Thermally Conductive Potting Solutions for Electric Motors

By potting electric motors with thermally conducting casting resins, it is possible to achieve a significant increase in power. This requires high-tech casting resin systems with outstanding flow properties and excellent thermal conductivity. But what power increases can be achieved with the use of innovative, heat-conducting polyurethane potting compounds?

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The constantly growing electromobility market offers exciting opportunities. At the same time, it also means there are always new challenges to overcome. The rapid change to electrically driven vehicles is apparent and can be proven in the number of new vehicle registrations. If, in 2017, another 54,500 electric vehicles were approved for the roads, this number rose in 2018 to 67,500 /1/.

Heat management in electric motors

The core of modern electric vehicles includes both the battery and the electric motor. Both components generate heat during use, which leads to a reduction in the available power. For this reason, efficient cooling is needed to achieve the highest possible level of effectiveness. The immense importance of efficient cooling can be made evident by the example of an electric motor. In this component in particular, size and the subsequent weight are an important factor, as the motor weight also contributes to the total weight of the car. *Figure 1* shows an electric motor with a potted stator (emphasised in orange). By potting various areas of an electric motor with thermally conducting potting compounds, the power can be optimised. Here, the additional weight resulting from the potting and the power increase it generates must be balanced against each other. So, for example, you can pot just the winding head, bringing about a lower increase in weight. Alternatively, the entire stator can be fully potted. It is here that great demands are made of the flow behaviour of the potting compound. While it cannot be ignored, the weight increase remains within an acceptable range: in the motor potted here, under 6%. On the other hand, however, potting could bring about an increase with regard to the power to weight ratio of 15%.

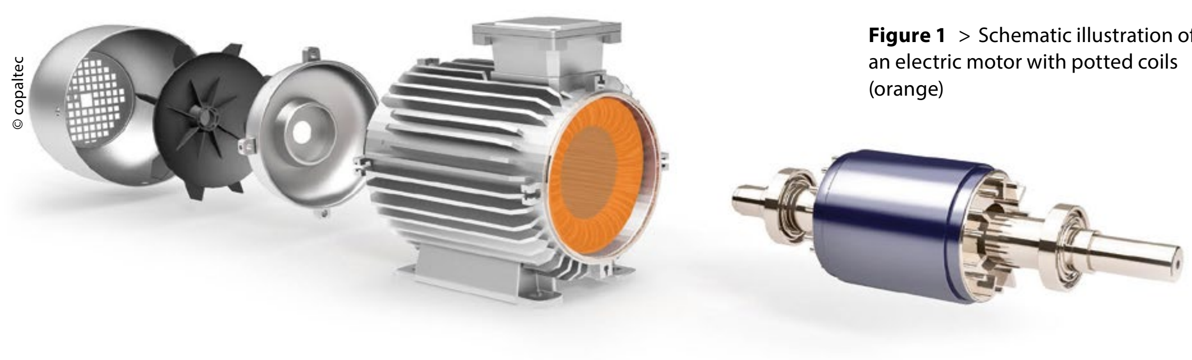

Figure 1 > Schematic illustration of an electric motor with potted coils (orange)

Thermally conducting potting compounds thus represent an attractive temperature reduction and power enhancing option. By using low-viscosity casting resins which also have increased thermal conductivity, it is possible to penetrate between the close-set copper windings and achieve optimal connection of the windings to the thermally conductive polymer matrix. Here, heat dissipation from the source to an external, active cooling system is made possible. Filled polymer systems in particular are excellent for such applications, as they work as electrical insulators as well as thermal conductors.

Thermally conducting potting compounds

Of great importance in potting compounds is the combination of good flow properties and a complex filler matrix, ensuring even particle distribution in the polymer matrix and efficient heat dissipation. Optimally adjusted filling matrices and low viscosities are not just necessary to fill the interstices between the close copper windings, but also even out irregularities in the surface on the micro and sub-micro level. Here, the driving out of air to avoid bubbles is of vital importance, as air, with a thermal conductivity of approx. 0.03 W/m·K is a very poor thermal conductor. Similarly, attention must be drawn to the importance of even filler distribution and optimally adjusted particle size distribution, as a pure polymer matrix – based on polyurethane – has a thermal conductivity of approx. 0.2 W/m·K, and is thus more of a thermal insulator. Through the use of suitable fillers and optimised incorporation processes, it is possible to create 2-component polyurethane systems with thermal conductivities of 3.5 W/m·K. In 1-component thermal conductivity pastes on a polyol basis, values up to 4 W/m·K can readily be realised. An overview of thermal conductivities is shown in *Table 1*. In the particular field of stator potting, however, it is of great importance to select the potting compound not just from the point of view of thermal conductivity, but also for its flow properties. Here, the potting process must be regarded in general. For example, both the potting compound and stator can be pre-warmed gently to reduce the viscosity of the potting compound again and retain constant flow properties over the entire component, as no loss of temperature and increase in viscosity can take place.

