Thermally conductive plastic and optimized design –

allow Power Tools to achieve maximum performance and service life

Makrolon® TC

WHITEPAPER

covestro

Temperature management

Battery-operated power tools have been the standard for electric tools for many years. In addition to the large DIY market, these versatile and flexible tools have recently been conquering the challenging professional sector more and more and must therefore meet the highest demands. Today, power tools can also be powered by a battery, the use of which was otherwise only conceivable wired.

Extreme performance is usually also associated with a high current output/consumption of the battery. This means that high temperatures are generated in the battery during use, even with very fast charging times. The heat generated in this process must be released into the environment as efficiently as possible to avoid overheating. The reduction of the maximum cell temperatures in the charge/discharge cycle has a decisive influence on the service life of a battery pack. As a rough rule of thumb, every 9 degrees above room temperature halves the lifespan of the cells. In addition to reducing the maximum temperatures, the aim is also to ensure that the temperature load on all battery cells is as uniform as possible.

Optimized temperature management thus not only increases the performance of the battery, but also its service life.

With highly thermally conductive materials from Covestro, battery packs from Power Tools can be tailored specifically to meet special requirements.

Summary of detailed Product Characteristics

Property	Standard condition/Unit	Makrolon® TC629	Makrolon® TC621	Makrolon® TC421	Makrolon® TC210	Makrolon® TC110	Makrolon® TP5176
Thermal conductivity - in plane - through plane	ASTM E 1461-01 23°C [W/(m.K)]	15 1.2	16 1.4	8 0.9	1.4 0.3	1.0 0.3	0.8 0.2
Melt viscosity	ISO 11443-A 300°C Pa-s	270	180	160	180	170	150
Charpy impact strength	ISO 179-1eU 23°C [KJ/m²]	<10	<10	<10	12	70	90
Vicat softening temperature	ISO 306 50N;50 °C/h [°C]	144	128	130	146	145	145
Suitable for outdoor use with respect to exposure to Ultraviolet light, water exosure and immersion.	UL 746C	f1	f1	f1	-	-	-

Table 1: Excerpt of the **Makrolon® TC** product family

The right material, combined with the optimized design of a battery pack, help to achieve the decisive 2-3 degrees temperature reduction for maximum performance of the power tool.
We examined the two decisive parameters – material and design – using a simplified model of a battery pack.

Battery Pack Model Description

The simplified model of the battery pack consists of 8 battery cells, each of which is plugged into a cell holder at the ends. Furthermore, the battery pack contains two PCBs to accommodate the control electronics. This package is finally enclosed by a housing and protects the batteries from moisture and also mechanical load during use or in the event of a possible fall.

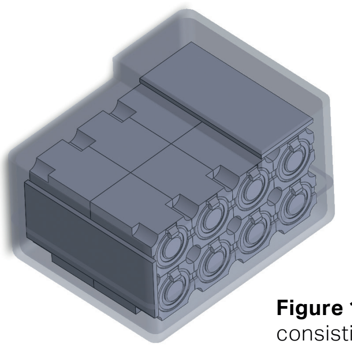


Figure 1: CAD model of a battery pack consisting of housing, cell holder, battery cells and circuit boards

An impact-resistant PC/ABS blend **(Bayblend® FR3010)** was used as the housing material, which also contains a flame retardant package and achieves a flame retardant classification of V0 at 1.5mm wall thickness according to UL94.

In the case study, the cell holders are either made of the same material as the housing or of a special, more thermally conductive **Makrolon® TC110.**

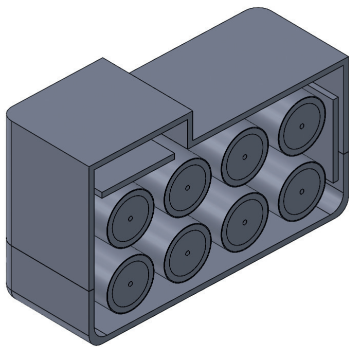


Figure 2a: Cross section of the power Pack with PCB

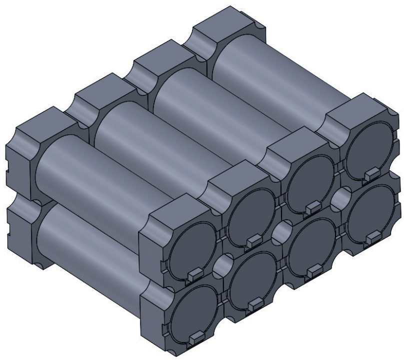


Figure 2b: First variant of the cell holder

In addition to an almost 5 times higher thermal conductivity compared to a normal PC/ABS, **Makrolon® TC110** also offers sufficient toughness to be able to absorb the external loads without damage.

