FAB-HEX: Fractal Based Additive and Bio-Inspired Heat Exchanger

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Heating and cooling systems account for nearly 50% of the global energy consumption. Heat exchangers are critical components of all heating and cooling systems. Heat transfer efficiency is a key lever for energy savings and decarbonization and depends on the surface area. I propose a novel, bio-inspired approach to increase heat transfer efficiency using fractals. Fractals are complex, geometric patterns that are self-similar. A key property of fractals is that they can have infinite perimeter for a finite area. Additionally, advances in additive manufacturing have made it possible to realize complex, fractal structures with high accuracy. The goals of my research are two-fold: (a) design novel fractal-shaped heat exchangers and show that they can significantly increase the heat transfer rate and (b) realize complex fractal designs using 3D printing. First order analysis was used to model a concentric, double-pipe heat exchanger. The main goal is to maximize heat transfer rate by increasing the perimeter. I considered two different approaches to construct fractal shapes to increase the perimeter while keeping the cross-sectional area constant. A Matlab model was created to compare different fractal designs with the baseline design. Simulations showed that fractal-based designs can increase the heat transfer rate by up to 80%. CAD models for the fractal designs were built using OnShape and 3D printed to realize the fractal designs. The results clearly show that bioinspired fractal geometries along with additive manufacturing provide a feasible way to design highly efficient heat exchangers.

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