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Uncertainty and Sensitivity Analysis of Radioactive Source Terms from Intact Containment Category for Nuclear Power Plants Based on BEPU Method

摘要

本研究提出了一套利用最佳估算加不确定性方法对核电厂严重事故源项进行不确定性与敏感性分析的综合流程。该流程纳入了严重事故管理指南行动，并探讨了其对放射性释放份额的影响。分析应用于中国某双环路压水堆安全壳完整释放类别（源自二级概率安全评估）。通过 MAAP 程序运行 200 个案例，识别并量化了影响源项的关键参数（包括低压安注和安全壳喷淋启动时机）的不确定性。结果表明，低压安注注入时机对惰性气体和碘化铯释放份额的影响最大，通过斯皮尔曼等级相关系数分析证实二者存在强相关性。安全壳喷淋启动对惰性气体具有中等程度影响，但对碘化铯的作用较小。研究还强调了气溶胶行为和严重事故进程参数的重要性，这些参数虽有一定影响，但与严重事故管理指南行动相比相关性较弱。这些发现表明，在选择释放类别的代表性事故序列时，需特别关注源项计算中严重事故管理指南行动的不确定性。该研究有助于提高二级概率安全评估中源项预测的准确性和可靠性，并为未来在严重事故分析中应用最佳估算加不确定性方法的研究提供了参考。

关键词

不确定性分析，敏感性分析，源项，SAMG，BEPU

Abstract

This study presents a comprehensive procedure for uncertainty and sensitivity analysis of source terms in severe accidents of nuclear power plant, utilizing the Best Estimate Plus Uncertainty (BEPU) methodology. The procedure incorporates Severe Accident Management Guidelines (SAMG) actions and explores their impact on radioactive release fractions. The analysis is applied to the containment intact release category for a two-loop pressurized water reactor (PWR) in China, derived from Level 2 Probabilistic Safety Assessment (PSA). Key parameters influencing the source term, including the timing of Low-Pressure Safety Injection (LPSI) and containment spray activation, are identified and their uncertainties quantified following running of 200 cases by MAAP code. The results demonstrate that the LPSI injection timing is the most influential factor on both noble gases and Cesium Iodide (CsI) release fractions, with a strong correlation identified through Spearman's rank correlation
coefficient analysis. The containment spray activation has a moderate influence on noble gases while it plays a less significant role for CsI. The study also highlights the importance of aerosol behavior and severe accident progression parameters, which, although influential, exhibit weaker correlations than SAMG actions. These findings indicate the importance of selecting representative accident sequences for release categories with particular attention to SAMG action uncertainties during source term calculation. The research contributes to enhancing the accuracy and reliability of source term predictions in Level 2 PSA and provides an insight for future investigations into the application of BEPU in severe accident analysis.

Keywords

Uncertainty Analysis, Sensitivity Analysis, Source Term, SAMG, BEPU

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