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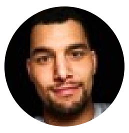
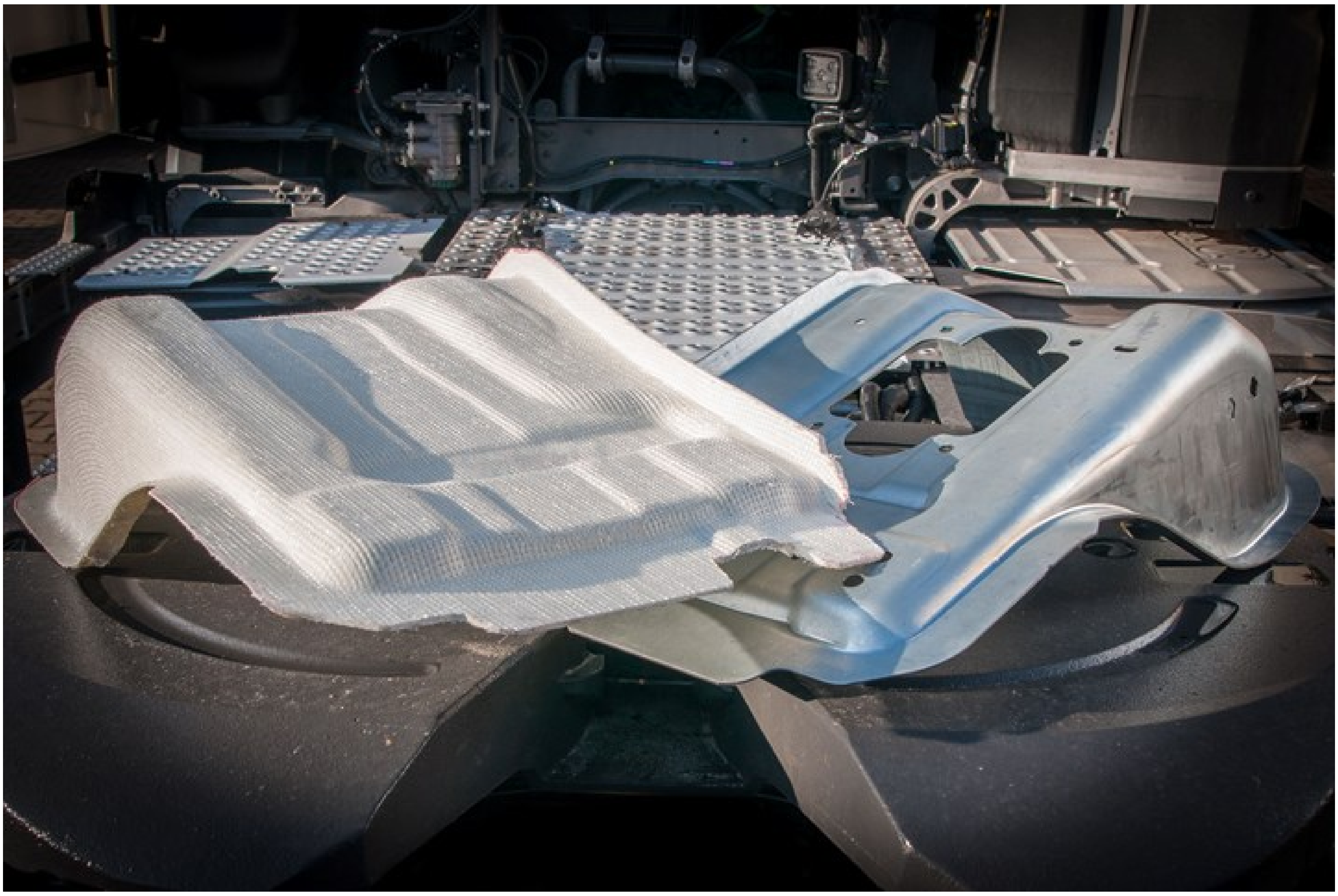
One-shot manufacture of 3D knitted hybrid thermoplastic composite structures

MAPICC 3D project replaces steel seat support in heavy-duty vehicle with a 3D knitted composite made from thermoplastic hybrid yarns comprising the matrix and reinforcing components.

#focusondesign



STEWART MITCHELL
Contributing Writer



The MAPICC 3D project (2011-2016) realized a process capable of producing net-shape preforms from topology-optimized, high-performance structural 3D thermoplastic textile composites. The final product, a GF/PP Volvo truck seat reinforcement plate, was made in one shot using a knitting technique. At 1.3 kilograms, it weighs 2.7 kilograms less than its steel predecessor — a reduction of 67.5%. Photo Credit (above and in landscape image): Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden

Heavy-duty vehicle (HDV) transport is the automotive sector's most prominent climate problem. To illustrate, in the European Union (EU), HDVs account for 22% of road vehicle emissions, though they represent less than 5% of the vehicles on the road. To combat their effect on climate change, emissions legislators reduce the emissions targets for HDVs ever few years, pushing manufacturers to develop cleaner technologies. The European Commission recently proposed a 15% CO_2 reduction by 2025 compared to 2019, and a 30% reduction by 2030.

It is a similar story in the U.S. The California Air Resources Board recently finalized its HDV Low NOx Omnibus Regulation which phases in more stringent emissions standards starting in model year (MY) 2024; these standards will be updated again in MY 2027 to target a 90% reduction in NOx emissions by 2031. The U.S. National Highway Traffic Safety Administration and Environmental Protection Agency, which have had emissions and fuel efficiency standards for HDVs across the U.S. for over a decade, are poised to follow suit.

Lower emission powertrains such as hybrid and electric solutions, and exhaust gas treatment technology, generally increase vehicle weight. In addition, HDV gross weight and axle loads are limited by their class which further compounds the challenge of implementing these technologies. For example, for HDVs in the EU that weigh 18,000 kilograms when laden, every kilogram on the front axle above this weight means 3 kilograms must be taken off the payload to provide safe counterbalancing of the truck and the trailer. In markets like Brazil and Australia, every kilogram above the front axle weight threshold requires 15-20 kilograms off the payload.

