ICCES, 2026, vol.36, no.1

Tech Science Press

DOI: 10.32604/icces.2026.014385

PROCEEDINGS

Structural Optimization and Thermohydraulic Performance Study of Ordered Porous Tritium Breeding Units

Huzhe Yu[1], Jili Cai[1], Lei Shi[1], and Chao Cai[1,*]

[1]State Key Laboratory of Material Processing and Die & Mould Technology and School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan, 430074, China

[*]Corresponding Author: Chao Cai. Email: chaocai@hust.edu.cn

ABSTRACT

Tritium breeder is a key functional material for achieving tritium regeneration in nuclear fusion reactors. The conventional pebble bed configuration for tritium breeders is formed by stacking lithium-containing ceramic pebbles. However, this configuration suffers from several limitations, including a restricted packing fraction, severe stress concentration, high gas flow resistance, and low thermal conductivity. These issues constrain tritium production efficiency. This study proposed a design approach that replaced the traditional pebble bed configuration with a Gyroid porous structure tritium breeder. Through fluid-solid coupled heat transfer simulation, the thermohydraulic performances of the Gyroid porous structure and the pebble bed structure were comparatively analyzed. The results showed that the Gyroid structure was superior to the pebble bed structure. Within the inlet velocity range of 0.1–0.2 m/s, the Gyroid structure exhibited an average flow velocity about 56% higher than that of the pebble bed structure, and its pressure drop was reduced by about 50%. Moreover, the convective heat transfer coefficient was increased by 56%, and the effective thermal conductivity was increased by 13.7%. The service performances of the tritium breeder blankets based on the Gyroid structure and the pebble bed structure were evaluated and compared. The maximum temperature of the Gyroid tritium breeder blanket was reduced by approximately 10%, meeting the temperature requirements for tritium breeders. Meanwhile, the energy consumption for gas flow within the Gyroid tritium breeder blanket was only 10% of that in the pebble bed blanket. This study can provide theoretical basis and technical support for the design and engineering application of a next generation of tritium breeder blankets.

KEYWORDS

Ceramic tritium breeders; numerical simulations; nuclear fusion; thermohydraulic performance

Acknowledgement: Acknowledge the State Key Laboratory of Materials Processing and Die & Mould Technology and the Analysis and Testing Center of Huazhong University of Science and Technology for technical assistance.

Funding Statement: The work was financially supported by the National MCF Energy R&D Program (No. 2022YFE03210400), and the National Natural Science Foundation of China (Nos. 52375335, U22A202494).

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.

Copyright © 2026 The Author(s). Published by Tech Science Press.
This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.