Taking the Heat

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Developing thermally conductive thermoplastic materials

Electronics represent an increasing share of the value of vehicles. While they only accounted for 1% of the value of a car in the 1950s, they represent nearly 35% today. As the industry leaps from petroleum-powered motors to electrical powertrains, that number will only increase, and is expected to reach 50% by 2030. Yet all of this electrification presents challenges too.

One of the greatest challenges is the production of more hot spots in the electronic and electrical systems. Several factors contribute to the development of hot spots. Some applications – such as electrical drive trains – run at much higher electrical power. Some applications see heat generating components placed much closer together because of miniaturization and system integration.

Reducing the temperature of hot spots has numerous advantages. We can increase the power of individual components. We can extend component lifetime. And we can reduce sizes. While metals intrinsic high heat conductivity means heat is dissipated faster and fewer hot spots are created, it also makes for heavy components and makes system integration complex or expensive. These two factors will lead to more and more metal to plastic conversion – particularly to mitigate the weight increase caused by more electrical and electronic systems. In addition, creating these complex three-dimensional shapes in metal would result in heavy parts that require multiple costly production steps.

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Balancing needs in material development

Engineering plastics are meeting the industry's greatest challenges. Their low density and ease of processing ensure manufacturers can create complex shapes that are light in weight. While traditional plastics have low thermal conductivity, DSM has developed a portfolio of material grades specifically engineered to have better thermal conductivity that can help to reduce hot spots.

Making thermoplastics thermally conductive is not a straightforward task – thermal conductivity is just one of many characteristics the material needs to demonstrate. Striking the right balance between properties – including stiffness, strength, elongation at break, and processability – can be challenging, even before trying to incorporate more advanced material properties, such as low outgassing for components used in headlamps or high insulation performance for e-motor coils. It is also necessary to predict the effect of higher thermal conductivity on the material's peak temperatures. This type of design support requires dedicated simulation tools that model both the heat transfer of the part, as well as how heat is moved out of the part, whether by radiation or convection.

Modelling heat build-up in LED lights

Maintaining low temperatures within LED light housing is important both to the amount of light emitted, as well as its lifetime. Decreasing the junction temperature of an LED by a mere 10°C can triple the light's lifetime. This emphasizes the importance of reducing the peak temperature, both through the use of thermally conductive materials, and innovative design approaches to LED holders and heat sinks.

We calculated the temperature – as a function of ambient temperature, and the temperature of the LED – of a heat sink made from our Stanyl® TC material grade, and compared it with measured values at a number of different locations on the heat sink. We found good correlation between the measured values and those predicted by our simulation tools.

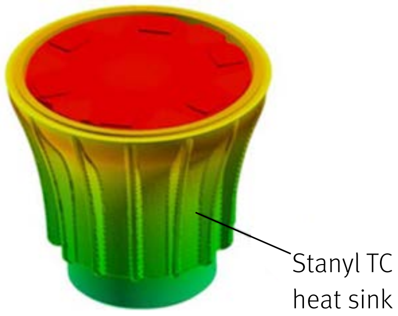


Figure 1 — Schematic of an LED heat sink

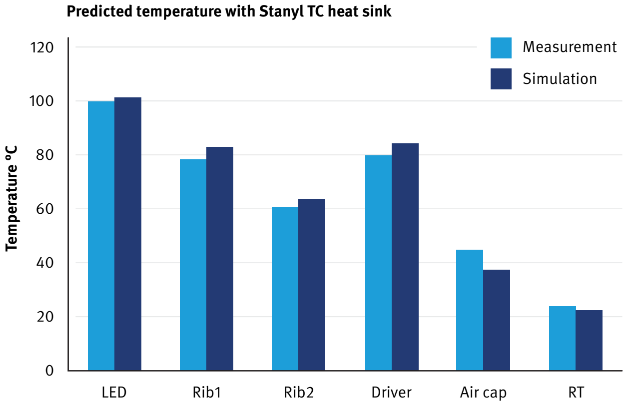


Figure 2 — Comparison of calculated and measured temperatures at different locations on the surface of a heat sink

We can also study the effect of the part geometry using these simulation tools. For example, we studied the effect of the thickness and spacing of cooling fins on how effectively heat is removed. This simulation demonstrated that, while increasing the number of fins increases the total surface area, there is a limit in how closely the cooling fins can be positioned. If they are too close together, they limit air flow and radiate heat towards neighbouring fins – reducing the cooling effectiveness. Using our simulation tools, we were able to calculate the optimal spacing of the fins to maximize heat removal via air flow – in this specific case, 10mm.