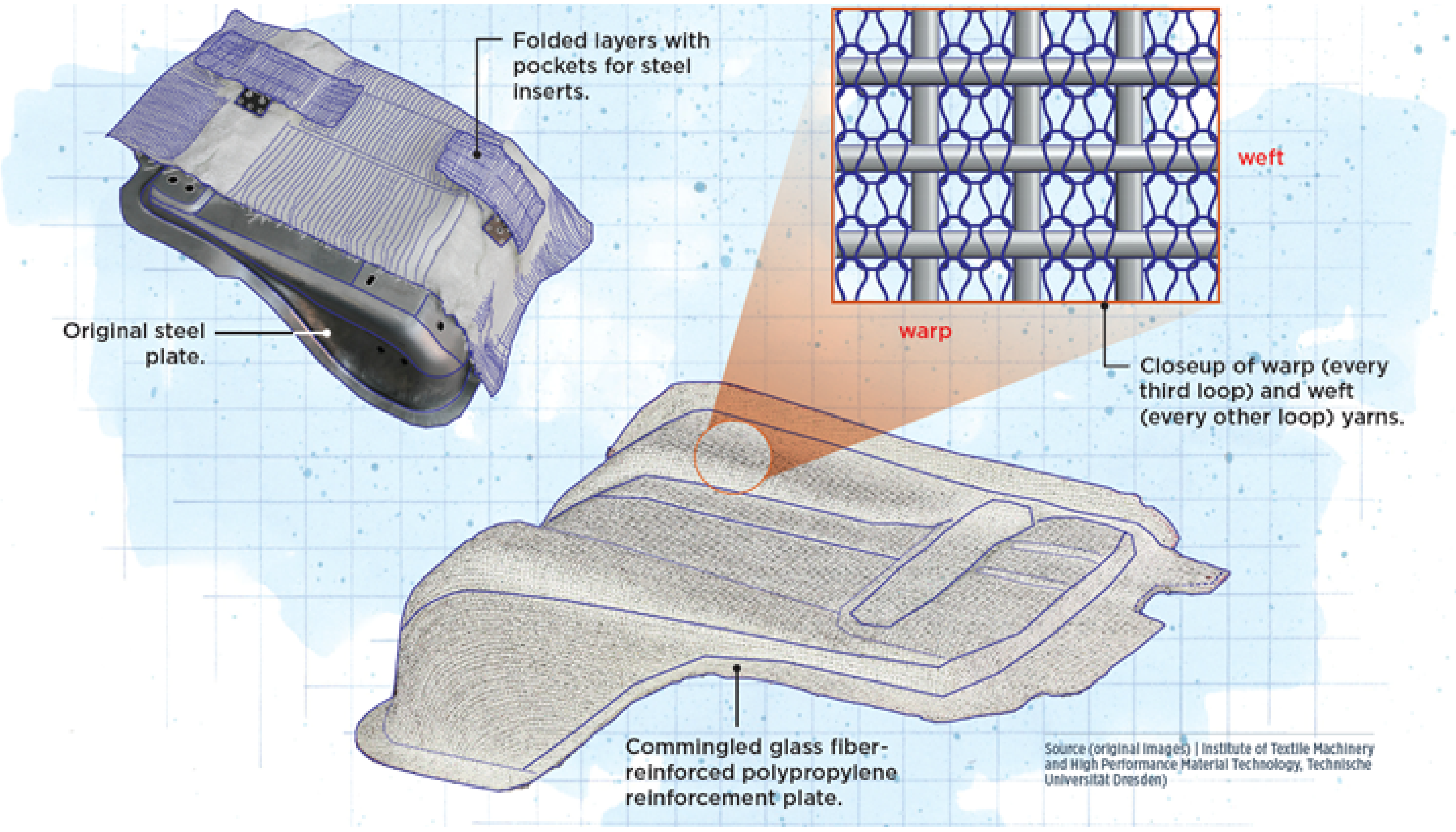


Image illustrated by Susan Kraus

Composites provide a lightweighting opportunity for the HDV industry’s weight issues, especially if they are structurally optimized to the given set of loads, boundary conditions and constraints to maximize the system's performance. A lightweight truck chassis could accommodate new lower emission powertrain solutions before it reaches a weight threshold. This could also enable increased payload, so transport firms could haul more cargo, improve the transport economy and reduce the number of required journeys.

MAPICC 3D project

To help realize industrialized lightweight vehicle components, the European Commission backed a project called MAPICC 3D (2011-2016). It sought to develop a process capable of producing net-shape, high-performance structural 3D thermoplastic textile composite preforms with topology-optimized fiber reinforcement orientation made in one shot using a knitting technique.

Volvo Group Europe used the MAPICC 3D project to develop and validate a thermoplastic textile composite seat reinforcement plate for its N2 Class truck (axle weight between 3.5 and 12.5 metric tons) to replace the steel version. Photo Credit: Volvo Group Europe

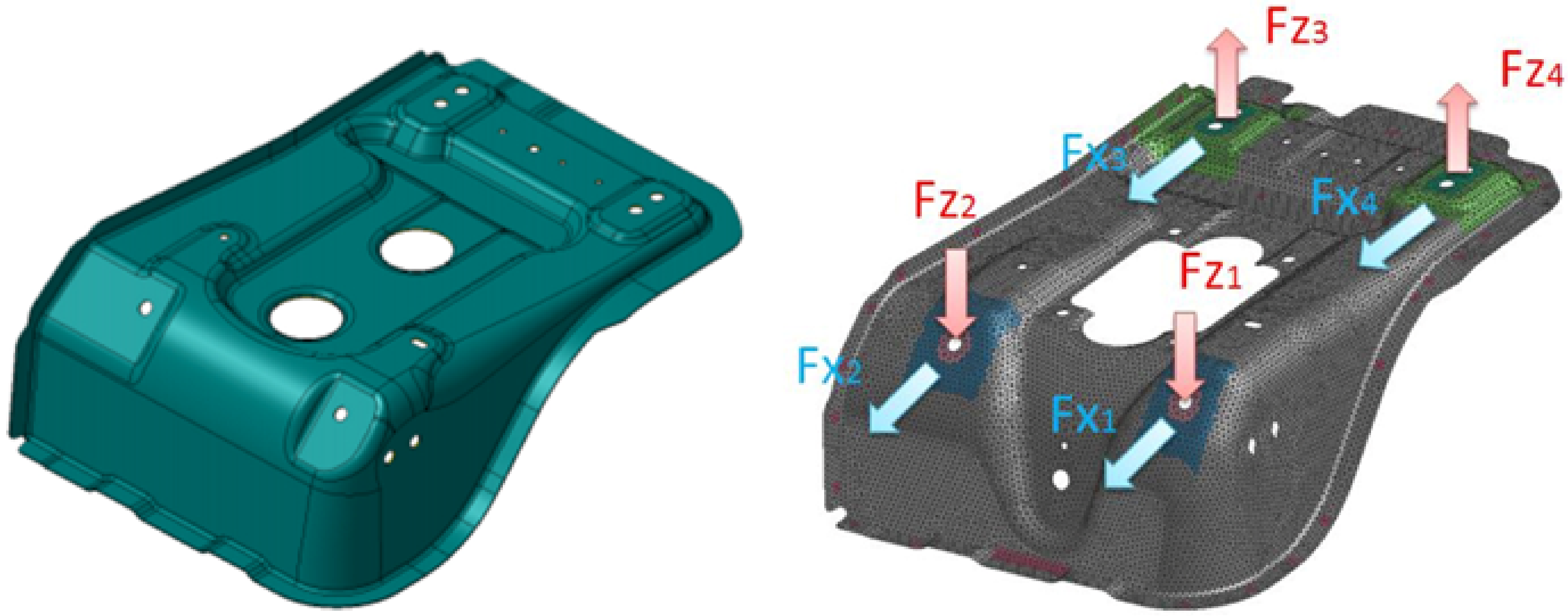
The project included the development of virtual tools capable of modeling 3D composite structures and predicting their mechanical behavior according to textile architecture and resin choice, allowing for customized end products and better accessibility to SMEs/OEMs. It also saw the development of thermoplastic hybrid yarns comprising both matrix and reinforcing fibers. The resulting manufacturing procedure can precisely steer the fibers in three dimensions, tailoring them to the component's load paths with minimal raw material waste.

