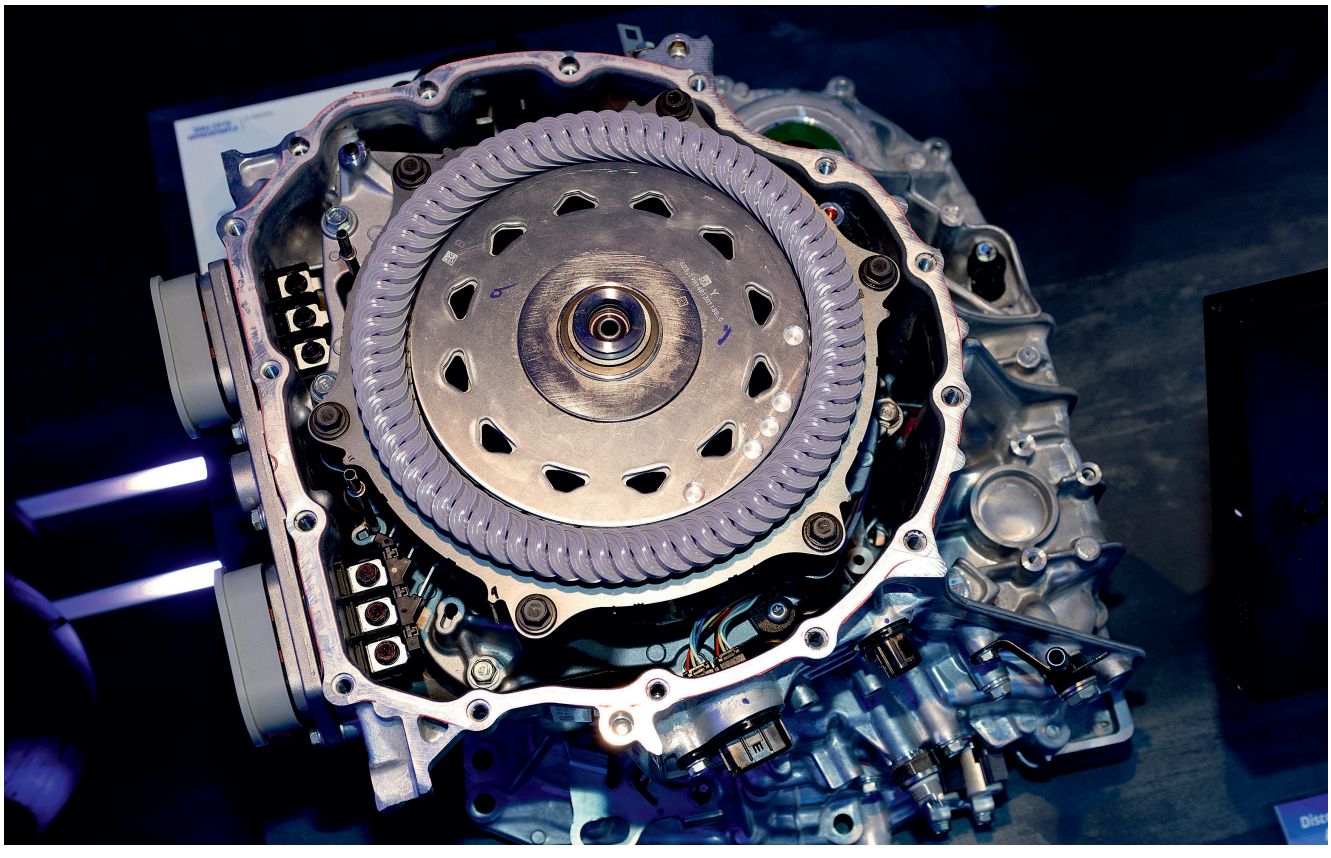
PEEK and Epoxy Provide Efficient Insulation for High Voltage E-Motor

Partner for PEEK

The rising voltages in electric vehicles are creating higher requirements on insulation materials. This is why PEEK is increasingly used for this purpose. A problem with this high-performance polymer used to be its adhesion to the secondary insulation material. An epoxy resin now promises to solve the issue.



Due to higher voltages, manufacturers are increasingly using PEEK as insulation material for electric motors. © G.Mitzner Fotodesign

In an effort to increase battery electric vehicle range and decrease the battery charging time, automotive OEMs and tier suppliers have begun to adopt high voltage systems ranging from 800 to 1200 V. These systems require special insulation materials to meet the high requirements in the high-voltage range. With KetaSpire, plastics manufacturer Solvay has introduced an appropriate polyetherether ketone (PEEK) for magnet wire insulation in electric vehicles (**Fig. 1**).

