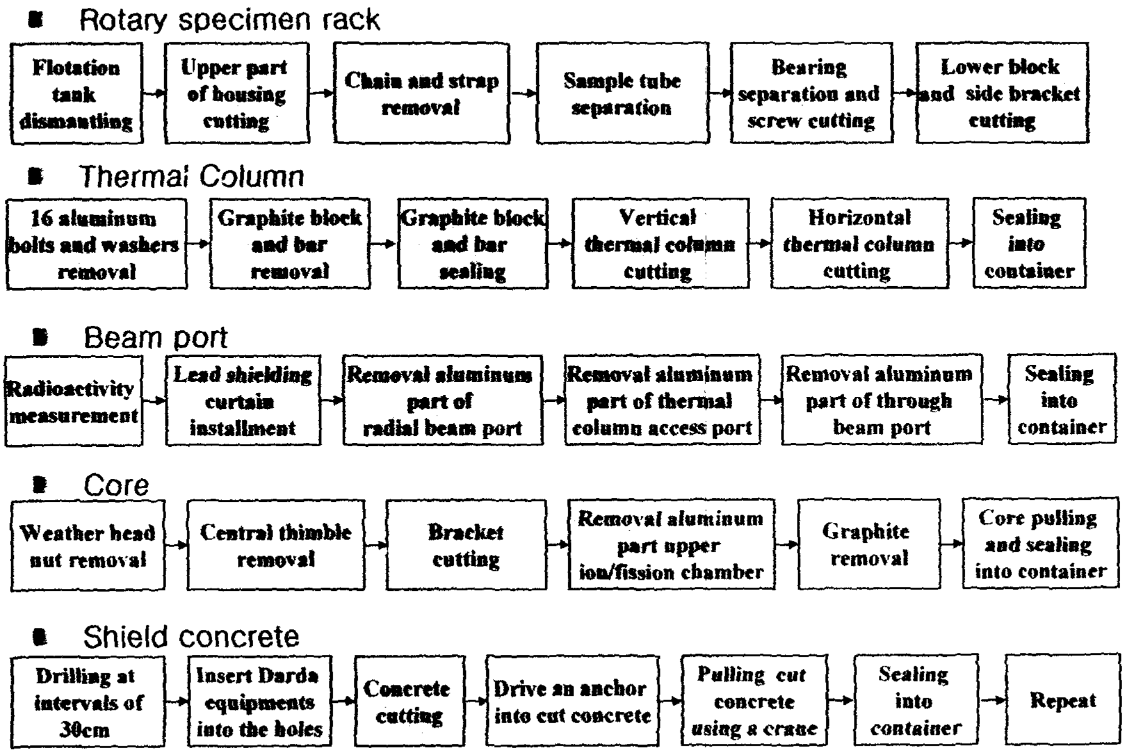


Figure 7: The shielding concrete CAD modeling

5. SETTING UP THE DECOMMISSIONING PROCEDURE

To carry out a dismantling simulation it should be preceded by a proper dismantling scenario and appropriate dismantling technology selection. As shown in Figure 8, mutually the characteristic analysis results and the 3D models for the items are reviewed. On the basis of these the dismantling scenario for the main dismantling items is set up. Also we compared several dismantling techniques that are possible for the dismantling and then we choose the best dismantling methods and technologies and applied them to creat the simulation. The scenarios of the 5 main dismantling items are as follow.



6.SIMULATION RESULT AND DISCUSSION

Shield concrete dismantling simulation

Figure 8 shows the process of the shielding concrete dismantling work. As shown in Figure 8, it carries out the drilling is carried out using a core drill at intervals of 30cm and 3 sets of concrete dismantling equipment are inserted into 3 holes of each face and then the cutting of the shielding concrete is carried out. Next, an anchor is driven into an upper concrete plate and the concrete mass moves using the crane that is installed in the KRR-2. The concrete is moved into the container and then it is sealed in the special container.