Twenty partners from 10 countries fulfilled the MAPICC 3D project’s manufacturing chain from raw materials to completed component testing and verification. Key partners included Volvo Group Europe (Gothenburg, Sweden), Steiger Participations (Vionnaz, Switzerland), Rajasthan Technical University (RTU, Kota, India), Institute of Textile Machinery and High Performance Material Technology at the Technische Universität Dresden (TUD, Germany), Ecole Nationale Supérieure des Arts et Industries Textile (ENSAIT, Roubaix, France), virtual testing specialist Reden (Hengelo, Netherlands), Toray Advanced Composites (TAC, Nijverdal, Netherlands) and resin suppliers Axson Technologies (now Sika Advanced Resins, Baar, Switzerland) and Huntsman (The Woodlands, Texas, U.S.).

Design results

- Development of virtual tools to model 3D composite structures and predict their mechanical behavior according to textile architecture and resin choice.
- Development of thermoplastic hybrid yarns comprising the matrix and reinforcement.
- A one-shot process that precisely steers the fibers in three dimensions, tailoring them to the component’s load paths and allowing integrated mechanisms with minimal waste.

Volvo Group Europe used the MAPICC 3D project to develop and validate a thermoplastic textile composite seat reinforcement plate for its N2 class truck (axle weight between 3.5 and 12.5 metric tons) to replace a steel plate. The resulting composite part was to match the steel version's technical requirements, including the strength needed to pass the mandatory ECE R14 seat belt anchorage test for the N2 class vehicle, and realize significant weight savings.



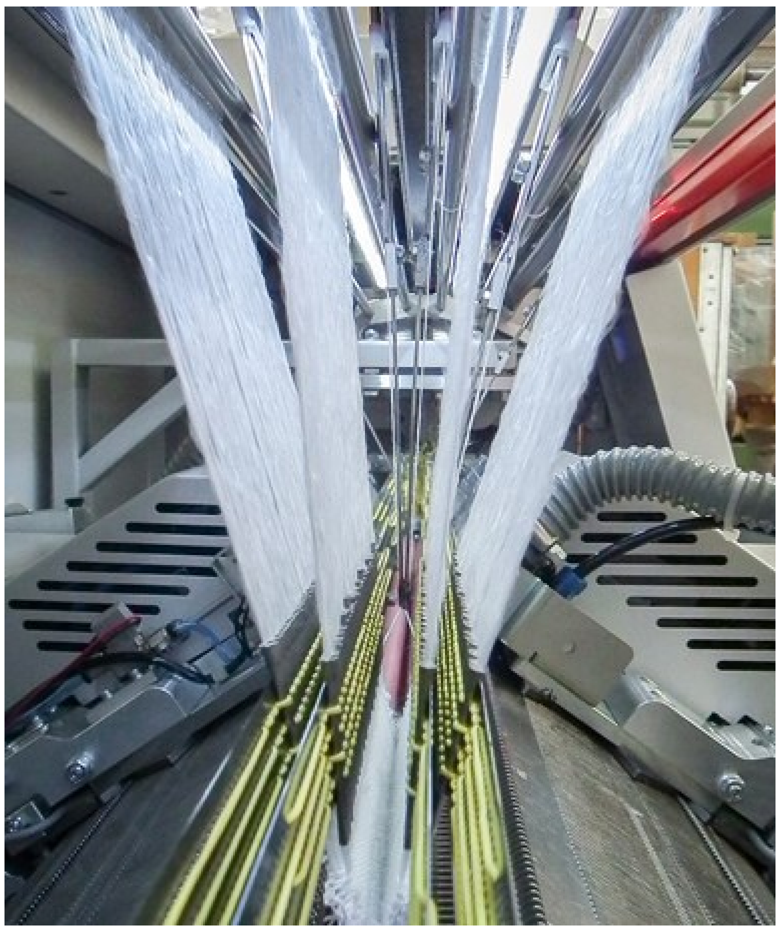
RTU conducted finite element analysis (FEA) and simulated the ECE R14 seat belt anchorage test to acquire the loads produced during the experiment. Above is the resulting CAD and mesh with load vector map generated by these simulations. Photo Credit: Volvo Group Europe

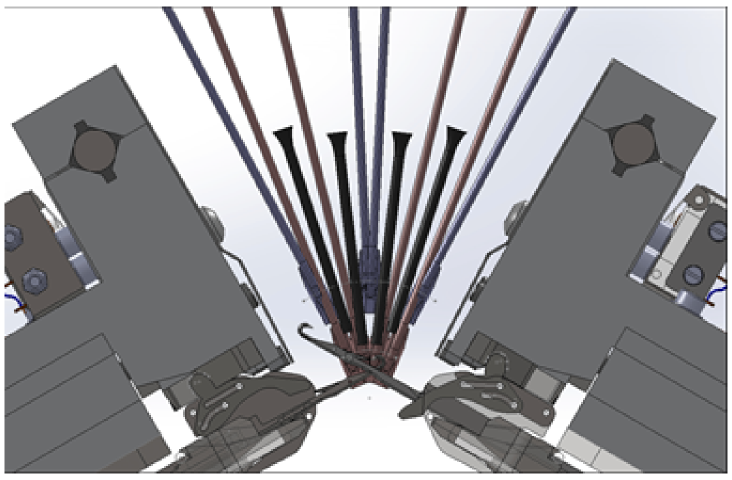
Philippe Lefort, lead engineer for Volvo Group Europe, explained the rationale for choosing the seat reinforcement plate for the lightweighting study: "We developed a formula associated with the vehicle's balance to identify the location of the most effective weight saving. It determined that the weight reduction should be as far forward on the truck as possible for the largest axle load reduction. The seat reinforcement plate is close to the front, has significant high-performance design criteria and is reasonably heavy. As such, it was the right challenge for this study."

The composite seat reinforcement plate replicates the steel version's design to avoid cabin modification. As a first step to making the composite version, RTU conducted finite element analysis (FEA) on the steel reinforcement plate using Ansys Shell 93 (Canonsburg, Pa., U.S.). Next, VISUAL CRASH PAM (ESI Group, Rungis, France) software was used to simulate the ECE R14 seat belt anchorage test to acquire local loads produced during the experiment.

A load vector map generated by these simulations indicated that a single preform layer would not be sufficient to support some areas of the reinforcement plate well enough to pass the seat belt pull-out test. It was decided that extra layers of material would be placed in areas with the most severe stress. Steel inserts with a threaded section would be incorporated into the composite for bolting the seat to the reinforcement plate. These inserts would fit into pockets knitted into the preform during the one-shot manufacturing process.

Manufacturing





MAPICC 3D developed spacer knitting technology with controlled fiber placement to locally knit pockets for the steel inserts and excess material to make multiple layers of foldable fabric where further reinforcement was needed. Steiger produced a bespoke laboratory knitting machine to create this fabric. Photo Credit: Steiger Participations

The chosen composite was a commingled glass fiber-reinforced polypropylene (PP) at a 50% volume fraction. “We produced our own hybrid yarn from separate glass fiber and PP yarns which we fed through an air jet texturizer, combining them at the chosen ratio,” explains Wolfgang Truemper, scientific director at the Institute for Textile Machinery and Textile High Performance Materials Technology at TUD. “We align the glass fibers in the desired orientation in the hybrid yarn during the air jet texturizing, and the PP yarns support that structure. The glass fibers were orientated to provide load path optimization in the final composite structure. Additionally, this interspersion means the PP protects the glass fibers during fabric production and reduces the flow path length during molding.