Examples of efficiency increase by potting

It follows that, for example, with the use of a 2-component polyurethane potting compound with a thermal conductivity of approx. 1 W/m·K, potting results have been shown to be clearly improved if not only the potting compound but also the stator are suitably tempered. In a further test, the full potting of a water-cooled motor of medium power at a water temperature of 25 °C was able to achieve an average power increase of 13 % as compared to an unpotted motor. This efficiency increase was even more apparent when the water tem-

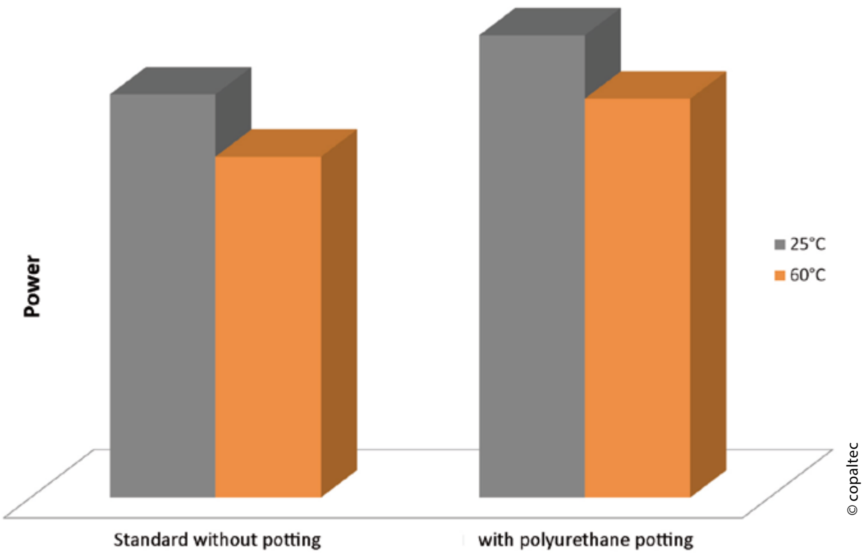

Figure 2 > Power comparison between an unpotted electric motor and one potted with thermally conductive polyurethane (1 W/m•K) at different water cooling temperatures

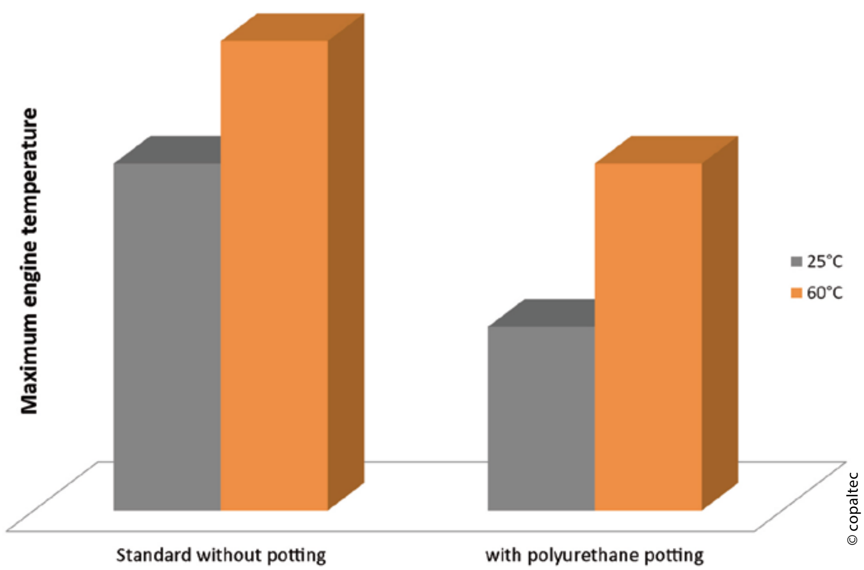

Figure 3 > Comparison of maximum engine temperature between an unpotted and a potted electric motor at different water cooling temperatures

perature at the inflow was raised to 65 °C. Here, the power increase from full potting was almost 20 %. The results are graphically portrayed in *Figure 2*.

Analogous to the increase in power achieved by full potting of the stator with a polyurethane potting compound, the end temperature was reduced. A comparison of the end temperatures at various inflow water temperatures with and without thermally conducting potting is shown in *Figure 3*. In general, end temperatures of 140 °C were not exceeded. This temperature is of particular importance when selecting the material for the potting.

Polyurethane as a promising potting compound

Polyurethanes, because of their mechanical properties and low tendency to stress fracture, are an option of interest. Their comparatively low deployable temperature range, however, often leads this polymer group to be overlooked. Long-term temperature exposures of up to 130 °C, however, are in general not a problem for this material group, and systems with temperature ranges up to 160 °C are also available on the market. We must point out again at this point that this temperature is the range for long-term operation. Isolated temperature peaks that surpass this temperature can be easily withstood by the material. In addition, the results presented here should be taken account of. If a clear increase in power and reduction in temperature are achieved through complete stator potting, the temperature can thus be reduced while retaining the same power as against unpotted motors. So, for example, in further tests, the use of thermally conducting polyurethane potting compounds can achieve a reduction in the long-term operating temperature of up to 30 °C while retaining constant power. In addition, in

Material	Thermal conductivity [W/m•K]
Air	0.03
Polymer, unfilled	0.2
PU resin, filled	0.6 – 3.5
PU pastes	1.5 – 4

Table 1 > Comparison of thermal conductivities of various materials

the potted motors, an efficiency increase of up to 3 % has been determined.

Summary and outlook

With the continuing electrification of the automotive sector, new challenges are always opening up, which can only be solved by the use of innovative materials. It has already been proven that the potting of an electric motor with a thermally conductive polyurethane-based potting compound leads to an increase in power and efficiency. Similarly, it has been possible to reduce the running temperature significantly while retaining constant power. From this it is apparent that the use of filled polymer potting compounds, especially on a polyurethane basis, creates new opportunities for efficiency increases. As the operating temperatures can also be decreased through this, polyurethanes, with their flexible mechanical properties, clearly present many opportunities from an economic perspective. Although the potting masses used still have low densities of approx. 2 g/cm³, a weight increase in the motor after potting is unavoidable. For this reason, it must be decided on a case-by-case basis whether a potting of the winding heads or full potting is more appropriate. The fact is incontrovertible, however, that innovative potting compounds with increased thermal conduction and optimal flow characteristics will help decisively to shape progress in e-mobility. //

References

/ 1 / www.zsw-bw.de

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