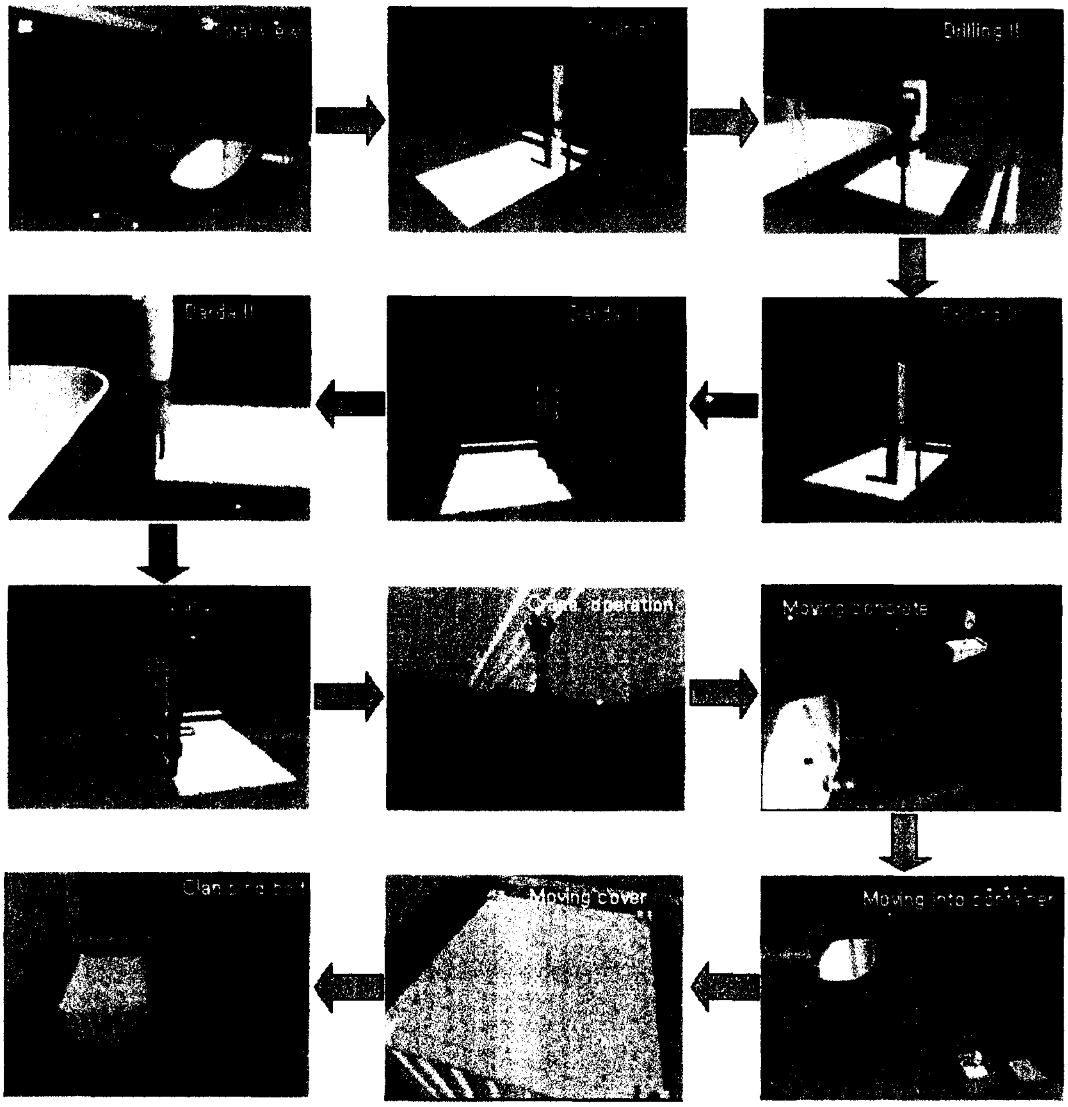


Figure 8: The graphic simulation process of the shielding concrete

<u>Rotary specimen rack dismantling simulation</u>

Figure 9 shows the simulation process for the RSR. Since it has highly activated stainless parts such as bolts, nuts, chains, etc, only the stainless parts are removed from the RSR using the RSR dismantling equipment. We estimate that its waste amount will be reduced as other aluminum parts are treated to become clearance level wastes. As shown in the Figure 10, the upper block, upper floatation tank, and the thread area of the upper housing block are cut and then the stainless parts are removed. And the floatation tank is removed by cutting the drive shaft and the drive block is removed by taking off the chain and the bearings.