The fabric preform comes out of the knitting machine with all the desired part features. As it's manufactured from thermoplastic hybrid yarns, only consolidation is needed before it heads into operation. Photo Credit: Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden

3D knitting enables one-shot production of preforms that accommodate the final product's net shape. Here, the knitted element is traditional in that the fabric comprises consecutive rows of interlocking loops. Warp and weft yarns were woven through the knitted fabric at 90° to each other to reinforce the preform. A bespoke spacer knitting technology with controlled fiber placement was developed to locally knit pockets for the steel inserts and excess material to make multiple layers of foldable fabric where further reinforcement is needed.

"An additional GF/PP yarn feed delivers adequate material locally during production," explains Truemper, describing how the yarn for the folded layers was integrated into the one-shot knitting process. "An extra needle set knits this feed into the main part to produce the insert pockets and foldable reinforcing layers. The machine applies the foldable layers and pockets with a defined distance to the part's outer layers per the regional strength requirement. Afterward, the additional yarn feed is turned off until it is needed again."

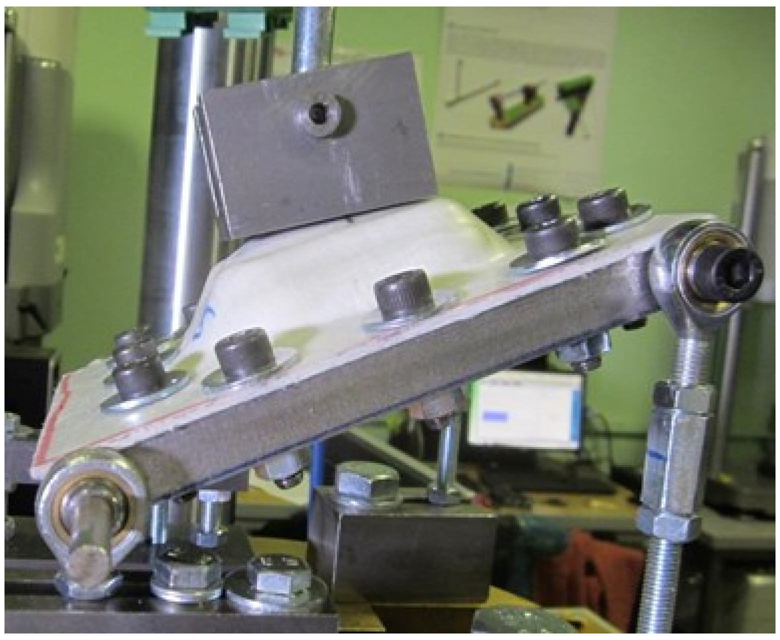
RTU built thermally resistant molds based on Volvo's steel seat reinforcement plate. The preform was loaded onto the tool and vacuum bagged. Consolidation took place in an autoclave at 5 bar pressure. The mold and preform were preheated at 170°C for 40 minutes, held at 180°C for 40 minutes and then cooled in the oven for 30 minutes. The mold and part were then extracted from the oven and cooled at room temperature for several hours before the consolidated part was demolded. Truemper explains the reasons for the lengthy cooling time are two-fold. He says, "One was handling — we needed to cool down the part

Consolidation took place in an autoclave (shown above) before being extracted and cooled at room temperature for several hours and then demolded. Photo Credit: Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden

handle it safely without harming people and the other was to prevent warpage caused by cooling the part too fast.” Being a prototype, the MAPICC 3D team didn't want to risk damaging the parts as each was valuable for the research goals. “We did not examine any cooling time influence on warpage,” adds Truemper. “There was to be some optimization during the industrialization stage of the project to accurately define the temperature that enables detooling the composite part for each specific application.”

RTU tested several preform coupons to validate the final construction’s mechanical properties. The university performed bolt pull-out tests on a one-quarter section of the composite seat reinforcement plate. “It was important to validate the construction because the digital model did not fully integrate the stresses at the interface between steel inserts and GF/PP structure,” remarked Lefort. “The critical local load to pass the pull-out test was 23.2 kilonewtons, corresponding to the peak load the bolts would see during the seat belt anchorage test. The test results showed that the composite reinforcement plate needed 4-millimeter steel inserts to achieve this. We chose this for the final structure with nuts and captive washers in addition to the steel inserts for extra support.”

Sika Advanced Resins and Huntsman oversaw the adhesive bonding for affixing the composite seat reinforcement plate to the truck’s steel cabin floor. The companies tested several types of adhesives from various chemical families with different stiffness and behaviors. PP is difficult to bond due to its low surface energy, so surface activation was needed to increase the adhesion. Flame treatment was selected for this as it performed best in shear and intersection bond strength. The chosen adhesive was Sika’s ADEKIT A280A.



Shown here is RTU’s bolt pull-out tests on a one-quarter section of the composite seat reinforcement plate. The critical local load to pass the pull-out test was 23.2 kilonewtons, corresponding to the peak load the seat bolts would see during the seat belt anchorage test. Photo Credit: Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden

Volvo Group Europe tested the MAPICC 3D composite seat reinforcement plate in a truck cabin on a seven-actuator dynamic shaker rig. Volvo bolted the seat to the reinforcement plate and loaded it with a total of 80 kilograms across the seat’s shoulder and lap sections. Cables connected to an actuator pulled the weights forward in the cab during the ECE R14 seat belt anchorage test. Here, the main load interacting with the composite structure is a horizontal drag force. The composite seat reinforcement plate surpassed the required N2 class 6.75-kilonewton load on the upper and lower torso without rupture, achieved 9.2 kilonewtons on the upper torso load and 12.3 kilonewtons on the lower torso load before observed failure. At that load, severe deformation of the seat rails led to complete adhesive rupture on the front of the composite seat base. The performance of the MAPICC 3D composite seat reinforcement plate in the ECE R14 seat belt anchorage test deemed the structure a successful replacement for the steel version.

Read: UniFORM: High-quality, high-complex EV battery enclosures at low cycle times, low tooling costs

Volvo Group Europe performs the ECE R14 seat belt anchorage test on the composite seat reinforcement plate, which is attached to a truck cabin. The seat was loaded with a total of 80 kilograms across the seat's shoulder and lap section while cables connected to an actuator pulled the weights forward in the cab. Photo Credit: Volvo Group Europe

The future of 3D knitted preforms

The final glass fiber-reinforced PP Volvo truck seat reinforcement plate weighs 1.3 kilograms, 2.7 kilograms less than its steel predecessor, for a total weight reduction of 67.5%. The MAPICC 3D technology achieved its goals of producing complex, production-ready 3D preforms with controlled three-directional fiber placement — and with the potential to integrate third-party components — in one shot. The technology's high design flexibility and low manual operations make manufacturing composite structures using this technique as versatile as 3D printing is for isotropic material structures. The limitations associated with manufacturing preforms are significantly reduced and so, too, are the design limitations of the structures.

"Through this project, 3D knitted preforms from thermoplastic hybrid yarns consisting of the matrix and reinforcing components becomes a tool of significant economic output for vehicle industries," notes Pierre-Yves Bonvin, CEO of Steiger Participations, which developed the knitting machine for the MAPICC 3D project. "We can now accomplish hyper-specialized workshops and make 3D knitting a competitive composite manufacturing solution compared to other technologies that are slower, more expensive, polluting and wasteful."