Key drivers for using PEEK-insulated magnet wire above all include the material's resistance in high voltage environments with typical partial discharge inception voltage values of 1600 to1700 V at 150 µm. With a lower level of defects versus pure enamel solutions, the material is also very reliable. In addition, the use of PEEK can raise the efficiency of high-voltage systems. Utilizing the extrusion-based PEEK materials developed by Solvay together with hairpin technology, various OEMs have been able to increase their copper slot fill by over 10 % (**Fig. 2**).

A remaining challenge for e-motor designers has been to identify suitable secondary insulations with perfect adhesion to PEEK magnet wire and PEEK slot liner insulation materials.

Epic Resins company developed ProPreg E240, a single component epoxy secondary insulation specifically designed to increase the adhesion to PEEK while also being compatible with other common insulation materials such as polyamide imide (PAI). ProPreg E240 provides the industry's highest adhesion in a variety of applications including: wire to wire, wire to aramid paper, aramid-paper to steel, and wire to PEEK slot insulation. The development work event-

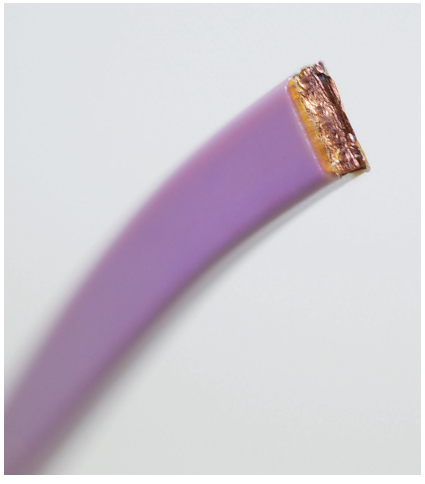


Fig. 1. PEEK magnet wire insulations are becoming increasingly popular in the high-voltage range. They are very resistant and can withstand high temperatures and voltages. This ensures higher reliability compared to the use of enameled wires. © Solvay

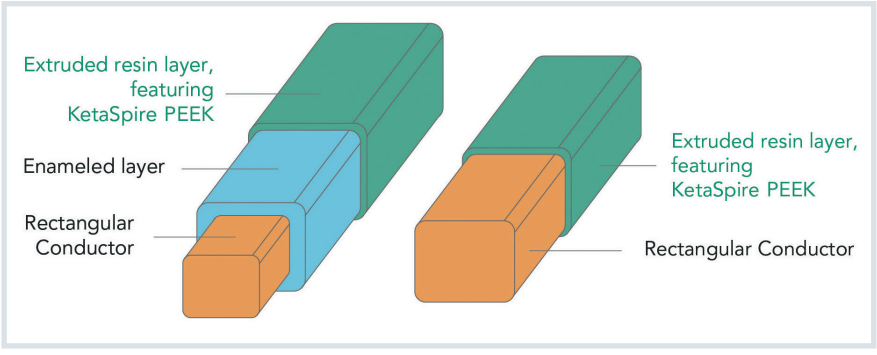


Fig 2.. Multi-layer and mono-layer magnet wire design with PEEK: the copper fill factor can clearly be raised if the enamel wire layer is eliminated.

Source: Solvay; graphic: © Hanser

ually resulted in an epoxy resin capable of penetrating the tight conductor spacings of efficient high copper slot fill factor applications. Currently, 5000 hour thermal testing is underway, targeting a temperature rating of 240 °C to match the thermal ratings of PEEK.

Seeking Good Adhesion to PEEK

One of the first optimization steps was to adjust ProPreg E240 to the mechanical properties of PEEK products such as Solvay's KetaSpire KT-880 and Ajedium slot insulation. By matching the thermal transitional properties, Epic Resins was able to minimize differences in coefficient of thermal expansion which had resulted in failures of brittle polyester resins used in the market today. Another challenge was to ensure that the epoxy resin could be used in existing trickle processing equipment with minimal changes. The material should also offer potential to reduce cure and process times.

Clearly Stronger Adhesion

Once the ProPreg E240 formulation had been finalized, Epic Resins worked closely with Solvay to generate the required adhesion and compatibility data. To determine the adhesion strength between the epoxy resin »

		500 h immersed	500 h vapor exposed	1000 h immersed	1000 h vapor exposed	1500 h immersed	1500 h vapor exposed
Pull force, max. (N)	Mean	423	442	351	384	398	439
	Standard deviation	18	30	24	17	31	31

Table 1. Adhesion strength of PEEK and ProPreg E240 after 1500 hours of ATF exposure (test method: IEC 60133). Source: Eltek International Laboratories

