

Transient Heat Transfer of Pin-Fin and Plate-Fin Heat Sinks under Non-Uniform Heating of Hot Impinging Jet

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Upon launching jet aircrafts create high temperature and high speed exhaust sweeping across sweeping across an aircraft carrier flight deck surface. Jet blast deflectors (JBDs) are commonly used to deflect the dangerous exhaust upward to protect people and any equipment behind the JBDs. After launch the JBDs are quickly rotated flush with the deck surface such that the next aircraft awaiting take-off can roll over the structure into the launch position. JBDs require rapid cooling to avoid damaging the aircraft tires. Besides the intensive thermal load, the JBDs should also carry significant static and dynamic loads, such as the compressive stress due to the aircraft weight, the impact from accidental tail hook drops and that from foreign objects emitted from the engines. The current use is a series of seawater-cooled aluminum panels. In such a system, the plumbing and water pumping systems contribute a significant amount of weight for each JBD, resulting in maintenance complexities. Furthermore, the seawater causes severe corrosion problems.

It has been established that all-metallic lightweight sandwich panels with lattice truss cores possess excellent mechanical and thermal properties. These attributes can be exploited to design novel JBDs that require effective heat dissipation in addition to carry mechanical loads. This study aims to investigate the feasibility of using lattice truss sandwich panels under forced air cooling for JBD. The air cooling eliminates the currently used plumbing and water pumping systems, reducing the extra weight and simplifying the maintenance. As an initial step, for easy analysis and simple fabrication, sandwich panels with the conventional pin-fin and plate-fin array cores are concerned instead of the lattice truss structures. Due to morphological similarities, the heat transfer performance of lattice trusses is somewhat similar to that of pin-fin arrays.

To accurately simulate pin-fin or plate-fin heat sinks under non-uniform impinging jet heating, the use of Computational Fluid Dynamics (CFD) typically requires several million mesh elements and hence extremely time-consuming. To address the issue, we present two cost-effective semi-empirical models, a fin analogy model for pin-fin heat sink and a uniform porous medium model for both pin-fin and plate-fin heat sinks, both solved with the finite volume method. Experimental measurements are conducted to validate the steady and transient predictions of the two models. Under non-uniform heating boundary conditions, the morphological advantage of the pin-fins is compared with that of the plate-fins using the porous medium approach. The fin analogy model can predict the local thermal behavior in the facesheets around each pin-fin root, important when local thermal stresses at the pin-fin roots that may cause failure are needed. Furthermore, the fin analogy model can be extended to cover 3-D heat transfer in lattice truss-cored sandwich panels. In comparison, as the porous medium approach employs the volume-averaging technique, it cannot predict local thermal behavior in each pin-fin unit. Subsequently, to mimic multiple aircraft take-offs within a given period of time, the transient response of pin-fin sandwich panels to cyclic impinging jet heating is examined. The maximum temperature at the impinging center and the required cooling time in each cycle are obtained for selected input heat flux levels.