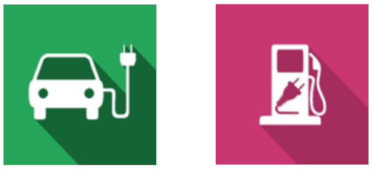
EV Thermal Management Improved by Unique Fin Design

Author: Brian Costello - Advanced Development Engineer - Senior Flexonics



Electric and hybrid vehicles demand high efficiency and performance. The power inverter is one of the critical components in an electric vehicle system. The inverter converts DC to AC when power is required to drive the electric motors, and converts in the opposite direction during regenerative braking. The main component inside the inverter is the IGBT (insulated gate bipolar transistor), and it generates heat.

An effective method of cooling the IGBT is through a liquid cooled heatsink.

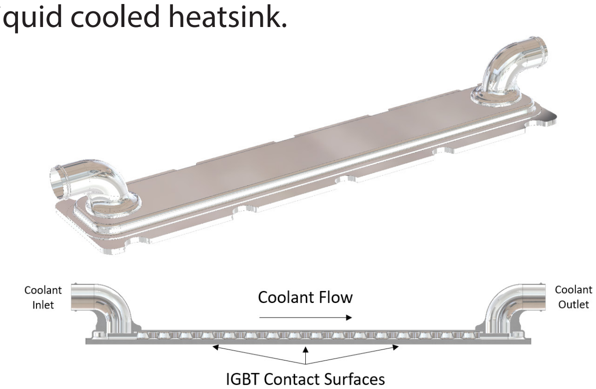


Figure 1. Overview of inverter heatsink and coolant flow.

The IGBT heatsink is made up of a base plate, cover plate, and fin. Coolant enters through a spigot in the cover plate and then flows across the fin and exits through the spigot on the opposite side. The base plate sits on top of the IGBT to allow for surface contact cooling.

Increasing the heatsinks ability to transfer heat is important to achieve the increasing demands for reducing size and increasing current of the IGBT. The Omega Fin design was created in order to solve the challenge of increasing the performance of the heatsink while maintaining a minimum gap for particle size. The Omega Fin works by increasing the amount of fin surface area inside the heatsink.

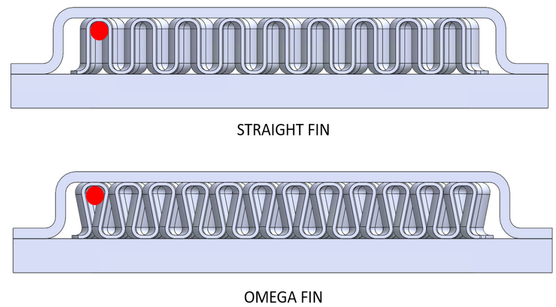


Figure 2. Cross-section of straight fin and Omega Fin, red circle represents identical particle diameter.

It's common in a coolant loop to have a requirement for a minimum gap (particle size). This minimum gap creates a set amount of fin passageways that can be used within a defined distance. In figure 2 above, 9 straight fins were able to be sized into the heatsink while meeting the particle requirement. In the Omega Fin design the same minimum particle size gap is met but there are 12 fins. This results in 33% more fin surface area with same particle size gap. This innovative solution was developed using a new fin forming process.

A CFD (computational flow dynamics) analysis of both the straight (9) fin and the Omega (12) Fin designs were run to show the differences in base plate surface temperature and pressure drop. A steady state analysis was performed using copper for the heat sink and 50/50 water and ethylene glycol for the coolant side.

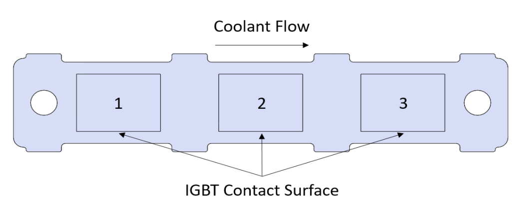


Figure 3. Bottom of heatsink, IGBT contact surfaces relative to coolant flow.

IGBT contact surfaces were broken up into three different sections as seen in figure 3. These three surfaces represent the areas of the heatsink that are in direct contact with the IGBTs. These surfaces were selected and a 135W was applied to each surface, for a total of 400W.

The results of the analysis, seen in figure 4, show the benefit of the Omega Fin design in reducing average surface temperature. On average the contact surface temperature is reduced by about 1°C when compared to the straight fin design. This improvement in heat transfer allows the Omega Fin design to handle about 50% more wattage (600W) while maintaining the same temperature as the straight fin design.

