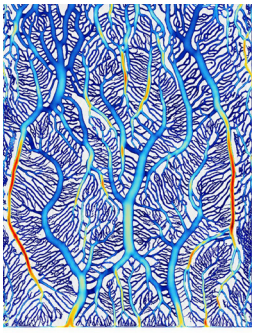
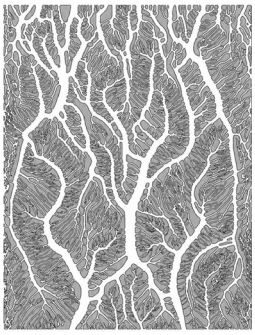


Fraunhofer

Simulation-driven heat exchanger design for enhanced thermal performance

From function to geometry: CFD-driven topology optimization meets additive manufacturing





Instead of refining existing geometries, Fraunhofer IWU starts with the function itself. Using CFD-driven topology optimization with ToffeeX, cooling structures evolve directly from thermal and fluidic requirements, while material properties and manufacturing constraints are considered from the very beginning. Additive manufacturing turns these designs into real components.

Conventional heat exchanger design usually starts from an existing geometry that is refined step by step. Fraunhofer IWU reverses this approach. The design process begins with the physical requirements of the application: How should the fluid flow? Where must heat be removed? How much pressure loss is acceptable? From these targets, the CFD-driven topology optimization tool ToffeeX generates the geometry directly. Material properties and manufacturing constraints are part of the optimization from the very beginning - this way, function, material and manufacturability are considered together.

The approach was demonstrated on a liquid-cooled power electronics module with six semiconductor chips, each generating a heat load of 125 W. The design space was divided into regions with defined fluid-to-solid volume fractions. It took 1,500 autonomous design iterations to minimize both chip temperature and pressure loss, within a strict limit of 150 mbar at a flow rate of 10 l/min. The result is a bionic, branched channel structure that guides the coolant precisely to the heat sources. Conventional manufacturing could hardly produce such geometries, and they would probably never have been designed manually.

Physics makes these design possible. Additive manufacturing makes them manufacturable.

Fraunhofer Institute for Machine Tools and Forming Technology IWU

Nikolaus Milaev, M. Sc.
nikolaus.milaev@iwu.fraunhofer.de
www.iwu.fraunhofer.de
www.toffeex.com

exhibit overview