CARBON FIBERS | ATL/AFP | DESIGN/SIMULATION | THERMOPLASTICS | AUTOMOTIVE

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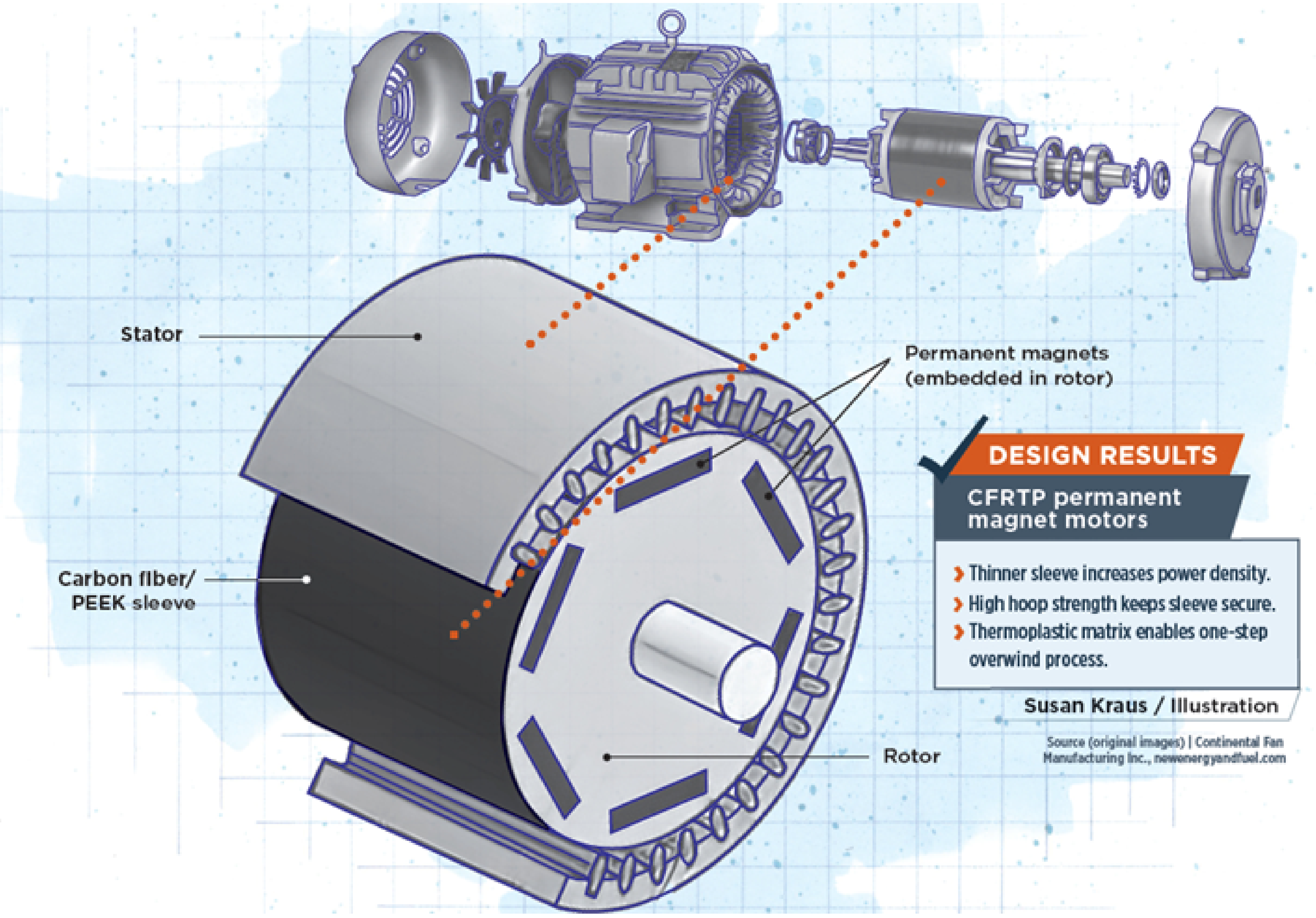
Protecting EV motors more efficiently

Motors for electric vehicles are expected to benefit from Trelleborg's thermoplastic composite rotor sleeve design, which advances materials and processes to produce a lightweight, energy-efficient component.

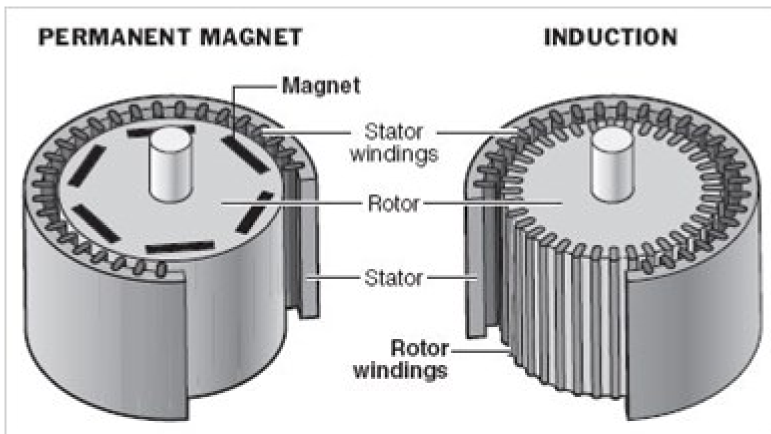
#electricvehicles #focusondesign

KAREN MASON
Contributing Writer



As electric vehicle (EV) technology advances to improve vehicle performance and range, battery technology may be grabbing many of the headlines, but equally important are the electric motors that convert battery energy to vehicle propulsion. For many years, one type of EV motor called a permanent magnet motor (PMM) has incorporated a carbon fiber-reinforced thermoset sleeve that wraps around the PMM's rotor. The sleeve keeps the rotor assembly from flying apart at high rotational speeds. In a recent advancement, Trelleborg Sealing Solutions (Albany, N.Y., U.S.) has leveraged some advantages of thermoplastic resins to develop an improved design for the sleeve. Increased motor efficiency may soon propel the Trelleborg design into production EV motors.

In the EV market, PMMs have recently been selected for several production vehicles over the more common induction motor. These include the Tesla *Model 3* and the Chevrolet *Bolt* and *Volt*. Induction motors feature a relatively low cost and high reliability, but PMMs offer higher power density and lighter weight. The price of PMMs is a decided disadvantage, due to the high cost of permanent magnets — most commonly made of rare earth metals. Therefore, every advancement that increases the efficiency of these motors is critical to building a business case for them. This is why Trelleborg's carbon fiber-reinforced thermoplastic (CFRTP) sleeve for PMMs is under serious consideration for the EV market.



Electric vehicle motor options. Permanent magnet motors produce their own electromagnetic field via embedded magnets, different from induction motors, which are magnetized by electric power from the battery. Photo Credit: newenergyandfuel.com

"We have built a couple sleeves for evaluation in this market, though we can't elaborate at this time," Trelleborg product manager, Reid Hislop reports. But commercial application to the EV market seems likely on the near horizon. Trelleborg's proven composite design and manufacturing technology have already been incorporated into PMMs for other commercial applications, such as industrial pumps and drives for machine tools, down-hole oil and gas pumps, and HVAC equipment.