To ensure that the temperature development in the battery pack can be realistically reproduced, a single cell was examined in advance with regard to its temperature behavior during the charge/discharge cycle

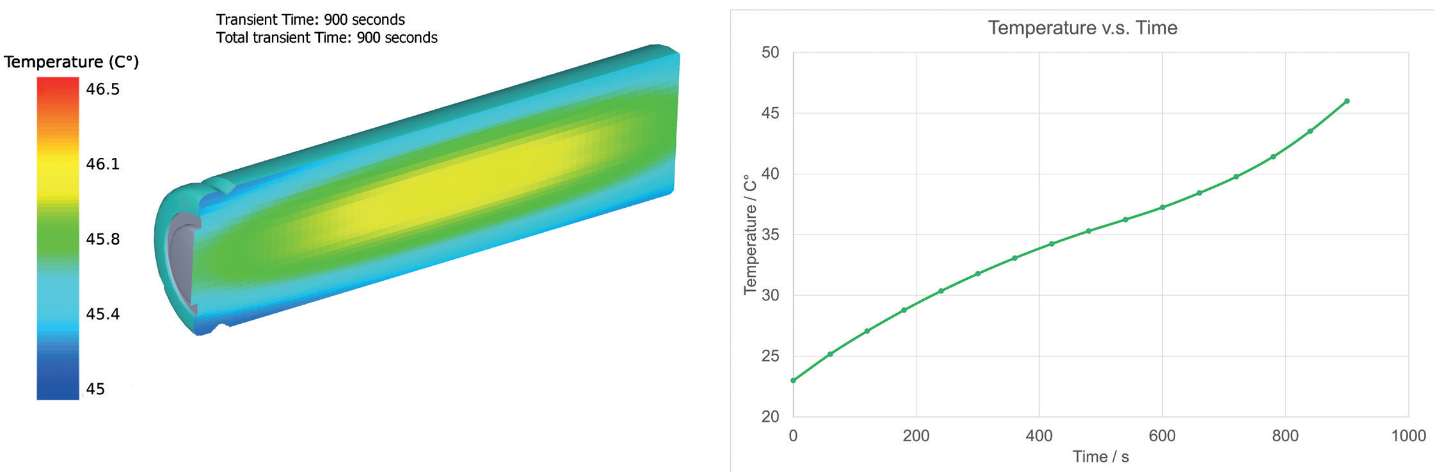


Figure 3: CFD simulation of a battery cell – convection to air during a charging cycle

The battery cell was charged with a charging current of 5A, which corresponds to a charge/discharge of significantly more than 2C. The modelling of the cell was carried out with the help of a CFD simulation, taking into account all heat transfer mechanisms in the air at room temperature.

The battery model heated up to approx. 47°C in the simulation, which correlates very well with practical tests and thus creates the prerequisite for a realistic modelling of an entire battery pack. In the following, a battery pack was modeled in which both the housing and the cell holders are made of a PC/ABS with typical thermal conductivity (a=0.2W/mK).

Model Description of Battery Pack

The battery cells were again charged with a charging current of 5A and now the temperature development of the cells in the installation situation of the battery pack was calculated.

Since the heat from the cells can no longer be dissipated directly into the air, the heat accumulates and thus leads to an extreme temperature of T=75°C. For optimal cell life and performance, temperatures above T=60°C should be avoided. In order to ensure safe operation with this battery pack, the power output would have to be significantly reduced, with subsequently significantly longer charging times. This would not be an option for high-end devices

