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Research on hydrogen risk prediction in probability safety analysis for severe accidents of nuclear power plants

摘要

福岛核事故后氢气燃烧风险始终是核电行业关注的重点问题。在核电厂概率安全分析的氢气风险评估中，传统方法采用集总参数程序计算，计算速度快但可能存在较大不确定性，而新近发展的 CFD 分析方法更为精确，但由于多种因素尚未广泛应用于 PSA 的氢气风险分析。本文首先针对中国某第三代大型压水堆核电厂华龙一号，采用集总参数分析程序 MAAP 分析小 LOCA 严重事故下的氢气参数，进而分析氢气爆燃向爆轰转变的概率及其不确定性。其次，采用 CFD 程序 GASFLOW 对同一事故序列进行分析，以获得更准确的氢气分布及其他参数，同时获取氢气的 DDT 概率值。CFD 计算获得的氢气分布可用于指导集总参数程序的不确定值，从而获得更准确的氢气 DDT 值。分析结果表明，采用集总参数程序方法进行氢气风险评估存在一定的不确定性，可结合 CFD 软件给出的气体分布分析结果进行修正，以获得更准确、可靠的概率值。

关键词

氢气风险，DDT，MAAP，Sherman-Berman，GASFLOW，华龙一号

Abstract

The risk of hydrogen combustion after the Fukushima nuclear accident has always been a topic of concern for the nuclear power industry. In the hydrogen risk assessment of probability safety analysis (PSA) in nuclear power plants, the traditional methods by using lumped parameter program method is fast but may have large uncertainties,
while the newly developed CFD analysis method is more accurate but has not yet been widely applied to the hydrogen risk analysis of PSA due to a variety of factors. The lumped parameter analysis program MAAP is used firstly to obtain the hydrogen parameters under the severe accident of small LOCA in this paper, based on China's third-generation large-scale pressurized water reactor (PWR) nuclear power plant HPR1000, and then the probability of deflagaration to detonation (DDT) for hydrogen risk is analyzed with uncertainty. Secondly, the CFD software GASFLOW program is used to analyze the same accident sequence to obtain more accurate hydrogen distribution and other parameters, and at the same time to obtain the DDT probability value of hydrogen risk. The hydrogen distribution obtained by CFD calculation can be used to guide the uncertainty value
of the lumped parameter program to produce more accurate DDT value of hydrogen risk. The analysis results show that there is a certain uncertainty in hydrogen risk assessment when using lumped parameter program method, which can be corrected by combining the gas distribution analysis results given by CFD software, to obtain a more accurate and reliable probability value, so as to provide

Keywords

Hydrogen risk, DDT, MAAP, Sherman-Berman, GASFLOW, HPR1000

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