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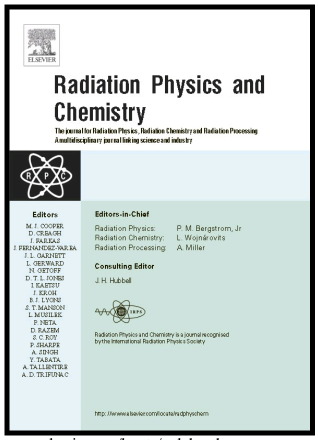

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PII: S0969-806X(18)30003-3
DOI: https://doi.org/10.1016/j.radphyschem.2018.04.035
Reference: RPC7845

To appear in: *Radiation Physics and Chemistry*

Received date: 2 January 2018
Accepted date: 27 April 2018

Cite this article as: Nan Chao, Yong-kuo Liu, Hong Xia, Abiodun Ayodeji and Huang Yang, Adaptive Point Kernel Dose Assessment Method for Cutting Simulation on Irregular Geometries in Nuclear Facility Decommissioning, *Radiation Physics and Chemistry,* https://doi.org/10.1016/j.radphyschem.2018.04.035

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Adaptive Point Kernel Dose Assessment Method for Cutting Simulation on Irregular Geometries in Nuclear Facility Decommissioning

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Abstract:

Nuclear decommissioning tasks involve a large number of cutting activities and many irregular objects are produced. The objective of the paper is to propose a flexible dose assessment method for the cutting of contaminated structures with irregular geometries and radiation source. The method is based on virtual reality technology and Point-Kernel method. The initial geometry is designed with the three-dimensional computer-aided design tools. To simulate a cutting operation on an arbitrary structure, the cutting geometry and the approximate models of the products are built automatically with virtual reality technology. Point kernels are generated within the approximate models, and dose rates are calculated with the Point-Kernel method. In order to improve the dose calculation efficiency while maintaining the accuracy, an adaptive point kernels generation technique that can deal with arbitrary geometries is developed, and the density and distribution of point kernels are adapted to the position of the detecting point. To account for radiation scattering effects, buildup factors are calculated with the Geometric-Progression formula in the fitting function. The effectiveness and superiority of the proposed method were verified by simulating different geometries, and comparing the dose rate results with those derived from VRBM, CIDEC, and MCNP codes.

Keyword: dose assessment; cutting geometry; point kernel method; virtual reality; nuclear facilities decommissioning

1. Introduction

The cutting or demolition works during the nuclear facility decommissioning is characterized by high radioactivity and high risk. It is essential to perform the dose assessment and safety analysis to occupational workers in such radioactive environments before or during the task. However, because of the existence of radioactivity, it is difficult to analyze the working process through practical experiments; especially as the structure and the radiation field are frequently changing during cutting operation. To address the issue, researchers such as Mól et al. (2009), Jeong et al. (2014) used virtual reality (VR) technology to aid decommissioning of nuclear facilities, and the VR technique presents a more feasible and safe way to analyze the environment and train workers. In order to perform dose assessment and safety analysis during the cutting works, it is necessary to provide a flexible gamma dose rates calculation method for cutting simulation on irregular geometries and radiation sources to improve the efficiency and accuracy of simulations.

The Monte Carlo and the Point-Kernel methods are commonly used for calculating radiation shield effectiveness and dose rates. The Monte Carlo method is a probabilistic method with high-precision but suffers from long computing time. The typical program based on the Monte Carlo method is the Monte Carlo Neutron and Photo Transport Code (MCNP) (Breismeister, 2000). By contrast, the Point-Kernel method is an analytical method with less computing time but lacks rigor. Commonly used codes based on the Point-Kernel method are the QAD (Cain, 1977), the PUTZ (Ingersoll, 1986), and the Microshield. These codes build the geometric space manually by combining geometry technology and modeling, which makes it difficult and inefficient to describe large-scale complex environments, especially tasks in dynamic environments such as the cutting or demolition in a decommissioned nuclear facility.

In order to model the complex geometries efficiently, Vela et al. (2006) took advantage of the geometric modeling capabilities of computer-aided design (CAD) tools to construct the geometry, and developed a code based on point kernel method. The code is named CIDEC and can assess dose rate in complex geometries. However, the code cannot obtain the details of geometries, such as the volume, and has a limitation in dealing with the cutting operation.

Caracena et al. (2013) presented an algorithm to calculate gamma dose rates for VR simulation applications in nuclear safeguards and security. The algorithm can cope with both accuracy and time requirements by calculating dose rates via a

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