Powering EVs

EV motors operate through electromagnetic forces. A rotating magnetic field is produced in the stationary component, the stator, by applying an alternating electric current. The stator surrounds the rotating component — the rotor — which is also magnetized. The resulting magnetic attraction and repulsion between the two components forces the rotor to rotate and power the drivetrain.

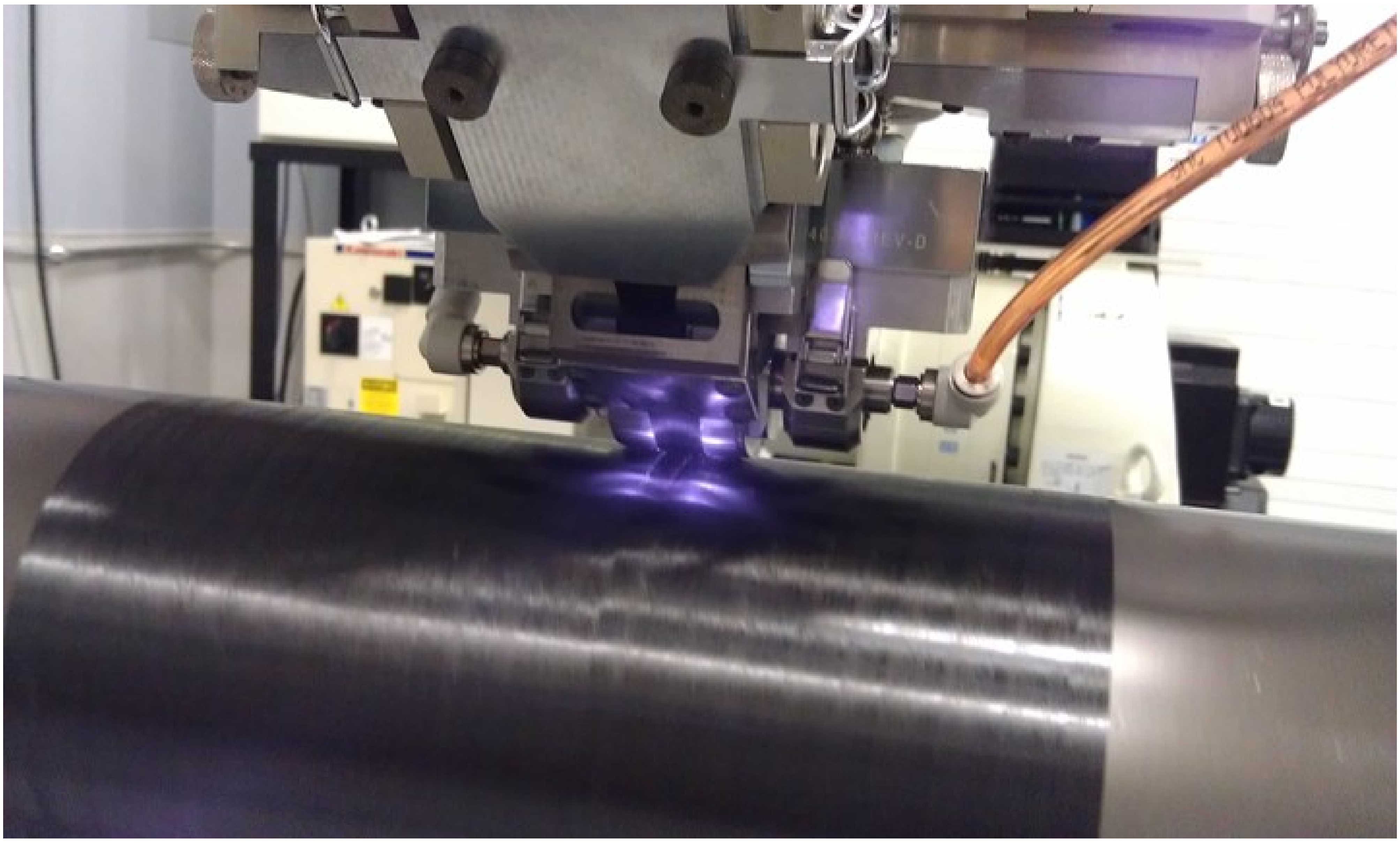
In induction motors, conductors such as copper or aluminum are wound or embedded within the rotor's steel laminate cylinder, and the stator's AC current induces the rotor's magnetic field. A permanent magnet rotor, on the other hand, generates its own magnetic field by either encasing or bonding permanent magnets to the rotor.

PMMs are inherently more efficient than induction motors because the induction rotor consumes electric power to generate its magnetic field while the PMM rotor does not. PMMs also offer a high power density and torque density: Compared to an induction motor, a PMM can provide an EV's targeted power and torque with a smaller, lighter weight motor — supporting the critical EV objectives of higher performance and greater driving range. PMMs also feature low noise generation, which is attractive to the EV market.

Design for efficiency

Trelleborg's thermoplastic composite sleeve is fabricated from a continuous fiber-reinforced prepreg that is overwound directly onto the PMM rotor. The company's manufacturing process, automated fiber placement (AFP) with in-situ consolidation, is capable of making sleeves suitable for EV PMMs and nearly any other PMM application. They range in size from a diameter under 2.5 centimeters all the way up to a sleeve for the 33-centimeter-diameter rotor of a prototype electric motor, designed for commercial single-aisle class aircraft propulsion.

CFRTP sleeve. With its automated fiber placement (AFP) with in-situ consolidation, Trelleborg overwinds carbon fiber/thermoplastic composites directly onto metal structures. Pretensioning the composite material keeps it in place even for applications with high rotational speeds, like permanent magnet motors. Photo Credit: Trelleborg Sealing Solutions.



AFP/ISC for design. Trelleborg's manufacturing process offers new design freedom — structurally stable thin overwinds and thick overwinds with no fiber waviness or buckling, for example. It also enables one-step manufacture of the composite PMM sleeves. Photo Credit: Trelleborg Sealing Solutions

For the high-performance requirements of an EV application, the sleeve is made from carbon fiber-reinforced polyetheretherketone (PEEK) prepreg tape. The materials and process for Trelleborg's thermoplastic composite sleeve create advantageous design freedom compared to other materials and processes. Alternatives to the carbon fiber/PEEK sleeve include the thermoset composite version mentioned above, and a steel version. The properties of thermoplastic matrices, including their superior toughness and their resistance to wear, fatigue and chemicals, make them well suited to the harsh conditions that an EV drivetrain experiences.

Design results

- Thinner sleeve increases power density.
- High hoop strength keeps sleeve secure.
- Thermoplastic matrix enables one-step overwind process.

Thinness is one key advantage of the Trelleborg design and process. The rotor sleeve adds distance between the rotor magnets and the stator, and the larger this gap, the lower the motor's electromagnetic power and efficiency. This means that the ideal sleeve offers high strength in as thin a structure as possible. Trelleborg's design produces a sleeve that is both thinner than can be fabricated from thermoset composites and stronger per unit thickness than can be produced with steel. Trelleborg program manager, Graham Ostrander, expects that sleeves for EV motors will be five to 20 plies thick.

Another important performance characteristic is the much lower electrical conductivity of carbon fiber-reinforced composites as compared to steel. Low conductivity reduces interference with the magnetic field. The combination of thinness and low conductivity helps the carbon fiber/PEEK sleeve to maximize the PMM's power density.

