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The International Magazine for the Wire & Cable Industries

ISSN1463-2438

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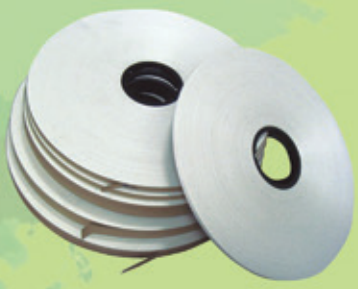
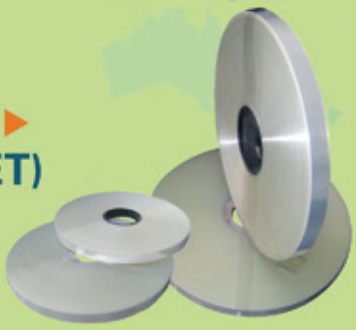


High temperature calcined mica tape

Polyester film tape (PET)



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Issued to Mario Frigerio S.p.A.

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See page 84 for further details

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Expanding for a busy and bright future

We all hear and read of companies expanding, building new premises, buying new machinery, recruiting more staff.

This is obviously to be embraced as our industry prepares itself for the future and the technological changes that it will bring.

So it is especially encouraging to see Messe Düsseldorf, organisers of the largest wire and cable exhibition in Düsseldorf, Germany, firmly keeping its eye on the future with a massive redevelopment of its Fairgrounds site.

The company, which also organises wire China, wire Southeast Asia, wire South America and wire Russia, is spending €140 million expanding its southern entrance and Hall 1.

That is just part of a €636 million plan the company has in investments for its premises before 2030.

If those figures fail to give an impression of the size, the fact that the south entrance and Hall 1 development began in May and will not be completed until summer of 2019 leave no doubt as to the scale of the works.

Turn to page 9 for the full story.

It would also be remiss of us not to look back at North America's largest and oldest exhibition, Interwire.

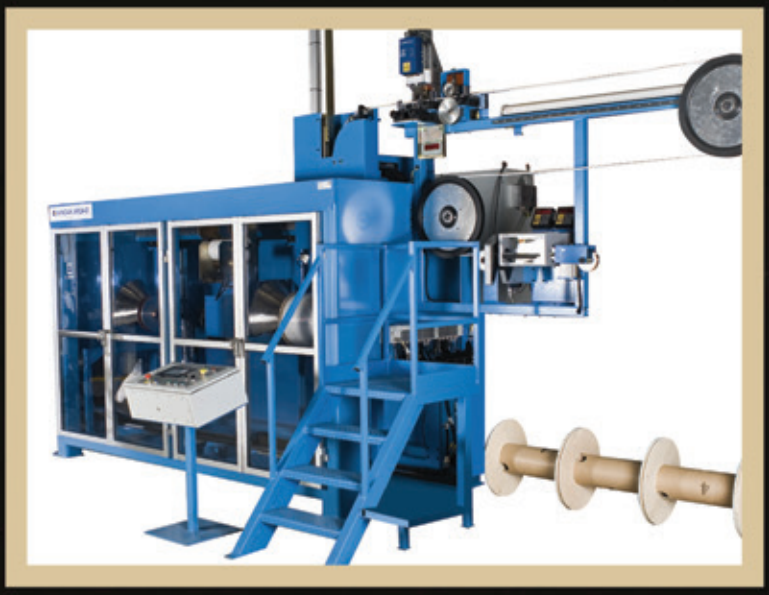
Staged at the World Congress Center, Atlanta, Georgia, in May, Interwire was hailed as a great success by many exhibiting companies.

"Atlanta is such a great venue for this show," enthused one exhibitor, while "this was one of the best Interwires on record," exclaimed another.

Our review of the three-day exhibition can be found on page 36.

David Bell
Editor

2016 EMPLOYEE OF THE YEAR



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Technical Articles

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Getting Technical:

New stretch-bend-levelling line for very thin copper strips is energy-efficient and operates with minimal tolerances

Feature

wire South America 2017
IWCS 2017

wire Southeast Asia

19-21 September:
wire Southeast Asia –
trade exhibition – Bangkok,
Thailand, China
Organisers: Messe Düsseldorf
Asia Pte Ltd
Fax: +65 6337 4633
Email: wire@mda.com.sg
Website:
www.wire-southeastasia.com

bigstockphoto.com "Bangkok, Thailand", Photographer: kittikorn14

dates for your diary . . .

2017

October

3–5 October:
wire South America –
trade exhibition –
São Paulo, Brazil
Organisers:
Messe Düsseldorf GmbH
Fax: +49 211 4560 668
Email: info@wire-south-america.com
Website: www.wire-south-america.com

8–11 October:
IWCS Technical Symposium –
conference and exhibition –
Orlando, Florida, USA
Organisers: IWCS
Tel: +1 717 993 9500
Email: phudak@iwcs.org
Website: www.iwcs.org

November

7 November:
CabWire 2017 – conference –
Düsseldorf, Germany
Organisers: IWMA
Fax: +44 121 781 7404
Email: info@iwma.org
Website: www.iwma.org

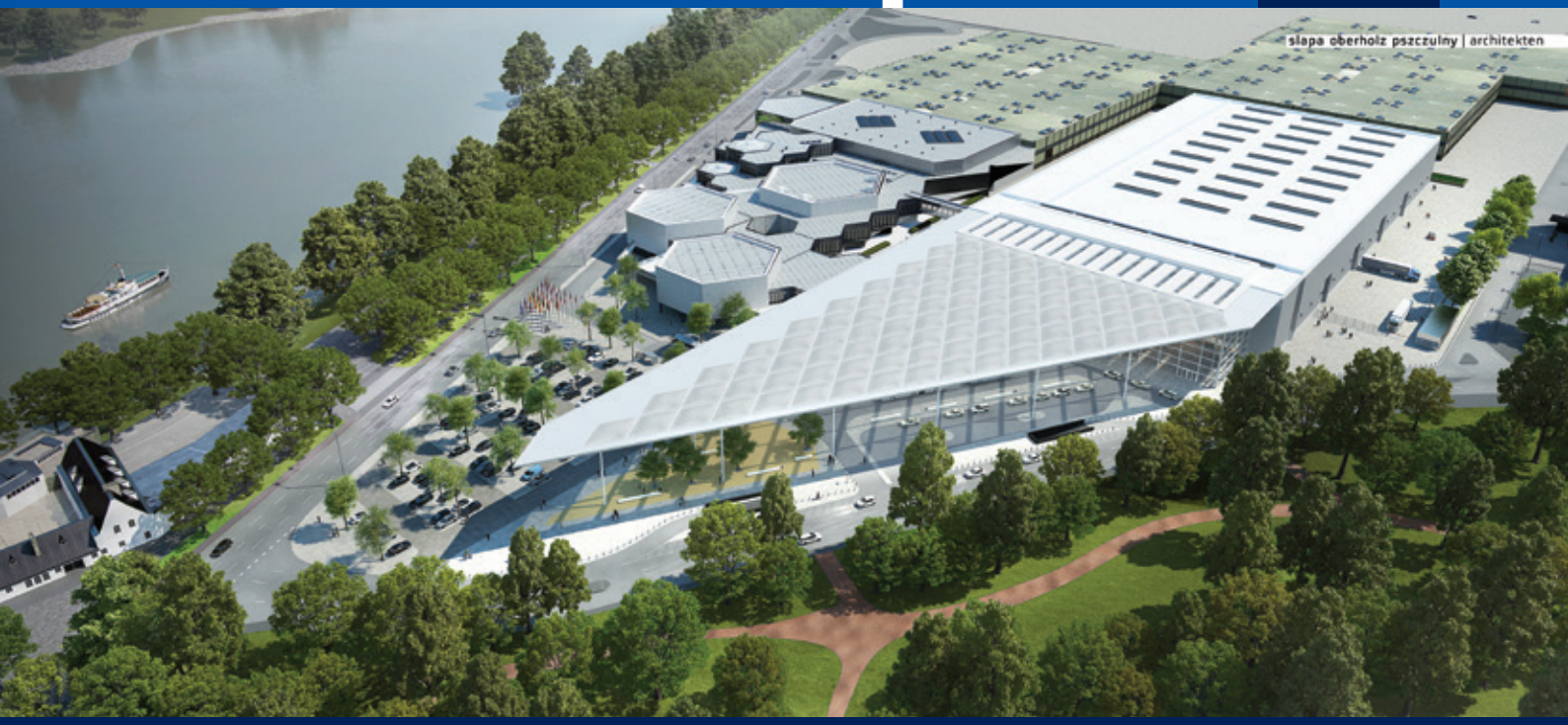
December

5–8 December:
Iran Wire – exhibition –
Tehran, Iran
Organisers:
Messe Düsseldorf GmbH
Fax: +49 211 4560 668
Email: info@iranwire.ir
Website: www.iranwire.ir

2018

March

6–8 March:
AMI Cables Conference – conference –
Cologne, Germany
Organisers:
Applied Market Information LLC
Tel: +44 117 314 8111
Email: lr@amiplastics.com
Website: www.amiplastics-na.com



▲ *An architect's plan for the new South entrance at the Düsseldorf Fairgrounds*

wire 2018 and Tube 2018 benefit from renovation

COMPLETE reconstruction of the southern entrance and the adjoining Hall 1 has begun at the Düsseldorf Fairgrounds.

The supervisory board and shareholders of Messe Düsseldorf GmbH have declared their approval, and thus the starting point has been reached for one of the most ambitious construction projects in the history of the company.

"We can now implement our master plan for the complete modernisation and renovation of our premises, our home base," said Werner M Dornscheidt, chairman and CEO of Messe Düsseldorf, adding: "As usual, it will all be done without subsidies."

The capital expenditure for the southern section amounts to €140 million. In total, Messe Düsseldorf will invest around €636 million in its premises before 2030.

The work started in May and is scheduled to be completed by summer 2019. The blueprint for the work comes from the Düsseldorf-based architectural company slapa oberholz pszczulny architekten.

The new South entrance will give Messe Düsseldorf a modern presence on the banks of the river Rhine, looking out over the city of Düsseldorf. Trade fair visitors and convention delegates will be welcomed by a new illuminated and translucent canopy, 7,800m² in size and around 20m high.

This structure will be a strong architectural landmark at this highly visible point in the exhibition centre. Jurek Slapa, managing partner at sop architekten, said: "The canopy will give the Messe Düsseldorf a new façade and a distinctive location at this unique position between the Rhine and the Nordpark."

The South entrance is to open onto the forecourt via a façade constructed entirely of glass, 93 metres in length. Required services such as cash desks and cloakrooms will be found in this 2,000m² space.

The first floor is to contain a glass-walled meeting room coming out into the foyer, affording a view of the entrance and the forecourt. In addition, the entire foyer will be available as an event location. The forecourt will also contain the entrance to the underground car park with 300 spaces as well as bus stops and a taxi rank.

The scope of the renovation of the South entrance also includes the reconstruction of Hall 1. To this end, Messe Düsseldorf plans to demolish the current Halls 1 and 2, which are smaller, and replace them with a new build. Hall 1, measuring 158m x 77m, with over 12,000m² of floor space, will then be around the same size as Halls 8a and 8b.

The new hall will meet the high technical standards that the entire trade fair centre is subject to. It will be accessible via seven gates, with suspensions from the hall ceiling being as easy to configure as it is to set up stands using the hall floor.

Pedestrians can use the bridge on the first floor to cross between the hall and the Congress Center Düsseldorf (CCD). As well as being connected to Halls 3 and 4, there will be a main route leading from the South entrance directly to the rest of the premises.

In 2017 and 2018, the transitioning years during which the building work will occur, the Tube exhibitors previously housed in Halls 1 and 2 will be provided with alternative, attractive stand options in halls 16 and 17, so Tube 2018 will be held in halls 3 to 7 and halls 16 and 17. The exhibitors of wire 2018 will present their innovations in halls 9 to 16.

Messe Düsseldorf GmbH – Germany
Website: www.messe-duesseldorf.de

Key speakers announced for cable conference

GERMANY has emerged as a world renewable energy leader, which makes the country the perfect place to understand the future of wire and cable consumption in power generation.

This year's Wire & Cable conference hosted by CRU will include special highlight sessions that focus on the future of renewable energy, connected living, automotive electronics and subsea wire and cable usage.

CRU provides analysis of the optical fibre and cable industry from every angle, giving insight into industry trends, from price movements to changes in demand. CRU Events creates industry-leading commercial and technical events around the world, and opted to take the conference to Munich.

"We are very excited to be bringing our Wire & Cable Conference to Munich, one of the world's largest IT, communication and automotive industry hubs," said CRU's Richard Mack, managing consultant and industry expert.

"CRU held its 7th annual Wire and Cable conference in Berlin in 2013. This event was very successful, and one factor was the strong representation of German companies among speakers and attendees.

"Germany is among world leaders in R&D in such areas as electric power generation and transmission, electric vehicles and advanced transportation, ICT networks and applications, cable-making materials and equipment, and advanced manufacturing processes.

"As with previous years, the event will open with shared plenary sessions and then split into streams that focus on the separate energy cable and communication cable issues. In this way, we bring together the entire supply chain from across global wire and cable industry."

The event will have over 30 presentations packed into a two-day programme, in addition to a site visit to the Niehoff plant.

There will be a number of in-depth papers on copper, aluminium, optical fibre, coatings and other input markets, as well as a showcase of the latest technical innovations that may disrupt this sector.

High-level speakers confirmed to present this year include: Rich Stinson, CEO, Southwire, USA; Roberto Candela, CEO, Prysmian Electronics, Italy; Arnd Kulaczewski, president and CEO, Niehoff, Germany; Oliver Schlodder, EVP services and accessories, nkt cables, Germany; Hasegawa Takashi, principal analyst, Global Network System Div, Sumitomo Electric Industries, Japan; Max Yates, industrials analyst, Credit Suisse, UK; Craig Morris, senior fellow, Institute for Advanced Sustainability Studies (IASS) and lead author of Energy Democracy, Germany; David Smith, sales director, H Folke Sandelin AB, Sweden; Michael Weiss, senior director, purchasing, Siemens, Germany; Andrew Shaw, managing director, DUCAB, Dubai; and Bernhard Schipper, head of technical council cables, Siemens, Germany.

The CRU Wire & Cable conference is being held 17th to 19th July at The Westin Grand in Munich, Germany.

CRU – UK
Website:
www.wireandcableconference.com

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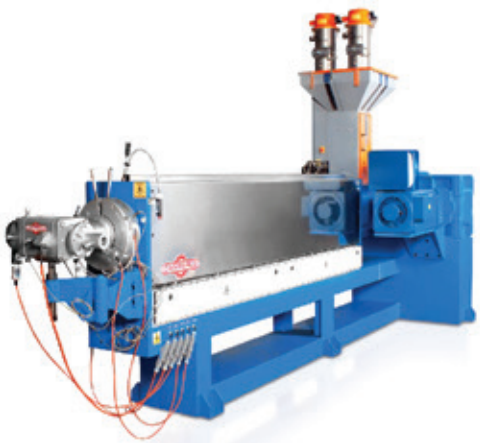

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Pruftechnik celebrates 45 years

INDUSTRY 4.0 and IoT have been dominating the industrial space in 2017. "So far, these have been merely buzzwords," said Dr Sebastian Busch, managing director of Pruftechnik AG.

"However, our customers have changed in the last 45 years – that is correct. They are not linear anymore."

Prufetchnik's path has always been linear for more than four decades– always ahead as innovative driver and providing a direct link between customer and solution. On its 45th anniversary, the company is travelling in time and opening the door to the future.

From the first simple ideas to today's user-friendly, cloud-based measuring devices, Pruftechnik's image has changed drastically. The living room in Schwabing, Munich, Germany, where the first devices were produced, has long been replaced with a high-tech production line based on lean management in Ismaning (to the north of Munich).

The company-owned premises not only accommodate production, but also, among others, an in-house R&D department (hard and software), quality management, sales and sales support, product management, marketing, logistics, service and tech support.

At the same time, Pruftechnik has its own branch offices in 18 countries worldwide and agents and distributors in 70 additional countries.

To maintain the service, support and sales quality at the highest level possible, the company continuously invests in the development of new company-owned branch offices. It is currently completing new offices in Wroclaw, Poland, which also accommodates a part of its development efforts.

Another new building has started in St Petersburg for the Russian sales and service subsidiary. Furthermore, two new offices were opened in the past two years in the USA. The Philadelphia headquarters manage the operations of the North American market with area-covering sales and service partners.

Pruftechnik has always focused on the customer, rather than on the product itself. "We must understand our customers and their problems every single day and offer them sustainable and customised solutions," added Dr Busch.

"Simultaneously, the demand for our expertise is constantly growing. Selling products is only a part of our business. Our maintenance services have long gained their own importance in providing holistic solutions."

The variety of industry awards Pruftechnik has won for its products in recent decades is another testament to the importance of staying close to the customer. Several products have been nominated for further awards in 2017.

The Vibguard Online Condition Monitoring System is one of the frontrunners for the renowned US-American "Maintenance Solution Awards".

Out of more than 500 products, Rotalign received the Finalist Certificate of the "Industry Award 2017" of Huber Verlag (Huber Publishing House) in April.

Pruftechnik AG – Germany
Website: www.pruftechnik.com

JDR selects Cimteq to implement CableBuilder

CIMTEQ, a software provider for the design and manufacturing of subsea cables and umbilicals, has been selected by JDR Cables Systems (JDR), to implement CableBuilder engineering and costing software for the wire and cable industry.

The implementation of CableBuilder will support JDR's plans to increase its market share in the oil and gas sector as well as driving innovation in the global offshore wind industry.

CableBuilder will play an important role in delivering on that strategy by streamlining the design, production and bidding process, enabling JDR to effectively manage its top three operational metrics: increasing efficiency; achieving budget; and realising cost-savings, whilst significantly ramping up production and turnover.

Adam Wells, commercial director, JDR, said: "The implementation of CableBuilder is a great step for JDR as it will allow our designers to improve the performance of the business through faster, more advanced controls and by reducing risks."

Ali Shehab, CEO at Cimteq, added: "I am delighted to have the trust of JDR Cable Systems in CableBuilder and Cimteq to deliver the infrastructure necessary to facilitate their growth.

"I would like to welcome JDR to the community of CableBuilder users who number over 2,000 individuals worldwide."

CableBuilder is an innovative software solution that simplifies the complex management of cable design data from the initial design concept all the way through to delivering the full bill of materials directly to the ERP system.

CableBuilder has automation and logic built in with the flexibility to mirror the manufacturer's operations, capturing the intellectual capital that resides within the company. The focus on automation for calculating costs, weights, routings and bill of materials as well as auto-generating reports and documentation significantly reduces the time on tasks and ensures accuracy and consistency.

The modular nature of CableBuilder gives the cable manufacturer the flexibility to deploy the core design and production module and introduce additional modules as requirements dictate.

Cimteq Ltd – UK
Website: www.cimteq.com

New website and logo

Tensor Machinery Ltd has launched its new website – www.tensormachinery.com. Robert Kepes, the son of founder George Kepes, assumed the position of president and CEO last year after the passing of his father. The company was established in 1984.

Tensor Machinery Ltd – Canada
Website: www.tensormachinery.com

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Strong exhibitor registration for wire 2018

wire 2018 and Tube 2018 have experienced strong exhibitor registration one year before the start of the events. Companies applying after the exhibitor registration deadline end of April were placed on a waiting list. wire and Tube will be held concurrently from 16th to 20th April 2018 at the Fairgrounds in Düsseldorf, Germany.

Over 2,600 key players from the industry will present innovations from the wire, cable and pipe industries on 1.18 million ft² of net exhibition space in 15 halls.

As in the past, well-represented countries at wire 2018 will be Italy, Belgium, France, Spain, Austria, the Netherlands, Switzerland, Turkey, UK, Sweden and Germany. From overseas, many companies from the USA, South Korea, Taiwan, India and China are expected.

wire 2018 will be held in halls 9 to 16. On display will be machinery and equipment for wire manufacturing and finishing, process technology tools and auxiliary materials for process engineering as well as materials, special wires, cable, measuring and control technology and test engineering.

In order to address the increasing use of fibre glass cables in the energy, construction and communications sectors, wire 2018 will focus even more strongly on glass fibre cables next year. The segments wire, cable and glass fibre machinery will be presented in Halls 9 to 13 and 16, fastener technology in Hall 15 and mash welding and spring making in Hall 13.

At Tube, the majority of the exhibitors will be from Italy, the Netherlands, Spain, Turkey, France, UK, Austria, Switzerland, Poland and Germany. Most overseas exhibitors will come from India, the USA, China and South Korea.

The Tube 2018 exhibits will be presented in Halls 3 to 7 and Halls 16 and 17.

Messe Düsseldorf GmbH – Germany
Website: www.wire.de
Website: www.tube.de

New chief sales officer

Arnold Büscher has taken over the role of chief sales officer for Germany at U I Lapp GmbH, a Lapp Group company.

Mr Büscher, a mechanical engineer by training, has previously held various managerial posts in big-name industrial companies. He acquired international experience in his role as managing director of Rittal Corp in the USA, to name one example. He was most recently responsible for business operations in Germany and Central Europe as managing director of Weidmüller GmbH & Co KG. He is keen to strengthen all the sales channels and the focus on the growth markets in the railway, food and robotics industries.

Lapp Group – Germany
Website: www.lappgroup.com

▲ *The Acciaierie di Verona site*

Group's 'Masterplan'

PITTINI Group, a steel company producing long products for the building sector and mechanical industry, has presented an industrial plan called 'Masterplan' at Acciaierie di Verona SpA.

Pittini Group's plants are located in Italy, Austria and Slovenia, their products being sold in more than 50 different markets. More than 1,700 people are employed in 17 production sites, with a total capacity amounting to more than three million tons of steel per year. In 2016, turnover exceeded €1bn.

Active since the beginning of the 20th century, the productive plant located in Verona, Italy, includes a steel mill, a wire rod mill, a rebar mill and a cold rolling section.

The industrial 'Masterplan' entails a great technological upgrade of the production plants in order to enhance the quality of products. Therefore, the project is going to imply a requalification of infrastructure and plants, thus improving the working environment for the benefit of all.

The investment will allow Pittini Group to broaden and strengthen its position within the sector of long steel products in Italy and especially on foreign markets, widening the range of products offered.

Federico Pittini, president of FIN FER SpA – Pittini Group's holding company – said: "Pittini Group's acquisition of the plant located in Verona is a milestone in our company's growth process. A relaunch plan has been carried out in order to allow the plant in Verona to be competitive on the steel market and to specialise in the production of high quality goods.

"In recent years markets have become more and more demanding, which is why a plant development and technological upgrade project is needed in order to meet the quality needs expressed by the customers. Such an investment plan will allow Acciaierie di Verona to open up to new opportunities on foreign markets.

"The industrial 'Masterplan' carried out in Verona is a major strategic move for the future of our group and will spark off an additional growth within the sector of long steel products, thus widening the range of goods offered on the market."

Pittini Group – Italy
Website: www.pittini.it

Exporter award for Allied

The National Small Business Exporter Summit takes place each year as a celebration of World Trade Day. This year, Allied Wire & Cable (AWC) was awarded as an Outstanding Exporter for 2017. This summit recognises top small and medium-sized business exporters in the USA.

Natalie Beers, director of marketing, accepted the award on behalf of AWC and addressed the audience on best practices and lessons learned in regards to lead generation. Allied welcomed the opportunity to share its knowledge with industry members on how to improve exporting capabilities to provide "Made in USA" products abroad.

Allied Wire & Cable – USA **Website**: www.awcwire.com

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Solutions and advice from Agir

INVOLVED in the fields of tungsten carbide tools since 1870 and machinery for decades, French company Agir Technologies takes advantage of its broad skills to provide the best to all customers. Agir is able to provide solutions and competent advice to a variety of requests.

The investments made in the company, such as a wire cutting EDM with two-wire spool of 0.03mm, a five-axle CNC machine to cut the electrodes, and new CAD/CAM software, allow Agir to widen its range of high precision and quality tools.

The company specialises in the production of tungsten carbide tools for wire and cable manufacturing and other wire transformation, including wire drawing dies (round, shaped, pressure), drawing dies and plugs, cable extrusion tools, straightening tools, wire-guides, and tools for welding rods and plated wires. Agir is able, thanks to its software, to calculate any drawing station for round wire just like for any shaped wire.

The company exports its tungsten carbide tools, machines and know-how on five continents and to more than 60 countries.

First for its own needs in tungsten carbide dies and then for its partners, Agir has made a point of developing the machinery sector by creating and building a wide range of machines.

From a unique shaving head to the various polishing lathes, not forgetting the numerous grinding machines, the company is shaped to bring an answer to the most demanding of requirements.

Horizontal or vertical, for large or small diameters, half or fully automatic, with a whole variety of options (spindle, chuck, motorisation), substantial possibilities exist to help improve efficiency and master the manufacturing processes.

Agir Technologies – France
Website: www.agir-technologies.com

▲ *Internal grinding machine IG100A*

Heading to Canada

Allied Wire and Cable has welcomed a veteran of the wire and cable industry, Eric Tremblay, to its sales force. He will be running the company's newest office in Montreal, Canada.

"I'm excited to join the Allied team, and expand our reach internationally with feet on the ground," said Mr Tremblay on his move.

He has over 20 years of experience in the mil-aero wire and cable industry in North America and Europe.

His background encompasses inside sales, outside sales, account management, and office and branch management.

Allied Wire & Cable – USA
Website: www.awcwire.com

Expansion for fire retardant additives business

THE Fire Retardant Additives (FRA) business unit, part of the Huber Engineered Materials division of J M Huber Corporation, has announced a 20 per cent capacity increase at its manufacturing plant in Bauxite, Arkansas, USA.

The capacity increase supports the transfer of Huber's proprietary technology for production of its fine precipitated Martinal® LEO alumina trihydrate products obtained from the 2016 acquisition of the Martinswerk facility in Bergheim, Germany.

The expansion will also support the on-going growth of existing product lines at Bauxite, which includes both Hydral® 710 and Hydral® PGA fine precipitated hydrates.

"Since Martinswerk is now part of Huber, it is a logical step to create a strategic global product platform for our customers," said Martin Schulting, managing director of Huber's FRA European business.

"The transfer will allow customers in North America to source high quality Martinal LEO grades locally resulting in reduced lead times and freight costs," added Jerry Bertram, vice president and general manager of Huber's FRA business.

