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反应堆工程

# 聚变-裂变混合堆水冷包层中子物理性能研究

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摘要 研究直接应用国际热核聚变实验堆（ITER）规模的聚变堆作为中子驱动源，采用天然铀为初装核燃料，并采用现有压水堆核电厂成熟的轻水慢化和冷却技术，设计聚变-裂变混合堆裂变及产氚包层的技术可行性。应用MCNP与Origen2相耦合的程序进行计算分析，研究不同核燃料对包层有效增殖系数、氚增殖比、能量放大系数和外中子源效率等中子物理性能的影响。计算分析结果显示，现有核电厂广泛使用的$UO_2$核燃料以及下一代裂变堆推荐采用的UC、UN和$U_{90}Zr_{10}$等高性能陶瓷及合金核燃料作为水冷包层的核燃料，都能满足以产能发电为设计目标的新型聚变 裂变混合堆能量放大倍数的设计要求，但只有UC和$U_{90}Zr_{10}$燃料同时满足聚变燃料氚的生产与消耗自持的要求。研究结果对进一步研发满足未来核能可持续发展的新型聚变-裂变混合堆技术具有潜在参考价值。

关键词 聚变-裂变混合堆 水冷包层 核燃料 中子物理性能

分类号

# Neutron Physical Characteristics of Light Water Cooled Blanket of Fusion-Fission Hybrid Reactor

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**Abstract** Technology feasibility was studied on direct application of ITER (International Thermonuclear Experimental Reactor) scale nuclear fusion reactor as driving neutron source to design a new type of fusion-fission hybrid power reactor and its tritium producing-nuclear fission blanket, which can cooperate the advantages of loading natural uranium fuels in initial blankets and adopting mature light water moderating and cooling technologies widely used in current PWRs. Numerical analysis with the computer code by coupling MCNP and Origen2 was performed to investigate the influences of different nuclear fuels to neutron physical characteristics of the blanket, such as the effective neutron multiplying coefficient, the tritium breeding ratio, the energy amplifier and the effectiveness of the driving fusion neutrons. The calculation results show that $UO_2$ employed in current nuclear power plants, the high performance ceramics of UC, UN, and the $U_{90}Zr_{10}$ metal alloy fuels recommended to be applied in various types of next generation nuclear fission reactors are promising candidates as the nuclear fuel of achieving adequate energy amplifying factor. However, only UC ceramics and $U_{90}Zr_{10}$ metal alloy fuels can satisfy simultaneously the requirement of the self-sustainable balance between tritium production and consumption for the nuclear fusion in a typical hybrid reactor. The research results are expected to have potential reference value for further exploring the new type of fusion-fission hybrid reactor to fulfill the requirement of future sustainable development of nuclear energy.

**Key words** fusion-fission hybrid reactor _ water cooled blanket _ nuclear fuel _ neutron physical characteristics

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