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Numerical Investigation of 3D Printed Pin Fin Heat Sinks for Automotive Inverter Cooling Application

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Abstract : E-mobility poses new challenges for inverters (e.g., higher switching frequencies) in terms of thermal behavior and thermal management. Due to even higher switching frequencies, thermal losses become greater, and the cooling of critical components (like insulated gate bipolar transistor and diodes) comes into focus. New manufacturing methods, such as 3D printing, enable completely new pin-fin structures that can handle higher waste heat to meet the new thermal requirements. Based on the geometrical specifications of the industrial partner regarding the manufacturing possibilities for 3D printing, different and completely new pin-fin structures were numerically investigated for their hydraulic and thermal behavior in fundamental studies assuming an indirect liquid cooling. For the 3D computational fluid dynamics (CFD) thermal simulations OpenFOAM was used, which has as numerical method the finite volume method for solving the conjugate heat transfer problem. A steady-state solver for turbulent fluid flow and solid heat conduction with conjugate heat transfer between solid and fluid regions was used for the simulations. In total, up to fifty pinfin structures and arrangements, some of them completely new, were numerically investigated. On the basis of the results of the principal investigations, the best two pin-fin structures and arrangements for the complete module cooling of an automotive inverter were numerically investigated and compared. There are clear differences in the maximum temperatures for the critical components, such as IGTBs and diodes. In summary, it was shown that 3D pin fin structures can significantly contribute to the improvement of heat transfer and cooling of an automotive inverter. This enables in the future smaller cooling designs and a better lifetime of automotive inverter modules. The new pin fin structures and arrangements can also be applied to other cooling applications where 3D printing can be used.

Keywords : pin fin heat sink optimization, 3D printed pin fins, CFD simulation, power electronic cooling, thermal management
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