"It will increase global capacity for Martinal LEO grades and creates more flexibility in our supply chain to service customers in the Asia Pacific and other regions of the world, as we will have two plants on two continents capable of manufacturing the Martinal LEO product portfolio."

Production trials for the Martinal® LEO products at Bauxite have been completed and commercial availability is planned for third quarter 2017.

In addition to the Martinal LEO grades, the Bauxite plant will continue production of its existing portfolio of Hydral® precipitated hydrate products.

Huber – USA
Website: www.huber.com

New role at Miltec

Herbert Freyre joined Miltec at the end of September 2016 as a manufacturing engineer and was recently promoted to manufacturing engineering manager.

He has years of experience in several industries, including aerospace and oil and gas.

Mr Freyre has a diverse set of skills that he uses to define manufacturing processes while working closely with production staff.

He has experience with cost reduction, continuous improvement, training of staff, quality systems, and equipment maintenance and reliability.

He has a BS degree in mechanical engineering from Catholic University of Peru. He also has an MBA and holds a Lean Six-Sigma Green Belt Certification.

Bob Blandford, Miltec's president, said: "We are fortunate to have found such a talented individual to support our growth and development."

Miltec UV – USA
Website: www.miltec.com

New record for HVDC technology at 640kV

BOREALIS and Borouge, providers of innovative, value-creating solutions for the wire and cable industry, has set a new world record of 640 kilovolt (kV) for extruded high voltage direct current (HVDC) cable technology.

The record-breaking voltage level and the robustness of a cable system based on Borlink™ LS4258DCE and Borlink™ LE0550DC was proven by way of successful type and pre-qualification testing in accordance with CIGRÉ recommendation TB496.

This innovative material technology enables the efficient delivery of even more transmission capacity over longer distances, better interconnectivity among countries and grids, and better connection of renewable energy sources to future grids.

Borealis is building on more than 15 years of operational experience in extruded HVDC materials and its proprietary Borlink™ technology to set higher standards in proven system performance. This new step-change in electrical performance has been made possible due to the properties offered by tailored polymers based on Borlink, in combination with the high levels of chemical and physical cleanliness these compounds offer. Production of these tailor-made compounds takes place at Borealis' facilities in Stenungsund, Sweden, and Antwerp, Belgium.

▲ *Borlink extruded HVDC technology set a new record at 640kV. Photograph courtesy of nkt*

This HVDC innovation was developed in partnership with nkt cables. It was first unveiled in 2014 at the CIGRÉ Session in Paris, France, after a record-breaking 525kV proven performance level based on Borlink LS4258DCE and the semicon Borlink LE0550DC. The same HVDC material solution based on cross-linked polyethylene (XLPE) now offers the next level of performance.

By leveraging their combined industry experience and proven track records, both companies have now set the 640kV record. This is the highest voltage ever for extruded HVDC technology, therefore a clear proof of system robustness and technical margin.

In real terms, one pair of 640kV HVDC extruded cables can transmit over 3 gigawatt (GW) of power from renewable sources. This is equal to the combined output of the six biggest hydroelectric power plants in Sweden. Put another way, a single pair of 640kV extruded HVDC cables could, for example, transmit enough green power to supply about three million households. This equals around 80 per cent of the 3.8 million Austrian households.

The broader significance of this HVDC innovation is apparent when considering the challenges and opportunities faced by the energy industry. HVDC connections can deliver power over longer distances with less energy loss, and are thus well suited for subsea and underground applications, including transmission from offshore windfarms. The innovation addresses the need for better interconnection of countries and grids, increased transmission capacity, efficiency and supply security.

Borealis AG – Austria
Website: www.borealisgroup.com

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Cutting edge technology, superior service and support

THE latest issue of *Niehoff Magazine*, the customer journal of the Niehoff Group, is available now. The magazine relates to the trade fairs Interwire 2017 and wire Russia 2017.

Under the title "Cutting edge technology, superior service and support", the exhibits shown at Interwire 2017 by Maschinenfabrik Niehoff and its subsidiary Niehoff Endex North America Inc (NENA) are described along with technical data: An MMH 121 + RM 201 multiwire drawing line, an MSM 85 rod breakdown machine and a D 801 type double-twist bunching machine. Also the Niehoff Original+ After Sales service range is introduced.

At wire Russia 2017 trade fair Maschinenfabrik Niehoff and its sales and service subsidiary Niehoff of Russia (NoR) displayed a double spooler type SV 402 D, also described in the magazine.

Two articles analyse the outlook for the wire and cable industry on the North American and Russian markets while the main article of the magazine deals with conductors made from aluminium materials and their application for energy transmission in overhead conductors, automotive wires and installation cables.

Additionally, readers get some information about current further developments of Niehoff technology such as a completely new spool type NPS 400/400 PP and current-regulated corrective anodes for the WPT galvanic wire plating lines.

The new spool type raises the profitability of the Niehoff Package System, NPS.

The corrective anodes keep the tin content of the electrolyte constant, resulting in several economic advantages for users.

Maschinenfabrik Niehoff GmbH & Co KG – Germany
Website: www.niehoff.de

myNDC is launched

NDC has launched its NDC service cloud, myNDC, which will simplify the customer's interaction with the company, ensure focus of the customer service team on problem solving, and enable flawless execution, supporting its customers.

The company is offering incident management tools to its customers in the Americas, EMEA and Asia Pacific immediately, and these will be introduced to the China market later this year.

myNDC will simplify IT infrastructure to replace multiple applications that were used to provide customer service. myNDC enables a seamless customer service agent experience to create tickets, and view a customer's installed base or service history.

NDC's service team will be able to execute service requests more comprehensively using a knowledge base, and optimise its global resources to deliver excellent levels of service.

Beta LaserMike
(an NDC Technologies brand) – USA
Website: www.betalasermike.com

Press and die perfectly tailored to one another

WHEN the press, automation and die all originate from a single source, the advantages are numerous: It is no longer the customer's concern to ensure that all components perfectly interact, it is now the manufacturer's.

Schuler has incorporated system solutions of this kind for lines for producing laminations for electric motors and generators in its range.

▲ *The Smartline from Schuler for the interlocking of electric motor laminations machines a blank thickness of 0.2mm. Photograph courtesy of Schuler*

"Indeed, we not only produce the presses and automation, but the dies as well," said Johannes Linden, division manager of systems at Schuler. Aweba's, CEO, Udo Binder, added: "As such, the lines are optimally tailored, service lives are increased and the costs for our customers are reduced." Furthermore, with more than 900 service employees worldwide, Schuler provides expert support 24/7.

The system solutions for the manufacture of electric motors became possible following the acquisition of Aweba in 2016. The Saxony, Germany-based die manufacturer is a specialist for electric motor laminations and constructs cutting dies in all conceivable versions and sizes.

The portfolio ranges from small precision progressive dies for small transformer blanks, to interlocking dies with hard metal active parts for maximum production rate and maximum precision, through to the overall cutting of metre-long segment blanks for large-scale generators with pneumatic or servo-regulated ejector systems.

With the PerFormer S, Schuler presented a new notching machine in 2016, which is able to produce electric motor laminations with a diameter of 80 to 1,800mm.

With a notching precision of hundredths of a millimetre, the machine ensures the precision required for thin blanks with a low cutting clearance.

For the interlocking of electric motor laminations, Schuler developed the "Smartline" press, which has been on the market since 2011.

The line machines a blank thickness from 0.2 to 1mm and enables the production of electric motors with lower eddy current losses and a higher degree of efficiency with decreasing current consumption.

The Smartline also operates to a hundredths of a millimetre precision, despite its 3.3m-long press bed.

Schuler AG – Germany
Website: www.schulergroup.com

Transatlantic Cable

Telecom

In Washington the charged issue of net neutrality is back, with opponents of the strict Obama-era rules now in the driver seat

US regulators on 18th May took the first formal step toward repealing tough net neutrality rules enacted two years previously during the presidency of Barack Obama – rules which introduced strict oversight of Internet service providers to ensure the free flow of online content. The prospect of the dismantling, enthusiastically welcomed by major broadband providers, is strongly opposed by consumer advocates and lawmakers of Mr Obama's Democratic party. The net neutrality rules prohibit Internet service providers from blocking websites, slowing connection speeds, and charging extra for faster delivery of certain content. To facilitate enforcement, the FCC in 2015 classified broadband as a utility-like service under telecommunications law.

Writing from Washington DC in the *Los Angeles Times*, Jim Puzzanghera observed that the intended reversal by the newly Republican-controlled Federal Communications Commission (FCC) is part of a broader effort under President Donald Trump to undo regulations promoted by Mr Obama. FCC chairman Ajit Pai said the goal of his agency is to return to the looser regulatory framework of the early days of the Internet. ("'Light-touch' Regulations: FCC Takes Step to Repeal Tough Net Neutrality Rules," 18th May). Supporters of strict government oversight assert that it is essential to preserving ready access to high-speed Internet. Senator Kamala Harris, a California Democrat, told Mr Puzzanghera, "Those net neutrality rules guarantee that gatekeepers to the Internet cannot tilt the competitive playing field."

A final vote in the FCC is not likely before winter, but the makeup of the three-person agency – two Republicans and one Democrat – favours repeal of the net neutrality rules. Meanwhile, public controversy has been heating up. In the view of the Trump appointee Mr Pai, now the nation's top telecommunications regulator, the current rules give regulators too much control over the Internet and have led to reduced investment in broadband networks. As the *Los Angeles Times* pointed out, the evidence on this is open to dispute.

John Oliver redux

One of the loudest and most influential disputants is the cerebral British-American cable TV host John Oliver, whose appeal to his viewers to besiege the FCC with their protests was a major factor in the passage of the net neutrality rules. Battle lines between Messrs Pai and Oliver have been drawn in the current fracas. No doubt in anticipation of another tsunami of support for the rules during the public comment phase of the review process, Mr Pai said, "As in any FCC rule-making what matters most is the quality of the comments, not the quantity."

- But the civic-minded Mr Oliver is known for quality – in his grasp of the issues as much as for his presentation. On 17th May, Mr Puzzanghera reported that, in the three weeks since the FCC began accepting public comments, more than 1.6 million of them had been submitted. Many of these were inspired by another net neutrality segment on "Last Week Tonight with John Oliver," aired 7th May. Now, as in 2014 when the issue first came to the boil, a majority of the respondents are believed to favour retaining the tough rules.

Industrial Internet of Things awareness has accelerated in the last year, but identifying opportunities is a stumbling block

According to the results of a survey of 374 manufacturers worldwide undertaken by the MPI Group late last year and published this spring, the industrial Internet of Things (IoT) has gathered steam. As reported by Ian Scales of *TelecomTV*, the 2017 survey is a follow-up to one conducted by MPI (Sunnyvale, California) a year earlier. Those results disclosed that a full two-thirds of the executives polled were without an IoT strategy. That proportion has flipped, noted Mr Scales, with two-thirds of the respondents now saying they have an IoT strategy and many reporting that they already have seen concrete results. ("Industrial Internet Suddenly Fires Up: Executives Claim Productivity and Profit Gains," 16th May). The 2017 study looked at the production of smart devices and the implementation of embedded intelligence within plants, processes and products of manufacturers around the world. While many smaller manufacturers are still unsure how to get started, MPI Group CEO John R Brandt told *TelecomTV*, "There's been a dramatic jump in awareness."

Among the mixed results the good news predominates:

- Implementation is up, with 50 per cent of production processes now using the IoT, and 68 per cent of the manufacturers reporting plans to embed smart devices or intelligence into their products;
- Seventy-two per cent of the interviewees reported increased productivity from application of the IoT to plants and processes; 69 per cent, increased profitability;
- Sixty-five per cent of the respondents reported increased profitability from sales of IoT-enabled products (eg embedded intelligence).

Image: www.bigstockphoto.com Photographer Zsolt Ercsel

Transatlantic cable

According to 46 per cent of the manufacturers, identifying opportunities for implementing the IoT remains the biggest challenge. Another concern is ensuring the availability of IoT data to everyone within the company who needs it. Only 34 per cent of the MPI respondents expressed confidence that all their pertinent people have this ready access. Even so, noted Mr Brandt, his company's research from two years ago showed that a significant percentage of manufacturers had not even heard of the Internet of Things. Now, he said, "It's become a crucial weapon in their arsenals."

In brief . . .

- T-Mobile Netherlands in mid-May claimed that it would be the first Dutch operator to provide nationwide coverage for its Internet of Things network. Activation of NB-IoT was scheduled within weeks of the announcement. T-Mobile Netherlands also said that it is looking to invest in business partnerships to explore opportunities in IoT applications. In other words, wrote Mr Scales of *TelecomTV*, "[They've] got the tech if you've got the brilliant idea."

Automotive

USA diesel sales are fading fast as post-Volkswagen regulator scrutiny keeps some models off the market

While Mercedes-Benz said its exit from the American passenger diesel market may not be permanent, the German car maker's decision to pause its USA diesel plans dealt a further blow to the technology's small and dwindling share of auto sales in the country. Mercedes says that fewer than one out of every 100 cars sold in the USA is a diesel. On 9th May, Daimler AG's luxury car brand halted efforts to obtain certification to sell 2017 model year diesel versions of its C-Class sedan, GLE SUV and other cars in the USA. The reason cited was the tiny share of the market commanded by diesels and the 'increased effort' needed to obtain approvals from USA environmental regulators.

To Ryan Beene of *Bloomberg News*, the explanation highlights the struggle of auto makers trying to sell diesels in the USA. Their prospects are worsening as costs rise to meet toughening pollution rules and as scrutiny from the Environmental Protection Agency (EPA) keeps models off dealers' lots. ("America's Diesel Car Market Gets Even Smaller," 10th May). Dave Sullivan, an industry analyst with car consultancy *AutoPacific* (Tustin, California), gave *Bloomberg* a dismal reckoning of the situation: "Diesel's future has been relegated back to what it was about 20 years ago – an engine choice for pickup trucks."

Much of the decline in sales derives, of course, from the scandal at Volkswagen AG, which pulled 12 diesel models sold by its Audi, Porsche and namesake VW brand out of the US market after acknowledging in 2015 that it had been cheating to pass federal emissions tests.

The fleeting 2017 model year

Mr Beene summed up what ensued. After VW admitted cheating, the EPA began subjecting all diesel passenger cars to a new battery of tests designed to ensure there was no other wrongdoing elsewhere in the industry.

In January, that testing led the EPA to accuse Fiat Chrysler Automobiles NV of installing diesel Jeep SUVs and Ram pickups with emission controls without the proper disclosures. The agency has since refused to certify that Fiat Chrysler's diesel Jeep Grand Cherokee and Ram 1500 pickup variants conform to USA tailpipe rules amid talks with the company to resolve the issues.

- As for Daimler, by mid-spring it had put considerable effort into trying to get its diesels approved by the EPA. But, wrote Mr Beene on 10th May, "[You can] put that process on hold as the 2017 model year enters its final months."

Of related interest . . .

- Even as it was second-guessing its USA diesel commitment, Mercedes-Benz was recruiting Utah-based Vivint Solar to introduce its home battery storage solution in the United States. By summer, Vivint was to start selling the Mercedes home batteries in California, to new customers only.

  As noted by Sean O'Kane in the *Verge* (18th May), Mercedes batteries for the home are functionally the same as those from Tesla (Palo Alto, California), its most visible competitor in this category and another car maker with an ambitious side business. Both companies' batteries let homeowners store and save electricity generated by solar panels for use around the clock.

  But a small but important difference provides prospective customers with a choice. As described by Mr O'Kane, Tesla's $5,500 Powerwall 2 has a capacity of 13.5 kilowatt-hours (kWh). The Mercedes home battery has a smaller capacity of 2.5kWh.

  Offsetting this, Vivint's offerings will be cheaper than Tesla's. The company plans to sell a basic 2.5kWh package for $5,000 for pairing with solar panels; while the complete 20kWh system will run around $13,000, including installation.

A USA investigation into Fiat Chrysler emissions controls raises the question of what constitutes a 'defeat device'

A civil complaint, filed on 23rd May in Detroit, is the formal accusation by the US Department of Justice (DoJ) that Fiat Chrysler Automobiles (FCA) fitted defeat devices to some of its vehicles. It follows the notification in January of an Environmental Protection Agency (EPA) probe of the Italian-American company's compliance with the Clean Air Act in the USA. Since then, other countries, including the UK and France, have also said they were investigating the car maker.

BBC business correspondent Theo Leggett was asked just how serious this is for Fiat Chrysler. ("US Accuses Fiat Chrysler of Using 'Defeat Devices,'" 23rd May). "It isn't into Volkswagen territory yet," said Mr Leggett. "For a start, the number of vehicles is much smaller. But there's also the question of what is, and what isn't, a defeat device." Volkswagen admitted it could not both make its cars clean enough to pass emissions tests and ensure their good performance on the road. So, wrote Mr Leggett, "It designed a software tool to do just that."

Fiat Chrysler has been accused of fitting software to its cars – not disclosed to regulators – enabling the vehicles to produce lower emissions during roadworthiness tests than they did when under normal driving conditions.

Transatlantic cable

But, noted Mr Leggett, "Car makers do use a variety of software to regulate emissions control systems – to ensure that they only work at the correct temperature, for example. Otherwise parts of the system can be damaged."

Fiat Chrysler insists that it did not set out to cheat the testing process. Nevertheless, earlier this year it was informed of the EPA's concerns and asked to provide an explanation. Mr Leggett summed up: "It seems the authorities, so far at least, aren't satisfied with what they've heard."

General Motors may be quitting the Indian domestic market but it is bullish about exports of its cars from India

Another car maker recalibrating its international ambitions is General Motors of the USA. Having determined on a global business restructuring, the firm on 19th May announced that it would stop turning out Chevrolet cars for the Indian market by the end of 2017. Its plant in Maharashtra will continue making cars but exclusively for overseas markets, mainly in Central and South America.

As noted by the *BBC*, GM had planned to invest $1 billion to boost its presence in India, but its sales for the year ended in March fell below one per cent of the market. The disappointing results were in striking contrast to another set of company figures for the same period.

"In India, our exports have tripled over the past year, and this will remain our focus going forward," GM's international president Stefan Jacoby said in a statement.

An irony of the decision is that it comes amid predictions that India will become the world's third-biggest vehicle market by 2020. But GM, nothing daunted, has disclosed roughly similar export-centred plans for South and East African markets.

The American car maker said it would stop offering cars in South Africa and sell its manufacturing business there to Isuzu Motors. The Japanese maker of commercial vehicles and diesel engines will also purchase a 57.7 per cent share in GM's East Africa operations, assuming management control.

"As a result of these actions, GM expects to realise annual savings of approximately $100 million and plans to take a charge of approximately $500 million in the second quarter of 2017," the company said in a statement.

- As a small indication of possible ambivalence about taking itself out of the domestic Indian market forever, GM said it will continue to provide maintenance services to Indian owners of its cars.

'Big rigs'

Owing more on their equipment than the resale value, long-haul carriers in the USA are stymied at a bad time for the industry

The term "underwater" was heard often in the USA during the recession of 2007-2009, when a precipitous drop in the value of real estate left many owners with high-payment mortgages on low-worth properties. Similarly, now, a market glut of used heavy-duty trucks has brought "upside down" into common use among long-haul carriers, many of whom owe more on their trucks than they can expect to realise at resale.

Large American long-haul trucking companies typically run a truck for three to five years. Because repair and maintenance costs tend to soar after about 500,000 miles, the owner will generally seek to offload the equipment before the warranty expires.

This background was provided by Jennifer Smith of the *Wall Street Journal*, who recently reported on the glut of used big rigs that is oppressing USA trucking companies already affected by a prolonged slump in the freight market. When transportation demand was booming a few years ago, fleets bought scores of new trucks – main assets for many of them.

"Then US manufacturing activity flagged and import growth slowed as retailers rang up disappointing sales," Ms Smith wrote. "Freight volumes started stalling out in late 2015, leaving too many trucks competing for cargo." Following one of the steepest plunges in used-truck prices since the recession, that pattern has been disrupted. ("Trucking Industry's Tale of Woe: Too Many Big Rigs," 12th May)

According to JD Power Valuation Services, the average retail price for a used Class 8 sleeper, the heavy-duty tractor used for long-haul routes, plunged some 22 per cent, to about $49,000, over the two years through March. As noted by Ms Smith, that translates to a decrease of some $140 million across a fleet of 10,000 trucks.

- In April, Ryder System Inc (Miami, Florida), a commercial-truck operator with a large leasing and commercial rental division, reported that its first-quarter earnings fell 32 per cent from a year earlier. The company blamed in part the soft used-vehicle market, as well as weaker-than-expected demand for commercial-vehicle rentals.

  "Some carriers that expanded their fleets now are cutting the number of trucks they run," wrote Ms Smith. "That feeds more vehicles into the market and works to keep used-truck values down."

- Chris Visser, senior commercial-truck analyst at JD Power, told the *Journal* that, while used-vehicle prices are showing signs of bottoming out, the supply of used big rigs is expected to remain substantial into 2020. If freight demand fails to improve, he said, pricing will remain depressed.

Steel

A falcon 41 feet tall and with a 68-foot wingspan is made entirely of stainless steel – 36.5 tons of it

Already home to the National Football League (NFL) team Atlanta Falcons and the professional soccer club Atlanta United, the huge Mercedes-Benz Stadium (seating capacity: 70,000) is about to welcome another impressive tenant – the world's largest free-standing bird sculpture.

The engineering marvel being installed on the main plaza of the stadium faces the city skyline and is vividly present to those approaching. As described by Joe Reisigl of *Atlanta* magazine, "It seems poised to intimidate any fans of the opposing team with its fierce glare, razor-sharp steel plates stabbing out of its body like daggers, and talons seized tight around a bronze

football." ("A Giant Stainless Steel Falcon Is Rising Up in Front of Mercedes-Benz Stadium," 7th May). The sculpture was designed and assembled by Hungarian artist Gabor Miklos Szoke, who makes a speciality of monumental steel animals and crafted the bird at his studio in Budapest. Mr Reisigl reported that the 1,000 laser-cut pieces travelled more than 5,000 miles by container ship to Savannah, then went by truck to Atlanta.

Special packaging was required to prevent humidity and salt air from rusting the steel, both in transit and in the subtropical climate of Georgia.

After the arrival of the components, in March, the sculpture was assembled via crane. Because it weighs a whopping 36.5 tons – the wings weigh 3.5 tons each – placement was an important consideration. To prevent collapse under its own weight, the structure and its platform are precisely positioned over a buried load-bearing vertical column.

- According to *Atlanta* magazine, the falcon project originated two years ago with Atlanta Falcons owner Arthur Blank, whose artistic vision for the new stadium went beyond the customary sports photos and paintings. But it seems possible that a certain spirit of rivalry may also have stirred in Mr Blank. Among the figures studied by his art committee were the bronze panthers at Bank of America Stadium in Charlotte, North Carolina, headquarters of the Carolina Panthers of the NFL; and the nine heroic-sized tiger statues at Comerica Park (home of the Detroit Tigers baseball team), including the two prowling the scoreboard in left field. The beasts' eyes light up after a victory by the home team, to sound effects of growling tigers.

Elsewhere in steel . . .

- In April, President Donald Trump instructed the US Department of Commerce to commence an investigation into imports of steel on grounds of concern for national security.

  Although Chinese steel makers have a quarter of the USA steel market – about 30 million metric tons (mt) a year – USA authorities denied that the initiative, which could see huge tariffs placed on imports of foreign steel, targets any single nation.

  If the investigation should lead to across-the-board tariffs on steel imports, Britain's steel makers fear they could be dealt a heavy blow. Industry editor Alan Tovey of the *Telegraph* reported that the trade association UK Steel has appealed to Liam Fox, the secretary of state for international trade, to contact his opposite number in the USA requesting assurance. ("UK Steel Makers Lobby Not to Be Cut Out of Vital American Market," 13th May)

  The USA is a leading market for British steel, taking 250,000 metric tons of the 7.6 million mt produced annually in the UK. These exports to the USA account for $442 million in sales each year.

- According to an article in *Numismatic News Express* (6th May), since 2006 it has cost more than their face values to produce the USA one-cent and nickel coins, and the US Mint has been looking into cheaper alternative compositions.

Dorothy Fabian – USA Editor

▲ *CFCRANE.PUR from igus*

Medium voltage cable for long-travel crane installations

IGUS has developed the new chainflex medium voltage cable, called CFCRANE. PUR, suitable for very long travels of up to 1,000 metres, such as those found in crane installations.

Motor cables of this series are highly flexible, flame retardant, and oil and UV resistant.

As a retrofit solution or for special projects, they are now available to order from stock.

"In the crane and material handling sectors, installations are getting increasingly larger and working at ever-higher dynamics and duty cycles," said Justin Leonard, igus.

Rated for voltages of 6/10kV, the cables are suitable for use in both indoor and outdoor applications, due to the special conductor structure and combination of the materials used. In addition, the CFCRANE.PUR series is up to 20 per cent smaller in diameter in comparison to conventional motor cables, with a bending radius of 10xd.

Tested in the igus test laboratory, as with all 1,244 chainflex cables, these cables are available from stock with a lifetime guarantee of 36 months.

igus – UK **Website**: www.igus.co.uk

Meeting requirements

Ajex & Turner, India, produces high quality trapezoidal wire drawing dies and sector shaped conductor dies.

The company is able to serve its customers with any special tooling, such as shape drawing dies (trolley, oval, trapezoidal, rectangular, square, triangle, sector, etc) and sector shaped compacting dies for bunching and stranding lines. Fundamentally this kind is used in the wire design and cable manufacture industries.

Trapezoidal/shaped wire drawing dies apply to rod break down machines and drawing machines, and are used in wire drawing. Sector shaped compacting dies (D shape sector dies) are used on rigid stranding machines and are suitable for use in the production of low voltage underground power cables or similar.

Ajex & Turner Wire Dies Co – India **Website**: www.ajexturner.com

Next-generation connectivity solutions on show

Huber+Suhner, a manufacturer of components and systems for optical and electrical connectivity, unveilled its latest data centre solutions to the American market at Data Center World Global earlier this year.

At the event, the company showcased its LISA side access system – designed to further improve flexibility, practicality and user-friendliness with regard to cross-connect solutions – as well as IANOS, Huber+Suhner's most advanced and adaptable fibre management system to date.

The expanded IANOS system offering is based on a modular cassette/tray solution. This facilitates rapid deployments as well as easy alterations for best-in-class handling and scalability, all of which are key factors in operating data centres.