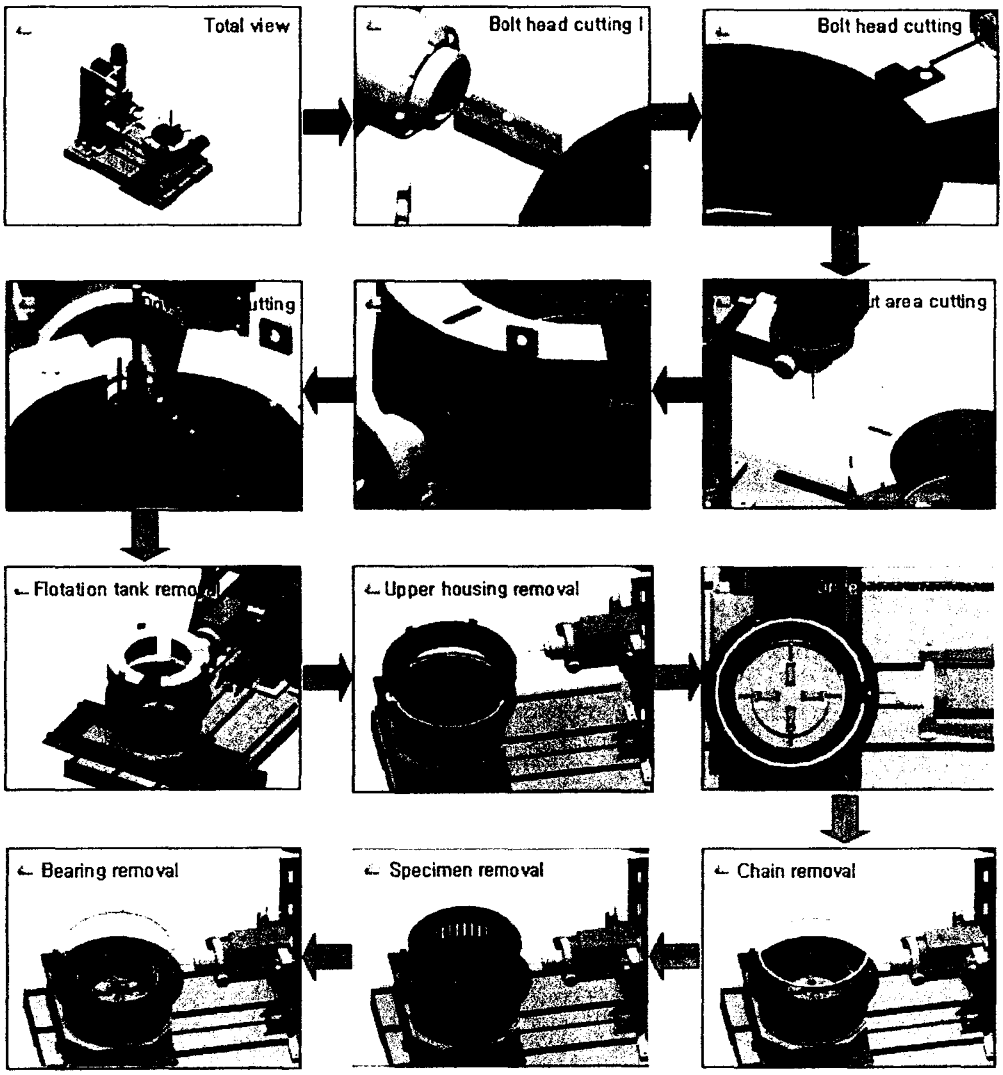


Figure 9: The graphic simulation process of the shielding concrete

Reactor core dismantling simulation

Figure 11 shows the simulation process for the reactor core. The core is supported by the bridge in the center of the KRR-2. As shown Figure 11, the bolts that connect the core and the support panels are removed and then the separated panels are also removed. And then a hydraulic cutting machine cuts some pipes and the container that is produced for the core is moved into the pool. And then the core is moved into the container and then by using a crane the container is moved to the floor and then the core is taken out in front of the lead shield block. And then using the special screw removing tool, the 40 screws that connect the upper part and the lower part of core are removed from the core.

