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Integrated risk assessment for spent fuel transportation using developed software

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1. Introduction

As on-site spent fuel storage meets limitation of their capacity, spent fuel need to be transported to other place. In this research, risk of two ways of transportation method, maritime transportation and on-site transportation, and interim storage facility were analyzed. Therefore, this research aims to develop restriction guidance of spent fuel transportation, sinking accident and aircraft strike to spent fuel repository by doing safety assessment with risk model, total management frame.

2. Methods and Results

2.1 Maritime transportation

2.1.1. Probability and release fraction analysis for ship collision

Spent nuclear fuel (SNF) management has been an indispensable issue in South Korea [1]. While the country currently ranks 6th worldwide on the number of nuclear reactors in operation, it has yet to implement any long-term SNF solution. As new SNF assemblies are continuously stored in the existing SNF pools, there exists the need to distribute the pool storage loads. Transportation of SNF assemblies from populated pools to vacant ones may preferably be done through the maritime mode since all nuclear power plants in South Korea are located at coastal sites. To determine its feasibility, it is necessary to assess risks of the maritime SNF transportation [2].

In this section, a methodology to assess the risk arising from ship collisions during the transportation of SNF by sea will be suggested. Its scope is limited to the damage probability of SNF packages given a collision event. The effect of transport parameters' variation to the package damage probability is investigated to obtain insights into possible ways to minimize risks. A reference vessel and transport cask are given in a case study to illustrate the methodology's application.

In this research, specific type of ship is chosen for collision risk assessment and ship collision coordinate is shown in Fig 1. Ship collision probability is analyzed by using AIS 2014 data and graphical route intersection analysis process depicted in Fig 2. After that, damage type is specified according to collision type and struck location, etc. Finally, event tree was developed as shown in Fig 3.

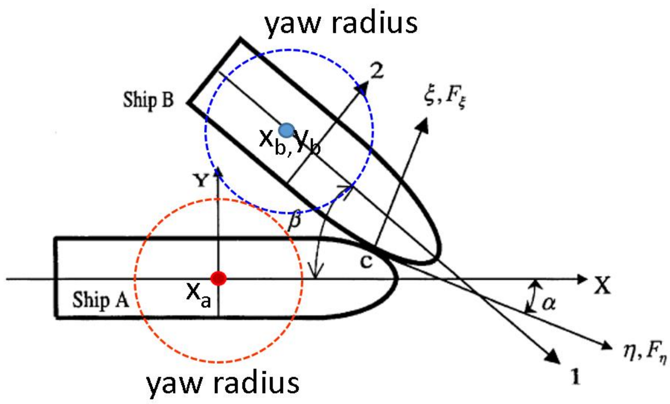

Fig 1. Coordinate system of ship collision

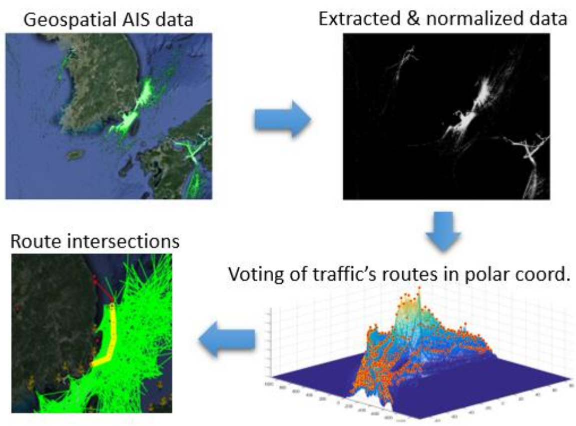

Fig 2. Graphical route intersection analysis process

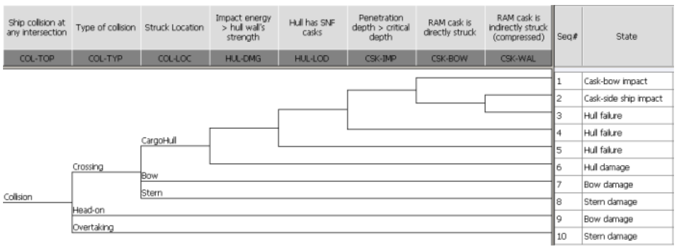

Fig 3. Ship collision event trees

2.1.2. Consequence analysis for ship sinking after collision

MARINRAD code was used for consequence analysis. In this code, there are two steps as shown in Fig 4.

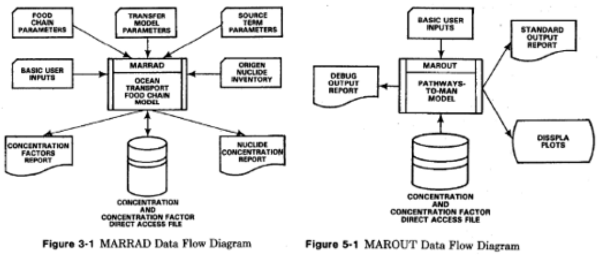

Fig 4. MARINRAD data flow diagram [3]

For applying MARINRAD, ocean area need to be divided to cell. Fig 5 is cell based map that we used in this research.

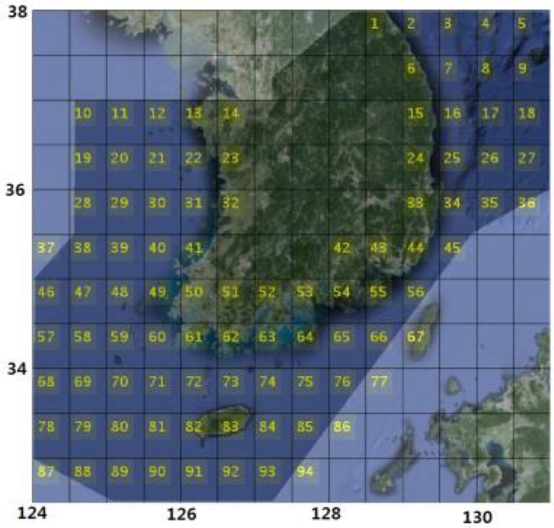

Fig 5. Cell division map for Korean ocean

There are four data processing steps like source, user, trans, food in this code and each step is combined in software.