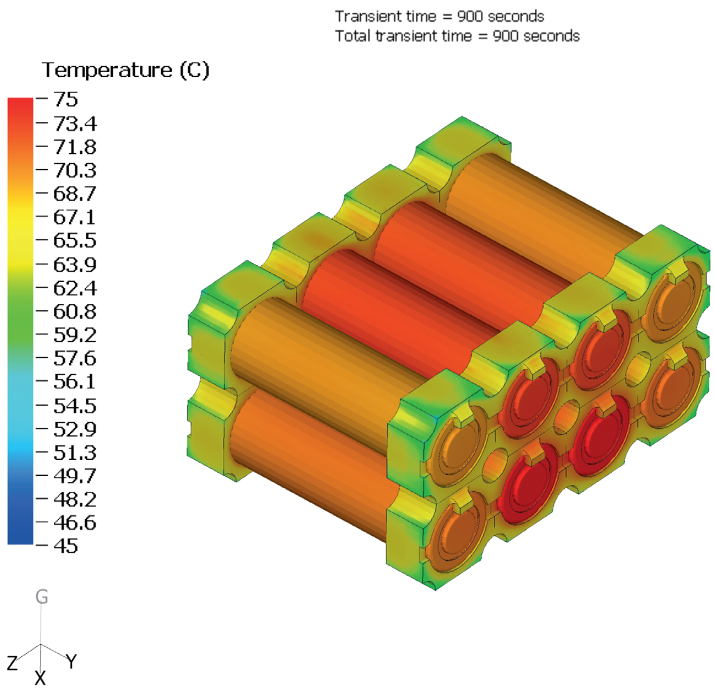


Figure 4: Maximum temperature of the battery cell in the battery pack during charging

An existing battery pack can already be optimized with quite simple means without changes to the design. If the relatively short cell holders are designed in a **Makrolon® TC110,** they not only guide the cells but also perform the function of a "heat spreader" that can quickly absorb heat and release it directly to the housing wall. This measure can reduce the temperatures in the cells by as little as 3°C

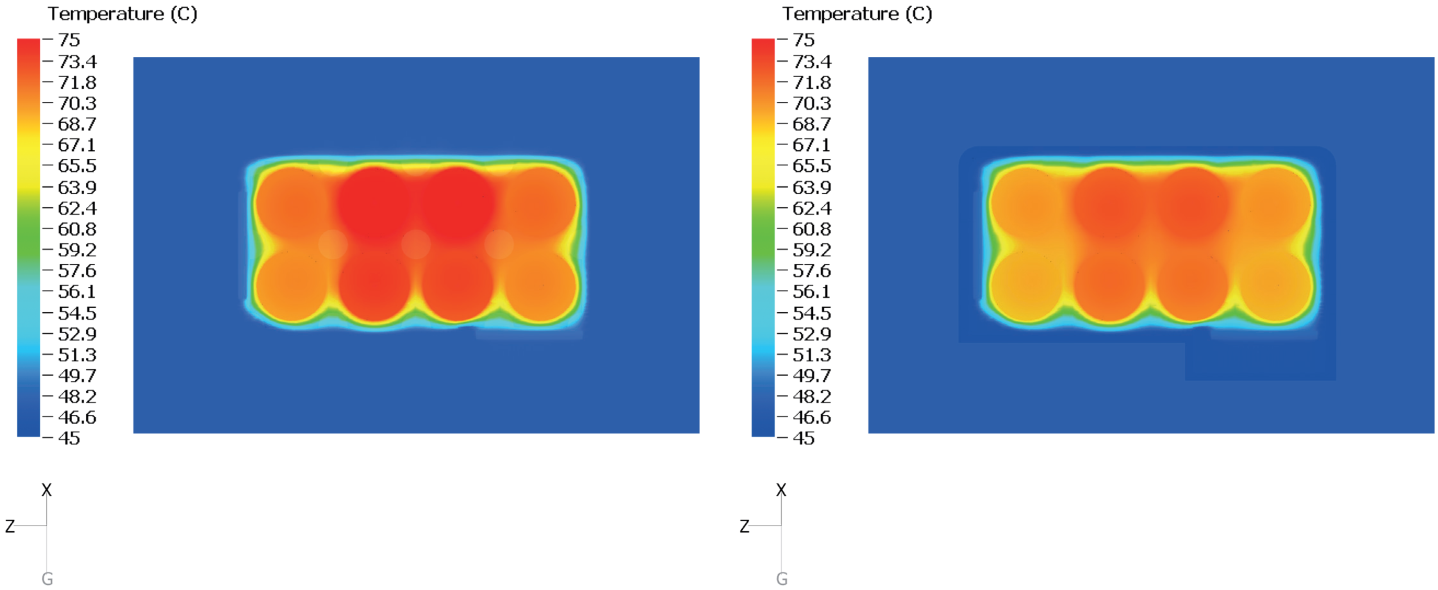


Figure 5: Maximum temperature of the battery cell with cell holders made of standard PC/ABS (T=75°C) on the left and **Makrolon® TC110** on the right (T=72°C)