The design allows complete customisation and configuration offerings according to various customer needs.

Huber+Suhner has a history of involvement in the modernisation and future-proofing of large-scale data centres in a multitude of network systems around the world.

Its 'Building Block' technology has seen the company upgrade outdated and inefficient networking infrastructures from a 10G serial to be capable of supporting a 40G and 100G parallel optics, a network that is modern, reliable and future-proof.

Data centres in general face issues including overheating, limited network cable transmission range and reliability of service.

These issues are directly addressed and mitigated through the integral modular and compact design of Huber+Suhner's data centre solutions reducing the risk of system failures and maintaining a reliable, sustainable and cost-effective communication infrastructure.

Huber+Suhner – Switzerland
Website: www.hubersuhner.com

Data cable manufacturing systems

▲ *Data cable stranding line with DSI 631 type double-twist stranding machine combined with an upstream backtwist pay-off and a longitudinal tape pay-off*

CABLES for vehicles, IT systems, the energy sector and other application sectors must meet continuously increasing requirements.

In order to keep pace with this development, cable manufacturers need machinery which can produce complexly designed cables, work in an energy, raw materials and cost-effective way and can be flexibly adapted to new production requirements.

Cable machinery developed and built by Niehoff meets all these requirements.

One example is the DSI 631 type double twist stranding machine which has been designed for the stranding of insulated conductors into pairs and quads and the stranding of four conductor pairs into LAN cables.

The machine is able to manufacture reliably LAN cables of all categories – even of future generations – as well as pairs with tape shielding, bus cables and other telecommunications cables. The DSI stranding machines system includes a lot of additional auxiliary equipment, so that customer-specific production lines can be created and rapidly rebuilt depending on the order situation.

Maschinenfabrik Niehoff GmbH & Co KG – Germany **Website**: www.niehoff.de

Stable energy chain for lift devices

TSUBAKI Kabelschlepp has launched the TKK series, a new cable carrier for small installation spaces in harsh conditions, as required, for example, with lifting devices.

TKK39 is self-cleaning and extremely stable, while remaining light and compact. It delivers particularly high torsional rigidity and supports long unsupported travel of up to 5m.

The space-saving design of the TKK39 offers, among other things, an installation height of only 142mm – in comparison to alternative solutions, Tsubaki Kabelschlepp was able to reduce the installation height by 65 per cent.

The energy chain can be used when both self-supported and gliding. It supports speeds of up to 3m/s and accelerations of 9m/s^2. Short steel connecting elements allow for swift and easy assembly – they are directly bolted onto the console or support.

The chain links are made entirely of plastic, whereby Tsubaki Kabelschlepp also offers hybrid chains with aluminium stays and steel chains as an alternative to this particular weight-optimised version.

In lifting devices, energy chains in an external arrangement are exposed to the weather conditions and, depending on the application, can be affected by dirt or falling objects.

To ensure smooth operation despite these difficult conditions, the cable carriers of the TKK series are equipped with a dust, dirt and chip-proof stroke system as standard. The dirt simply runs off the very smooth surface. The energy chain is self-cleaning in movable applications: specially installed bevels break up the dirt so that it can then be discharged – compacting or caking is therefore avoided.

The divider construction of the TKK39 is also ingenious: the cable carrier is equipped with lockable brackets for optimal cable protection which swivel inwardly at any position depending on the stay variant.

Dividers which are adjustable or fixable in 2mm increments together with a flexible height separation made of plastic or aluminium enable optimal separation of the cables.

Tsubaki Kabelschlepp – Germany
Website: www.kabelschlepp.de

▲ *Tsubaki Kabelschlepp presents with the TKK series a new cable carrier for small installation spaces in harsh environmental conditions*

Sikora service competence

Fast, competent and reliable support for customers all over the world – Sikora meets these requirements with the Smart Assistance Manager (SAM). For its customers, this means a significantly more efficient support and, therefore, optimised service processes.

A device for professional service, Sikora's Smart Assistance Manager is a 13.3" tablet optimised for the rough industrial environment. With the Smart Assistance Manager, customers are able to establish a direct connection with a support engineer to receive instructions for all maintenance, support and diagnostic tasks via the integrated video chat feature (5 MP camera). The support engineer uses the SAM for a direct connection to the Sikora device to receive an immediate diagnosis in real-time or to upload software updates.

The assignment of the Smart Assistance Manager starts with the installation of the measuring device. With the SAM, customers can show the company the environmental conditions as well as the line layout. The support team is happy to assist, starting with information on the best possible positioning of the equipment.

Due to diverse connection possibilities, such as USB 3.0, RJ 45 Ethernet, Bluetooth 4.0 and the LTE/UMTS module, as well as various application possibilities, the Smart Assistance Manager is an important tool for modern production lines, for example to support maintenance and diagnosis tasks, as well as for Smart Factories in the era of Industry 4.0.

The individually designed licence module guarantees the most current version of the Sikora diagnosis software.

Sikora AG – Germany **Website**: www.sikora.net

Lower operating cost and increased efficiency

A NEW vacuum resin dryer enables more moulding and extrusion processors to obtain the advantages of vacuum dryers over conventional desiccant systems, including lower operating cost, increased efficiency and greater control over the drying process.

The VBD™ 300 vacuum dryer from Maguire Products Inc achieves throughputs of up to 300lb (136kg) per hour, which is double the capacity of the company's VBD 150 model.

While the VBD 150 is sized for the throughputs of many injection moulding machines and of small extrusion lines like those for medical tubing, the new VBD 300 model opens the benefits of vacuum resin drying to a broader range of applications.

Maguire also offers the VBD 1000 dryer for high-volume operations.

In comparison with desiccant dryers, the VBD vacuum dryer consumes 60 per cent less energy, dries resin in one-sixth the time, and substantially reduces the heat history to which polymer is exposed.

The speed with which the VBD system removes moisture makes properly dried polymer available for production only 35 minutes after a cold start.

Like other VBD models, the VBD 300 dryer is a gravimetric system that employs load cells that precisely monitor the weight of material at two critical points, enabling precise control over material consumption and documentation of process conditions for certification to customers.

Use of load cells also enhances control over the drying process, according to Frank Kavanagh, vice president of sales and marketing for Maguire Products.

VBD vacuum dryers use gravity to move material through three vertically arranged stages of the drying process, with the discharge of material from one stage to the next controlled by high-speed slide-gate valves with an accuracy per dispense of ±4 grams.

The vessels for the three stages are, from top to bottom: a heating hopper that brings resin to a target temperature; a vacuum vessel in which vacuum reduces the boiling point of water, causing moisture within the pellets to volatilise and be forced out of the pellet into the low-pressure environment surrounding it; and a pressurised retention/take-away hopper that is continually purged by a membrane air dryer to maintain the target level of dryness until the material is discharged.

▲ *The VBD™ 300 vacuum dryer from Maguire Products*

The vacuum vessel and retention hopper are mounted on load cells.

The VBD 300 dryer has an intuitive, easy-to-use touchscreen controller that allows operators to manage all drying parameters from just one screen.

Like all Maguire equipment, the new dryer comes with a five-year warranty.

Maguire Products Inc – USA
Website: www.maguire.com

Inspection and analysis of plastic pellets

THE purity of the material is an important criterion in plastic production and processing. Sikora's programme of innovative inspection, analysis and sorting devices inspects raw plastic material and detects impurities inside the pellets as well as on their surface.

Online analysis: The Purity Scanner for the on-line inspection and sorting of plastic pellets has been successfully integrated into production lines worldwide. Plastic manufacturers, processors and end users use this innovative device that combines X-ray and optical technologies to check their plastic material on-line for contamination. Contaminated material is automatically sorted out.

▲ *Purity Concept X with tray*

In the segment of cable production, specifically those companies producing medium, high and extra-high voltage cables as well as subsea cables are focusing on this technology.

Off-line analysis: For smaller throughputs as well as production lines where sample testing is sufficient, or for the control of incoming goods, Sikora developed the Purity Concept Systems.

The analysis devices offer inspection by X-ray technology (X), optics (V) or infrared technology (IR). Detected are contamination in pellets, flakes and films/tapes.

The Purity Concept X inspects up to 3,000 pellets (200ml) that are placed on a tray. Within seconds, these pellets are inspected for contamination.

Subsequently, contaminated pellets are optically highlighted, which makes the extraction of the individual contamination significantly easier.

Sikora recommends the combination of the Purity Scanner and Purity Concept X for a comprehensive process optimisation.

After the Purity Scanner has successfully detected and sorted contaminated pellets, these pellets are again checked and optically marked by the Purity Concept X.

This interaction of on-line and off-line inspection and analysis enables the absolute control of the material purity as well as knowledge to prevent future contamination.

Sikora AG – Germany
Website: www.sikora.net

Compounds for the automotive world

MELOS and cooperation partner Inhol offer a wide range of radiation cross-linkable, high temperature-resistant compounds for automotive applications such as battery cables and primary wire.

Various halogen-free and halogenated products are formulated to meet standards like SAE, HMC, JASO, ISO and LV. Automotive wires, made of Melos Cable Compounds, have been approved worldwide by well-known car manufacturers. The Mecoline RDX product portfolio features a variety of solutions for cable and wire manufacturers supplying to the automotive industry.

The Mecoline range consists of six thin-wall insulation compounds for primary wire, selected to meet the high demands of the industry. Furthermore, several solutions for battery cables can be chosen, including full- or semi-flexible and oil-resistant compounds, based on either polyolefins or fluoroelastomers.

Halogen-free insulation compounds (Mecoline I RDX 1213 F & Mecoline I RDX 1229 F) are suitable for operating temperatures up to 125°C.

These fast-curing radiation cross-linkable formulations can be processed at very high line speeds. The main applications include small gauge primary insulation (SAE J1128) and appliance wire.

To reach the higher spheres of the thermometer, you should consider halogenated Mecoline RDX compounds. Maximum operating temperatures of 150°C to 225°C can be achieved. For temperatures over 200°C, sophisticated formulations based on fluoropolymers are required.

▲ *A wide range of radiation cross-linkable, high temperature-resistant compounds for automotive applications from Melos and Inhol*

Additionally, certain products offer high abrasion- or chemical media-resistance, flexibility and unique setups to serve applications such as battery cables in hybrid cars or electric vehicles. Formulations are specifically designed for standards like ISO 6722, ISO 14572, SAE J1127 or SAE J1128.

Melos GmbH – Germany
Website: www.melos-gmbh.com

Inhol BV – The Netherlands
Website: www.inhol.com

Advertorial on behalf of Decalub

Die wear – way to eliminate it

Unavoidable fines (abrasive particles) generation, the most destructive lubricant contaminants in wire drawing, is no longer an alarming phenomenon since the introduction of the Decalub green and dry rod preparation and wire lubrication including PDH coating system.

▲ *Wire coating by PDH system*

In the most demanding wire drawing applications, the PDH die's wear is reduced to a unmeasurable level (about 0.2 micron per tonne), meaning that three-body abrasive wear is virtually eliminated, thus revolutionising the wire drawing process.

The PDH lubricant film created is of such a configuration as to induce a hydrodynamic lubricant activity causing migration of all lubricant contaminants, including fines, rust oxide and scale, without interference with the die, meaning the removal of encapsulated abrasive particles prevents die wear, enabling wire frictionless drawing at extreme speed and much lower temperature, and achieving an excellent wire smooth finish not difficult to water clean in-line.

Applications include all plain carbon wires up to 0.98 per cent carbon, coated or uncoated, and stainless steel alloy wires up to 26 per cent chromium, where the PDH high-performance specific anti-friction coat is automatically controlled in hardness and thickness, adjustable at will up to 15 microns, largely sufficient to capture, encapsulate and retain liberated abrasive particles from wire surface and ensure abrasive particles removal without interference with drawing dies.

Decalub – France
Email: info@decalub.com
Website: www.decalub.com

INTERWIRE
TRADE EXPOSITION
8-11 May

Overview

- **The show proved a successful one for PWM, a manufacturer of cold welding equipment, which exhibited two of its best-selling machines at the event. "Visitor numbers were good and the booth was busy, with our EP500 rod welder and heavy-duty M101 cold welder in particular generating a lot of interest," said managing director Steve Mepsted.**

- **Exhibitor Orlando Martinez of Davis-Standard LLC said: "The overall impression of the D-S team is that Interwire 2017 was a solid show and provided us with good leads. We learned about good projects we did not know about, and had a chance to meet with customers we're currently working with in a more relaxed setting. Atlanta is such a great venue for this show."**

- **"This was one of the best Interwires on record," said Jeff Swinchatt, director of sales and marketing for The MGS Group. "We were excited to see all our friends from the industry and meet some new ones. This year's event highlighted serious conversations and enthusiasm for our newest system capability. It was a great opportunity to show off our latest accomplishments and catch up with our friends."**

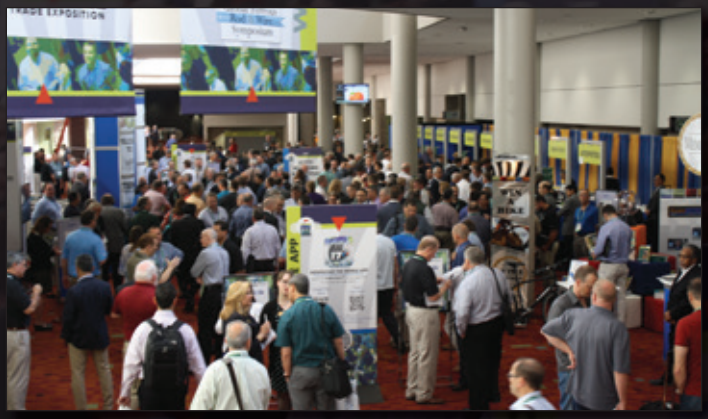


Photo credits – www.wirenet.org

www.wirenet.org

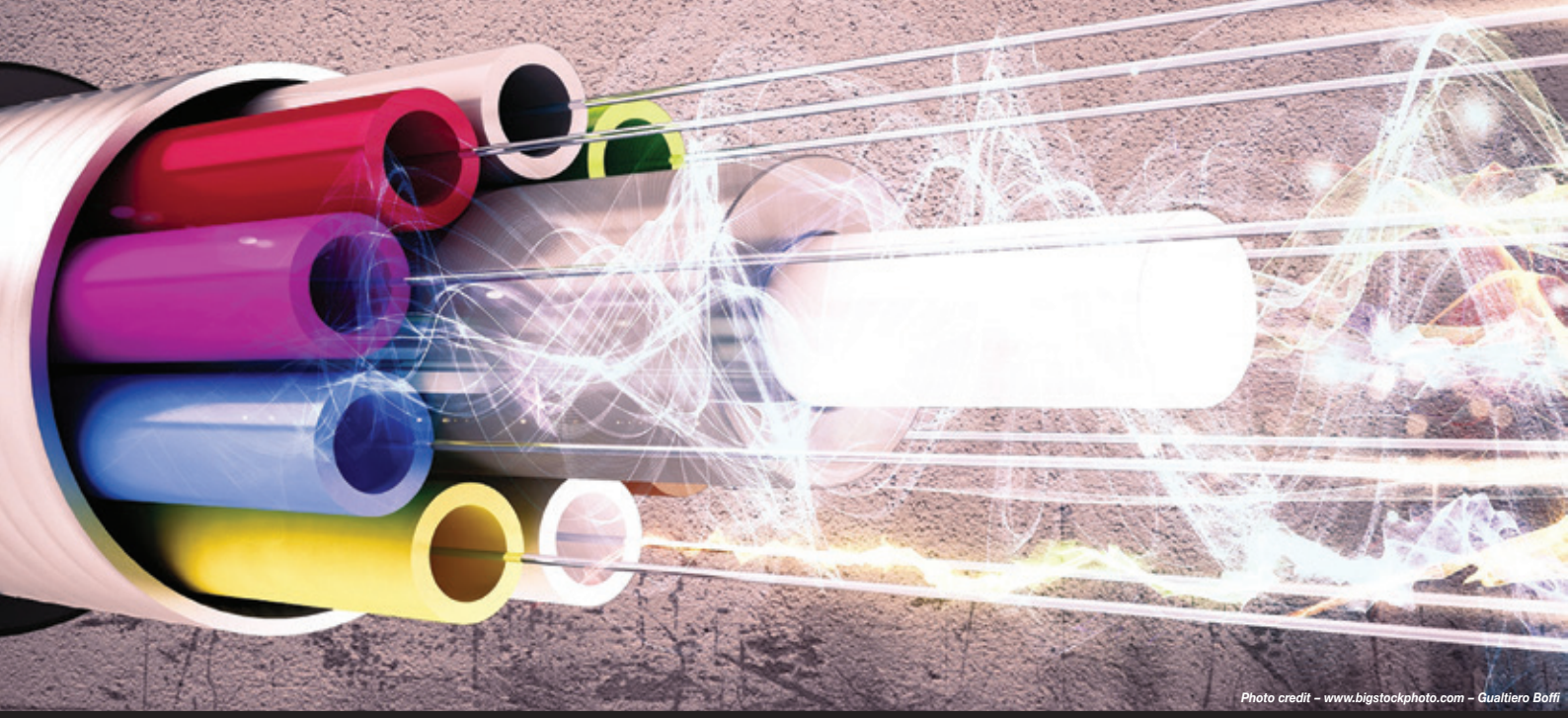


Photo credit – www.bigstockphoto.com – Gualtiero Boffi

Review 2017

Praise heaped on Interwire 2017

President of organisers the Wire Association International, David Hawker, led the plaudits to Interwire, which was staged in Atlanta, Georgia, USA, in May. "Interwire was a success and it accomplished a number of our objectives. The training and technical programmes and the Ferrous Symposium helped educate a cross section of industry professionals," enthused Mr Hawker.

This year's event comprised three sections: Interwire 2017; WAI's 87th Annual Convention; and its first Global Ferrous Rod & Wire Symposium. More than 3,800 attended. "We had a sold-out exhibit floor, tremendous involvement of corporate sponsors, and incredible level of volunteer participation, which all point to the health and commitment of WAI's support network," added Mr Hawker. "The level and stature of the attendees confirm that Interwire is a core event in our industry. During the show, we recognised four individuals from our manufacturing base for their contributions to the industry. I thank all who contributed to and attended the event and I look forward to Interwire 2019."

The Interwire exposition comprised more than 400 exhibitors from 25 countries that participated to showcase wire and cable products, machinery, ancillary equipment, and services, with 65 companies being first-time exhibitors. The footprint of the show consumed 110,000ft$_2$ of exhibition space in Hall A of the Georgia World Congress Center.

This first-time "conference within a conference" was a discrete programme focusing exclusively on topics of interest to the ferrous industry.

The GFRWS schedule ran concurrently with Interwire offering technical presentations on processing, equipment improvements, testing, quality, and measurement techniques. The programme also featured a reception at the College Football Hall of Fame. The WAI issued its top honours to Richard R Miller, a former Southwire Company executive and winner of the Donnellan Memorial Award; and to Harold Moss, Mordica Memorial Award winner. Keynote speaker Rick Smith, a 3D printing expert and best-selling author, had the full attention of the audience during his talk.

The manufacturing management workshop provided tailored instruction for operations managers and supervisors to pick up where on-the-job training leaves off.

Additional highlights included a two-part tour of Southwire Company LLC in Carrollton, Georgia, where visitors saw its utility products plant and its building wire cable plant; WAI's welcome reception at the Omni Hotel; a member rewards luncheon and raffle; and association leadership meetings.

The Wire Association International – USA
Website: www.wirenet.org

TPV-Based Insulation for Medium Voltage Applications

By Andrea Galanti, Stefano Dossi and Andrea Magri of Mixer SpA, Ravenna, Italy, and Camillo Cardelli, iPool Srl, Pistoia, Italy

Abstract

The development of three fully thermoplastic lead-free medium-voltage (MV) insulation compounds based on the thermoplastic vulcanisate (TPV) technology is presented in this paper. The TPV MV insulation compounds were prepared starting from a peroxide curable lead-free MV insulation, which is the actual market benchmark. For this reason, they were extensively investigated in comparison to the standard lead-free MV insulation. To evaluate the results of the dynamic vulcanisation process, the compounds were studied by means of differential scanning calorimetry (DSC). To simulate the extrusion behaviour, their rheology was investigated. Mechanical properties were measured before and after ageing at 135°C and 150°C up to 21 days. Finally, a comprehensive study on their electrical features, in dry conditions (from 25°C to 90°C) and wet (up to 28 days at 90°C in water), is presented.

1 Introduction

Twenty years ago, both XLPE and EPDM-based insulation systems were used in many parts of the world for MV cable applications. North America remains a very active market for EPDM-based MV insulations, while in other parts of the world XLPE is preferred. Recently, we are seeing a renewed interest in EPDM-based MV insulations in the global market due to the unmatched performance in cable lifetime for long-term applications (>20 years).

Since 1996, Mixer SpA has produced MV insulation compounds based on EPDM and EPDM/LDPE blends: its strategy is to offer innovative and competitive materials to the cable market, believing that the continuous improvement of materials will give a new life to rubber cables for special applications.

▲ **Figure 1**: *MV insulation containing lead (orange) and lead-free (white), from pellets to cables*

The first step of this approach was the development of lead-free EPDM solutions, which were presented in 2012 and are now commercially available (see *Figure 1*)[1]. Due to the fact that lead salts are insoluble in water and therefore do not contribute to any leakage current through the insulation layer, lead oxide is one of the most effective additives in MV insulation compounds. However, lead oxide is listed in Reach SVHC (Substances of Very High Concern) for its well-known bioaccumulation risk and long lasting effects, leading to severe damage to the environment and life[2].

Mixer has successfully replaced lead oxide with an inorganic ion scavenger system capable of immobilising ions, succeeding in the production of EPDM-based lead-free MV insulation compounds with superior thermal and electrical stability. From this starting point, it has developed a new fully thermoplastic TPV for MV insulation dynamically crosslinking the lead-free MV insulation compound in a PP matrix. Mixer presents three upgrades of MV TPV compounds towards a material able to pass thermomechanical testing for 90°C and 105°C continuous operation temperature and 250°C short circuit emergency, according to the Italian standard CEI 20-86, which is, so far, the only standard on thermoplastic compounds for MV insulation.

Firstly, the preparation and the macroscopic properties of the novel MV TPV compounds is discussed. The company then investigated the novel MV TPV compounds by means of DSC to study the dynamic vulcanisation process. In the third part, the rheology of the MV TPV was analysed at low shear to simulate their extrusion behaviour.

Subsequently, the MV TPV compounds were tested for mechanical properties before and after heat ageing up to 150°C and 21 days. Electrical properties of the compounds were studied at Imerys Laboratories, Par, UK. In detail, loss factor (Tanδ), dielectric constant (εr) and volume resistivity were measured up to 90°C in dry conditions.

Additionally, Tanδ and εr were investigated after immersing the compounds in water at 90°C up to 28 days. Test results were compared to the standard lead-free MV IS79 demonstrating that an innovative, highly electrically insulating compound that simultaneously combines the properties of lead-free XL-EPDM compound with the possibility to process it as a thermoplastic material, can be offered.

2 Lead-free MV TPV compounds

2.1 Preparation of the MV TPV compounds

Lead-free MV insulation compound, MV IS79, and MV thermoplastic vulcanisate compounds, MV TPVs, were prepared in an internal mixer equipped with two counter-rotating rotors and a chamber

with 8cm³ volume. The composition of the MV TPV compounds is summarised in *Table 1*. Obviously, MV TPV79 A and B have the same ratio between elastomeric and thermoplastic phase; nonetheless, different co-agents were utilised in their formulation. This was done following the studies on co-agents influencing the properties of TPVs compounds by preventing the decomposition of PP via β-scission caused by free radicals[3].

MV IS79 was prepared by mixing all the components in the internal mixer leading to a complete blending of the ingredients. After unloading, peroxide was added at low temperature in a two-roll mill. Samples for testing were obtained by pressing the milled sheets in a compression moulding machine at 180°C for ten minutes. Specimens for mechanical properties were die cut in the milling direction.

MV TP79 compounds were prepared by mixing the lead-free compound (MV IS79) with thermoplastic polypropylene (PP) according to the ratio shown in *Table 1*. During the mixing process, as the radical reaction takes place, while the temperature rises continuously, the torque follows a characteristic pattern, which is graphically represented in *Figure 2*[4,5].

After loading the ingredients, the torque grows due to the high viscosity of the components at low temperature. Increasing the temperature, the materials start to soften and the torque drops while the blending takes place.

TPV Composition	MV TP79 A	MV TP79 B	MV TP79 C
MV IS79	75%	75%	70%
PP-1[1]	25%	25%	20%
PP-2[2]	-	-	10%

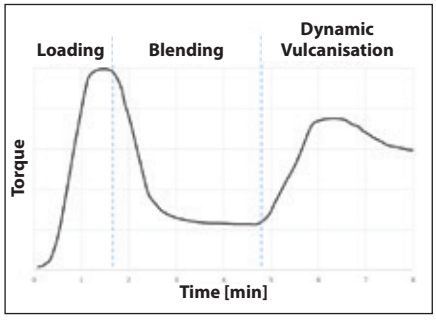
[1]d = 0.891 gr/cm³, MFI (230°C; 2.16kg) = 8.0 gr/10min; [2]d = 0.900 gr/cm³, MFI (230°C; 2.16 kg) = 10.0 gr/10 min

▲ **Table 1**: *Formulation of the MV TPVs*

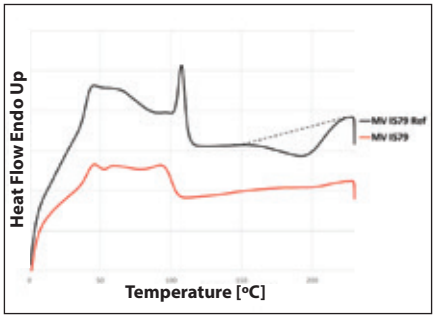
As the radical reaction begins, the simultaneous crosslinking of rubber phase and β-scission of PP phase occurs, with consequent phase inversion leading to the torque rapidly increasing. The final temperature, at which the TPVs were unloaded after about eight minutes of processing, was between 200°C and 220°C. The still hot compounds were calendered in a two-roll mill in sheet shape; plaques were obtained by pressing the sheets in a compression moulding machine at 180°C for one minute. Specimens for mechanical properties were die cut in the milling direction.