2.2 Aircraft crash for interim fuel storage facility

In order to support promoting activities for the future interim storage facility (ISF) and to evaluate the safety during the long-term storage phase, we are executing research mainly related to most severe external human induced event (aircraft strike), that recommended by the recent revisions of regulatory safety requirements. The objective of this research is to provide a systematic evaluation method of the aircraft risk model considering a wide spectrum of mechanical impact loads using probabilistic safety assessment approach [4].

In this research, cask failure and O-ring failure is mainly considered. Research process is shown in Fig 6 and final event tree is shown in Fig 7.

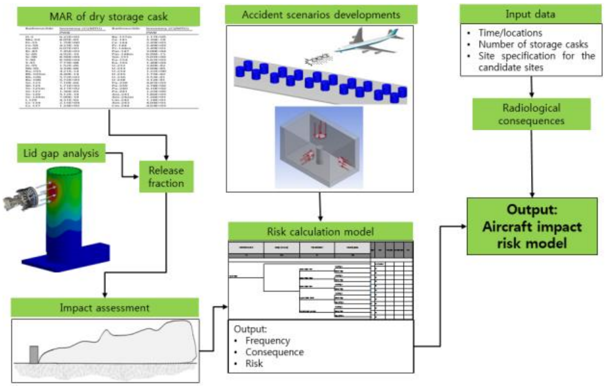

Fig 6. Research structure for ISF

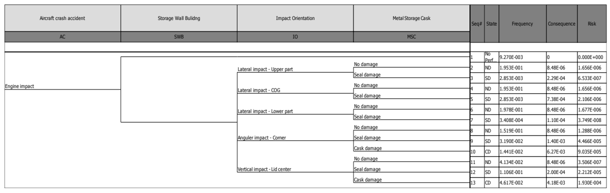

Fig 7. ISF event tree

2.3 On-site transportation

For road transportation, because of weight limit of express road and Korean law, it is impossible to transport spent fuel to another city. Therefore, in this research, we restricted on-site transportation. Cask drop from high height and second drop after first drop was dominant risk in this process. This is analyzed by using FEM and it is depicted in Fig 8.

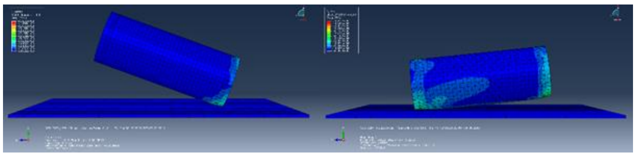

Fig 8. 3-D FEM model for drop accident simulation

Final event tree is shown in Fig 9.

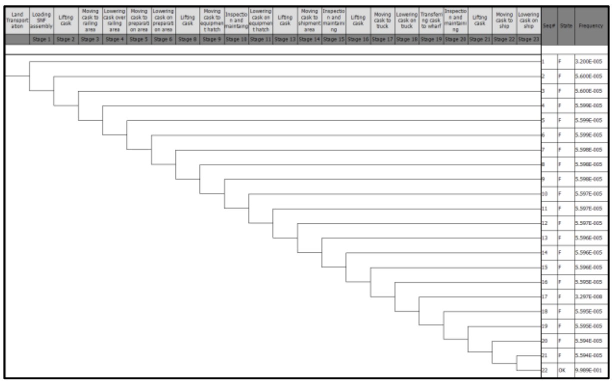

Fig 9. Event tree for on-site transportation

2.4 Software development

We integrated all results from three cases in a software. AIMS which is developed in KAERI is imbedded in this software and also sub-software from maritime transportation is imbedded. From this software, risk for each case is easily assessed and user have freedom to decide spent fuel case specification data. Here is developed software image.

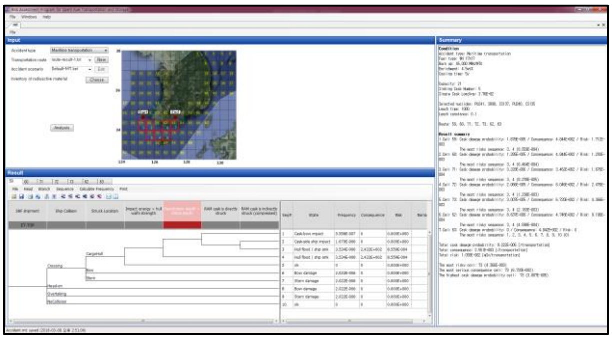

Fig 10. Developed software image

2.5 Current issue

In this software, because we targeted Korea, we need to use Korean reference data. However, there were few Korean reference data. Especially, there was no food chain data for Korean ocean. In MARINRAD, they used steady state food chain model, but it is far from reality. Therefore, to get Korean realistic reference data, dynamic food chain model for Korean ocean need to be developed. This research's result from this paper will be extended to this region.

3. Conclusions

Easier and integrated risk assessment for spent fuel transportation will be possible by applying this software. Risk assessment for spent fuel transportation has not been researched and this work showed a case for analysis. By using this analysis method and developed software, regulators can get some insights for spent fuel transportation. For example, they can restrict specific region for preventing ocean accident and also they can arrange spend fuel in interim storage facility avoiding most risky region which have high risk from aircraft engine shaft. Finally, they can apply soft material on the floor for specific stage for on-site transportation.

After extend this research to solve current issue, we can get specific ocean data which have the most severe influence for human in accident situation.

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