However, we see a much greater reduction in temperature when the cell holder encloses a larger area of the cell. This has two main effects: on the one hand, the air volume (insulation) between the battery cells and the housing wall is reduced and, on the other hand, the heat can be passed on to the housing via an enlarged area.
In a basic PC/ABS configuration, this geometric optimization can now significantly reduce the temperature to T=63°C. If the thermally conductive **Makrolon® TC110** is used again for the cell holders, a temperature of T=58°C can be reached and the maximum permissible temperature can now even be undercut by 2°C.

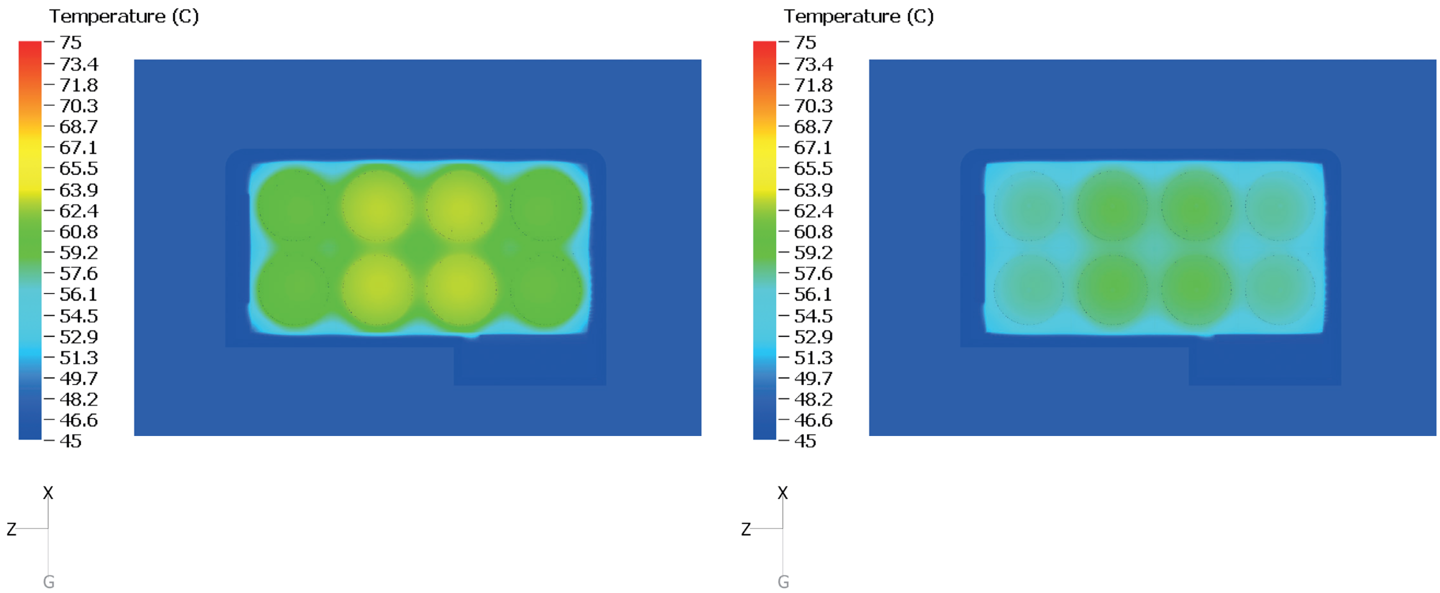
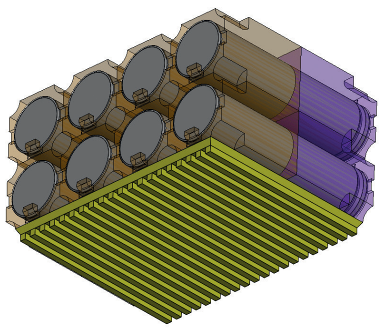


Figure 6: Geometric optimization of the cell holders made of standard PC/ABS (T=63°C) on the left and **Makrolon® TC110** on the right (T=58°C)

If the design of the battery pack even allows the **Makrolon® TC110** to be used on the outer wall of the housing, this leads to an even heat flow and a very homogeneous temperature distribution of the individual cells.