As shown in *Table 2*, all the compounds show comparable mechanical properties, namely tensile strength (TS), elongation at break (EB) and TS at 200 per cent elongation. The choice of PP and its ratio seem not to influence greatly the mechanical properties, which are close to the standard MV IS79. On the contrary, the crystallinity of PP leads to a conspicuous increment of hardness (HS), which is 48 Shore D for MV TP79 C, ie the compound with the highest content of PP.

▼ **Figure 2**: *Representation of the torque pattern in function of time during the production of the MV TPV compounds. The three main steps of the process are indicated*



▼ **Figure 3**: *DSC analysis of uncured (top) and cured (bottom) MV IS79. Dotted line: graphical representation of the baseline used to compute the reaction enthalpy*



▼ **Table 2**: *Typical physical properties of the MV insulation compounds*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
TS[1] [N/mm²]	16.61	17.31	17.19	15.73
EB[1] [%]	321	360	310	341
TS @ 200% [N/mm²]	14.23	13.57	14.48	13.62
HS[2] [Shore A-D]	80-/	96-45	95-46	96-48
MFI[3] [gr/10min]	27.6[4]	4.4	4.2	21.3

[1]ASTM D412; [2]ASTM D2240; [3]ASTM D1238 (190°C, 21.6kg), [4]Measured on the compound without peroxide

Due to the high viscosity of MV TP79 A and B, the melt flow index (MFI) was measured at 190°C with 21.6kg weight.

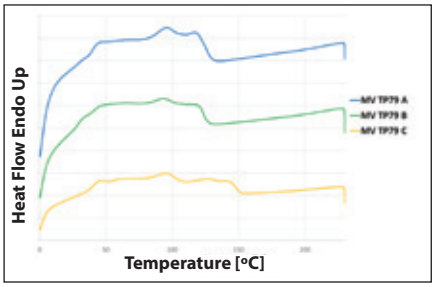
Their low flow rate can be ascribed principally to two main factors: the ratio between thermoplastic and elastomeric phases and the choice of a PP with low MFI at the test temperature. However, it can be noted that, by a careful balancing of the ratio between the two phases and an accurate choice of PP, it was able to obtain an MFI for MV TP79 C comparable to the standard MV IS79. Those results are confirmed by the rheological studies presented in section 2.3.

For the sake of comparison and to highlight the successful achievement of the MV TPV compounds, reference materials without peroxide were produced. Thereby, in those compounds, the dynamic vulcanisation could not take place after the blending of the components. The reference compound MV Ref AB has the same composition of MV TP79 A and B (without peroxide and co-agents); the reference compound MV Ref C was formulated as MV TP79 C (without peroxide). Rheology and mechanical properties of both the reference compounds were analysed in comparison to the MV TPV compounds presented in this paper to demonstrate the capability to obtain TPV compounds in a reproducible and controlled fashion.

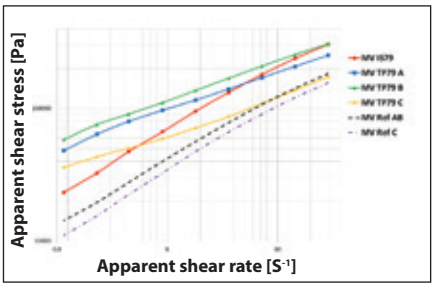
2.2 DSC analysis

In order to determine the unreacted peroxide remaining in the compounds after the curing process, DSC was implemented. The spectra were measured in a Perkin-Elmer DSC 6000 in inert nitrogen atmosphere from 0°C to 230°C with a heating rate of 20°C/min; after heating, the samples were cooled down to 0°C with 10°C/min rate. This cycle was repeated three times. However, as the aim of this study was to quantify the ratio between initial and residual (after curing or dynamic vulcanisation) peroxide, only the first heating cycle is presented and discussed in the following.

Firstly, the uncured MV IS79 containing 100 per cent of unreacted peroxide was analysed and used as reference. From the DSC shown in *Figure 3*, the calculated enthalpy of reaction (ΔH) given by the peroxide decomposition was -8.97 J/g.



▲ **Figure 4**: *DSC analysis of MV TP79 A (top), MV TP 79 B (middle) and MV TP79 C (bottom)*



▲ **Figure 5**: *Apparent shear stress in function of apparent shear rate measure at 180ºC of the MV insulation compounds. Dotted lines: reference compounds*

In the same figure is represented the DSC plot of the cured MV IS79 (ten minutes at 180°C). A ΔH of -1.16 J/g was detected, corresponding to a residue of about 13 per cent of unreacted peroxide. This indicates that MV IS79 was almost completely vulcanised. In the same way, the amount of unreacted peroxide of the MV TPV compounds was computed, considering that MV TP79 A, B and MV TP79 C were formulated with 75 per cent and 70 per cent of uncured MV IS79, respectively.

From the data collected and shown in *Figure 4*, the residual peroxide detected in MV TP79 A was about 4 per cent (ΔH = -0.27 J/g) and in MV TP79 B was about 5 per cent (ΔH = -0.33 J/g). For MV TP79 C the computed residual peroxide was around 11 per cent (ΔH = -0.68 J/g). Those results confirm beyond any doubt the almost complete decomposition of the initial peroxide during the dynamic vulcanisation.

2.3 Rheology

Rheological studies are fundamental to predict the extrusion behaviour of compounds. As such, we have investigated the rheology at apparent shear rates from 200 s^{-1} to 1 s^{-1} in a Göttfert Rheograph 2002 capillary rheometer. The L/D of the capillary was 30 and measurements were carried out at 180°C. The temperature was chosen to allow the complete fusion of the PP. Normally, standard compounds as MV IS79 are characterised at 125°C before the curing step, however, at this temperature the PP is not molten resulting in misleading results. Due to the high test temperature, to prevent the decomposition of the peroxide during the analysis, MV IS79 was investigated without peroxide. As previously mentioned, the reference compounds MV Ref AB and C, were included in this study to underline the change of rheological behaviour as a consequence of the dynamic vulcanisation. The plots of the apparent shear stress in function of the apparent shear rate are shown in *Figure 5*.

The response of MV IS79 is typical of EPDM/PE-based compounds: the shear stress diminishes rapidly in an almost linear fashion decreasing the shear rate. Small deviations from a perfect linearity can be noted and are usually ascribed to EPDM rubbers. MV Ref AB and C exhibit the same pattern with the shear stress translated toward lower values. This effect is caused by the thermoplastic phase, which shows lower viscosity at this temperature.

Accordingly, by increasing the content of PP the shear stress decreases. Owing to the different nature of the MV TPV compounds, their rheological behaviour is rather different[6,7]. Essentially, such a dissimilar character stems from the elastic response of the elastomeric crosslinked particles, which is dominant at low shear stresses. On the contrary, at high shear stresses, the behaviour of the TPV compounds is governed by the thermoplastic phase. As a result, the three MV TPV compounds have a similar behaviour to the reference compounds at high shear rates. Diversely, at low shear rates, the curves are clearly divergent.

Focusing only on the MV TPV compounds, as noted previously for the MFI in section 2.1, by careful balancing of the components and a correct choice of PP, it is possible to "tune" the rheological behaviour of the TPV MV compounds, keeping or even improving the thermomechanical properties. In this regard, MV TP79 C exhibits lower stresses, ie viscosity, until very low shear rates together with the best thermomechanical properties among the studied TPV MV compounds.

2.4 Mechanical testing

The stress strain properties of the MV insulation compounds were measured according to the method ASTM D412, averaging the results of five dumb-bell test specimens obtained in a Gibitre Tensor Check Profile. The specimens were die cut along the milling direction from plaques obtained in a compression moulding machine at 180°C. MV IS79 was pressed ten minutes to complete the curing process. MV TP79 A, B and C were pressed for one minute and cooled down under pressure. MV Ref AB and C were treated identically to the MV TPV compounds to obtain the test specimens. *Figure 6* illustrates one example of the stress strain curve for each compound.

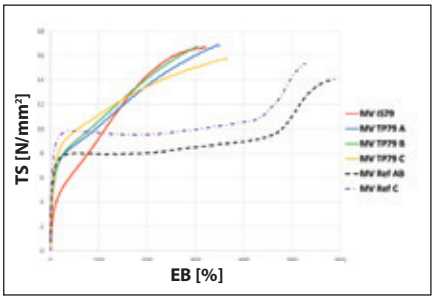
At first sight, the analysis of the stress strain curves of the materials reveals that the MV TPV compounds have similar performance to the benchmark MV IS79 in terms of TS and EB, as already pointed out in section 2.1. Besides the absolute values, the outlined curves follow a similar pattern with a strong elastic response to the stress applied. The main difference which can be observed is the higher Young's modulus of the MV TPV compounds. This is caused by the crystallinity of the thermoplastic phase and therefore is larger for MV TP79 C.

The same behaviour is recognisable in the reference compound MV Ref AB, which has a Young's modulus virtually identical to MV TP79 A and B. Likewise, MV Ref C has a similar Young's modulus to MV TP79 C. However, those reference compounds, not being vulcanised and lacking the elastic character, yield until the final rupture.

In contrast, the MV TPV compounds behave as crosslinked materials with high elongation[8-10]. These results are in agreement with the rheological studies, confirming the successful achievement of thermoplastic vulcanisate compounds.

According to CEI 20-86, to evaluate the performance of the MV TPV compounds at high temperature, a hot pressure test was carried out and the longitudinal shrinkage at 130°C summarised in *Table 3*, which is mandatory for thermoplastic insulating materials rated for 90°C and 105°C.

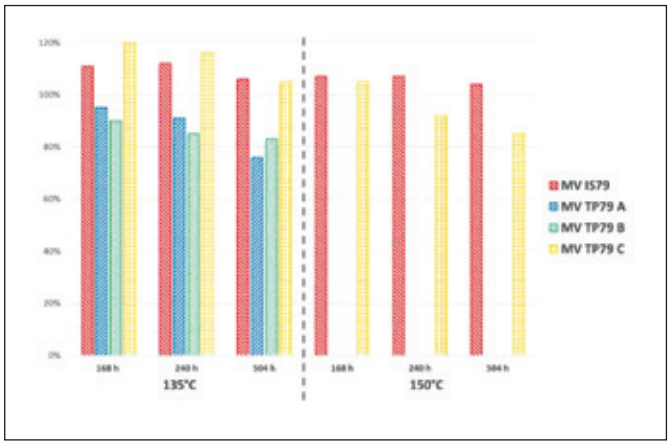
▼ **Figure 6**: *Stress strain plots of the MV insulation compounds. Dotted lines: reference compounds*



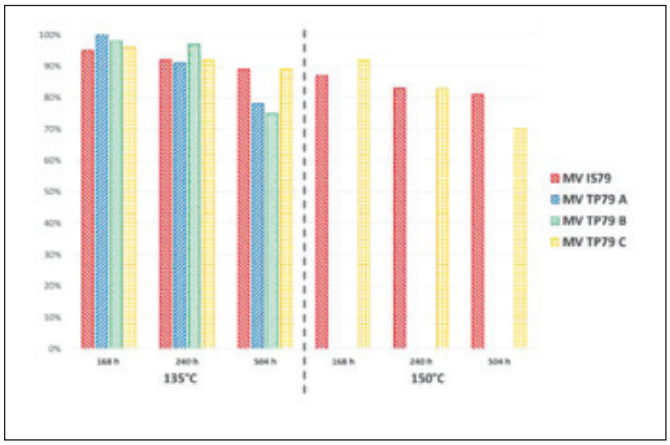
▼ **Table 3**: *Hot pressure test and longitudinal shrinkage at 130ºC of the MV TPV compounds*

	MV TP79 A	MV TP79 B	MV TP79 C
Hot Pressure Test[1] [%]	n.a.[2]	27	3
Longitudinal Shrinkage[1] [%]	14	11	2

[1]CEI 20-86; [2]Not applicable



▲ **Figure 7**: *Tensile strength retained after air ageing at 135ºC and 150ºC for 168h, 240h and 504h*



▲ **Figure 8**: *Elongation at break retained after air ageing at 135ºC and 150ºC for 168h, 240h and 504h*

The results show an improvement of the results going from MV TP79 A to MV TP79 C. However, this is not a consequence of the ratio between thermoplastic and elastomeric phase, but results from the addition of a PP (see *Table 1*), which can withstand such high temperatures.

2.4.1 Heat ageing resistance

MV insulation compounds were tested at 135°C and 150°C for 168, 240 and 504h, to assess their resistance to accelerated ageing. Retained TS and EB are graphically shown in *Figure 7* and *Figure 8*.

MV TP79 A and B could not be tested at 150°C, as the thermoplastic phase completely melts at this temperature. In this regard, MV TP79 C, which contains PP with higher melting temperature, represents the only alternative to MV IS79 at the test temperature of 150°C.

First, it must be pointed out that all the compounds have good to excellent resistance at 135°C in terms of retained TS and EB, which are higher than 70 per cent after 504h. Both MV IS79 and MV TP79 C excellently withstand the heat ageing at 135°C, achieving retained TS and EB > 90 per cent. Although the heat resistance performance slightly decays in comparison to MV IS79, MV TP79 C exhibits a TS retained > 80 per cent and a EB retained ca 70 per cent after 504h at 150°C.

The tests indicate that MV TP79 C can withstand the same ageing conditions as MV IS79. It has to be considered that MV IS79 is rated for a service temperature of 105°C and therefore routinely tested for 508h at 150°C with typical values of TS and EB retained of 95 per cent and 75 per cent. According to CEI 20-86, MV insulation compounds must withstand ageing for 240h at 135°C and 150°C for service temperature rating of 90°C and of 105°C, respectively. Thus, MV TP79 C represents a valid thermoplastic alternative to standard lead-free elastomeric MV insulation compounds.

2.5 Electrical performance

Insulating properties of the compounds were estimated by measuring loss factor (Tanδ), dielectric constant (εr) and volume resistivity in function of temperature from 25°C to 90°C in dry conditions.

In addition, loss factor and dielectric constant were measured after immersing the compounds in water at 90°C for up to 28 days. The electrical properties were measured on 2mm thick press moulded samples. An Omicron MI600 system was utilised to evaluate Tanδ and εr; a QuadTech model 1868A was implemented in investigating volume resistivity. All the electrical properties of the compounds were studied at the Imerys laboratories.

Figure 9 shows the plot of Tanδ from 25°C to 90°C in dry conditions. The four compounds are characterised by small variations of the loss factor, which remains in the same order of magnitude (10^{-3}) up to 90°C. Furthermore, all the compounds present a similar trend of Tanδ increasing the temperature. In more detail, the loss factor of the four compounds is virtually identical at room temperature, about $1.5{\cdot}10^{-3}$, and grows steadily with the temperature to values between $3.5{\cdot}10^{-3}$ and $5.0{\cdot}10^{-3}$ at 90°C for MV IS79 and MV TP79 A, respectively. As described for Tanδ, εr varies in a narrow range for all the compounds raising the temperature.

In *Figure 10*, only a small lowering of the dielectric constant is observed increasing the temperature. As εr is calculated through the following formula:

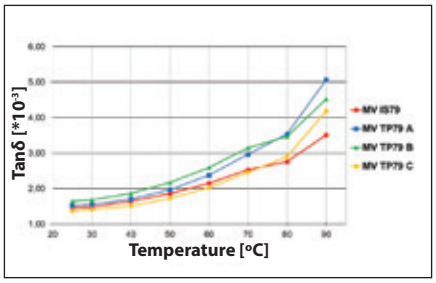
$$\varepsilon_r = \left(\frac{C}{\varepsilon_0}\right)\left(\frac{t}{A}\right)$$

in which C is the capacitance measured by the instrument and ε_0 is the permittivity of vacuum, while t and A are geometrical factors indicating the separation between the plates (electrodes) and their area, respectively. The lower dielectric constant of the MV TPV compounds in comparison to MV IS79 is given by their content of PP, which increases the insulation performance of the overall compound. As a consequence, MV IS79 is characterised by the larger dielectric constant, in contrast to MV TP79 C characterised by the lower. However, it has to be pointed out that the difference between the compounds is rather limited at either low or high temperature.

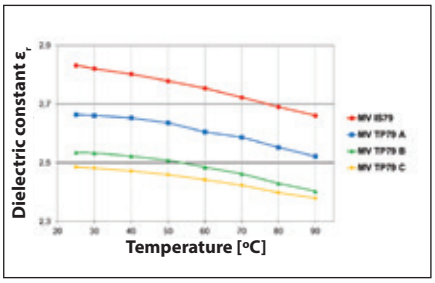
▼ **Table 4**: *Volume resistivity measured at 25ºC and 90ºC with 500V potential*

Volume Resistivity [*10¹⁴]	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
At 25ºC [Ω-cm]	47.0	41.6	41.3	50.3
At 90ºC [Ω-cm]	2.54	0.378	0.284	0.321

▼ **Figure 9**: *Loss factor (Tanδ) in function of temperature at 500V and 50Hz*



▼ **Figure 10**: *Dielectric constant (εr) in function of temperature at 500V and 50Hz*



Lastly, the volume resistivity was measured at 25°C and 90°C applying a potential of 500V (see *Table 4*). At 25°C, all the compounds have a volume resistivity in the order of magnitude of 10^{15} Ω-cm, which is standard value for MV insulants. At 90°C the volume resistivity of the MV TPV compounds is about one order of magnitude lower than that of MV IS79.

Most probably, this difference results from a partial melting of the thermoplastic phase of the TPV compounds, which leads to a higher mobility of the charge carriers in the material. However, besides this, the volume resistivity of the four MV TPV compounds is above 10^{13} Ω-cm.

2.5.1 Electrical performance in water

Electrical properties were also tested upon immersion in water at 90°C up to 28 days. At first, the absorption of water of the MV TPV compounds was estimated in comparison to MV IS79, according to the Italian standard CEI 20-86.

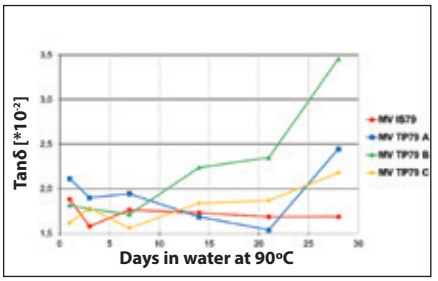
The results summarised in *Table 5* indicate that the compounds have virtually identical water absorption after 14 days in water at 85°C, well below the upper limit (5mgr/cm²).

The low water absorption reflects on the variation of Tanδ after immersing the samples in water at 90°C (see *Figure 11*). The compounds have a good retention of the loss factor, which is, after 28 days in water, in the worst case about 0.035 and in the best 0.017.

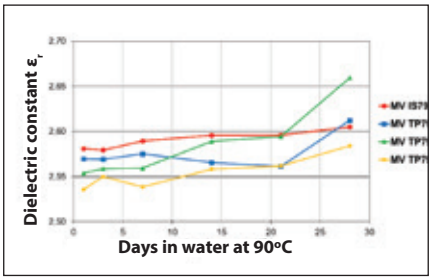
Again, MV TP79 C, thanks to its superior stability, has the best performance, close to the benchmark performance of MV IS79.

Having low water absorption, εr remains almost unvaried after immersion in water at 90°C. As illustrated in *Figure 12*, the increasing of the dielectric constant is rather small after immersion in water.

Among the MV TPV compounds, MV TP79 C displays the best stability over time, having a lower εr compared to the benchmark MV IS79 even after 28 days in water.



▲ **Figure 11**: *Loss factor (Tanδ) in function of days immersed in water at 90°C measured at 500V and 50Hz*



▲ **Figure 12**: *Dielectric constant (εr) in function of days immersed in water at 90°C measured at 500V and 50Hz*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
Water absorption [1] [mgr/cm²]	0.34	0.32	0.35	0.34

[1]Gravimetric method, CEI EN 60811-402

▲ **Table 5**: *Water absorption according to CEI 20-86*

Conclusions

Newly developed MV TPV compounds have been presented in this paper. The promise is to produce MV insulation compounds with properties equal to the actual lead-free MV insulation market standard and the easy processing of thermoplastics.

The preparation of such compounds was described along with their full characterisation in comparison to the standard lead-free MV insulant. By means of DSC the dynamic vulcanisation process was investigated. Indeed, the capability to produce in an industrial pilot plant TPV compounds for application as MV insulation was investigated.

Despite the complex formulation containing polymers, fillers, co-agents and antioxidants, the MV TPV were obtained in a fully reproducible and reliable process. The results of the technology are the overall properties of the MV TPV compounds, which resemble the performance of the standard lead-free MV IS79.

Rheological studies, besides confirming the TPV nature of the compounds, simulate their extrusion behaviour, demonstrating that, thanks to an accurate choice of the thermoplastic PP, it is possible to lower the shear stress maintaining unaltered the typical elastic response of TPV compounds.

A detailed analysis of the stress-strain plots of the MV TPV compounds confirms their elastic behaviour is affected only partially by the crystallinity of the thermoplastic phase, resulting in mechanical properties similar to the benchmark MV IS79.

Upon ageing at 135°C, MV TPV compounds proved their resistance up to 504h with TS and EB retained > 70 per cent. After ageing for 504h at 150°C, MV TP79 C preserved 80 per cent of its TS and 70 per cent of its EB, almost matching the reference MV IS79.

Lastly, dry and wet electrical properties were measured for all the compounds at 500V and 50Hz. Dry Tanδ raises with the temperature until an upper limit of about $5{\cdot}10^{-3}$ at 90°C for MV TP79 A, which is still comparable to Tanδ of MV IS79 at the same temperature, $3.5{\cdot}10^{-3}$.

Similarly, εr varies in a very narrow range (between 2.8 and 2.4) at 25°C and up to 90°C for all the compounds. Volume resistivity measurements confirm excellent insulating properties at 25°C (10^{15} Ω-cm), slightly decreasing at 90°C (10^{13} Ω-cm).

Wet electrical properties were measured immersing the samples in water at 90°C up to 28 days. Wet Tanδ increases to a maximum of $3.5{\cdot}10^{-2}$ for MV TP79 B.

MV TP79A and C exhibited better resistance to water; the latter close to the performance of MV IS79 after 28 days in water at 90°C, $2.2{\cdot}10^{-2}$ and $1.3{\cdot}10^{-2}$, respectively.

The same trend was observed for εr, which slowly increases after immersing the samples in water. However, the fluctuations are virtually irrelevant, being between 2.53 and 2.66 and considering the error associated to the measure.

In conclusion, a full study on TPV compounds as insulation materials for MV applications was presented.

The step-by-step approach showed how it could incrementally improve the properties of the compounds, obtaining a fully thermoplastic lead-free material, namely MV TP79 C, with mechanical, rheological and electrical performance comparable to those of the lead-free market standard MV IS79.

According to the standard CEI 20-86, MV TP79 C has the potential to be implemented as MV insulation with 105°C rating for continuous operating temperature and emergency shortcut of 250°C. Pushing forward the strategy, Mixer expects to develop MV TPV compounds with higher resistance and better electrical properties at high temperature and in water in the near future. ■

Acknowledgements

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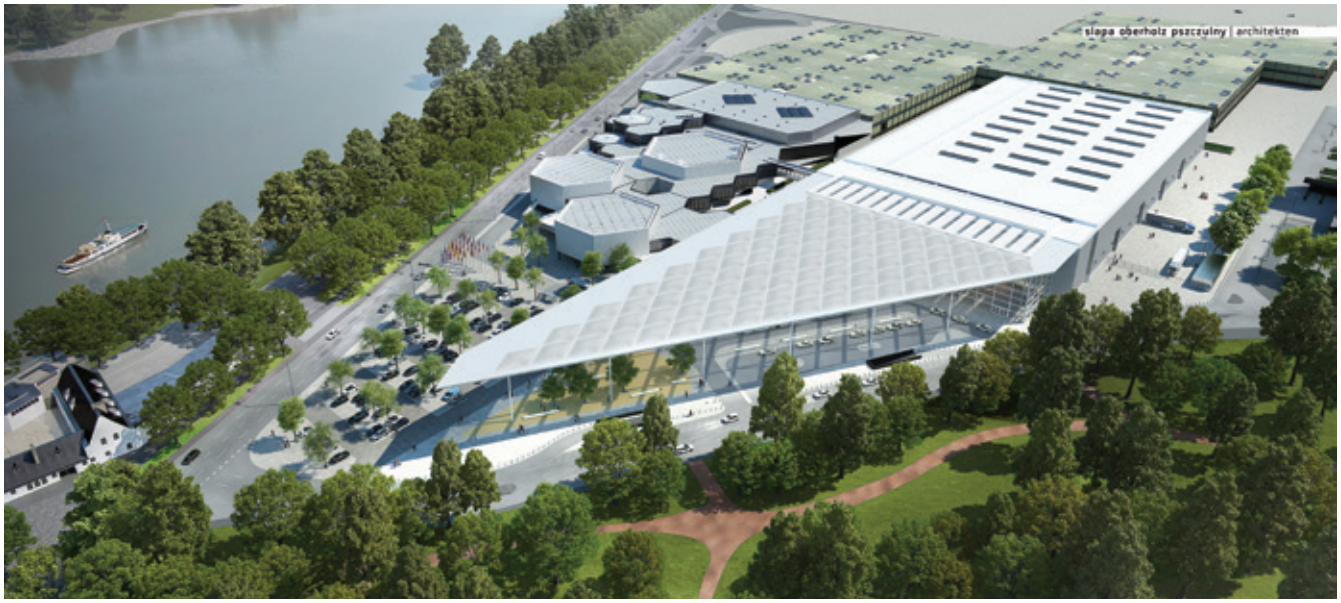

▲ *Ein Architektenplan für den neuen Eingang Süd bei den Messegeländern in Düsseldorf*

Neuer südlicher Bereich der Messe Düsseldorf: wire 2018 und Tube 2018 profitieren von der Umgestaltung

EIN kompletter Neubau des Eingangs Süd und der sich daran räumlich anschließenden Messehalle 1 wurde auf dem Düsseldorfer Messegelände begonnen.

Aufsichtsrat und Gesellschafter der Messe Düsseldorf GmbH haben ihre Zustimmung erteilt und damit ist der Startschuss gefallen für eines der ambitioniertesten Bauprojekte in der Geschichte des Unternehmens.

"Jetzt werden wir unseren Masterplan zur vollständigen Modernisierung und Erneuerung unseres Geländes an der Homebase fortsetzen können," so Werner M. Dornscheidt, Vorsitzender der Geschäftsführung der Messe Düsseldorf, der hinzufügt: "Und das alles geschieht wie immer ohne Subventionen."

