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# 基于 **RMC** 的自主蒙卡子通道核热耦合系统开发

## 摘要

高保真核热耦合分析是研究反应堆复杂物理行为的重要手段。为建立自主可控的核热耦合分析体系，本文基于自主开发的蒙特卡罗中子输运程序 RMC 与热工水力子通道程序 RTH-SC，构建了以 Python 脚本为驱动的核热耦合计算系统 RMC/RTH-SC。

本工作的主要内容涵盖两个方面：一是 RTH-SC 程序全堆 pin-by-pin 分析能力的开发与实现；二是耦合计算平台的设计与搭建。针对商用压水堆全堆 pin-by-pin 精细化建模的复杂性，开发了预处理工具 SC-Pre，实现了全堆几何模型的自动化构建；在此基础上，建立了基于 Picard 迭代的耦合计算框架，并完成了中子物理网格与热工水力网格之间的映射关系处理。

为验证系统的计算精度，以 VERA7 基准题反应堆为对象开展了全堆模拟，并与 RMC/CTF 耦合结果进行对比。结果表明：有效增殖因子的相对偏差为 7.1 pcm；堆芯组件功率分布的平均偏差约为 1.4%；慢化剂温度的平均偏差为 0.74 ℃；慢化剂密度的平均偏差为 $0.83\times10^{-3}$ g·cm$^{-3}$。上述结果表明，所建立的 RMC/RTH-SC 耦合系统具有良好的计算准确性，可为压水堆精细化核热耦合分析提供有效支撑。

## 关键词

RMC；核热耦合；RTH-SC

## Abstract

High-fidelity neutronics–thermal-hydraulics coupled analysis is an essential approach for investigating the complex physical behavior of nuclear reactors. To establish an independently developed and fully controllable coupled analysis framework, this study presents the RMC/RTH-SC coupled system, which is built upon the in-house Monte Carlo neutron transport code RMC and the thermal-hydraulic subchannel code RTH-SC, with Python scripts serving as the coupling driver.

The scope of this work encompasses two primary aspects: first, the development and implementation of full-core pin-by-pin analysis capability within the RTH-SC code; and second, the design and construction of the coupled computational platform. To address the complexity inherent in full-core pin-by-pin modeling of commercial pressurized water reactors (PWRs), a preprocessing tool, SC-Pre, was developed to enable automated construction of the full-core geometric model. On this basis, a coupled computational framework based on Picard iteration was established, along with the implementation of mesh mapping between the neutronics and thermal-hydraulic domains.

To verify the computational accuracy of the coupled system, a full-core simulation was performed for the VERA Benchmark Problem 7 reactor, and the results were compared against those obtained from the RMC/CTF coupled solution. The comparison shows that the relative deviation in the effective multiplication factor is 7.1 pcm, the mean deviation in assembly-wise power distribution is approximately 1.4%, the mean deviation in moderator temperature is 0.74 ℃, and the mean deviation in moderator density is $0.83\times10^{-3}$ g·cm$^{-3}$. These results demonstrate that the developed RMC/RTH-SC coupled system possesses satisfactory computational accuracy and can serve as an effective tool for high-fidelity neutronics–thermal-hydraulics coupled analysis of PWRs.

## Keywords

RMC; Neutronics/thermal-hydraulics coupling; RTH-SC

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