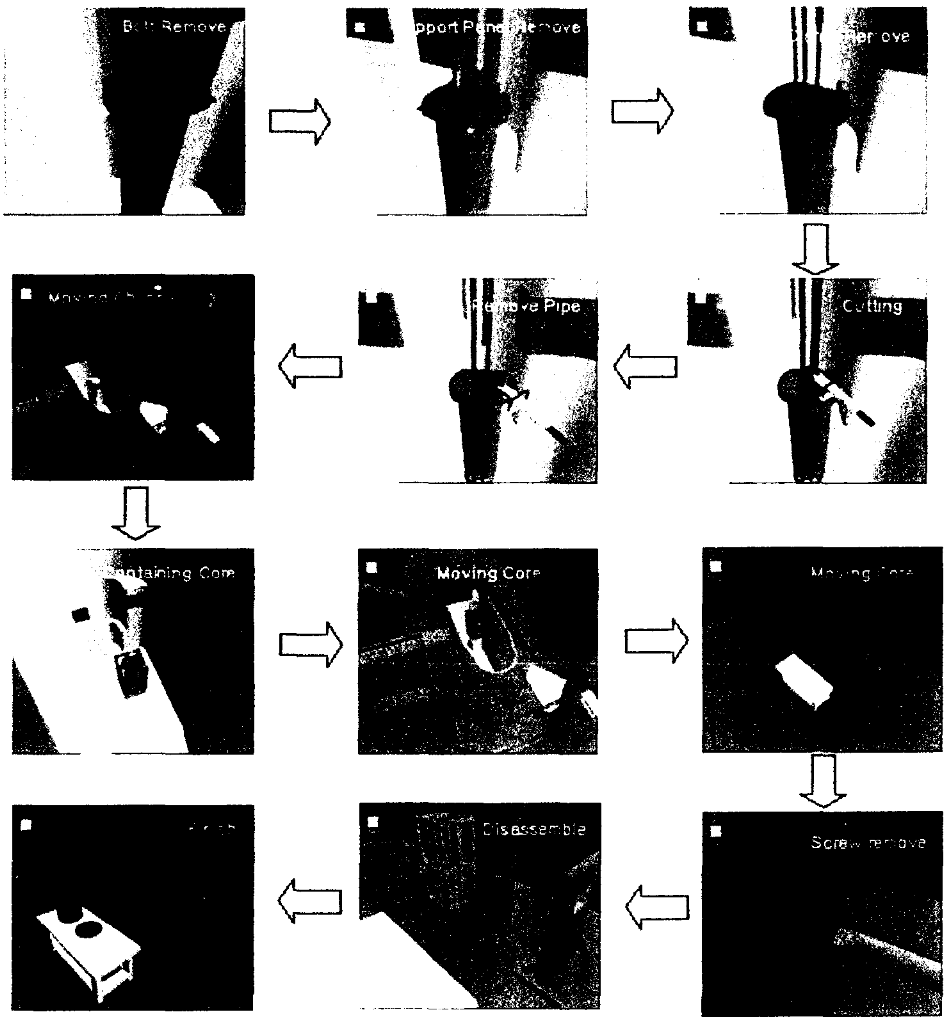


Figure 10: The graphic simulation process of the reactor core

CONCLUSION

In this paper the main dismantling items were selected considering the expected dose, risk, difficulty of the work, and special training required and also their 3D CAD modeling was performed. These dismantling scenarios were set up by considering the 3D models, physical information, and radioactive information. Finally the concrete dismantling work and the RSR dismantling work were simulated for the main items. As a result of the concrete dismantling simulation we can expect to produce about 800 concrete masses so we know that we should prepare enough area in order to treat them. After we finished the RSR simulation, we establish how reliable the RSR dismantling machine was. Especially since it is designed for treating the high-level activity material we had to carefully review its reliability. So it is good information for designing the RSR dismantling machine. After analyzing the reactor core simulation results, we think that it is too dangerous to dismantle the core on the floor so we think that it is better that the core dismantling work is processed under water because the water can block the radiation that emits from the activated parts so workers can more safely achieve the dismantling work.

Since a computer graphic simulation for designing a new machine and a dismantling process offers a lot of information we are prevented from making errors. And also we can produce optimal scenarios to meet several changing parameters. Therefore computer graphic simulation technology can be widely used in the decommissioning and decontamination field.

ACKNOWLEDGMENTS

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