Das Investitionsvolumen für diesen südlichen Bereich beträgt 140 Millionen Euro. Insgesamt wird die Messe Düsseldorf bis 2030 rund 636 Millionen Euro in ihr Gelände investieren. Die Arbeiten wurden im Mai 2017 begonnen und sollen im Sommer 2019 abgeschlossen sein. Realisiert wird der Entwurf vom Düsseldorfer Architektenbüro slapa oberholz pszczulny architekten.

Mit dem neuen Eingang Süd wird die Messe Düsseldorf einen modernen Auftritt direkt am Rheinufer mit Blick auf die Stadt Düsseldorf schaffen. Ein 7.800m² großes und etwa 20m hohes, neuartig beleuchtetes transluzentes Vordach heißt Messe- und Kongressbesucher willkommen.

Diese Struktur ist gleichzeitig ein starkes architektonisches Zeichen an dieser exponierten Stelle des Messegeländes. Jurek Slapa, Geschäftsführender Gesellschafter bei sop architekten, hierzu: "Das Vordach verschafft der Messe Düsseldorf ein neues Gesicht und eine unverwechselbare Adresse an der einmaligen Lage zwischen Rhein und Nordpark."

Der Eingang Süd öffnet sich über eine komplett verglaste Front von 93m Länge zum Vorplatz hin. Auf 2.000m² Fläche finden hier die notwendigen Services wie Kassen oder Garderoben Platz. Im ersten Obergeschoss schiebt sich ein verglaster Konferenzraum in das Foyer und bietet einen Blick in den Eingangsbereich bis auf den Vorplatz. Zudem ist das gesamte Foyer als Veranstaltungsort nutzbar. Auf dem Vorplatz liegen auch der Eingang zu einer Tiefgarage mit 300 Parkplätzen sowie Halteplätze für Bus und Taxi.

Die Neugestaltung des Eingangs Süd beinhaltet auch den Neubau der Halle 1. Dazu plant die Messe Düsseldorf, die heutigen kleineren Hallen 1 und 2 abzureißen und durch einen Neubau zu ersetzen. Mit Abmessungen von 158m x 77m und mehr als 12.000m² Fläche, entspricht Halle 1 dann in etwa den Hallen 8a und 8b.

Technisch wird die neue Halle den hohen Standards des gesamten Messegeländes gerecht. Erschlossen wird sie über sieben Tore, Abhängungen von der Hallendecke sind ebenso leicht möglich wie die Versorgung der Stände über den Hallenboden.

Für Fußgänger ist die Halle über eine Brücke im ersten Obergeschoss mit dem Congress Center Düsseldorf (CCD) verbunden. Neben der Anbindung an die Hallen 3 und 4 führt eine Magistrale vom Südeingang direkt auf das übrige Messegelände.

In den Übergangsjahren 2017 und 2018, in denen die Umbaumaßnahmen erfolgen, werden den bislang in den Hallen 1 und 2 platzierten Ausstellern der Tube mit den Hallen 16 und 17 attraktive Standmöglichkeiten angeboten.

Die Tube findet 2018 dann in den Hallen 3 bis 7 und 16 und 17 statt. Die Aussteller der wire 2018 werden ihre Innovationen in den Messehallen 9 bis 16 präsentieren.

Messe Düsseldorf GmbH – Deutschland
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Datenkabel-Fertigungssysteme plus Prozess-Know-how

▲ *Datenkabel-Verseilanlage mit DSI 631 Typ Doppelschlag-Verseilmaschine kombiniert mit einem vorgeschalteten Rückdrehablauf und einem Längsbandablauf*

LEITUNGEN für Fahrzeuge, IT-Systeme, der Energiesektor und andere Anwendungsbereiche müssen ständig steigenden Anforderungen nachkommen.

Um mit diesem Trend Schritt zu halten, brauchen Kabelhersteller Maschinen, die Kabel mit komplexen Konstruktionen erzeugen und energie- wie rohstoff- und kosteneffizient arbeiten können. Dabei müssen sich die Maschinen an neue Produktanforderungen flexibel anpassen lassen.

Die von der Niehoff entwickelten und hergestellten Kabelmaschinen erfüllen all diese Anforderungen.

Ein Beispiel ist die Doppelschlag-Verseilmaschine Typ DSI 631, die für das Verseilen von isolierten Adern zu Paaren und Vierer und für das Verseilen von vier Leiterpaaren zu LAN-Kabeln entwickelt wurde.

Die Maschine kann LAN-Kabel aller Kategorien – auch künftiger – sowie Paare mit Band-Abschirmung, Bus-Leitungen und andere Telekommunikationskabel zuverlässig fertigen.

Das DSI-Verseilmaschinensystem umfasst viele Zusatzaggregate, so dass sich kundenspezifische Fertigungsanlagen erstellen und je nach Auftragssituation rasch umbauen lassen. Im Vergleich zu anderen Maschinen und Verfahrenstechniken erbringen die Kombinationsmöglichkeiten dieses Systems für die Fertigung eines bestimmten Produkts oder für eine bestimmte Fertigungsleistung große finanzielle Vorteile.

Ein weiterer Vorteil für die Anwender dieser und anderer Niehoff-Systeme ist, dass das Unternehmen, mit jahrzehntelanger Erfahrung im Design der Kabel- und Drahtmaschinerie, den Kunden mit ein Rundum-Prozess-Know-how und einem professionellen Kundendienst zur Seite steht.

Maschinenfabrik Niehoff GmbH & Co KG – Deutschland
Website: www.niehoff.de

Neuer Geschäftsführer für den Vertrieb

Arnold Büscher hat die Geschäftsführung für den Vertrieb Deutschland der U I Lapp GmbH, einer Gesellschaft der Lapp Gruppe, übernommen. Als Maschinenbau-Diplomingenieur war Büscher zuvor in unterschiedlichen Führungspositionen bei renommierten Industrieunternehmen tätig.

Internationale Erfahrungen sammelte er unter anderem als Geschäftsführer der Rittal Corp. in den USA. Zuletzt verantwortete er als Geschäftsführer der Weidmüller GmbH & Co. KG die Geschäfte in Deutschland und Zentraleuropa.

"Wir freuen uns, dass wir mit Herrn Büscher einen erfahrenen Manager gewonnen haben, der unseren Markt bestens kennt und unseren Wandel zum Systemanbieter vorantreiben wird," so Andreas Lapp.

Büscher will alle Vertriebskanäle stärken und den Fokus auf die Wachstumsmärkte in den Branchen Bahn, Lebensmittel- und Robotik-Industrie legen.

Seine Tätigkeiten umfassen auch den Auf- und Ausbau von Systemlösungen unter dem Namen Ölflex® Connect mit einem umfangreichen Spektrum an Produkten und Dienstleistungen rund um konfektionierte Leitungen.

"Lapp hat stabile Kundenbeziehungen, aber auch nennenswertes Wachstumspotenzial. Ich möchte die Kundenansprache auf allen Kanälen intensivieren, den Fokus auf Potenziale schärfen und das Neukundengeschäft vorantreiben," sagt Büscher über seine neue Aufgabe.

Lapp Group – Deutschland
Website: www.lappgroup.com

▲ *Arnold Büscher*

TPV-basierte Isolierung für Mittelspannungsanwendungen

von Andrea Galanti, Stefano Dossi und Andrea Magri, Mixer SpA, Ravenna, Italien, und Camillo Cardelli, iPool Srl, Pistoia, Italien

Übersicht

In diesem Artikel wird die Entwicklung von drei vollthermoplastischen bleifreien Mittelspannungs- (MV-) Isoliermischungen beschrieben, die auf der Technologie des thermoplastischen Vulkanisat (TPV) basieren. Die TPV MV-Isoliermischungen wurden ausgehend von einer mit Peroxid vulkanisierten bleifreien MV-Isolierung vorbereitet, die die aktuelle Marktbenchmark darstellt. Aus diesem Grund wurden sie im Vergleich zur standardmäßigen bleifreien MV-Isolierung intensiv untersucht.

Um die Ergebnisse des dynamischen Vulkanisationsverfahrens auszuwerten, wurden die Mischungen mittels dynamischer Differenzkalorimetrie (DDK) untersucht. Zur Simulierung des Extrusionsverhaltens wurde deren Rheologie erforscht. Die mechanischen Eigenschaften wurden vor und nach der Alterung bis zu 21 Tage lang bei 135°C und 150°C gemessen. Schließlich wird eine umfassende Studie über deren elektrischen Eigenschaften präsentiert und zwar unter trockenen (von 25°C bis 90°C) sowie unter nassen Bedingungen (bis zu 28 Tage lang bei 90°C in Wasser).

1 Einleitung

Vor zwanzig Jahren wurden beide VPE- und EPDM-basierten Isolationssysteme in vielen Teilen der Welt für MV-Kabelanwendungen eingesetzt. Nordamerika bleibt ein sehr aktiver Markt für EPDM-basierte MV-Isolierungen, während in anderen Teilen der Welt VPE bevorzugt wird. Neuerdings beobachtet man im Weltmarkt ein erneuertes Interesse an EPDM-basierten MV-Isolierungen wegen der unübertroffenen Leistung der Lebensdauer von Kabeln für langfristige Anwendungen (>20 Jahre). Seit 1996 stellt Mixer SpA MV-Isoliermischungen her, die auf EPDM- und EPDM-/LDPE-Mischungen basieren: seine

▲ **Abb. 1**: *Bleihaltige (orange) und bleifreie (weiße) MV-Isolierung, von Pellets zu Kabeln*

Strategie liegt darin, dem Kabelmarkt innovative und konkurrenzfähige Werkstoffe anzubieten, denn es wird angenommen, dass Gummikabeln für Sonderanwendungen durch eine ständige Verbesserung der Werkstoffe ein neuer Aufschwung gegeben wird.

Der erste Schritt dieses Ansatzes lag in der Entwicklung bleifreier EPDM-Lösungen, die 2012 präsentiert wurden und nun handelsüblich sind (siehe *Abb. 1*)[1].

Aufgrund der Tatsache, dass Bleisalze in Wasser unlöslich sind und daher nicht zu Leckstrom durch die Isolierungsschicht beitragen, ist Bleioxid eines der wirkungsvollsten Additive in MV-Isoliermischungen. Dennoch ist Bleioxid in der Reach-Verordnung für SVHC (besonders besorgniserregender Stoffe) für sein bekanntes Risiko der Bioakkumulation und den langfristigen Auswirkungen aufgelistet, die zu schweren Umweltschäden und Verletzung des Lebens führen[2].

Mixer SpA hat Bleioxid erfolgreich mit einem anorganischen Ionenfänger-System ersetzt, das imstande ist Ionen zu immobilisieren und somit die Produktion von EPDM-basierten bleifreien MV-Isoliermischungen mit höherer thermischen und elektrischen Stabilität realisiert. Von diesem Anfangspunkt wurde vom Unternehmen ein neues völlig thermoplastisches TPV für MV-Isolierung entwickelt, das die bleifreien MV-Isoliermischungen in eine PP-Matrix dynamisch vernetzt. Mixer SpA stellt drei Aufrüstungen von MV-TPV-Mischungen vor, um ein Material zu erzielen, das thermomechanischen Prüfungen bei einer Dauereinsatztemperatur von 90°C und 105°C und bei 250°C im Kurzschlussnotfall bestehen kann, entsprechend der italienischen CEI-Norm 20-86, die bisher die einzige Norm über thermoplastische Mischungen für MV-Isolierung ist.

Zunächst werden hier die Vorbereitung und die makroskopischen Eigenschaften der neuen MV-TPV-Mischungen beschrieben.

Das Unternehmen erforschte die neuen MV-TPV-Mischungen mittels DDK, um das dynamische Vulkanisationsverfahren zu untersuchen. Im dritten Teil wurde die Rheologie der MV-TPV-Mischung bei niedrigem Scherwerte analysiert, um deren Extrusionsverhalten zu simulieren.

Die MV-TPV-Mischungen wurden anschließend hinsichtlich der mechanischen Eigenschaften vor und nach einer 21 Tage langen Wärmealterung bei bis zu 150°C geprüft. Die elektrischen Eigenschaften der Mischungen wurden bei den Laboratorien von Imerys, Par, UK, erforscht.

Im Detail wurden der Verlustfaktor (Tanδ), die dielektrische Konstante (ε_r) und der spezifische Durchgangswiderstand bei bis zu 90°C unter trockenen Bedingungen gemessen. Darüber hinaus wurden der Tanδ und die ε_r nach dem Eintauchen der Mischungen in Wasser bei 90°C, bis zu 28 Tage lang, untersucht.

Die Prüfergebnisse wurden mit der standardmäßigen bleifreien Mischung MV IS79 verglichen und haben bewiesen, dass eine innovative, hochelektrisch isolierende Mischung erzielt werden kann, die gleichzeitig die Eigenschaften der bleifreien V-EPDM-Mischung mit der Möglichkeit vereinigt, diese Mischung als thermoplastisches Material zu verarbeiten.

2 Bleifreie MV-TPV-Mischungen

2.1 *Vorbereitung der MV-TPV-Mischungen*

Bleifreie MV-Isoliermischung, MV IS79 und thermoplastische Vulkanisat MV-Mischungen, MV TPVs, wurden in einem Innenmischer vorbereitet, ausgestattet mit zwei gegenläufigen Rotoren und einer Kammer mit einem Inhalt von 8cm³. Die Zusammensetzung der MV-TPV-Mischungen wird in der *Tabelle 1* zusammengefasst. Offenbar weisen MV TPV79 A und B dasselbe Verhältnis zwischen der elastomerischen und der thermoplastischen Phase auf, trotzdem wurden unterschiedliche Coagents in deren Ansätzen verwendet. Dies erfolgte im Anschluss an die Studien über Coagents, die durch das Verhindern der Zersetzung von PP über β-Spaltung, die durch freie Radikale verursacht wird, die Eigenschaften der TPV-Mischungen beeinflussen[3].

MV IS79 wurde durch das Mischen aller Komponenten in dem Innenmischer vorbereitet, um eine vollständige Durchmischung der Wirkstoffe zu erzielen. Nach dem Entladen wurde Peroxid bei niedriger Temperatur einem Zweiwalzenmischwerk hinzugefügt. Die Proben für die Untersuchung wurden durch das 10 Minuten lange Pressen der Folie in eine Formpressmaschine bei 180°C erzielt. Die Proben für die mechanischen Eigenschaften wurden in Längsrichtung gestanzt.

TPV Zusammensetzung	MV TP79 A	MV TP79 B	MV TP79 C
MV IS79	75%	75%	70%
PP-1	25%	25%	20%
PP-2	-	-	10%

[1]d = 0.891 gr/cm³, MFI (230°C; 2.16kg) = 8.0 gr/10min; [2]d = 0.900 gr/cm³, MFI (230°C; 2.16 kg) = 10.0 gr/10 min

▲ **Tabelle 1**: *Formulierung von MV TPVs*

MV TP79-Mischungen wurden vorbereitet, indem die bleifreie Mischung (MV-IS79) mit thermoplastischem Polypropylen (PP) gemischt wurde, entsprechend dem in der *Tabelle 1* dargestellten Verhältnis. Beim Mischverfahren, während die Radikalreaktion stattfindet und die Temperatur kontinuierlich ansteigt, folgt das Drehmoment einem charakteristischen Muster, das graphisch in der *Abb. 2* dargestellt wird[4,5].

Nachdem die Wirkstoffe geladen werden, nimmt das Drehmoment wegen der hohen Viskosität der Komponenten bei niedriger Temperatur zu. Mit der Erhöhung der Temperatur fängt das Material an aufzuweichen, das Drehmoment fällt ab und gleichzeitig findet die Mischung statt. Während die Radialreaktion beginnt, erfolgt die zeitgleiche Vernetzung der Gummiphase und die β-Spaltung der PP-Phase, mit daraus folgender Phaseninversion die zur raschen Erhöhung des Drehmoments führt. Die Endtemperatur, bei der die TPV nach zirka acht Minuten Verarbeitung entladen wurden, lag zwischen 200°C und 220°C. Die immer noch heißen Compounds wurden in einem Zweiwalzenmischwerk kalandriert und eine Folie wurde erzielt; danach wurden Platten durch das eine Minute lange Pressen der Folie in einer Formpressmaschine bei 180°C gewonnen. Die Proben für die mechanischen Eigenschaften wurden in Längsrichtung gestanzt.

Wie in der *Tabelle 2* dargestellt, zeigen alle Compounds vergleichbare mechanische Eigenschaften, und zwar Zugfestigkeit (TS), Bruchdehnung (EB) und TS bei 200% Dehnung. Die Wahl von PP und dessen Verhältnis scheinen die mechanischen Eigenschaften nicht stark zu beeinflussen, die neben der standardmäßigen MV IS79 liegen. Die Kristallisation des PP führt im Gegensatz zu einer deutlichen Erhöhung der Härte (HS), die 48 Shore D für MV TP79 C ist, d. h. das Compound mit dem höchsten Gehalt an PP. Wegen der hohen Viskosität der MV TP79 A und B, wurde der Schmelzfließindex (MFI) bei 190°C mit einem Gewicht von 21,6kg gemessen.

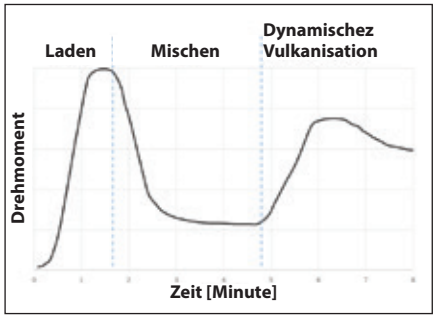
Deren niedriger Durchsatz kann hauptsächlich zwei Hauptfaktoren zugeschrieben werden: das Verhältnis zwischen den thermoplastischen und den elastomerischen Phasen und die Wahl eines PP mit einem niedrigen MFI bei Prüftemperatur.

Dennoch kann festgestellt werden, dass durch ein sorgfältiges Abwägen des Verhältnisses zwischen den zwei Phasen und einer genauen Auswahl des PP, ein MFI für MV TP79 C erzielt werden konnte, das mit dem standardmäßigen MV IS79 vergleichbar ist. Diese Ergebnisse sind durch rheologische Studien bestätigt, die im Abschnitt 2.3 dargestellt werden.

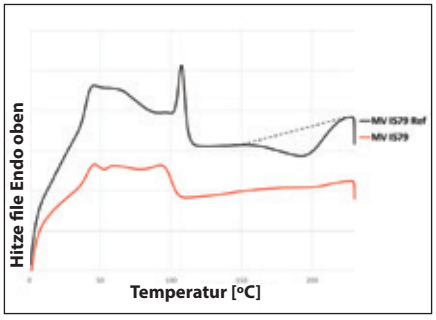
Zum Vergleich und um die erfolgreiche Erreichung der MV TPV-Compounds hervorzuheben, wurden Referenzmaterialien ohne Peroxid hergestellt. Dabei konnte bei diesen Compounds die dynamische Vulkanisation nicht nach dem Durchmischen der Komponente stattfinden.

Das Referenzcompound MV Ref AB zeigt die gleiche Zusammensetzung von MV TP79 A und B (ohne Peroxid und Coagents), das Referenzcompound MV Ref C ist als MV TP79 C (ohne Peroxid) formuliert worden.

▼ **Abb. 2**: *Abbildung der Drehmomentmuster in Abhängigkeit der Zeit während der Produktion von MV TPV-Compounds. Die drei wichtigsten Schritte des Verfahrens sind angegeben*



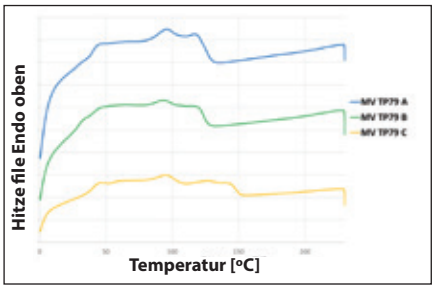
▼ **Abb. 3**: *DDK-Analyse von ungehärtetes (oben) und gehärtetes (unten) MV IS79. Punktierte Linie: graphische Abbildung der Grundlinie, die benutzt wird um die Reaktionsenthalpie zu berechnen*



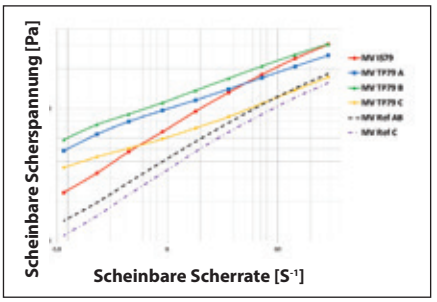
▼ **Tabelle 2**: *Typische physikalische Eigenschaften der MV-Isoliermischungen*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
TS[1] [N/mm²]	16.61	17.31	17.19	15.73
EB[1] [%]	321	360	310	341
TS @ 200% [N/mm²]	14.23	13.57	14.48	13.62
HS[2] [Shore A-D]	80-/	96-45	95-46	96-48
MFI[3] [gr/10min]	27.6[4]	4.4	4.2	21.3

[1]ASTM D412; [2]ASTM D2240; [3]ASTM D1238 (190°C, 21.6kg), [4]An der Mischung ohne Peroxid gemessen



▲ **Abb. 4**: *DDK-Analyse von MV TP79 A (oben), MV TP 79 B (Mitte) und MV TP79 C (unten)*



▲ **Abb. 5**: *Scheinbare Scherbeanspruchung abhängig von der scheinbaren Schergeschwindigkeit, bei 180°C der MV-Isoliermischungen gemessen. Punktierte Linien: Referenzmischungen*

Die Rheologie und die mechanischen Eigenschaften beider Referenzcompounds wurden im Vergleich zu den in diesem Artikel beschriebenen MV TPV-Compounds analysiert, um unser Potential aufzuzeigen TPV-Compounds reproduzierbar und kontrolliert herzustellen.

2.2 DDK-Analyse

Um das in den Compounds nach dem Härtungsverfahren verbleibende, unreagierte Peroxid zu bestimmen, wurde die DDK durchgeführt. Die Spektren wurden in einem Perkin-Elmer DSC 6000 in einer inerten Stickstoff-Atmosphäre von 0°C bis 230°C gemessen, mit einer Aufheizgeschwindigkeit von 20°C/min, nachdem die Proben erwärmt und auf 0°C mit einer 10°C/min Geschwindigkeit abgekühlt wurden. Dieser Ablauf wurde drei Mal wiederholt. Da jedoch das Ziel dieser Studie darin lag, das Verhältnis zwischen anfänglichem und restlichem Peroxid (nach der Aushärtung oder dynamische Vulkanisation) zu quantifizieren, wird nachfolgend lediglich das erste Heizzyklus präsentiert und diskutiert.

Zunächst wurde das ungehärtete MV IS79 analysiert - das 100% des unreagierten Peroxid enthält - und als Referenz verwendet. Entsprechend der in der *Abb. 3* dargestellten DDK, entsprach die aus der Peroxidzersetzung bewertete Reaktionsenthalpie (ΔH) -8,97 J/g. In derselben Abbildung wird das DDK-Diagramm des gehärteten MV IS79 (10 Minuten bei 180°C) dargestellt. Ein ΔH-Wert von -1,16 J/g wurde erfasst, was einer Restmenge von zirka 13% des unreagierten Peroxid entspricht.

Dies zeigt, dass MV IS79 fast völlig vulkanisiert war. Gleichfalls wurde die Menge an unreagiertem Peroxid der MV TPV-Compounds errechnet, in Anbetracht, dass MV TP79 A, B und MV TP79 C jeweils mit 75% und 70% ungehärteten MV IS79 formuliert wurden.

Aus den gesammelten und in der Abb. 4 dargestellten Daten ausgehend, ergab sich, dass das in MV TP79 A erfasste Restperoxid zirka 4% (ΔH = -0,27 J/g) und MV TP79 B zirka 5% (ΔH = -0,33 J/g) entsprach. Für MV TP79 C lag das errechnete Restperoxid um 11% (ΔH = -0,68 J/g). Diese Ergebnisse bestätigen zweifelsfrei die fast vollständige Zersetzung des anfänglichen Peroxids während der dynamischen Vulkanisation.

2.3 Rheologie

Rheologische Studien sind von wesentlicher Bedeutung, um das Extrusionsverhalten der Compounds vorauszusehen. Demzufolge haben wir die Rheologie bei scheinbaren Schergeschwindigkeiten von 200^{s-1} bis $1s^{-1}$ in einem Kapillarrheometer vom Typ Göttfert Rheograph 2002 untersucht. Das L/D des Kapillars lag bei 30 und die Messungen fanden bei 180°C statt. Die Temperatur wurde ausgewählt, um die vollständige Fusion des PP zu ermöglichen. In der Regel sind standardmäßige Compounds wie MV IS79 bei 125°C vor dem Aushärtungsschritt gekennzeichnet, dennoch ist das PP bei dieser Temperatur nicht geschmolzen, was irreführende Ergebnisse ergibt. Wegen der hohen Prüftemperatur wurde MV IS79 ohne Peroxid untersucht, um die Zersetzung von Peroxid während der Analyse zu verhindern. Wie zuvor erwähnt, wurden die Referenzcompounds MV Ref AB und C in dieser Studie eingeschlossen, um die Änderung des rheologischen Verhaltens als Folge der dynamischen Vulkanisation zu betonen. Die Diagramme der scheinbaren Scherbeanspruchung in Abhängigkeit der scheinbaren Schergeschwindigkeit sind in der Abb. 5 dargestellt.

Die Reaktion von MV IS79 ist typisch für EPDM/PE-basierte Compounds: die Scherbeanspruchung nimmt schnell in einer fast linearen Weise ab, indem die Schergeschwindigkeit sinkt. Geringe Abweichungen von einer perfekten Linearität können festgestellt werden und werden in der Regel EPDM-Kautschuk zugeschrieben.

MV Ref AB und C weisen dasselbe Modell auf, mit der Scherbeanspruchung auf niedrigere Werte übertragen. Diese Wirkung wird durch die thermoplastische Phase verursacht, die eine niedrigere Viskosität bei dieser Temperatur zeigt.

