Computational Modelling of Heat Sinks Enhancement with Triply Periodic Minimal Surface Structures

Welteji Iticha[1,*] and Tomasz Stręk[2]

[1,2]Institute of Applied Mechanics, Poznan University of Technology, Poznan, Poland
e-mails: welteji.iticha@doctorate.put.poznan.pl, tomasz.strek@put.poznan.pl

KEYWORDS: *heat sink, porous TPMS, fluid flow, heat transfer, numerical method*

Efficient thermal management is a critical challenge in modern electronic systems, where increasing power densities and device miniaturization demand advanced cooling solutions [1–3]. Conventional fin based heat sink device, often fail to meet demand for compactness and enhanced heat dissipation [4,5]. In this study, the effects of different triply periodic minimal surface (TPMS) structures on thermal performance of heat sink devices are investigated using finite element simulations conducted in COMSOL Multiphysics. The computational model consists of a fluid channel, a uniform heat source applied through copper base plate and three different TPMS heat sink geometries: gyroid, diamond and I-WP. The generated heat is conducted to the TPMS structure and subsequently dissipated to the surrounding fluid via convection at the outlet surface. The outlet boundary is defined as a pressure outlet, while the outer channel walls are assumed to be adiabatic with a no-slip condition. Water is used as the working fluid in the analysis.

Computational fluid dynamics (CFD) simulations were employed to analyze fluid flow and thermal performance subjected to cell size, structural arrangements and the inlet velocities. The fluid flow and heat transfer are governed by the Navier–Stokes and energy equations, respectively. The results of performance evaluation criterion (PEC), which combines heat transfer and friction factor, indicates that gyroid TPMS heat sink achieves the balanced thermo-hydraulic efficiency. This is due to smooth and continuous channel of gyroid structure, which promotes helical flow paths and ensures uniform fluid distribution. Furthermore, the results of Nusselt number is decreased along the channel length for all configurations due to thermal boundary layer development, while increasing inlet velocity improves overall heat transfer performance. In conclusion, TPMS based porous heat sinks, particularly gyroid geometry, offer effective solution for advanced thermal management applications.

ACKNOWLEDGEMENT: The work was supported by ‘PhDBoost’ Program for doctoral students of the Doctoral School of Poznan University of Technology (in 2026) from the University’s subsidy financed from the funds of Ministry of Science and Higher Education (0610/SPHD/2604).

[1] W. Iticha, T. Stręk, Materials 18(23), 5280, 2025. https://doi.org/10.3390/ma18235280

[2] M.Z. Saghir, M.M. Rahman, Fluids 9 (12), 297, 2024. https://doi.org/10.3390/fluids9120297

[3] S. Samson, P. Tran, and P. Marzocca, Applied Thermal Engineering 235, 121296, 2023. https://doi.org/10.1016/j.applthermaleng.2023.121296

[4] S. A. Jajja, W. Ali, H. M. Ali, A. M. Ali, Applied Thermal Engineering 64(1–2), 76–82, 2014. https://doi.org/10.1016/j.applthermaleng.2013.12.007

[5] Q. Wang, J. Tao, Z. Cui, T. Zhang, G. Chen, Int. Commun. Heat Mass Transf. 155, 107580, 2024. https://doi.org/10.1016/j.icheatmasstransfer.2024.107580