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Influence of Mesh Layer Count on Wick Performance: A Study on Figure of Merit for Microreactor Heat Pipes

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Abstract

Background: The efficient thermal management of microreactor systems relies heavily on passive heat transfer devices such as heat pipes, where capillary driven fluid return is entirely governed by the wick structure. In such applications, optimizing wick design is critical to ensure reliable operation without mechanical pumps or external power. While geometric parameters like mesh layer count are often adjusted to enhance performance, their impact is not always intuitive. This study investigates the influence of mesh layer count (10, 12, and 14) layers on the overall capillary efficiency of stainless steel screen wicks using the Figure of Merit (FOM) as the primary evaluation metric. FOM is dimensionally consistent performance metric that quantifies the balance between capillary pumping capability and flow resistance in porous wick structures.

$$FOM = \frac{k\,.\varepsilon.\sigma.cos\theta}{\mu\,.\;r_{eff}}$$

Where k = permeability, ε =porosity, σ = surface tension of the working fluid, μ = dynamic viscosity of the fluid, r_{eff}= effective pore radius, θ = contact angle

Methods: A computational simulation was conducted to evaluate the capillary performance of stainless steel mesh wicks (100×100) in three layered configurations: 10, 12, and 14 layers. Each wick was modeled as a uniformly rolled cylindrical structure, with ethanol selected as the working fluid due to its low contact angle and strong wettability on stainless steel. A custom MATLAB script was used to compute key transport parameters - permeability (K), porosity (ε), and effective pore radius (r_{eff}). These values were then used to calculate the Figure of Merit (FOM).

Results: The results demonstrate a clear degradation in performance with increasing layer count. The 10-layer wick achieved the highest FOM of 2.71×10^{-5} m indicating superior capillary efficiency. The 12 layer configuration exhibited a reduced FOM of 2.31×10 ^−5 m, reflecting a decline in overall transport effectiveness. The 14-layer wick recorded the lowest FOM at 1.98×10^{-5} m. This trend reveals that increasing mesh layers does not enhance performance; instead, it compromises the capillary pressure to flow resistance balance essential for passive fluid return.

Conclusions: This study concludes that the FOM is a powerful, integrative tool for evaluating wick performance beyond isolated structural parameters. The 10 layer wick emerges as the

optimal configuration, delivering the best compromise between fluid mobility and capillary action. These findings provide critical insight for the design of high efficiency heat pipes in compact thermal systems, emphasizing that more layers do not equate to better performance. Future wick optimization should prioritize FOM driven design to achieve reliable and efficient thermal management in microreactor applications.

Keywords Wick, Heat Pipes, Microreactor, Mesh, Thermal Transfer

Media:

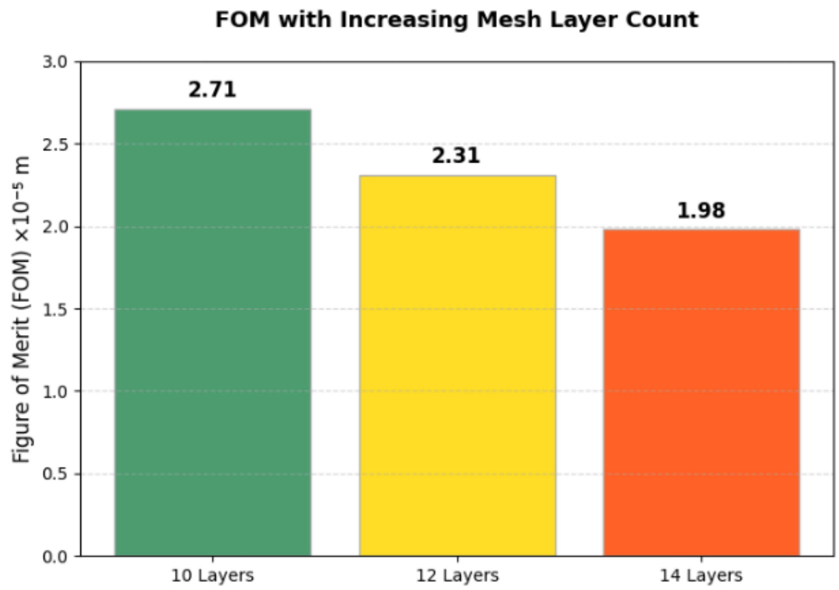

Fig 1. FOM decreases with increasing mesh layer count, indicating reduced capillary efficiency. The 10-layer wick delivers the highest performance, demonstrating that more layers do not improve wick function.