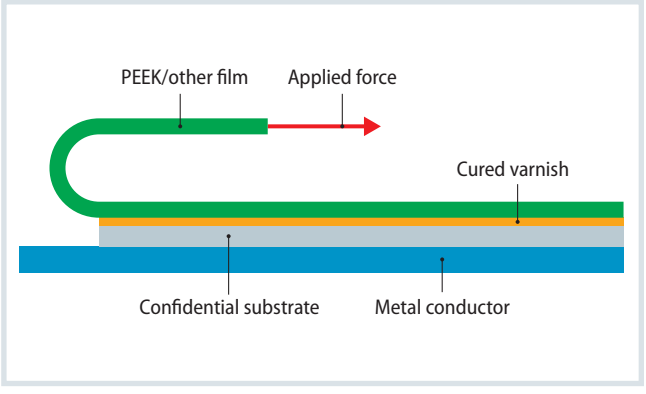


Fig. 3. Adhesion test method by Solvay for PEEK film and secondary insulation materials. The test clearly showed the better adhesion between PEEK and the ProPreg epoxy resin in comparison to PEEK and a standard polyester material for electric motors.

Source: Solvay; graphic: © Hanser

and PEEK, Solvay developed a 180-degree peel test method (**Fig. 3**).

The peel test benchmarked a standard e-motor polyester secondary insulation alongside the epoxy resin. Two tests were performed. One using a KetaSpire PEEK magnet wire grade and the other using Ajedium PEEK slot liners. In both cases, a significant increase in adhesion was observed. The relative peel force between the KetaSpire PEEK material and the ProgPreg epoxy resin was two times higher than the adhesion between PEEK and the standard e-motor polyester (**Fig. 4**). Similarly, adhesion between the epoxy resin and the PEEK slot liner also showed great improvement.

Good Resistance to ATF

In addition to the adhesion between PEEK and the epoxy secondary insulation, compatibility data is being developed on the adhesion of PEEK coated wire and ProgPreg E240 after 2000 hours of exposure to automatic transmission fluid (ATF) at 150 °C (**Table 1**). ATF is commonly used as a fluid to cool the e-motor windings. Present results show that PEEK and the epoxy resin maintain their adhesion strength when exposed to ATF for up to 1500 hours. In both cases, the polymer coating only separated from the copper wire, whereas the bond between the epoxy resin and the polymer remained intact. The results indicate that the adhesion strength of ProPreg E240 is greater than the tensile strength of the polymer coating and of the polymer copper bond strength.

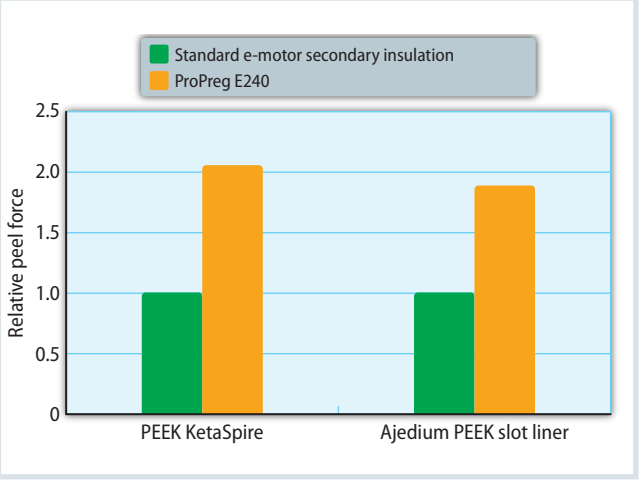


Fig. 4. Peel force test results: The adhesion between PEEK and the epoxy resin is more than twice as strong as with PEEK and a standard polyester. Source: Solvay; graphic: © Hanser

Adapting to meet the changing needs of electric vehicle is where innovation and collaboration becomes a game changer for suppliers and material manufacturers. The successful joint efforts between Epic Resins and Solvay demonstrate what can be achieved through collaboration. Epic Resins' new ProPreg E240 secondary insulation and Solvay's KetaSpire PEEK magnet wire grade and Ajedium PEEK slot liners show significant improvement in adhesion over conventional standard e-motor secondary insulations. ■

Info

Authors

Brian Baleno is Head of Marketing Transportation at Solvay.
Deedee Smith works as Marketing Manager Transportation for Solvay.
Mohammad Qasim Shaikh is ADL Project Engineer at Solvay.
Kayla Brown works as Marketing Coordinator for Epic Resins.
Jeffrey Southworth is Technical Sales Representative at Epic Resins.

Digital Version

You can find a PDF file of the article at
www.kunststoffe-international.com/archive

German Version

Read the German version of the article in our magazine ***Kunststoffe*** or at ***www.kunststoffe.de***