Thus, not only is the maximum temperature reduced to a very low level. The now very uniform temperature of all cells will increase the service life of the battery pack, as there is no isolated temperature load of individual cells.



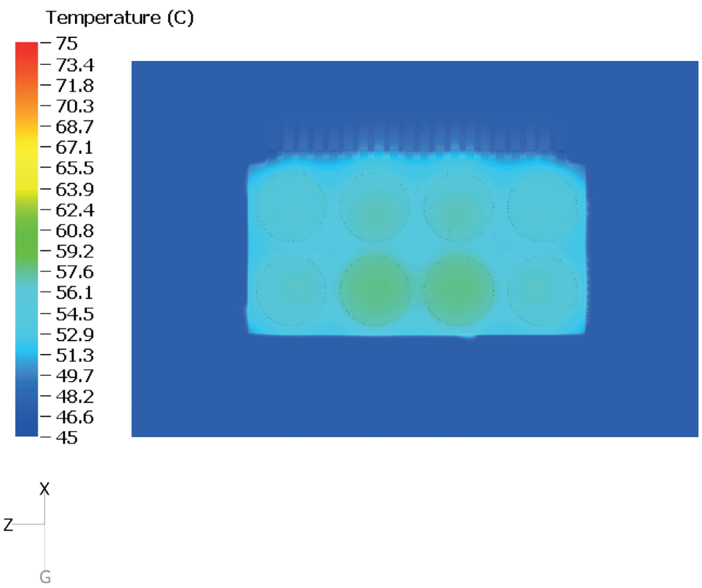


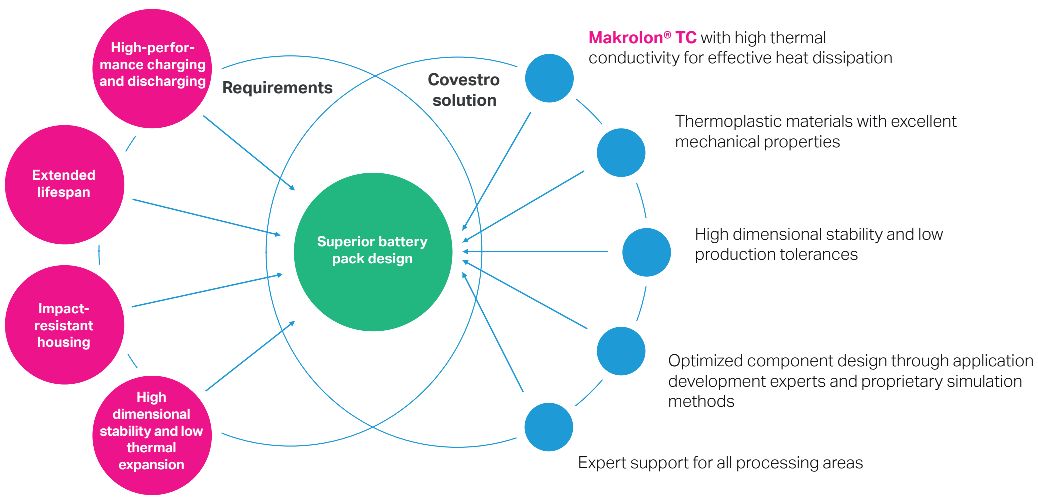
Figure 7: Optimized heat dissipation through integration - 2K injection molding - of **Makrolon® TC110** into the housing on the right (T=57°C)

