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DOSE EXPOSURE WORK PLANNING USING DMU KINEMATICS TOOLS

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ABSTRACT

The study on the possibility of using DMU Kinematics module in CAE tools for dose exposure work planning was carried out. A case scenario was created using 3D CAD software and transferred to DMU Kinematics module in a CAE software. The work plan created using DMU Kinematics module was animated to simulate a real time scenario. Data on the phantom position against the radioactive source was collected by activating positioning sensors in the module. The data collected was used to calculate the estimated dose rate exposure for the phantom. The results can be used to plan the safest and optimum procedures in carrying out the radiation related task.

Keywords: Dose exposure planning, irradiation safety, DMU Kinematics

INTRODUCTION

The primary purpose of radiation protection program in nuclear related activities is for the protection of humans, living things as well as the environment. Therefore, in performing any radiation related tasks, it is important to take the necessary precautions and procedures so that the workers involved are protected from excessive exposure. The application of ALARA principles is important to ensure the procedure involved is the safest possible for a particular task. According to the radiation protection management principles, one of the important processes in any radiation related task is the work planning. The process includes the tasks screening, work processes interface review, identification of hazards, and strategy to eliminate, minimize or control the risks [Ahier, 2009].

After the completion of work planning, adequate preparation should be conducted to avoid or minimize any undesirable accident/incidents during the actual work implementation. Discussion among various experts in different fields involved, followed by actual physical simulation is the typical methods to review the work procedures [Burnham, 2003]. However, due to the advancement of computing technology, soft simulation has been brought into the work planning process. Most of the simulation process is a combination of Virtual Reality, 3D CAD and dose mapping technology [Vermeersch et al., 2000; Sanders et al., 2005]. It is not only reducing the time and cost of planning and review processes but also providing reviewers with more parameters and factors to be considered due to the flexibility of virtual environment. Such simulation tool would be beneficial to enhance further the work planning and review processes. Among the available simulation programs developed are Virtual Radiation Field by University of Florida, VR Dose by Halden VR Centre in Germany, VISI PLAN 3D ALARA by SCK CEN in Belgium and DEXUS in Fugen, Japan. Most of the software systems are developed for radiation related tasks in Nuclear Power Plants [Feernand, 2007].

Among the project in nuclear facilities which employed virtual simulation for the work planning and review process is the VR decommissioning project carried out by Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA) in collaboration with Institute for Energy Technology (IFE), Norway, for dismantling of several contaminated glove boxes [IFE, 2002]. This is a critical operation because

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the contamination consists of plutonium isotopes. VR is used to visualize the workers movements and tasks, their equipment and their radiation protection gears. With VR techniques, external radiation conditions, nuclides in air and glove-boxes contamination can also be visualized in the system. Another example is the decommissioning and dismantling (D&D) project of nuclear power plant in Slovak Republic [Michal et al.,2001]. Tools such as digitalization of documentation, the real state verification, 3D scanning of construction parts and equipment, computer simulation of work procedures performed in high radiation environment, modeling of nuclear power plant equipment have been used to support the engineering and D&D activities. In Idaho Central Facilities for Sewerage Treatment Plant, USA; the Decontamination, Decommissioning, and Remediation Optimal Planning System (DDROPS) simulation software was developed to enable an operator to simulate a facility for remediation preplanning and waste minimization purposes. DDROPS has been able to reduce radiation exposure risk to workers, minimized waste volumes, shipping and disposal costs.

This paper will discuss an attempt to use available 3D CAD technology in work planning processes. The software only consists of 3D Modelling capability and Kinematics Simulation without Virtual Reality and Dose Mapping technology. A work scenario was created and simulated. The data obtained was used to estimate the dose rate received.

MATERIALS AND METHODS

3D Modeling

The 3D modelling of the work scenario was performed using CATIA Mechanical Design module. CATIA is integrated Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Aided Engineering (CAE) software, where it combines the 3D modelling, manufacturing work planning and engineering analysis in a software package. A source object, a phantom and surrounding equipment were created with normal 3D CAD design modeller. The positioning of the source object and the initial position of the phantom were created in such a way that it would take some times to perform the task. The positioning is based on distance and angle from the work path created. The work path was created in the form of single line, representing trajectory of work process. The dimension of the phantom was modelled to emulate the average size of a human being.

Work plan creation

The creation of the working path was performed using Digital Mock up (DMU) Kinematics module which comes with CATIA package. The DMU Kinematics module in CATIA is designed to perform kinematics simulation of mechanical moving parts. It is used to analyse the movement of mechanicals components such as the functions, joints or coupling selection, movement sequence, clash detection, moving path and swept volume. It may also be used to determine the appropriate speed for a particular movement as it could be simulated in real time.

DMU Kinematics could only be simulated when two or more parts are joined together with at least 1 fixed part. Thus, several single line parts representing the trajectory path were created and joined together with the phantom so as to function as a unit. Constraints were set to each joint accordingly. The joints between trajectory parts were set to fixed joint, whereas the joint of each individual path with the phantom was set as sliding joints. This was done to emulate the movement of a human being along each path.