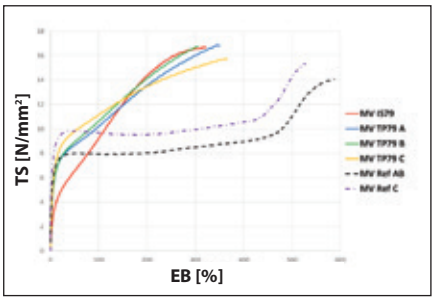
Dementsprechend, nimmt durch die Erhöhung des Gehalts an PP, die Scherbeanspruchung ab. Wegen der unterschiedlichen Beschaffenheit der MV TPV-Compounds, ist deren rheologisches Verhalten sehr unterschiedlich[6,7].

Im Wesentlichen ergibt sich eine derartige unterschiedliche Beschaffenheit durch die elastische Reaktion der elastomerischen vernetzten Partikeln, was bei niedrigen Scherbeanspruchungen vorherrschend ist. Bei hohen Scherbeanspruchungen unterliegt im Gegensatz das Verhalten der TPV-Compounds der thermoplastischen Phase. Infolgedessen weisen die drei MV TPV-Compounds ein ähnliches Verhalten wie das der Referenzcompounds bei hohen Schergeschwindigkeiten auf. Bei niedrigen Schergeschwindigkeiten sind die Kurven ansonsten deutlich abweichend.

Fokussiert man sich nur auf die MV TPV-Compounds, wie bereits für die MFI im Abschnitt 2.1 erwähnt, durch das sorgfältige Abwägen der Components und einer richtigen Auswahl des PP, wird es ermöglicht, das rheologische Verhalten der TPV MV-Compounds „abzustimmen", indem die thermomechanischen Eigenschaften erhalten bleiben oder sogar verbessert werden.

In dieser Hinsicht, zeigt MV TP79 C niedrigere Beanspruchungen d. h. Viskosität auf, bis zu sehr niedrigen Schergeschwindigkeiten gemeinsam mit den besten thermomechanischen Eigenschaften unter den erforschten TPV MV-Compounds.

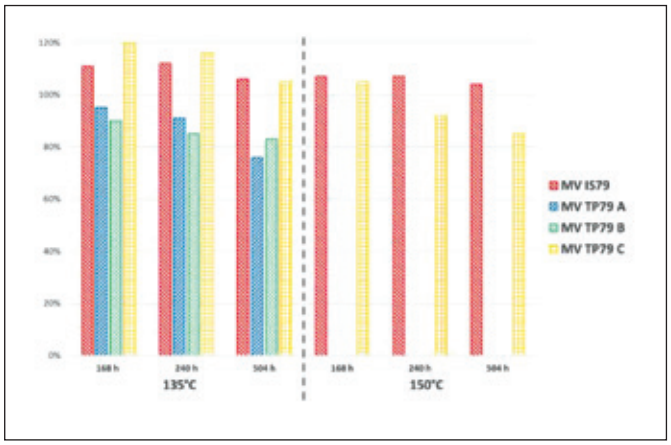
▼ **Abb. 6**: *Spannungs-Dehnungs-Diagramme der MV-Isoliermischungen. Punktierte Linien: Referenzmischungen*



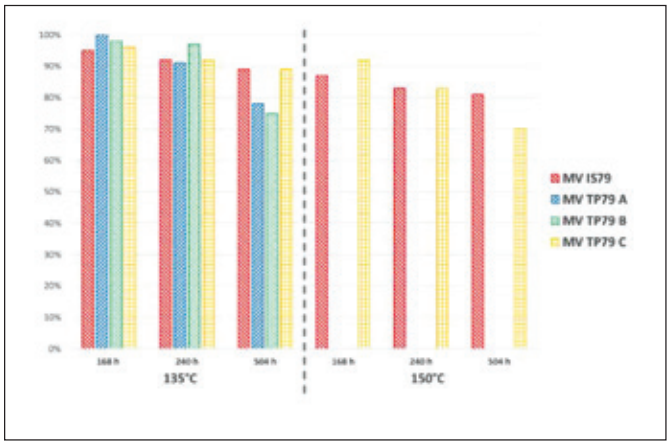
▼ **Tabelle 3**: *Prüfungen des Wärmedrucks und der Längsschrumpfung bei 130°C der MV TPV-Compounds*

	MV TP79 A	MV TP79 B	MV TP79 C
Wärmedruckprüfung[1] [%]	n.a.[2]	27	3
Längsschrumpfung[1] [%]	14	11	2

[1]CEI 20-86; [2]Nicht anwendbar



▲ **Abb. 7**: *Beibehaltene Zugfestigkeit nach Luftalterung bei 135°C und 150°C, 168, 240 und 504 Std. lang*



▲ **Abb. 8**: *Beibehaltene Bruchdehnung nach Luftalterung bei 135°C und 150°C, 168, 240 und 504 Std. lang*

2.4 Mechanische Prüfungen

Die Spannungs-Dehnungs-Eigenschaften der MV-Isoliermischungen wurden entsprechend der Methode ASTM D412 gemessen, wobei die Ergebnisse von fünf Proben des Typs Dumbbell gemittelt werden, die durch ein Tensor Check Profile von Gibitre erzielt wurden. Die Probekörper wurden entlang der Längsrichtung von Platten gestanzt, die in einer Formpressmaschine bei 180°C erstellt wurden. MV IS79 wurde 10 Minuten lang gepresst, um das Härtungsverfahren zu vervollständigen. MV TP79 A, B und C wurden 1 Minute lang gepresst und unter Druck abgekühlt. MV Ref AB und C wurden gleich behandelt wie die MV TPV-Compounds, um die Probekörper zu erzielen. In der Abb. 6 wird ein Beispiel der Spannungs-Dehnungs-Kurve je Compound dargestellt.

Auf den ersten Blick zeigt die Analyse der Spannungs-Dehnungs-Kurven der Materialien, dass die MV TPV-Compounds ähnliche Leistungen wie die der MV IS79-Benchmark hinsichtlich TS und EB aufweisen, wie bereits im Abschnitt 2.1 hervorgehoben. Neben den Absolutwerten, folgen die beschriebenen Kurven einem ähnlichen Model mit einer starken elastischen Reaktion auf die angelegte Spannung. Der wesentliche Unterschied, der beobachtet werden kann, ist der höhere Elastizitätsmodul in den MV TPV-Compounds. Dies entsteht durch die Kristallisation der thermoplastischen Phase und ist daher für MV TP79 C größer. Dasselbe Verhalten ist im Referenzcompound MV Ref AB erkennbar, das über einen Elastizitätsmodul verfügt, das praktisch MV TP79 A und B gleicht.

Auch MV Ref C verfügt über einen ähnlichen Elastizitätsmodul verglichen mit MV TP79 C. Jedoch geben diese Referenzcompounds, die nicht vulkanisiert sind und über keine elastischen Eigenschaften verfügen, bis zum endgültigen Bruch nach. Im Gegensatz dazu verhalten sich MV TPV-Compounds wie vernetzte Materialien mit hoher Dehnung[8-10]. Diese Ergebnisse stimmen mit den rheologischen Studien überein und bestätigen den Erfolg thermoplastischer Vulkanisatmischungen.

Entsprechend CEI 20-86, um die Leistung der MV TPV-Compounds bei hoher Temperatur zu bewerten, wurden die Prüfungen des Wärmedrucks und der Längsschrumpfung bei 130°C durchgeführt (in der Tabelle 3 zusammengefasst), dabei sind sie verbindlich für thermoplastische Isolierstoffe, die für 90°C und 105°C klassifiziert sind.

Die Ergebnisse zeigen eine Verbesserung der Ergebnisse aus MV TP79 A bis auf MV TP79 C. Allerdings ist dies keine Folge des Verhältnisses zwischen der thermoplastischen und der elastomerischen Phase, sondern die Folge des Zusatzes von PP (siehe *Tabelle 1*), das solchen hohen Temperaturen standhalten kann.

2.4.1 Wärmealterungsbeständigkeit

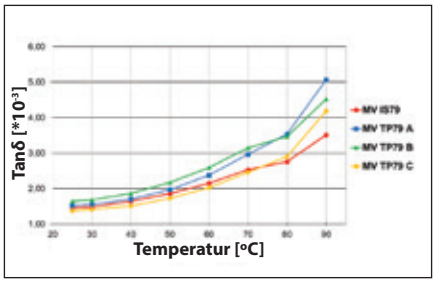
MV-Isoliermischungen wurden bei 135°C und 150°C für eine Dauer von 168, 240 und 504 Std. geprüft, um deren Beständigkeit gegen beschleunigte Alterung zu untersuchen. Beibehaltene TS und EB sind graphisch in den *Abb. 7* und 8 dargestellt. MV TP79 A und B konnten nicht bei 150°C geprüft werden, weil die thermoplastische Phase bei einer solchen Temperatur vollständig schmilzt. In dieser Hinsicht, stellt MV TP79 C, das PP mit höherer Schmelztemperatur enthält, die einzige Alternative zu MV IS79 bei der Prüftemperatur von 150°C dar.

Zunächst wird darauf hingewiesen, dass alle Compounds bei 135°C über eine gute bis zu einer ausgezeichneten Beständigkeit verfügen, bezogen auf beibehaltene TS und EB, die nach 504 Stunden 70% höher liegen. MV IS79 sowie MV TP79 C widerstehen auf hervorragende Weise der Wärmealterung bei 135°C, und erzielen beibehaltene TS und EB > 90%.

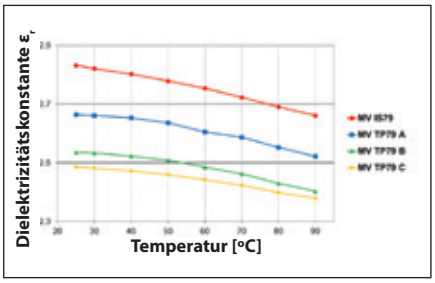
▼ **Tabelle 4**: *Spezifischer Durchgangswiderstand bei 25°C und 90°C mit 500V Potential gemessen*

Spezifischer Durchgangswiderstand [*10^{14}]	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
At 25°C [Ω-cm]	47.0	41.6	41.3	50.3
At 90°C [Ω-cm]	2.54	0.378	0.284	0.321

▼ **Abb. 9**: *Verlustfaktor (Tanδ) abhängig von der Temperatur bei 500V und 50Hz*



▼ **Abb. 10**: *Dielektrische Konstante (ε') abhängig von der Temperatur bei 500V und 50Hz*



Obwohl die Wärmebeständigkeitsleistung im Vergleich zu MV IS79 leicht herabsinkt, zeigt MV TP79 C eine > 80% beibehaltene TS und eine zirka um 70% nach 504 Std. bei 150°C beibehaltene EB. Die Prüfungen weisen darauf hin, dass MV TP79 C den gleichen Alterungsbedingungen von MV IS79 widerstehen kann. Es ist zu berücksichtigen, dass MV IS79 für eine Betriebstemperatur von 105°C eingestuft ist und daher routinemäßig 508 Std. lang bei 150°C mit typischen bei 95% und 75% beibehaltenen TS- und EB-Werten geprüft werden.

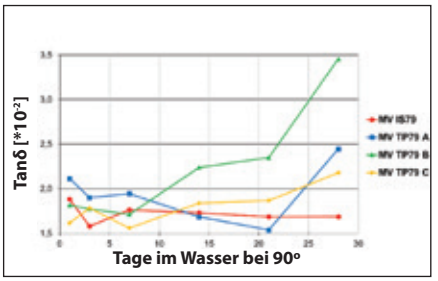
Entsprechend CEI 20-86, müssen MV-Isoliermischungen 240 Std. lang einer Alterung bei 135°C und 150°C widerstehen, jeweils bei Betriebstemperaturraten von 90°C und 105°C. Demzufolge stellt MV TP79 C eine wirksame thermoplastische Alternative zu standardmäßigen bleifreien elastomerischen MV-Isoliermischungen dar.

2.5 Elektrische Leistungen

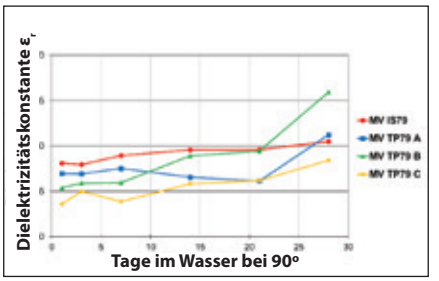
Isoliereigenschaften der Compounds wurden durch das Messen des Verlustfaktors (Tanδ), der dielektrischen Konstante (ε_r) und des spezifischen Durchgangswiderstands abhängig von Temperaturen von 25°C bis zu 90°C unter trockenen Bedingungen eingeschätzt. Darüber hinaus wurden der Verlustfaktor und die dielektrische Konstante nach dem Eintauchen der Mischungen in Wasser bei 90°C bis zu 28 Tage lang gemessen. Die elektrischen Eigenschaften wurden bei 2mm dicken Formpressproben gemessen. Ein Omicron MI600 System wurde eingesetzt, um Tanδ und ε_r zu bewerten; ein QuadTech-Modell 1868A wurde bei der Untersuchung des spezifischen Durchgangswiderstands implementiert. Alle elektrischen Eigenschaften der Mischungen wurden bei den Laboratorien von Imerys untersucht.

Abb. 9 zeigt ein Diagramm von Tanδ von 25°C auf 90°C unter trockenen Bedingungen. Die vier Compounds zeichnen sich durch leichte Abweichungen des Verlustfaktors aus, der in derselben Größenanordnung (10^{-3}) bis zu 90°C bleibt. Darüber hinaus weisen alle Compounds eine ähnliche Tendenz von Tanδ auf, indem die Temperatur erhöht wird. Im Detail, bei Raumtemperatur ist der Verlustfaktor der vier Compounds praktisch identisch, um $1,5 \cdot 10^{-3}$, und wächst kontinuierlich mit der Temperatur bis zu Werten zwischen $3,5 \cdot 10^{-3}$ und $5,0 \cdot 10^{-3}$ bei 90°C für MV IS79 bzw. MV TP79 A.

Wie für Tanδ beschrieben, variiert ε_r in einer engen Bandbreite für alle Compounds, die die Temperatur erhöhen. In Abb. 10 wird nur eine geringe Senkung der dielektrischen Konstante bei der Erhöhung der Temperatur beobachtet. Da ε_r durch nachfolgende Formel berechnet wird:



▲ **Abb. 11**: *Verlustfaktor (Tanδ) abhängig von den Tagen im Wasser eingetaucht bei 90°C, bei 500V und 50Hz gemessen*



▲ **Abb. 12**: *Dielektrische Konstante (ε_r) abhängig von den Tagen im Wasser eingetaucht bei 90°C, bei 500V und 50Hz gemessen*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
Wasseraufnahme [1] [mgr/cm²]	0.34	0.32	0.35	0.34

[1]Gravimetrische Methode, CEI EN 60811-402

▲ **Tabelle 5**: *Wasseraufnahme entsprechend CEI 20-86*

$$\varepsilon_r = \left(\frac{C}{\varepsilon_0}\right)\left(\frac{t}{A}\right)$$

wobei C die vom Gerät gemessene Kapazitanz und ε_0 die Permittivität des Vakuums ist, während t und A geometrische Faktoren sind, die jeweils die Trennung zwischen den Platten (Elektroden) und deren Bereich angeben. Die niedrigere dielektrische Konstante der MV TPV-Compounds im Vergleich zu MV IS79 ist durch deren Gehalt an PP angegeben, das die Isolierungsleistung des gesamten Compounds erhöht.

Demzufolge zeichnet sich MV IS79 durch die höhere dielektrische Konstante aus, im Gegensatz zum Compound MV TP79 C, das durch die niedrigere dielektrische Konstante gekennzeichnet ist. Allerdings muss hervorgehoben werden, dass der Unterschied zwischen den Compounds eher begrenzt ist, sowohl bei niedriger als auch bei hoher Temperatur. Schließlich wurde der spezifische Durchgangswiderstand bei 25°C und 90°C gemessen, indem ein Potential von 500V zugrundgelegt wird (siehe *Tabelle 4*).

Bei 25°C weisen alle Compounds einen spezifischen Durchgangswiderstand in einer Größenanordnung von $10^{15}\Omega$-cm, welcher Vorgabewert für MV-Isolierstoffe ist. Bei 90°C ist der spezifische Durchgangswiderstand von MV TPV-Compounds zirka um eine Größenanordnung niedriger als jene von MV IS79. Höchstwahrscheinlich ergibt sich dieser Unterschied aus einem teilweisen Schmelzen der thermoplastischen Phase von TPV-Compounds, die zu einer höheren Beweglichkeit der Ladungsträger im Material führen. Davon abgesehen, liegt jedoch der spezifische Durchgangswiderstand der vier MV TPV-Compounds über $10^{13}\Omega$-cm.

2.5.1 Elektrische Leistungen im Wasser

Die elektrischen Eigenschaften wurden auch nach dem Eintauchen in Wasser bei bis zu 28 Tagen bei 90°C geprüft. Zunächst wurde die Wasseraufnahme der MV TPV-Compounds im Vergleich zu MV IS79, entsprechend der italienischen Norm CEI 20-86, berechnet. Die in der *Tabelle 5* zusammengefassten Ergebnisse zeigen, dass die Compounds praktisch dieselbe Wasseraufnahme nach 14 Tage im Wasser bei 85°C aufweisen - eindeutig unter der Obergrenze (5mgr/cm²).

Die niedrige Wasseraufnahme spiegelt die Veränderung von Tanδ wider, nachdem die Proben in Wasser bei 90°C eingetaucht wurden (siehe *Abb. 11*). Die Compounds weisen eine gute Retention des Verlustfaktors auf, die nach 28 Tagen im Wasser, im Worst Case um 0,035 und im Best Case 0,017 entspricht. Hier zeigt wieder MV TP79 C, dank dessen überlegenen Stabilität, die besten Leistungen, nahe der Benchmarkleistung von MV IS79.

Mit einer niedrigen Wasseraufnahme, bleibt auch ε_r nach dem Eintauchen in Wasser bei 90°C fast unverändert. Wie in der *Abb. 12* dargestellt, ist die Erhöhung der dielektrischen Konstante eher gering nach dem Eintauchen in Wasser. Unter den MV TPV-Compounds, weist mit der Zeit MV TP79 C die beste Stabilität auf, mit einem niedrigeren ε_r im Vergleich zur MV IS79-Benchmark, selbst nach 28 Tagen im Wasser.

Schlussfolgerungen

Neuentwickelte MV TPV-Compounds wurden in diesem Artikel vorgestellt. Zugesichert wird die Herstellung von MV-Isoliermischungen mit Eigenschaften, die dem derzeitigen Marktstandard bleifreier MV-Isolierung gleichen sowie eine vereinfachte Verarbeitung von Thermoplasten.

Die Vorbereitung solcher Compounds wurde mit deren vollständigen Charakterisierung im Vergleich zu den standardmäßigen bleifreien MV-Isolierstoffen beschrieben. Mittels DDK wurde das dynamische Vulkanisationsverfahren untersucht. Untersucht wurde tatsächlich die Fähigkeit in einer industriellen Pilotanlage TPV-Compounds zur Anwendung als MV-Isolierung herzustellen.

Trotz der komplexen Formulierung, die Polymere, Füllstoffe, Coagents und Antioxidante enthält, wurden MV-TPV in einem völlig reproduzierbaren und zuverlässigen Verfahren erzielt. Die Ergebnisse der Technologie liegen in den Gesamteigenschaften der MV TPV-Compounds, die der Leistung von standardmäßigen bleifreien MV IS79 ähnlich sind.

Die rheologische Studien bestätigen die TPV-Beschaffenheit der Compounds und simulieren deren Extrusionsverhalten. Dabei beweisen sie, dass dank einer genauen Auswahl der thermoplastischen PP, es möglich ist die Scherbeanspruchung zu senken, während die typische elastische Reaktion der TPV-Compounds unverändert beibehalten wird.

Eine detaillierte Analyse der Spannungs-Dehnungs-Diagramme der MV TPV-Compounds bestätigt deren elastisches Verhalten, das nur teilweise durch die Kristallisation der thermoplastischen Phase beeinflusst wird, mit darauffolgenden mechanische Eigenschaften, die der MV IS 79S-Benchmark ähnlich sind.

Nach der Alterung bei 135°C, haben MV TPV-Compounds deren Widerstand bis zu 504 Std. lang mit beibehaltener TS und EB > 70% bewiesen. Nach einer 504 Std langen Alterung bei 150°C, bewahrt MV TP79 C 80% seiner TS und 70% seiner EB - mit den Bezug MV IS79 fast übereinstimmend. Schließlich wurden trockene und nasse elektrische Eigenschaften für alle Compounds bei 500V und 50Hz gemessen.

Der Tanδ unter trockenen Bedingungen erhöht sich mit der Temperatur bis zu einer oberen Grenze von zirka $5 \cdot 10^{-3}$ bei 90°C für MV TP79 A, was durchaus vergleichbar ist mit dem Tanδ von MV IS79 bei derselben Temperatur, $3,5 \cdot 10^{-3}$.

In ähnlicher Weise, variiert ε_r in einer sehr engen Bandbreite (zwischen 2,8 und 2,4) bei 25°C und bis zu 90°C für alle Compounds.

Die Messungen des spezifischen Durchgangswiderstands bestätigen hervorragende Isoliereigenschaften bei 25°C ($10^{15}\Omega$-cm), die bei 90°C ($10^{13}\Omega$-cm) leicht abfallen. Die elektrischen Eigenschaften unter nassen Bedingungen wurden durch Eintauchen der Proben in Wasser bis zu 28 Tage lang bei 90°C gemessen. Der Tanδ unter nassen Bedingungen erhöht sich höchstens auf $3,5 \cdot 10^{-2}$ für MV TP79 B.

Die Mischungen MV TP79A und C zeigten einen besseren Widerstand gegenüber Wasser; letzterer nahe der Leistung von MV IS79 nach 28 Tagen im Wasser bei 90°C, $2,2 \cdot 10^{-2}$ bzw. $1,3 \cdot 10^{-2}$. Dieselbe Tendenz wurde für die ε_r beobachtet, die langsam ansteigt nachdem die Proben in Wasser eingetaucht werden. Jedoch sind die Fluktuationen geradezu bedeutungslos, da sie zwischen 2,53 und 2,66 liegen und unter Berücksichtigung des Fehlers, der mit der Messung verbunden wird.

Abschließend wurde eine vollständige Untersuchung über die TPV-Compounds als Isoliermaterial für MV-Anwendungen vorgestellt. Der stufenweise Ansatz zeigte wie damit die Eigenschaften der Compounds zunehmend erhöht werden können und ein völlig thermoplastisches bleifreies Material erreicht werden kann, namentlich MV TP79 C, mit mechanischen, rheologischen und elektrischen Leistungen, die mit jenen des Marktstandards des bleifreien MV IS79 vergleichbar sind. Entsprechend der Norm CEI 20-86, kann MV TP79 C als MV-Isolierung hergestellt werden mit einer Einstufung von 105°C für eine kontinuierliche Betriebstemperatur und einem Notfall-Kurzschluss von 250°C.

Indem die Strategie vorangetrieben wird, nimmt Mixer SpA an MV TPV-Compounds mit höherem Widerstand und höheren elektrischen Eigenschaften bei hohen Temperaturen und im Wasser in der nahen Zukunft zu entwickeln. ■

Danksagung

Die Autoren möchten Imerys als Lieferant der Rohstoffe danken, die in dieser Studie benutzt wurden. Darüber hinaus möchten die Autoren die Laboratorien von Imerys in Par, UK, für die elektrischen Messungen danken, die an deren Compounds durchgeführt wurden.

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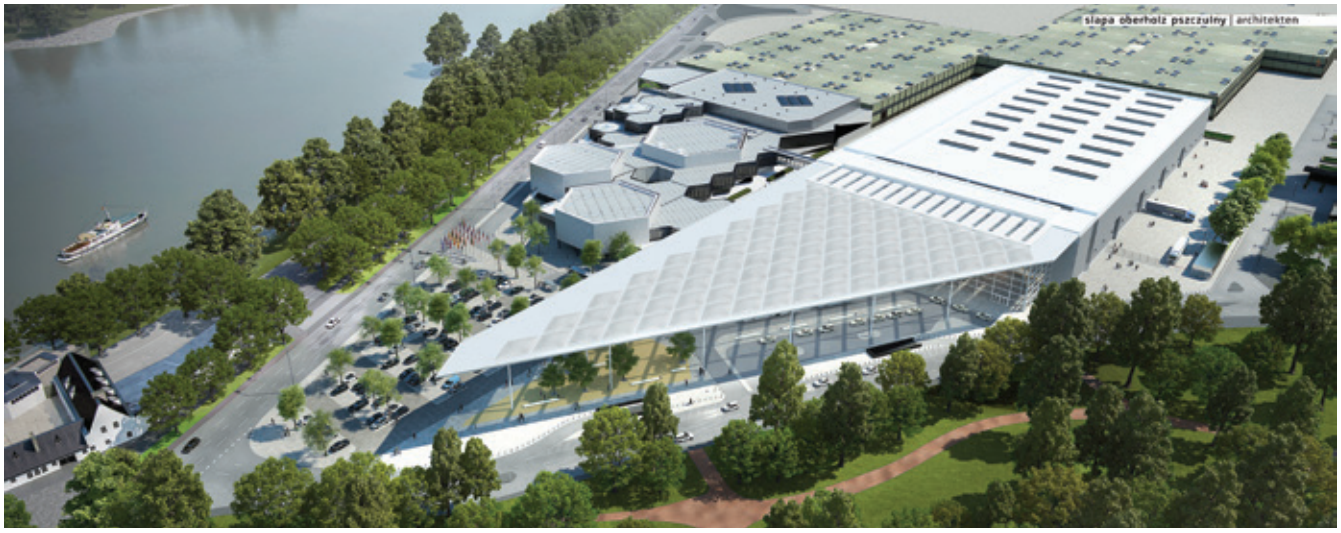

▲ *Архитектурный план нового южного входа в выставочный центр в Дюссельдорфе*

Новая южная секция Messe Düsseldorf: выставки проволока 2018 и трубная продукция 2018

Полная реконструкция южного входа и соседнего Зала 1 началась в выставочном комплексе в Дюссельдорфе. Совет директоров и акционеры Messe Düsseldorf GmbH подтвердили свое согласование, и, таким образом, была достигнута отправная точка для одного из самых амбициозных строительных проектов в истории компании. «Сейчас мы может осуществить свой основной план по полной модернизации и ремонту наших помещений, нашей базы», - сказал Вернер М. Дорншайдт, председатель и Генеральный директор Messe Düsseldorf, добавив: «Как обычно, работы будут выполняться без субсидий».