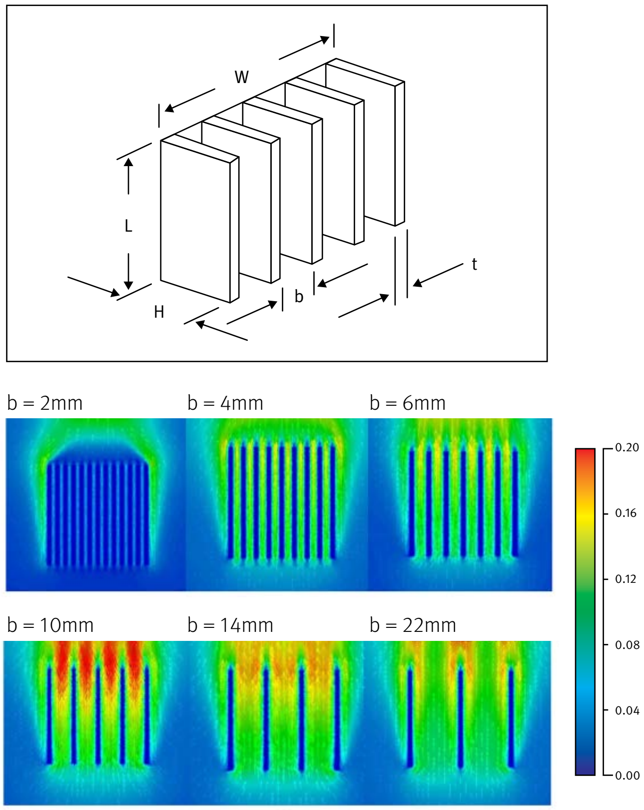
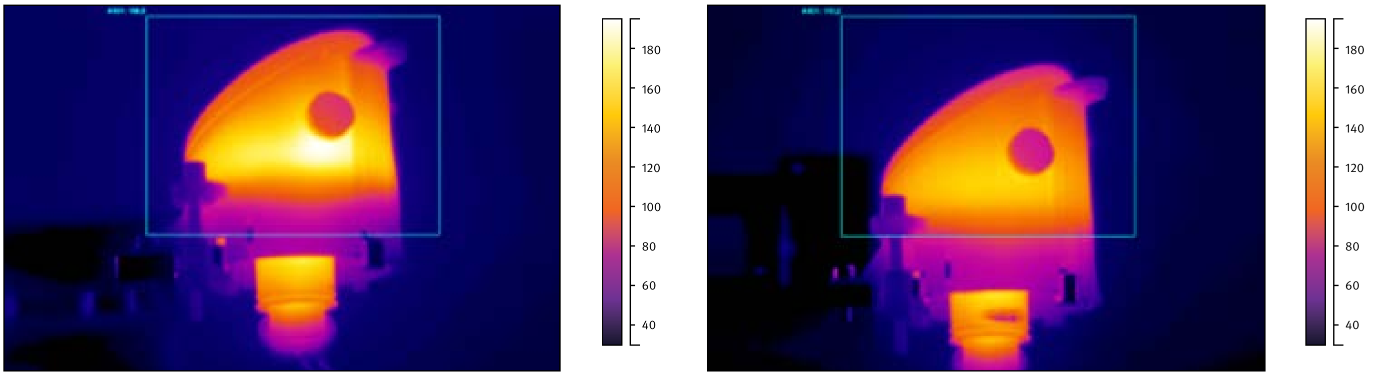


Figure 3 — Temperature modelling of a heat sink with different rib geometries

Arnite® PET for fog lamps

Our glass fiber reinforced Arnite PET GF50 is ideal for structural parts in car lighting modules. The material combines very high stiffness, which is important for vibration stability, with low outgassing. Making Arnite thermally conductive reduces the thermal load on the light source, and it can also be used in areas subject to significant heat load from the sun. This provides more freedom in part design, while also eliminating the need for heat shields. The images below demonstrate how our thermally conductive Arnite material reduces the maximum temperature within a fog lamp by almost 30°C.


Non TC: T_max = 196°C

Arnite XL-T = 170°C

Figure 4 — Effect of using thermally conductive material on peak temperatures in a fog light

A broad portfolio of materials

To service a wide variety of application fields, DSM has developed a broad portfolio of materials grades that incorporate different levels of thermal conductivity, mechanical properties, flammability and insulation.

	Grade name	Strain at break	Thermal conductivity in plane	EI/NEI	Insulation	UL94
High thermal conductivity	Stanyl® TC 502	1.1	14	NEI	N.A	HB
	Stanyl® TC 551	0.6	14	NEI	N.A	V0
	Stanyl® TC 153	0.6	8	EI	Primary	V0
High mechanical performance	Arnite® AV2 370 XL-T	1.5	1.65	1kV/mm	Secondary	HB
	Stanyl® XL-T P698A	2.5	0.8	5kV/mm	Secondary	HB
	Stanyl® TC168 (NC239B)	1.6	2.1	EI	Primary	V0
	Stanyl® TC170 (P823C)	2.5	2.1	EI	Primary	HB
	Xytron™ HV TC	1.7	1	EI	Primary	HB/V?
Performance improvement on standard plastics	Akulon® TC185	2.5	1.1	EI	Primary	V0
	Akulon® TC186	1.2	1.6	EI	Primary	V0

Figure 5 — Basic properties of the portfolio of thermally conductive materials
EI: Electrically Insulating
NEI: Not Electrically Insulating

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