Working simulation

Upon successful creation of mechanical joints the model is ready to be simulated. The simulation was performed through Kinematics Simulator in DMU Kinematics module. The simulation process involved defining the simulation command, the simulation sequence and movement speed. CATIA simulator checker would notify the user on any error during the development process and provide recommendations for correction. In order to emulate a real time working process, the movement speed of the phantom was set similar to walking step of an average human being. Thus, the time taken for the phantom to walk toward the radioactive source would closely represent an actual time taken by average human being.

Data collection

DMU Kinematics Simulator could record the position of the phantom throughout its movement. This was accomplished by the addition of virtual positioning sensor activated on the phantom's body. The position of the phantom was recorded according to event interval set automatically by the software. This event interval need to be converted to time event, based on the total real time taken by the phantom to perform the task. The position of the phantom was recorded by the computer according to the distance it moved from the starting position. The actual distance of the phantom to the source at each time interval, need to be calculated either by geometrical equation or reverse counting depending on the configuration of the trajectory paths.

Dose rate calculation

The data on time and distance obtained from the simulation was converted into dose rate received by the phantom. The dose rate was calculated according to the following equation:

$$\text{Dose rate at 1 m} = \text{RHM x Source strength}$$

$$\text{Dose rate at D m} = \frac{\text{Dose rate at 1 m}}{D^2}$$

Where RHM is the adsorbed dose factor for the source in Roentgen-hour per meter and D is the distance at each time interval.

A radioactive source with specific type and strength was selected to simulate a task exposed to radiation. The RHM value and strength of the source was inserted into the equations above. The dose rate at each time interval and distance were calculated using the equation. The dose rate values were then tabulated into graphical form to obtain the dose profile of the simulated task.

RESULTS AND DISCUSSION

The 3D model of the work scenario is shown in Fig. 1. It consists of a phantom, several surrounding objects, work path trajectory and the radioactive source. Three trajectory paths have been created which are straight line, cornering and another straight line at different direction as shown in Fig. 1.

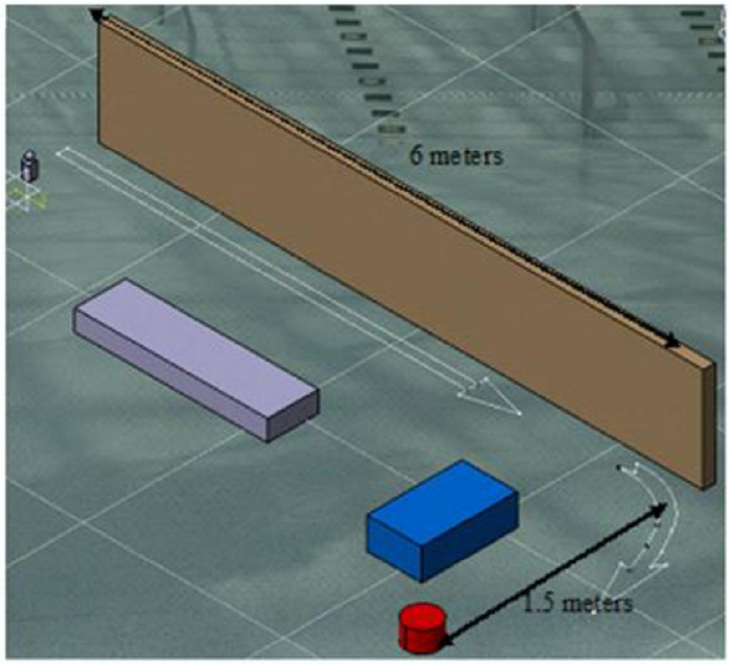

Fig. 1: The work scenario created (not to scale)

A sample of the data collected from the simulation is shown in Table 1. It consists of event interval and phantom position at each trajectory paths. The event interval was converted into time interval in seconds, whereas distance of phantom from the source was derived from the phantom position trajectory data. The table below shows a movement of the phantom in 41 seconds along the first trajectory path. It shows the phantom movement in only one direction where the position at path 2 and 3 remained constant.

Table 1: Sample of the data collected

Event number	Time (s)	Position at trajectory path 1 (mm)	Position at trajectory path 2 (mm)	Position at trajectory path 3 (mm)	Distance from source (mm)
0	0	0	-1300	0	5884.896
1	0.512	62.5	-1300	0	5825.024
2	1.025	125	-1300	0	5765.208
3	1.537	187.5	-1300	0	5705.450
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
77	39.462	4812.5	-1300	0	1872.740
78	39.975	4875	-1300	0	1845.975
79	40.487	4937.5	-1300	0	1820.963
80	41	5000	-1300	0	1797.776

Table 2 shows a sample of dose rate exposed to the phantom in the first trajectory path. The dose rate was calculated using dose rate equation mentioned in the previous section. The data shows that the dose intensity increases when the phantom moving toward the source.