Капитальные расходы на ремонт южной секции достигают 140 миллионов евро. В целом, инвестиции в офисы Messe Düsseldorf составят около 636 миллионов евро до 2030 года. Работы начались в мае и по графику должны завершиться к лету 2019 года. Проект для выполнения работ принадлежит архитектурной компании slapa oberholz pszczulny architekten, расположенной в Дюссельдорфе.

Новый южный вход обеспечит Messe Düsseldorf современной резиденцией на берегах Рейна с видом на город Дюссельдорф. Посетителей и участников выставки будут приветствовать под новым светящимся и прозрачным куполом размером 7800 м^2 и около 20 м высотой.

Данная конструкция будет служить мощным архитектурным символом, так как ее высшая точка видна в выставочном центре. Юрек Слапа, управляющий партнер в sop architecten, сказал: «Купол будет новым фасадом и отличительным местом Messe Düsseldorf в данном уникальном расположении между Рейном и Северным парком. «Он также объединит существующий конференц-центр и, таким образом, юудет деликатно сочетаться с существующими конструкциями». Купол будет достигать 170 м в длину и 93 м в ширину, создавая большое пространство для участников конференций и выставок непосредственно до выставочного центра и выставочного пространства.

Фасад южного входа должен выходить на передний двор через фасад, сделанный полностью из стекла, достигающий 93 м в длину. Необходимые услуги, такие как кассы и уборные будут располагаться на площади в 2000 м^2. На первом этаже будет располагаться стеклянная переговорная, выходящая в фойе, из которой будет открываться вид на вход и передний двор. Кроме того, все фойе будет доступно для мероприятий. В переднем дворе будет также находиться вход в подземную парковку на 300 мест, а также автобусные остановки и стоянка такси.

В объем ремонтных работ южного входа также включена реконструкция Зала 1. С этой целью Messe Düsseldorf планирует разрушить существующие Залы 1 и 2, которые меньше по размеру, и заменить их новым зданием. Зал 1, размеры которого будут 158м x 77м с площадью более 12000 м^2, будет затем такого же размера, как и Залы 8a и 8b.

Новый зал будет соответствовать высоким техническим стандартам, которым должен соответствовать весь выставочный центр. Доступ будет обеспечен с семи входов с подвесными конструкциями из потолка зала, которые так же легко установить, как и сами стенды на полу зала. Пешеходы могут использовать мост на первом этаже для перехода между залами в Конгресс-центр Дюссельдорф. Помимо соединения с Залами 3 и 4, будет основной вход, ведущий от южного входа непосредственно в остальные помещения.

В 2017 и 2018 гг. в переходный период, во время которого будут выполняться строительные работы, участникам выставки по трубной продукции, которые ранее располагались в Залах 1 и 2, предложат привлекательную альтернативу расположения стендов в Залах 16 и 17. Так, выставка трубной продукции Tube 2018 будет проводиться в Залах с 3 по 7 и Залах 16 и 17. Участники выставки проволоки wire 2018 смогут представить свои инновации в Залах с 9 по 16.

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Система производства кабелей данных и обработка данных

▲ *Линия скручивания кабеля данных с крутильной машиной двойного кручения типа DSI 631 в сочетании с машиной для скрутки пар с откруткой и продольной лентой отдатчиком*

Кабели для транспорта, ИТ систем, энергетического сектора и иных применений должны отвечать постоянно растущим требованиям.

Чтобы идти в ногу с разработками, производителям кабелей необходимо машинное оборудование, которое может производить кабели сложной конструкции, работать эффективно и экономично, а также гибко адаптироваться к новым производственным требованиям.

Кабельное оборудование, разработанное и изготовленное компанией Niehoff, отвечает всем данным требованиям. Одним из примеров является крутильная машина двойного кручения типа DSI 631, которая была разработана для скручивания изолированных проводников в пары и четверки, а также для скручивания четырех пар проводников в кабели LAN.

Оборудование также может надежно изготавливать кабели LAN всех категорий - даже будущих поколений - а также пары с ленточной оболочкой, магистральные шины, а также телекоммуникационные кабели.

Система скручивания DSI включает большое количество дополнительного оборудования для возможности создания и быстрой модификации индивидуальных производственных линий, в зависимости от ситуации.

По сравнению с иным оборудованием и технологиями обработки, сочетание возможностей данной системы может являться значительным преимуществом для производства определенного вида продукции или определенных производственных характеристик.

Дополнительным преимуществом для пользователей данных систем Niehoff является то, что компания с многолетним опытом в проектировании оборудования для кабеля и проволоки оказывает поддержку заказчикам в части технологических знаний и профессионального послепродажного обслуживания.

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Новый директор по продажам

Арнольд Бюшер стал новым директором по продажам в Германии в U I Lapp GmbH, Группе компаний Lapp Group. Госпдин Бюшер, инженер-механик по образованию ранее занимал ведущие должности в крупных промышленных компаниях с известным именем. К примеру, одним из предпоследних мест его работы была компания Rittal Corp в США, где он приобрел международный опыт в должности управляющего директора. В последнее время он отвечал за бизнес в Германии и Центральной Европе в должности управляющего директора компании Weidmüller GmbH & Co KG.

«Мы рады поприветствовать господина Бюшера, так как он опытный управляющий, который очень хорошо знаком с нашим рынком, и который будет способствовать трансформации на пути становления компании как системного поставщика», - сказал Андреас Лапп. Господин Бюшер планирует укрепить все каналы сбыта и сосредоточиться на росте рынков в железнодорожной, пищевой сферах и робототехнике. Его деятельность также включает учреждение и расширение системных решений под именем Ölflex® Connect с широким диапазоном продукции и услуг для кабелей предварительной заводской готовности. «Компания Lapp тесно сотрудничает с заказчиками, а также обладает высоким потенциалом роста. Я хотел бы усилить наш подход в общении с заказчиками по всем каналам, сосредоточить наши усилия на потенциале и способствовать развитию нового бизнеса с заказчиками», - сказал господин Бюшер, обсуждая свою новую должность.

Lapp Group – Германия **Вебсайт**: www.lappgroup.com

▲ *Арнольд Бюшер*

Изоляция на основе ТПВ для применения в линиях среднего напряжения

Андреа Галанти, Стефано Досси и Андреа Магри из Mixer SpA, Равенна, Италия,
а также Камилло Карделли iPool Srl, Пистоя, Италия

Аннотация

Разработка трех полностью термопластических бессвинцовых изоляционных компаундов для среднего напряжения основана на технологии термопластичной вулканизации (ТПВ) представлена в данной работе. Изоляционные компаунды на основе ТПВ для среднего напряжения были подготовлены, начиная с пероксидной отверждаемой изоляции, которая является фактическим рыночным ориентиром. По данной причине они активно изучались в сравнении со стандартной бессвинцовой изоляцией для среднего напряжения. Для оценки результатов технологического процесса динамической вулканизации компаунды изучались посредством дифференциальной сканирующей калориметрии (ДСК). Для моделирования поведения при экструзии была изучена их реология. Механические характеристики были измерены до и после износа при 135°C и 150°C до 21 дня. В заключение представлено комплексное изучение их электрических характеристик в сухих (от 25°C до 90°C) и влажных (до 28 дней при 90°C в воде) условиях.

1 Введение

Двадцать лет назад изоляционные системы как на основе ПЭ-С, так и на основе СКЭПТ, использовались во многих частях света для кабелей среднего напряжения. Северная Америка остается очень активным рынком для изоляций на основе СКЭПТ для кабелей среднего напряжения, тогда как в других частях света предпочтительным является ПЭ-С. В последнее время на глобальном рынке вновь возрос интерес к системам на основе СКЭПТ для кабелей среднего

▲ **Рисунок 1.** *Изоляция для среднего напряжения, содержащая свинец (рыжая) и бессвинцовая (белая), от заготовок до кабелей*

напряжения из-за несоответствующих рабочих характеристик срока службы кабеля и долгосрочного применения (>20 лет). С 1996 года Mixer SpA производил компаунды для изоляции среднего напряжения на основе смесей СКЭПТ/ПЭВД: их стратегия заключается в предложении инновационных и конкурентоспособных материалов для кабельного рынка, полагая что постоянное улучшение материалов даст новую жизнь кабелям с резиновой изоляцией для особых применений.

Первым шагом данного подхода была разработка бессвинцовых СКЭПТ решений, которые были представлены в 2012 году, а сейчас являются доступными на рыке (смотрите Рисунок 1)[1].

В связи с тем, что соли свинца не растворяются в воде, а, следовательно, это не способствует току потерь через слой изоляции, оксид свинца является одной из самых эффективных добавок в компаунды для изоляции среднего напряжения. Однако, оксид свинца указан в Reach SVHC (особо опасные вещества) из-за хорошо известного риска биоаккумуляции и продолжительного воздействия, что ведет к серьезным разрушениям окружающей среды и жизни[2].

Компания Mixer успешно заменила оксид свинца на систему раскисления неорганического иона, способную на иммобилизацию ионов, которая работает при производстве бессвинцовых изоляционных компаундов среднего напряжения на основе СКЭПТ со сверхвысокой термостойкостью и электрической стабильностью. С данной начальной точки был разработан новый полностью термопластичный ТПВ для изоляции среднего напряжения, динамично вулканизирующий в бессвинцовый компаунд для изоляции среднего напряжения в ПП матрице. Компания Mixer представляет три обновленных компаунда ТПВ для среднего напряжения в части прохождения материалом термомеханических испытаний при 90°C и 105°C постоянной температуры эксплуатации и 250°C при аварии с коротким замыканием в соответствии с итальянской нормой CEI 20-86, которая, до настоящего времени, является единственной нормой для термопластичных компаундов и изоляции среднего напряжения.

Во-первых, обсуждается подготовка и макроскпические характеристики новых компаундов ТПВ для среднего напряжения. Затем компания рассматривает новые компаунды ТПВ для среднего напряжения при помощи ДСК для изучения процесса динамической вулканизации. В третьей части была проанализирована реология ТПВ для среднего напряжения при нмзком сдвиге для стимуляции экструзионных характеристик. Впоследствии компаунды ТПВ для низкого напряжения проходили испытания на механические характеристики до и после износа температурой до 150°C и в течение 21 дня. Электрические характеристики компаундов были изучены в лабораториях Imerys

Laboratories, Пар, Великобритании. В деталях, коэффициент потерь (Tanδ), диэлектрическая постоянная (εr) и объёмное удельное сопротивление были измерены при температуре до 90°C в сухих условиях. Дополнительно Tanδ и εr были проанализированы после опущения компаундов в воду при 90°C на срок до 28 дней. Результаты испытаний были сравнены со стандартными бессвинцовыми компаундами для среднего напряжения IS79, демонстрирующие, что может быть предложен инновационный и надежно изолирующий компаунд, который сочетает в себе характеристики бессвинцового сшитого СКЭПТ компаунда с возможностью обработки его до термопластичного материала.

2 Бессвинцовые ТПВ компаунды для среднего напряжения

2.1 Подготовка ТПВ компаундов для среднего напряжения

Бессвинцовый изоляционный компаунд для среднего напряжения MV IS79 и термопластичные вулканизирующие компаунды для среднего напряжения ТПВ были подготовлены во закрытом смесителе, оборудованном роторами противоположного вращения и камерой объемом 8 см³. Состав ТПВ компаундов для среднего напряжения указан в Таблице 1. Очевидно, что компаунды MV TPV79 A и B имеют то же соотношение между эластомерной и термопластичной фазой, тем не менее, в их формуле используются разные соагенты. Это было сделано после исследований влияния соагентов на характеристики ТПВ компаундов путем предотвращения декомпозиции ПП через β-расщепление, вызванное свободными радикалами[3].

Состав ТПВ	MV TP79 A	MV TP79 B	MV TP79 C
MV IS79	75%	75%	70%
ПП-1[1]	25%	25%	20%
ПП-2[2]	-	-	10%

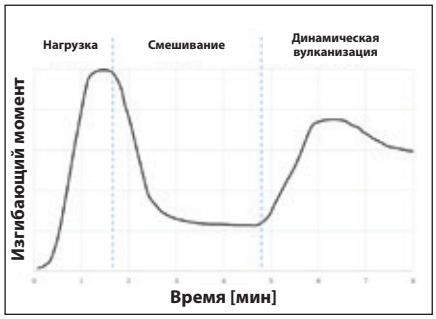
[1]d = 0.891 gr/cm³, MFI (230°C; 2.16kg) = 8.0 gr/10min; [2]d = 0.900 gr/cm³, MFI (230°C; 2.16kg) = 10.0 gr/10 min

▲ **Таблица 1.** *Состав ТПВ для среднего напряжения*

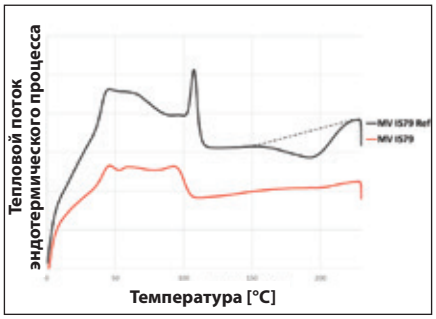
MV IS79 был приготовлен для смешивания всех компонентов в закрытом смесителе, что ведет к полному смешиванию ингредиентов. После выгрузки пероксид был добавлен при низкой температуре в двухвальцевом станке. Образцы испытаний были получены путем сжатия вальцованных листов в станке прямого прессования при 180°C в течение 10 минут. Образцы механических характеристик были высечены штампов в направлении фрезеровки.

Компаунды MV TP79 были подготовлены путем смешивания бессвинцового компаунда (MV IS79) с термопластичным полипропиленом (ПП) в соответствии с пропорцией, указанной в Таблице 1. Во время процесса смешения в момент реакции свободных радикалов при постоянном росте температуры с крутящим моментом в соответствии с определенной моделью, которая графически представлена на Рисунке 2[4,5]. После загрузки ингредиентов крутящий момент растет из-за большой вязкости компонентов при низкой температуре. При росте температуры материалы становятся мягче, крутящий момент уменьшается в то время, как происходит смешивание. При начале реакции радикалов происходит одновременная сшивка каучуковой фазы и β-расщепление ПП фазы, с последующей инверсией фазы, приводящей к быстро увеличивающему крутящему моменту. Окончательная температура, при которой ТПВ выгружались после примерно восьми минут обработки была между 200°C и 220°C. Все еще горячие компаунды были каландрированы в двухвальцовом станке в форме листа; были получены пластинки путем сжатия листов в станке прямого прессования. Образцы механических характеристик были высечены штампов в направлении фрезеровки.

▼ **Рисунок 2.** *Изображение изгибающего момента в функции времени во время производства ТПВ компаундов для среднего напряжения. Указаны три основных шага технологического процесса*



▼ **Рисунок 3.** *Анализ ДСК неосушенного (вверху) и осушенного (внизу) MV IS79. Пунктирная линия: графическое изображение основы, взятой для подсчета реакции энтальпии*



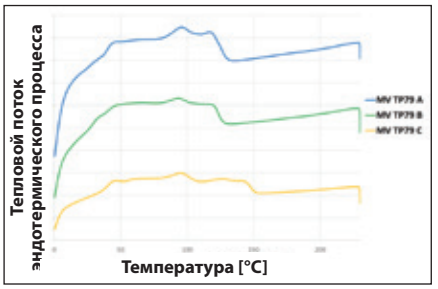
▼ **Таблица 2.** *Стандартные физические характеристики изоляционных компаундов для среднего напряжения*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
Прочность на разрыв[1] [Н/мм²]	16.61	17.31	17.19	15.73
Удлинение при разрыве[1] [%]	321	360	310	341
Прочность на разрыв при 200% [Н/мм²]	14.23	13.57	14.48	13.62
Жесткость[2] [Дюрометр A-D]	80-/	96-45	95-46	96-48
Индекс текучести расплава[3] [гр/10мин]	27.6[4]	4.4	4.2	21.3

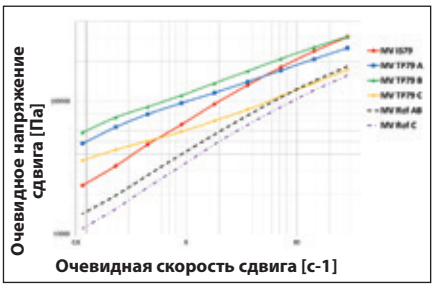
[1]ASTM D412; [2]ASTM D2240; [3]ASTM D1238 (190°C, 21.6kg), [4]Измерено на компаунде без пероксида

Выбор ПП и его коэффициент оказывает не очень большое влияние на механические характеристики, которые близки к стандартному MV IS79. Напротив, кристалличность ПП приводит к видимому увеличению жесткости, которое составляет 48 дюрометров для стандартного MV TP79 C, т.е., компаунда с самым высоким содержанием ПП. Из-за высокой вязкости MV TP79 A и B, индекс текучести расплава был измерен при 190°C и весе 21,6 кг.

Их низкая текучесть может быть принципиально обусловлена двумя факторами: коэффициентом между термопластичной и эластомерной



▲ **Рисунок 4.** *Анализ ДСК MV TP79 A (вверху), MV TP 79 B (посередине) и MV TP79 C (внизу)*



▲ **Рисунок 5.** *Очевидное напряжение сдвига в функции измерения очевидного сдвига при 180ºC изоляционных компаундов для среднего напряжения. Пунктирные линии: эталонные компаунды*

фазами и выбором ПП с низким индексом текучести расплава при температуре испытаний. Однако, необходимо отметить, что при аккуратном балансировании коэффициента между двумя фазами и точном выборе ПП, можно получить индекс текучести расплава для MV TP79 C, сопоставимый со стандартным MV IS79. Эти результаты подтверждены анализом реологии, представленном в разделе 2.3.

Для сравнения и выделения удачного достижения компаундов MV TPV, были произведены эталонные материалы без пероксида. Таким образом, в данных компаундах динамическая вулканизация могла произойти и после смешивания компонентов. Эталонный компаунд MV Ref AB имеет такой же состав, как и MV TP79 A и B (без пероксида и соагентов), эталонный компаунд MV Ref C был сформирован в качестве MV TP79 C (без пероксида). Реология и механические характристики обоих эталонных компаундов были проанализированы в сравнении с компаундами ТПВ для среднего напряжения, представленными в данной работе для демонстрации нашей возможности получения ТПВ компаундов в воспроизводимом и контролируемом режиме.

2.2 Анализ ДСК

Для определения непрореагировавшего пероксида, оставшегося в компаунде после процесса осушки, была проведена ДСК. Спектры были измерены в Perkin-Elmer DSC 6000 в инертной азотной атмосфере с 0°C до 230°C с быстротой нагрева 20°C/мин, после нагревания образцы были отсужены до 0°C при 10°C/мин. Цикл был повторен трижды. Однако, целью данного исследования было определить коэффициент соотношения между начальным и остаточным (после осушки или динамической вулканизации) пероксидом, только первый цикл нагревания представлен и обсужден далее.

Во-первых, неосушенный MV IS79, содержащий 100% непрореагировавшего пероксида, был проанализирован и использован в качестве эталона. Из ДСК, показанной на Рисунке 3, рассчитанная энтальпия реакции (ΔH), при учете распада пероксида была -8.97 Дж/г. На том же рисунке представлена диаграмма ДСК осушенного MV IS79 (10 минут при 180°C). ΔH of -1,16 Дж/г. Было обнаружено в соответствии с остатком около 13% непрореагировавшего пероксида. Это указывает на то, что MV IS79 почти полностью вулканизировался. В то же время, было подсчитано количество непрореагировавшего пероксида компаундов ТПВ среднего напряжения, с учетом MV TP79 A, B и MV TP79 C были сформулированы при 75% и 70% неосушенного MV IS79, соответственно.

Из собранных данных и продемонстрированных на Рисунке 4, оставшийся пероксид, обнаруженный в MV TP79 A, был около 4% (ΔH = -0,27 Дж/г), а MV TP79 B был около 5% (ΔH = -0,33 Дж/г). Для MV TP79 C посчитанный остаточный пероксид был около 11% (ΔH = -0,68 Дж/г). Данные результаты подтверждают вне всякого сомнения почти полное разложение первоначального пероксида во время динамической вулканизации.

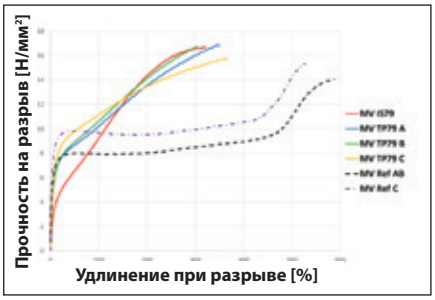
2.3 Реология

Реологические исследования являются фундаментальными для прогнозирования экструзионных характеристик компаундов. Как таковую, мы рассмотрели реологию при прямой скорости сдвига с 200 c^{-1} до 1 c^{-1} в капиллярном вискозиметре Göttfert Rheograph 2002. Отношение длины к диаметру капилляров было 30, а измерения выполнялись при 180°C. Температура была выбрана для обеспечения полного сплавления с ПП. Обычно стандартные компаунды, такие как MV IS79, характеризуются при 125°C до осушки, однако, при данной температуре ПП не расплавляется, что приводит к неверным результатам. Из-за высокой температуры испытаний для предотвращения распада пероксида во время анализа MV IS79 был проанализирован без пероксида. Как указывалось ранее, эталонные компаунды MV Ref AB и C, были включены в данную работу для подчеркивания изменений в реологических характеристиках в качестве последствия динамической вулканизации. Диаграммы прямого напряжения сдвига в функции прямой скорости сдвига, показаны на Рисунке 5.

Реакция MV IS79 стандартна для компаундов на основе СКЭПТ/ПЭ: напряжение сдвига резко уменьшается почти в линейной зависимости при уменьшении скорости сдвига. Могут быть отмечены небольшие отклонения от идеальной линейности, которые обычно приписываются к резинам СКЭПТ. MV Ref AB и C демонстрируют ту же модель с напряжением сдвига ближе к меньшим показателям. Данный эффект вызван термопластичной фазой, которая показывает более низкую вязкость при данной температуре.

Соответственно, при увеличении содержания ПП, уменьшается напряжение сдвига. Благодаря различной природе ТПВ компаундов среднего напряжения их реологические характеристики также довольно различны[6,7]. Существенно, такой отличный характер обусловлен эластичной реакцией эластометричных сшитых частиц, которые являются доминантными при низком напряжении сдвига. Напротив, при высоком

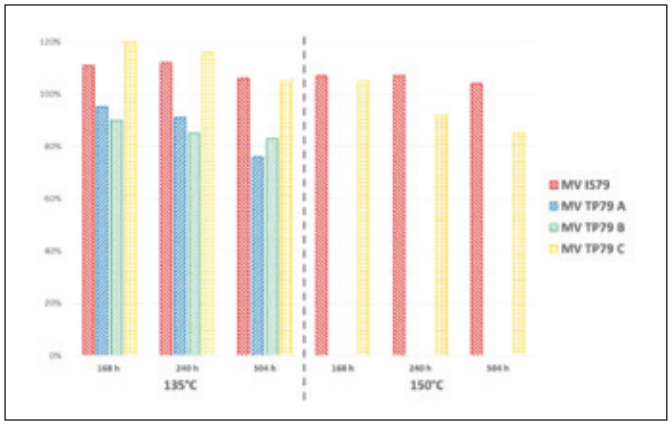
▼ **Рисунок 6.** *Диаграммы деформации изоляционных компаундов для среднего напряжения. Пунктирные линии: эталонные компаунды*



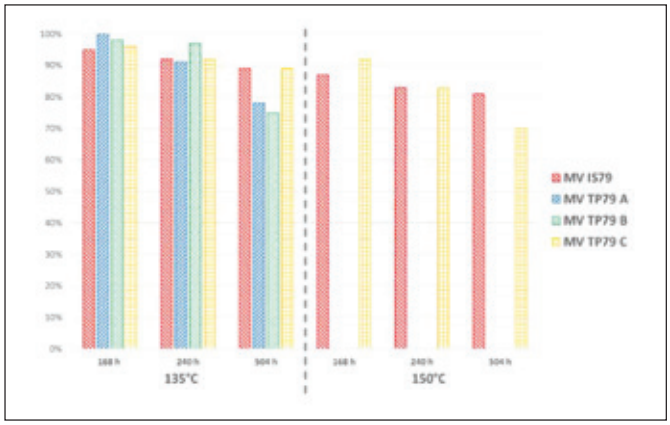
▼ **Таблица 3.** *Огневое испытание под давлением и продольная усадка при 130°C ТПВ компаундов для среднего напряжения*

	MV TP79 A	MV TP79 B	MV TP79 C
Огневое испытание под давлением[1] [%]	n.a.[2]	27	3
Продольная усадка[1] [%]	14	11	2

[1]CEI 20-86; [2]Не применимо



▲ **Рисунок 7.** *Прочность на разрыв сохранена после старения при 135°C и 150°C на протяжении 168 часов, 240 часов и 504 часов*



▲ **Рисунок 8.** *Удлинение на разрыв сохранено после старения при 135°C и 150°C на протяжении 168 часов, 240 часов и 504 часов*

напряжении сдвига поведение ТПВ компаундов обуславливается термопластичной фазой. В результате у всех трех ТПВ компаундов схожие характеристики с эталонными компаундами при высоких скоростях сдвига. Иным образом, при низких скоростях сдвига, кривые очевидно различаются.

Уделяя внимание только ТПВ компаундам среднего напряжения, как ранее указывалось для индекса текучести расплава в Разделе 2.1. путем аккуратного балансирования компонентов и правильного выбора ПП, возможно «приводить в соответствие» реологию ТПВ компаундов для среднего напряжения, сохраняя или улучшая термодинамические характеристики. В данном отношении MV TP79 C демонстрирует меньшие нагрузки, т.е. вязкость, вплоть до очень низких скоростей сдвига с самыми лучшими термодинамическими характеристиками среди рассмотренных ТПВ компаундов для среднего напряжения.

2.4 Механические испытания

Характеристики деформации вследствие напряжения компаундов изоляции для среднего напряжения были измерены в соответствии с методом ASTM D412 с усреднением результатов пяти образцов испытаний в форме лопатки были получены при помощи системы Gibitre Tensor Check Profile. Образцы были высечены штампом в направлении вальцевания из пластин, полученных при помощи станка прямого прессования при 180°C. MV IS79 прессовался на протяжении 10 минут до полного процесса осушки. MV TP79 A, B и C прессовались в течение одной минуты и охлаждались под давлением. MV Ref AB и C обрабатывались одинаково с компаундами MV TPV для получения образцов для испытаний. На рисунке 6 изображен один пример кривой деформации вследствие напряжения для каждого компаунда.