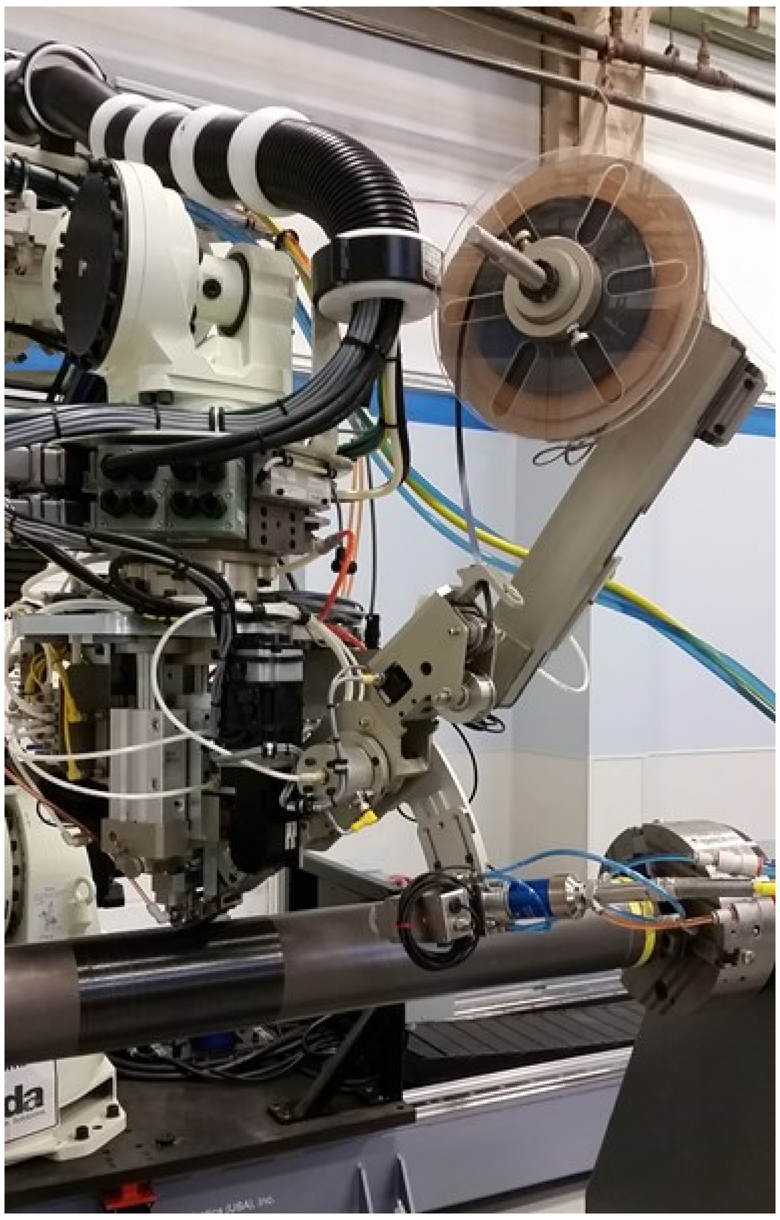
Because rotors spin at very high speeds, the sleeves must also be designed in a way that prevents radial forces from causing fatigue or sudden failure. The rare earth metals that comprise the permanent magnets are brittle, and so stress reduction on the magnets during spinning is critical to the PMM's performance and durability. The vast majority of the plies for the rotor application are 0° (hoop angle) to handle these radial forces, but axial reinforcement (90°) may also be incorporated as needed to increase bending stiffness. (Trelleborg's AFP machine is capable of laying down prepreg tape, from 3 to 25 millimeters wide, at any angle.)

Key to withstanding the radial forces is pretensioning the composite material — Trelleborg's current AFP machine is capable of up to 0.5 metric ton of tension (possible only with continuous fiber prepregs). "This pretension creates a hoop stress that acts as a compressive stress, keeping the composite sleeve in place over top of the item being overwound," Ostrander says.

"The composite's high tensile strength allows the rotor to spin at a much higher speed than any adhesive can hold," he adds. Carbon fiber's low coefficient of thermal expansion (CTE) also factors into the strong mechanical bond between sleeve and rotor, as does its light weight, which handles rapid acceleration and deceleration well.

The desired rotational speed of the rotor and the weight of the magnets together dictate the tension required. "Pretensioning the wind retains the sleeve on the rotor across a broad range of temperatures — a rating of -40°C to 80°C," Ostrander reports.

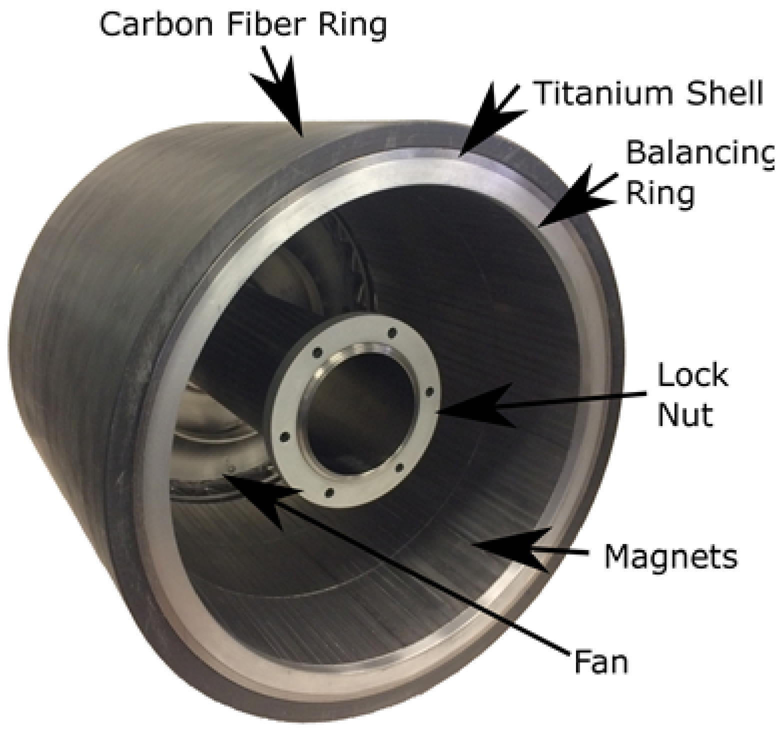
Manufacture for design



Raising throughput. The AFP/ISC technology can accommodate simultaneous overwind of multiple rotors. Instead of one long cylindrical component as seen here, the machine would line up the rotors end to end and be programmed to wind the rotors all at the same time. Photo Credit: Trelleborg Sealing Solutions

In recent years, the engineering community has often pursued "design for manufacture" — making adjustments to a product's design so that it can be manufactured more easily, more quickly, and/or more cost efficiently. In the case of PMM sleeves, however, one might characterize Trelleborg's process as "manufacture for design," or even "manufacture for design for manufacture." That is, Trelleborg engineers developed a manufacturing approach that has reduced some constraints on product design; and this design freedom has in turn enabled a more efficient manufacturing workflow.

Trelleborg's AFP can be used with either thermoset or thermoplastic composite prepreg, but of course in-situ consolidation is used only with thermoplastics. For the sleeve application, consolidation is performed using a laser heating system, which enhances the speed and efficiency of the process compared to conventional hot gas torch (HGT) heating.