Table 2: Dose received by the phantom

Time	Distance from source (mm)	Dose rate at 1m (R/hr)	Dose intensity mSv/hr
0.00	5885	5.00	1.44
0.51	5825	5.00	1.47
1.03	5765	5.00	1.50
1.54	5705	5.00	1.54
2.05	5646	5.00	1.57
.	.	.	.
.	.	.	.
.	.	.	.
39.46	1873	5.00	14.26
39.98	1846	5.00	14.67
40.49	1821	5.00	15.08
41.00	1798	5.00	15.47

Fig. 2 shows the plot of dose intensity received by the phantom when it is moving toward the radioactive source. It shows the time taken by the phantom to perform the task and the estimated dose it received at each particular time. The plot represents the dose profile for this particular task. Work planning may be decided based on this dose profile. The plot shows that the dose received is almost constant from the initial position to around 220 seconds where the dose started to increase. The dose increases in almost a linear fashion until at about 300 seconds. After that, the dose intensity increases exponentially when the phantom is very near to the source. The simulation was stopped at 380 seconds when the phantom arrived at the designated source. At this point, maximum exposure at about 7396 mSv/hr is received by the phantom, which is a very lethal dose for human being.

From the above dose profile, planner may decide on the working procedure that will reduce the dose exposure. For example, the task may be performed by using remote handling device. The position where the worker needs to stand to handle the device could be from 220 seconds position. The exact position can be determined from the 3D model. If the device is not available, time sharing method may be employed. The exact position and the time permitted for each worker to perform the job may be determined from the dose profile obtained from the modelling.

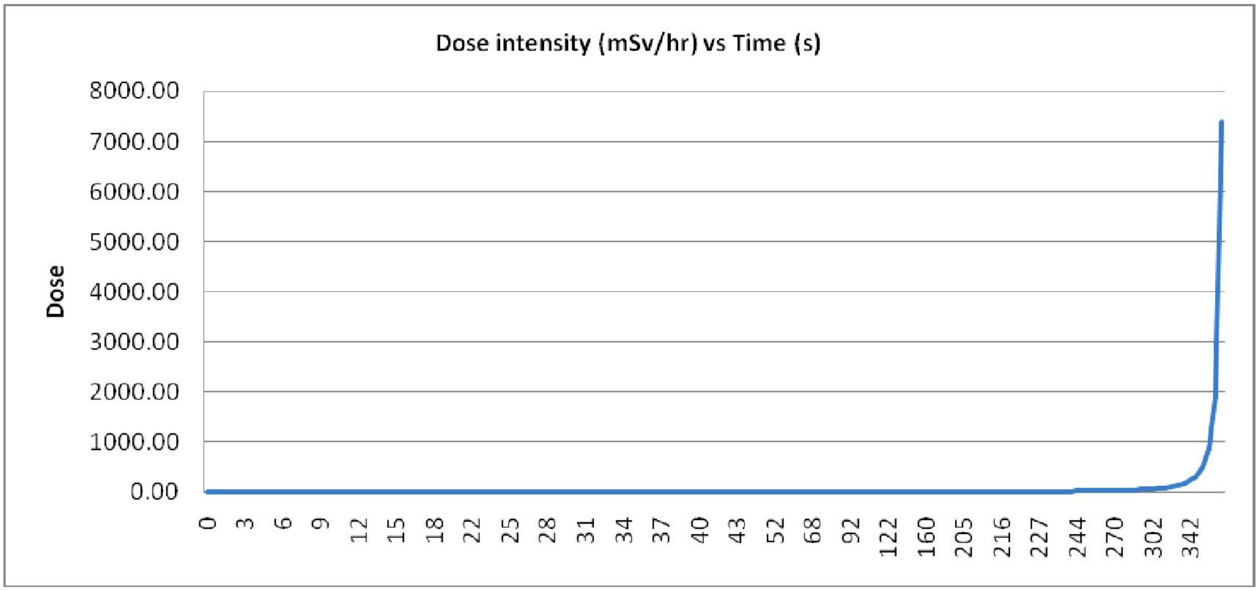

Fig. 2: Dose profile obtained from the simulation.

CONCLUSION

The attempt to use DMU Kinematics tool in CATIA to model a dose exposure work planning has shown promising results. The module has successfully created a working environment with trajectory paths for the particular task. The real time data from the model simulation can be used to estimate the dose received by the workers depending on the work planning created.

However, the module has limitations in creating phantom movement. This is due to the fact that DMU Kinematics is meant to simulate mechanical movement instead of planning a work trajectory path. The designer has to be creative in manipulating various functions in Kinematics modeller to be able to emulate the trajectory work path movement.

The calculation of the phantom distance from the source cannot be obtained by a single method. A lot of trigonometric manipulation and calculation need to be done to estimate the distance. It is also heavily dependent on the trajectory path created. A complex configuration of trajectory path will make it more difficult to calculate the distance. Thus, the DMU Kinematics tool is suitable to model a simple work planning scenario and would be sufficient to estimate the dose profile of the task.

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