Proceedings of the 4th International Conference on Fluid Flow and Thermal Science (ICFFTS'23)
Dubai, United Arab Emirates- December 07 - 09, 2023
DOI: 10.11159/icffts23.006

Design, Fabrication and Testing Of Topologically Optimized Heat Sinks for Electronic Cooling

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ABSTRACT

Increasing power dissipation by electronic devices requires matching improvements in the technologies used to cool them. Thermal management of electric vehicles poses additional challenges as on-board space is limited and cooling equipment must be compact and lightweight. Topology optimization software can be used to design high-efficiency heat sinks with complex geometries, but these are difficult to manufacture using traditional methods. Wire-arc spray is a widely used coating technology in which a voltage is applied across the tips of two continuously-fed metal wires, striking an electric arc that melts them. A high-velocity gas jet atomizes the molten metal into a spray of droplets that are propelled towards a substrate where they land, coalesce with each other and freeze, forming a dense deposit. Wire-arc spray is widely used to apply protective coatings but can also be used an additive manufacturing technique to make heat sinks.

Optimized, water-cooled heat sinks were made with 1 mm high internal flow channels. A topology optimization model was developed to generate a geometry for flow passages that maximized heat transfer while also minimizing the temperature non-uniformity. A polymer mask was made by 3D printing with openings where the topology optimization model placed structures in the flow path. The mask was placed in a recess machined in an aluminum plate and aluminum sprayed over it. The mask was removed, the sprayed structures ground to a uniform height of 1 mm, and the top of the recess sealed by spraying metal. Tests showed that when a heat flux was applied the average temperature of the optimized cold plate and temperature gradients across it much lower than for a conventional cold plate with parallel channels. This technique spray was also used to fabricate a topologically optimized heat sink for cooling an electrical vehicle fast charger. Experimental results demonstrated that the optimized heat sink gave a 27% reduction in average thermal resistance from the cooling fluid to the surface of the heat sink and a 25% reduction in maximum heat sink surface temperature difference.