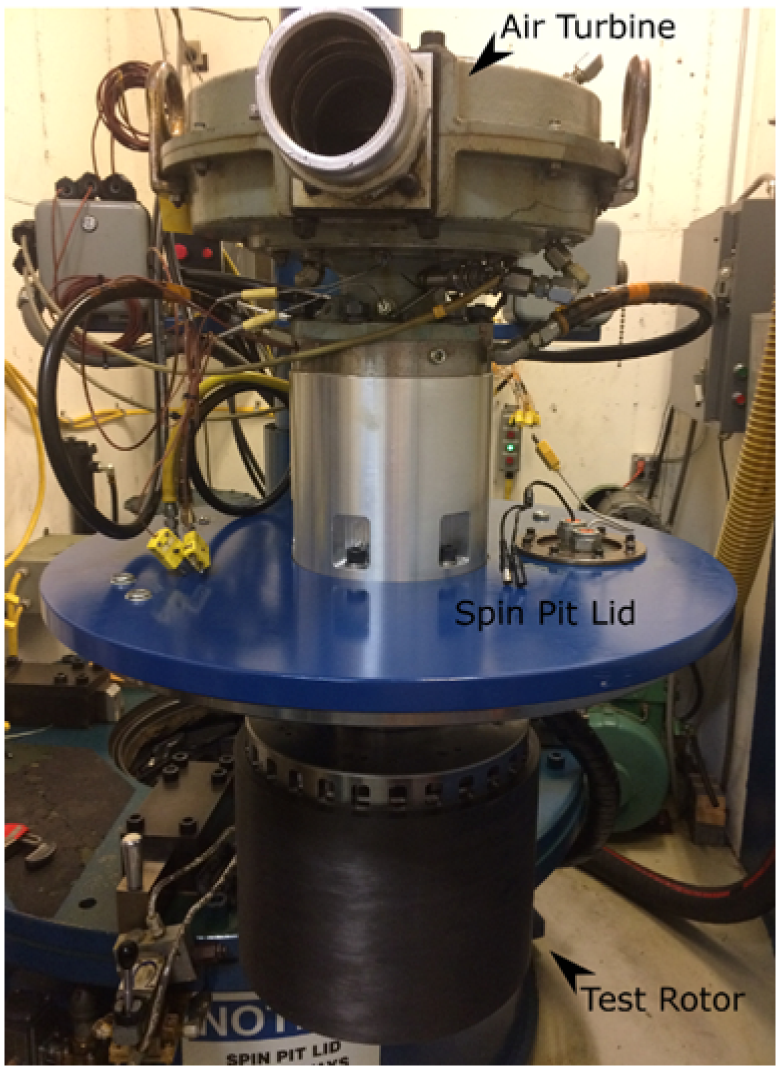


Aerospace application. As Trelleborg continues developmental work with EV manufacturers, the company has already helped in proof of concept research for 737-class electric aircraft. The PMM rotor here, with a carbon fiber/PEEK sleeve, was created and tested by NASA-funded researchers at the University of Illinois. Photo Credit: University of Illinois Urbana-Champaign

One important feature of this process is the localization and short duration of heat application. High temperatures would demagnetize the rotor, rendering it unusable. "Even though we are using high heat to melt the polymer together, the heat is only applied for a very, very short amount of time," Ostrander explains. "Our process does not increase the net temperature of the part we are overwinding more than a few degrees Celsius."

Overwinding of the thermoplastic composite sleeve is performed directly on the magnetic rotor surface. "We have a special process that allows us to place the composite material on the part and make it stay in place without any adhesive or bonding to the surface of the part," Ostrander emphasizes. The deposition head heats both the material it is laying down and the substrate beneath (initially the rotor surface in this application, then previously placed plies) and applies pressure while the resin is molten. This enables polymer chains to diffuse between the incoming tape and the substrate, creating a full bond.

The multiple passes of laser heat application — initially as the tape is first laid down, then reheating as the AFP goes over the area with subsequent plies — results in full crystallinity of the PEEK resin, maximizing its stability during use. Ostrander reports that temperature at the nip, where the incoming material is pressed against the substrate, is 450°C for carbon fiber-reinforced PEEK prepreg. PEEK melts at 343°C, and the nip temperature is typically set 60-120°C higher than the melt temperature. “The key is to stay below the degradation temperature of the polymer,” he says.



Spinning test. To verify analytical models of mechanical expansion, rotordynamics and rotating loss, the aircraft rotor prototype was tested inside a spin pit (for safety). The rotor performed successfully while spinning at 18,000 revolutions/minute, which is 20% faster than the intended operating speed. Photo Credit: University of Illinois Urbana-Champaign

Consolidating thermoplastic composites in-situ enables Trelleborg to overwind the PMM sleeve on the rotor in a one-step operation. Structures made with this manufacturing approach require no secondary oven or autoclave consolidation and typically achieve fiber volume of about 60%. “Once the part is done being wound, it is complete and ready for final machining,” Ostrander says.

“Our process allows us to combine a bunch of different manufacturing steps in one operation,” Hislop emphasizes. “This enhances the efficiency of the overall manufacturing process.”

In contrast, thermoset composite sleeves require a multi-step process. The thermoset version must be fabricated separate from the rotor because oven or autoclave consolidation would damage the magnets. After cure, these sleeves are pressed on or shrunk-fit over the rotor. This final step prevents the thermoset sleeve from being made as thin as the thermoplastic sleeve. “Since you don’t have to press the [thermoplastic] sleeve on the rotor [after cure], there’s no compressive load that would damage a thin sleeve,” Hislop explains.

The Trelleborg process has been used to make various kinds of composite structures, ranging in size from an inside diameter of 0.5 millimeter to an outside diameter of 150 centimeters. It has also fabricated stable structures as thin as two plies and as thick as 7.5 centimeters with no fiber waviness or buckling. Buckling can be a problem in thicker laminates fabricated with other consolidation methods, Ostrander says. “When you lay these materials in place, you wind up having air trapped in between the layers, but with ir situ consolidation, the air is squeezed out during the bonding process." Coupled with the virtually unlimited outtime of thermoplastic prepregs, Ostrander concludes, "the in-situ consolidation process can be scaled up to make structures as large as airplanes."

The indefinite outtime also enables the Trelleborg process to wind very long parts. In the case of the rotor sleeve, this capability means that a long chain of rotors can be set up in a line and wound all at the same time. "That way, we increase the throughput and decrease the overall cost to the customer," Hislop says.

The attraction of PMMs

The cost of rare earth metals remains a detriment to the total cost of ownership of PMMs, and this fact, along with geopolitical tensions (China is the predominant supplier of rare earth metals), may slow the application of PMMs to EV series vehicles. But the appeal of PMMs remains strong because of their greater efficiency, torque and driving range when compared to induction motors. Last year, Reuters reported numerous efforts by major automakers to reduce their reliance on rare earth metals. It appears that most are doing so by finding alternative materials for permanent magnets, rather than switching to induction motors.

Whether through alternative magnets or through an easier, less costly supply of rare earth metals, PMMs appear likely to be adopted by a growing number of EV makers. And advancements like Trelleborg's thermoplastic composite sleeve promise to catalyze this market.