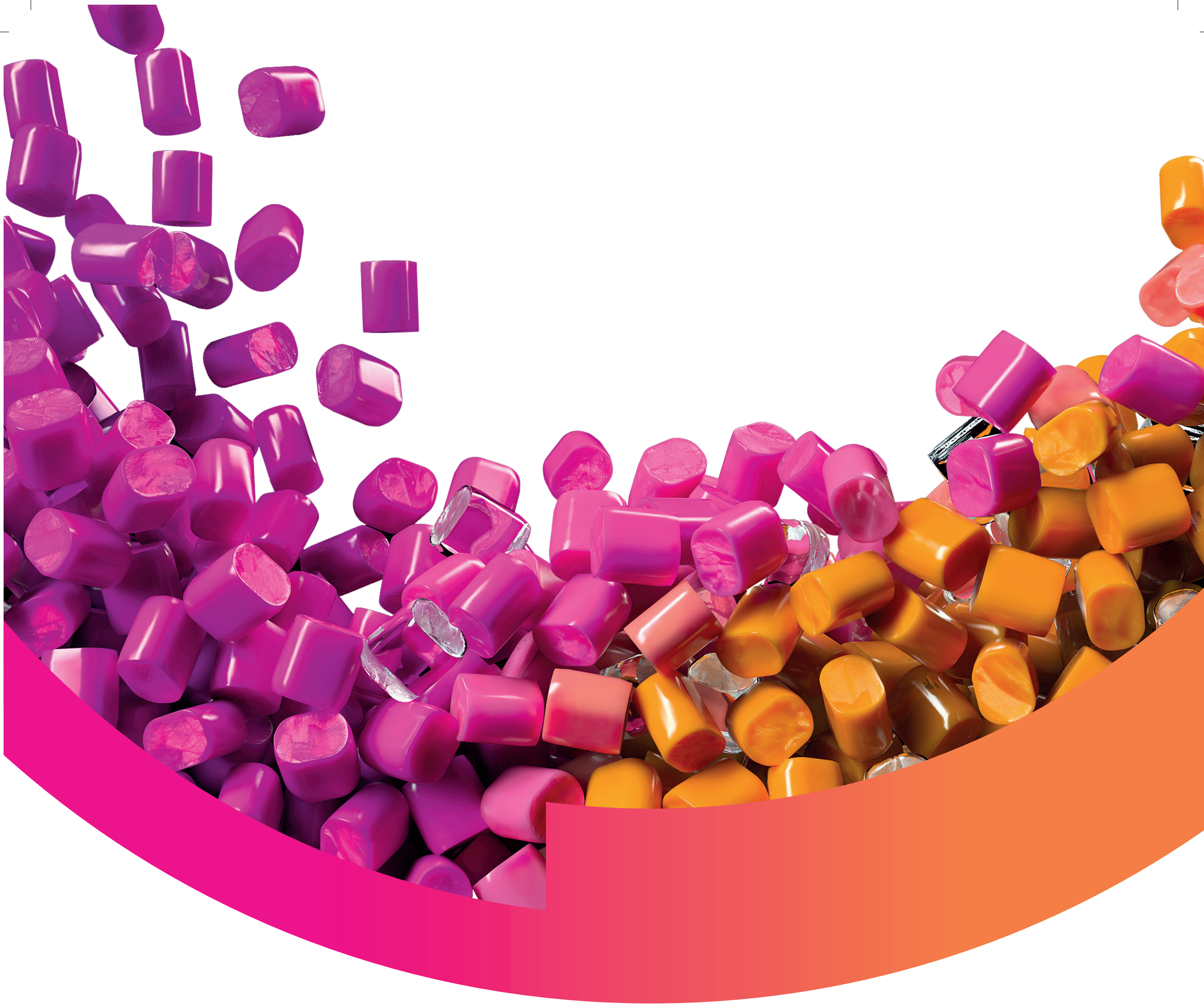
Conclusion thermal simulation of a battery pack

With the concept study carried out here, we were able to show that the thermal simulation of a battery pack or battery module is excellently suited for a qualitative and even quantitative analysis of the temperture budget. Measures can be easily implemented and assessed constructively using a modified CAD model.

Another advantage of simulation is the rapid estimation of the material's influence on temperature management. This means that the battery pack can be optimally designed in advance of toolmaking.

Today, battery packs for power tools are mainly made with conventional thermoplastics - with a typical thermal conductivity of 0.2W/mK. Conceptually, however, this quickly leads to a limit of heat dissipation, even with optimized geometry. For power tools with extreme requirements, however, only the material conversion to a more thermally conductive plastic (e.g. **Makrolon® TC110**) can offer a way out and enable the sometimes decisive 2-3 degree temperature reduction.





Covestro Deutschland AG
Engineering Plastics
Kaiser-Wilhelm-Allee 60
51373 Leverkusen
Germany

solutions.covestro.com
plastics@covestro.com

[1]See Guide for the Use of Covestro Products in a Medical Application.

Edition: 2024 · Printed in Germany