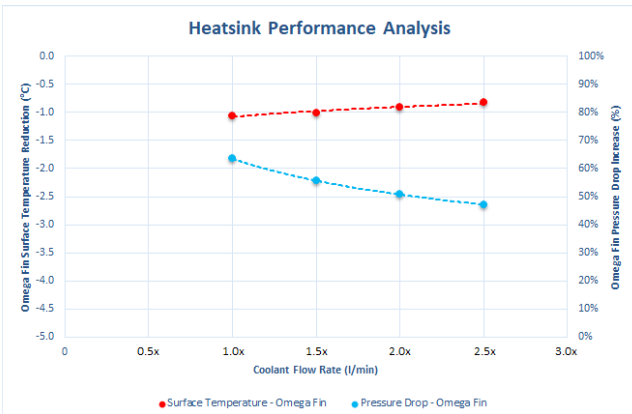


Figure 4. Average temperature rise and pressure drop graph from analysis (percent change from straight fin).

The benefits of the Omega Fin design are not without some cost. The pressure drop of the Omega Fin is about 58% higher on average when compared to the straight fin.

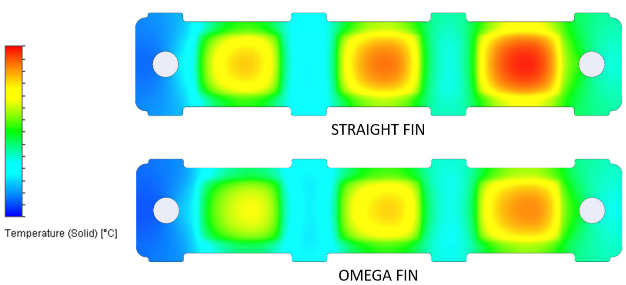


Figure 5. Temperature map of the bottom of the IGBT contact surface at 3 l/min coolant flow rate (Omega Fin vs straight fin). The scale represents a span of 10°C IGBT heatsink testing.

A set of parts were built to match the analysis models in order to provide physical data to correlate and validate the simulation results. The parts were built out of copper and 50/50 water and ethylene glycol was used to cool the heatsinks. A custom bench was built to run comparative testing on different heatsink designs.

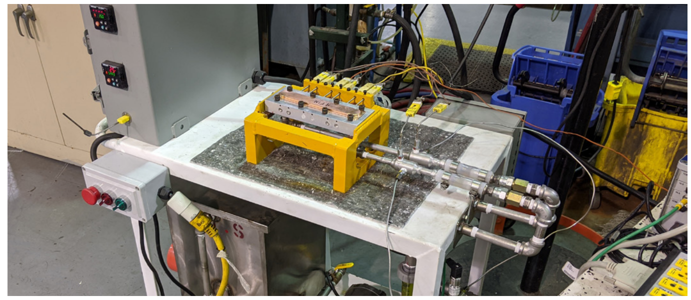


Figure 6. Custom test rig built at Senior Flexonics for IGBT heatsink testing.

The test bench uses a set of heaters to simulate the thermal input of the IGBTs and a coolant loop provides the cooling for the heatsinks. There are a set of instruments to measure all the necessary boundary conditions. Testing of both the straight fin and Omega Fin designs was completed using the same input conditions as the analysis.

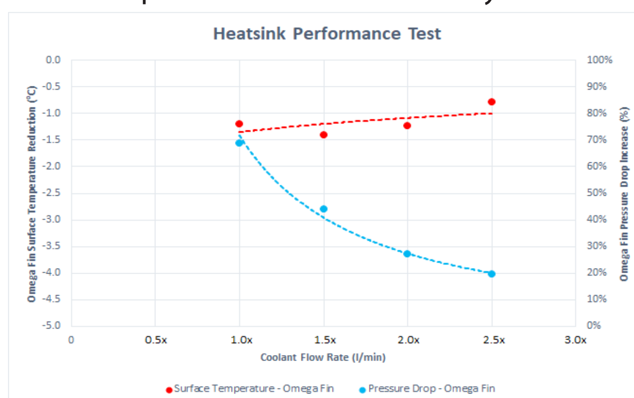


Figure 7. Average temperature rise and pressure drop graph from testing (percent change from straight fin).

The surface temperature results show about 1.1°C reduction in temperature which compares well to the analysis. The average pressure drop increased about 40% in the Omega Fin over the straight fin design.

The analysis and test results show that the Omega Fin design reduces the heatsink surface temperature when compared to the straight fin. The resulting increase in performance demonstrated by the Omega Fin will yield higher performing IGBTs and thus higher performing inverter modules.

senior
Flexonics
www.seniorflexonicsusa.com