На первый взгляд анализ кривых деформации вследствие напряжения материалов демонстрирует, что эксплуатационные характеристики компаундов MV TPV схожи с эталоном MV IS79 в части прочности на разрыв и удлинения при разрыве, как было указано в разделе 2.1. Помимо абсолютных показателей, указанные кривые соответствуют схожей модели с прочными эластичными характеристиками к применяемой нагрузке. Основным отличием, которое наблюдается, является более высокий модуль упругости компаундов MV TPV. Это вызвано степенью кристалличности термопластичной фазы, а поэтому, она выше у MV TP79 C. Те же самые характеристики отмечаются и у эталонного компаунда MV Ref AB, модуль упругости которого практически аналогичен MV TP79 A и B. Схожим образом, MV Ref C имеет одинаковый с MV TP79 C.модуль упругости. Однако данные эталонные компаунды при отсутствии вулканизации и нехватке эластичности деформируются до полного разрыва. Напротив, компаунды MV TPV имеют характеристики как у сшитых материалов с большим растяжением[8-10]. Данные результаты соответствуют анализу реологии, подтверждая успешное достижение компаундов с термопластичной вулканизацией. В соответствии с CEI 20-86 для оценки эксплуатационных характеристик компаундов MV TPV при высокой температуре было проведено огневое испытание под давлением, и данные по продольной усадке при 130°C указаны в таблице 3, которые являются обязательными для термопластичных изоляционных материалов, рассчитанных на 90°C и 105°C. Результаты демонстрируют улучшение, начиная от MV TP79 A и до MV TP79 C. Однако, это не следствие коэффициента между термопластичной и высокоэластичной фазой, это результат добавления ПП (смотрите таблицу 1), который может выдерживать такие высокие температуры.

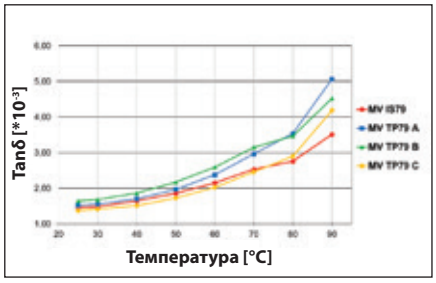
2.4.1 Сопротивление тепловому старению

Компаунды для изоляции среднего напряжения прошли испытания при 135°C и 150°C в течение 240 и 504

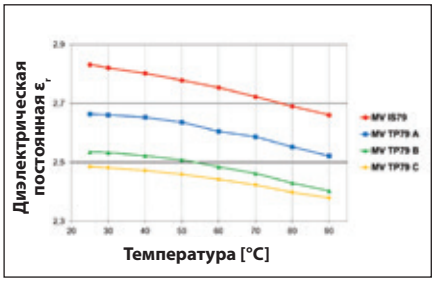
▼ **Таблица 4.** *Объемное удельное сопротивление, измеренное при 25°C и 90°C с потенциалом 500В*

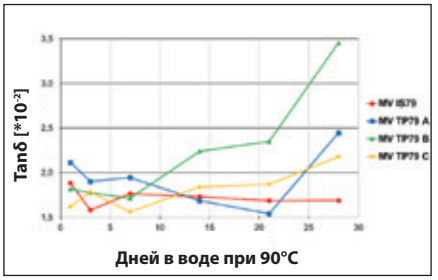
Объемное удельное сопротивление [*10^{14}]	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
на 25°C [Ω-cm]	47.0	41.6	41.3	50.3
на 90°C [Ω-cm]	2.54	0.378	0.284	0.321

▼ **Рисунок 9.** *Коэффициент потерь (Tanδ) в функции температуры при 500 В и 50 Гц*

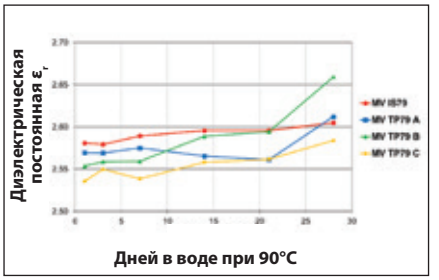


▼ **Рисунок 10.** *Диэлектрическая постоянная (εr) в функции температуры при 500 В и 50 Гц*





▲ **Рисунок 11.** *Коэффициент потерь (Tanδ) в функции дней при погружении в воду при 90°C, измеренный при 500 В и 50 Гц*



▲ **Рисунок 12.** *Диэлектрическая постоянная (εr) в функции дней при погружении в воду при 90°C, измеренная при 500 В и 50 Гц*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
Поглощение воды [1] [mgr/cm²]	0.34	0.32	0.35	0.34

[1]Гравиметрический метод, CEI EN 60811-402

▲ **Таблица 5.** *Поглощение воды согласно CEI 20-86*

часов для оценки их устойчивости к ускоренному старению. На рисунке 7 и на рисунке 8 графически показаны сохраненные прочность на разрыв и удлинение при разрыве. MV TP79 A и B не могли проходить испытания при 150°C, так как термопластичная фаза полностью плавится при данной температуре. В этом отношении MV TP79 C, который содержит ПП с более высокой температурой плавления представляет единственную альтернативу MV IS79 при температуре испытаний 150°C.

Во-первых, следует отметить, что все компаунды обладают отличной устойчивостью при 135°C в части сохраненных прочности на разрыв и удлинения при разрыве, которые выше 70% после 504 часов. Как MV IS79, так и MV TP79 C обладают превосходным сопротивлением тепловому старению при 135°C, достигая сохраненные прочность на разрыв и удлинение при разрыве > 90%. Хотя характеристики сопротивления тепловому старению слегка уменьшаются по сравнению с MV IS79, MV TP79 C демонстрирует сохраненную прочность на разрыв > 80% и сохраненное удлинение при разрыве примерно 70% после 504 часов при 150°C. Испытания показывают, что MV TP79 C может выдерживать те же условия старения, что и MV IS79. Следует учесть, что MV IS79 рассчитан для рабочей температуры 105°C, а, следовательно, обычно проходит испытания в течение 508 часов при 150°C со стандартными показателями прочности на разрыв и удлинения при разрыве 95% и 75%. В соответствии с CEI 20-86, изоляционные компаунды для среднего напряжения должны выдерживать старение на протяжении 240 часов при 135°C и 150°C для предельной температуры эксплуатации 90°C и 105°C соответственно. Таким образом, MV TP79 C представляет надежную термопластичную альтернативу стандартным бессвинцовым высоко эластичным изоляционным компаундам для среднего напряжения.

2.5 Электрические характеристики

Изоляционные свойства компаундов были оценены путем измерения коэффициента потерь (Tanδ), диэлектрической постоянной (ε_r) и объемного удельного сопротивления в функции температуры от 25°C до 90°C в сухих условиях. Дополнительно коэффициент потерь и диэлектрическая постоянная были измерены после опущения компаундов в воду при 90°C на срок до 28 дней. Электрические характеристики были измерены на прессованных образцах толщиной 2мм. Система Omicron MI600 использовалась для оценки Tanδ и εr; a QuadTech модель 1868A использовались при анализе объемного удельного сопротивления. Все электрические характеристики компаундов были изучены в лабораториях Imerys.

На рисунке 9 показан график Tanδ с 25°C до 90°C в сухих условиях. Четыре компаунда характеризуются небольшими колебаниями коэффициента потерь, который остается в том же порядке возрастания (10^{-3}) до 90°C. Кроме того, все компаунды имеют аналогичную тенденцию, при которой Tanδ повышает температуру. Более подробно, коэффициент потерь четырех компаундов фактически одинаковый при комнатной температуре, около $1{,}5{\cdot}10^{-3}$ и растет постепенно при показателях температуры в диапазоне между $3{,}5{\cdot}10^{-3}$ и $5{,}0{\cdot}10^{-3}$ при 90°C у MV IS79 and MV TP79 A, соответственно.

Как указано для Tanδ, ε_r меняется в узком диапазоне для всех компаундов, поднимающих температуру. На рисунке 10 наблюдается только небольшое понижение диэлектрической постоянной ε_r рассчитывается по следующей формуле:

$$\varepsilon_r = \left(\frac{c}{\varepsilon_0}\right)\left(\frac{t}{\lambda}\right)$$

в которой электроемкость измеряется прибором, и ε_0 является диэлектрической постоянной, тогда как и являются геометрическими факторами, указывающими на разделение между пластинами (электродами) и их площадью, соответственно. Более низкая диэлектрическая постоянная ТПВ компаундов для среднего напряжения по сравнению с MV IS79 обуславливается содержанием ПП, которое увеличивает изоляционные характеристики всего компаунда. Впоследствии MV IS79 характеризуется более высокой диэлектрической постоянной в отличие от MV TP79 C, который характеризуется более низкой постоянной. Однако, необходимо отметить, что разница между компаундами довольна ограничена как при довольно низкой, так и при высокой температуре.

Наконец, объемное удельное сопротивление было измерено при 25°C и 90°C с потенциалом 500 В (смотрите таблицу 4). При 25°C все компаунды имели объемное удельное сопротивление в порядке 10^{15} омосантиметров, что является стандартным показателем для изоляционного материала среднего напряжения. При 90°C объемное удельное сопротивление ТПВ компаундов среднего напряжения на один порядок ниже, чем у MV IS79. Вероятнее всего, данная разница обуславливается частичным расплавлением термопластичной фазы компаундов ТПВ, что ведет к более высокой подвижности носителей заряда в материале. Однако, помимо этого, объемное удельное сопротивление всех четырех компаундов ТПВ среднего напряжения выше 10^{13} омосантиметров.

2.5.1 Электрические характеристики в воде

Электрические характеристики также прошли испытания при погружении в воду при 90°C до 28 дней. Сначала было оценено, что поглощение воды ТПВ компаундов среднего напряжения по сравнению с MV IS79 соответствует итальянским нормам CEI 20-86. Результаты, указанные в таблице 5, демонстрируют, что поглощение воды компаундами фактически аналогичное после 14 дней в воде при 85°C, гораздо ниже верхнего предела мгр/см²).

Низкое впитывание воды отражает колебание Tanδ после опущения образцов в воду при 90°C (смотрите

рисунок 11). Компаунды обладают хорошими характеристиками сохранения коэффициента потерь, который после 28 дней в воде в самом худшем случае составляет примерно 0,035, а в лучшем случае - 0,017. Опять же MVTP79C, благодаря своей великолепной стабильности, имеет лучшие эксплуатационные характеристики, близкие к характеристикам эталона MV IS79.

При низком поглощении воды, εr так же остается почти без изменений при погружении в воду при 90°C. Как показано на рисунке 13б увеличение диэлектрической постоянной довольно небольшое после погружения в воду.

Среди ТПВ компаундов среднего напряжения MV TP79 C демонстрирует самую большую стабильность при более низком εr по сравнению с эталоном MV IS79 даже после 28 дней в воде.

Заключения

В данной работе представлены новые разработанные ТПВ компаунды для среднего напряжения. Перспективой является производство изоляционных компаундов для среднего напряжения с характеристиками, аналогичными рыночному стандарту бессвинцовой изоляции среднего напряжения и легкой в обработке термопластических материалов. Подготовка таких компаундов была описана наряду с их полной характеристикой в сравнении со стандартным бессвинцовым изоляционным материалом для среднего напряжения. Посредством ДСК был проанализирован технологический процесс вулканизации. Действительно была рассмотрена возможность производства на промышленной пилотной установке ТПВ компаундов для среднего напряжения и применения изоляции. Несмотря на сложный состав, содержащий полимеры, филеры, со-агенты и антиоксиданты, ТПВ для среднего напряжения были получены полностью репродуктивным и надежным процессом. Результатами технологии являются общие характеристики ТПВ компаундов для среднего напряжения, которые характеристиками напоминают бессвинцовый стандартный MV IS79. Анализреологии помимо подтверждения ТПВ природы компаундов моделирует их характеристики экструзии, демонстрируя, что благодаря точному выбору термопластичного ПП возможно снизить напряжение сдвига, сохраняя неизменными характеристики эластичности ТПВ компаундов.

Подробный анализ кривых напряжение-деформация ТПВ компаундов подтверждает их характеристики эластичности, которые только подвержены только частичному влиянию кристалличности термопластичной фазы, что приводит к механическим характеристикам, схожим с эталоном MV IS79. При старении при 135°C ТПВ компаунды для среднего напряжения доказали свою устойчивость на протяжении срока до 504 часов при сохранении прочности на разрыв и удлинения при разрыве > 70%. После старения на протяжении 504 часов при 150°C, MV TP79 C сохранил 80% прочности на разрыв и 70% удлинения при разрыве, что почти совпадает с эталоном MV IS79. Наконец, сухие и влажные электрические характеристики были измерены для всех компаундов при 500 В и 50 Гц. Сухой Tanδ повышается с температурой до верхнего предела около $5 \cdot 10^{-3}$ при 90°C у MV TP79 A, что все еще сопоставимо с Tanδ of MV IS79 при той же температуре, $3.5 \cdot 10^{-3}$.

Подобным образом, εr меняется в очень узкомдиапазоне (между 2,8 и 2,4) при 25°C и до 90°C у всех компаундов. Измерения объемного удельного сопротивления подтверждают отличные изоляционные характеристики при 25°C (10^{15} омосантиметров), слегка уменьшаясь при 90°C (10^{13} омосантиметров). Влажные электрические характеристики были измерены при погружении в воду при 90°C до 28 дней. Влажный Tanδ увеличивается до максимального $3,5 \cdot 10^{-2}$ у MV TP79 B. MV TP79A и C продемонстрировали повышенную устойчивость к воде, последний из которых по характеристикам ближе к MV IS79 после 28 дней в воде при 90°C, $2,2 \cdot 10^{-2}$ и $1,3 \cdot 10^{-2}$ соответственно.

Та же тенденция прослеживается и по εr, который медленно увеличивается после погружения образцов в воду. Однако, колебания практически малозначительны между 2,53 и 2,66 и с учетом погрешности при измерении.

В заключении был представлен полный анализ ТПВ компаундов в качестве материалов для изоляции среднего напряжения. Пошаговый подход показал, как можно постепенно улучшить характеристики компаундов, получая полностью термопластичный бессвинцовый материал, а именно MV TP79 C с механическими, реологическими и электрическими характеристиками, сопоставимыми со стандартом бессвинцового рынка MV IS79. По норме CEI 20-86, MV TP79 имеет потенциал исполнения в качестве изоляции для среднего напряжения с постоянной температурой эксплуатации 105°C и временным увеличением до 250°C. Продолжая стратегию Mixer планирует разработать компаунды для среднего напряжения с более высокой устойчивостью и усовершенствованными электрическими характеристиками при более высокой температуре в ближайшем будущем. ■

Благодарность

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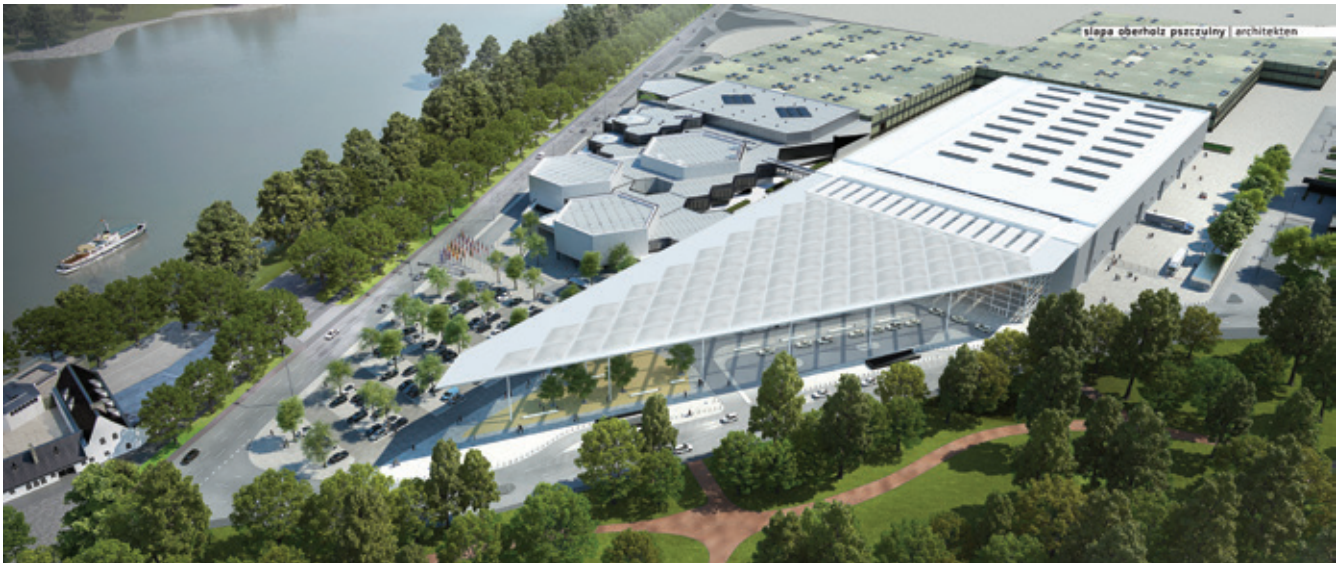

▲ *Le projet d'un architect pour la nouvelle entrée au centre d'expositions de Düsseldorf*

Nouvelle section sud de Messe Düsseldorf: wire 2018 et Tube 2018 bénéficient de la rénovation

LA reconstruction complète de l'entrée sud et du pavillon 1 adjacent a débuté au parc d'expositions de Düsseldorf.

Le conseil de surveillance et les actionnaires de Messe Düsseldorf GmbH ont donné leur approbation, et ainsi le point de départ a été atteint pour l'un des projets de construction les plus ambitieux de l'histoire de l'entreprise.

"Nous pouvons maintenant mettre en œuvre notre plan général pour la modernisation et la rénovation complètes de notre centre d'expositions, notre base", a déclaré Werner M Dornscheidt, président et Directeur Général de Messe Düsseldorf, qui a ajouté: "Comme d'habitude, tout se fera sans subvention."

Le volume d'investissement pour la section sud s'élève à 140 millions d'euros. Globalement, investira environ 636 millions d'euros dans son propre centre d'expositions avant 2030. Les travaux ont débuté en mai 2017 et devraient se terminer d'ici l'été 2019. Le programme des travaux a été réalisé par le cabinet d'architecture slapa oberholz pszczulny architekten de Düsseldorf.

La nouvelle entrée sud donnera à Messe Düsseldorf un aspect moderne sur les rives du Rhin, qui donne sur la ville de Düsseldorf. Les visiteurs du salon et les délégués du congrès seront accueillis sous un nouveau toit illuminé et translucide, d'une superficie de 7 800m^2 et d'environ 20m de hauteur.

Cette structure sera un important point de repère architectural dans cette position très visible du parc d'expositions. Jurek Slapa, associé directeur dans le bureau d'études sop architecten, a déclaré: "Le toit donnera à Messe Düsseldorf une nouvelle façade et un emplacement distinctif dans cette position unique entre le Rhin et le Nordpark."

La façade de l'entrée sud s'ouvre sur le toit par une façade entièrement en verre d'une longueur de 93 mètres. Les services requis tels que les guichets et les vestiaires se trouveront dans cet espace de 2 000m^2. Le premier étage comportera une salle de réunion à parois vitrées qui sort dans le foyer, en offrant une vue sur l'entrée et sur l'avant-cour. En outre, tout le foyer sera disponible pour accueillir les événements. L'avant-cour comprendra également l'entrée au parking souterrain de 300 places ainsi que des arrêts de bus et des places de parking pour taxis.

La portée de la rénovation de l'entrée sud comprend également la reconstruction du Pavillon 1. Dans ce but, Messe Düsseldorf prévoit de démolir les pavillons actuels 1 et 2, qui sont plus petits, et de les remplacer par une nouvelle construction. Le Pavillon 1, qui mesure 158m x 77m, avec une superficie de plus de 12 000m^2, aura environ la même dimension que les Pavillons 8a et 8b.

Le nouveau pavillon répondra aux normes techniques élevées auxquelles tout le centre d'expositions est soumis. Il sera accessible à travers sept portes, et les suspensions du plafond des pavillons seront aussi faciles à disposer que de mettre en place des stands en utilisant le plancher du pavillon.

Les piétons pourront utiliser le pont au premier étage pour passer du pavillon au Centre des congrès de Düsseldorf (CCD). En plus d'être relié aux pavillons 3 et 4, il y aura un parcours principal qui conduira de l'entrée sud directement au reste du parc d'expositions.

En 2017 et en 2018, les années de transition durant lesquelles les travaux de construction se dérouleront, les exposants de Tube précédemment hébergés dans les pavillons 1 et 2 se verront offrir d'autres options de stand attrayantes dans les pavillons 16 et 17. Ainsi, Tube 2018 aura lieu dans les pavillons de 3 à 7 et dans les pavillons 16 et 17. Les exposants de wire 2018 présenteront leurs innovations dans les pavillons 9 à 16.

Messe Düsseldorf GmbH – Allemagne
Website: www.messe-duesseldorf.de

Systèmes de fabrication de câbles de données et connaissances des processus

▲ *Ligne de toronnage de câble de données avec une toronneuse à double torsion DSI 631 combinée avec un dérouleur à détorsion en amont et un dérouleur longitudinal en aval*

LES câbles pour les véhicules, les systèmes informatiques, le secteur de l'énergie et d'autres secteurs d'application doivent répondre à des exigences de plus en plus croissantes.

Afin de suivre le rythme de ce développement, les fabricants de câbles ont besoin de machines pouvant produire des câbles complexes, en mesure de travailler efficacement en ce qui concerne l'énergie, les matières premières et les coûts, et pouvant être adaptés de manière flexible aux nouvelles exigences de production.

Les machines pour câbles développées et fabriquées par Niehoff répondent à toutes ces exigences. Un exemple est donné par la toronneuse à double torsion du type DSI 631 qui a été conçue pour le toronnage de conducteurs isolés en paires et quartes d'étoile et le toronnage de quatre paires de conducteurs dans des câbles LAN.

La machine est conçue pour une fabrication fiable, de câbles LAN de toutes catégories – même des générations futures – ainsi que de paires avec un blindage à bande, de câbles de liaison et d'autres câbles de télécommunication. Grâce aux nombreux accessoires supplémentaires, le système de toronneuses DSI permet de créer et de reconstruire rapidement des lignes de production spécifiques en fonction de la situation de la commande.

Par rapport à d'autres machines et technologies de processus, les possibilités de combinaison de ce système présentent des avantages financiers importants pour la fabrication de certains produits ou pour une certaine performance de production.

Un autre avantage pour les utilisateurs de ces systèmes et d'autres systèmes Niehoff est que la société, grâce à des décennies d'expérience acquise dans la conception de machines pour câbles et fils, supporte ses clients avec une connaissance approfondie des processus et un service après-vente professionnel.

Maschinenfabrik Niehoff GmbH & Co KG – Allemagne
Website: www.niehoff.de

Nouveau directeur des ventes

Arnold Büscher a repris le rôle de directeur commercial de l'Allemagne chez U I Lapp GmbH, une société du groupe Lapp.

M. Büscher, ingénieur mécanicien par formation, a précédemment occupé divers postes de direction dans des entreprises industrielles d'une grande notoriété. Il a acquis une expérience internationale dans son rôle de directeur général de Rittal Corp aux États-Unis, pour ne citer qu'un exemple. Plus récemment il a été responsable des opérations commerciales en Allemagne et en Europe centrale en tant que directeur général de Weidmüller GmbH & Co KG.

"Nous sommes heureux d'avoir M. Büscher à bord, car il est un directeur expérimenté qui connaît très bien notre marché et qui favorisera notre transformation en fournisseur de systèmes", a déclaré Andreas Lapp.

M. Büscher souhaite renforcer tous les canaux de vente et se concentrer sur les marchés en croissance dans le secteur ferroviaire, de l'industrie alimentaire et robotique.

Ses activités comprennent également la création et l'expansion vers des solutions de système sous le nom de Ölflex® Connect avec une vaste gamme de produits et de services concernant les câbles préassemblés.

Lapp Group – Allemagne
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▲ *Arnold Büscher*

Isolation à base de TPV pour applications à moyenne tension

Par Andrea Galanti, Stefano Dossi et Andrea Magri de Mixer SpA, Ravenna, Italie, et Camillo Cardelli, iPool Srl, Pistoia, Italie

Résumé

Le présent article porte sur le développement de trois composés isolants sans plomb entièrement thermoplastiques pour moyenne tension (MV) basés sur la technologie de vulcanisation des thermoplastiques (TPV). Les composés isolants MV TPV ont été préparés à partir d'une isolation en moyenne tension sans plomb vulcanisé au peroxyde, qui représente l'actuel paramètre de référence standard, raison pour laquelle ils ont fait l'objet d'une enquête approfondie par rapport à l'isolation MV standard sans plomb. Pour évaluer les résultats du processus de vulcanisation dynamique, les composés ont été étudiés au moyen de la calorimétrie à balayage différentiel (DSC). Pour simuler le comportement en extrusion, leur rhéologie a été étudiée. Les propriétés mécaniques ont été mesurées avant et après le vieillissement à 135°C et 150°C pendant 21 jours. Enfin, une étude approfondie sur leurs caractéristiques électriques, dans des conditions sèches (de 25°C à 90°C) et humides (à 90°C dans l'eau jusqu'à 28 jours) est présentée.

1 Introduction

Il y a vingt ans, les systèmes d'isolation à base de XLPE et d'EPDM ont été utilisés dans plusieurs régions du monde pour les applications sur les câbles en moyenne tension. L'Amérique du Nord reste un marché très actif pour les isolations pour moyenne tension à base d'EPDM, tandis que dans d'autres parties du monde, le XLPE est préféré. Récemment, nous constatons un intérêt renouvelé pour les isolations en moyenne tension à base d'EPDM sur le marché mondial en raison des performances inégalées sur la durée de vie des câbles pour les applications à long terme (>20 ans).

▲ **Figure 1**: *Isolation MV contenant du plomb (orange) et sans plomb (blanc), des boulettes aux câbles*

Depuis 1996, Mixer SpA a produit des composés isolants MV à base de mélanges d'EPDM et d'EPDM/LDPE: sa stratégie consiste à proposer des matériaux innovants et concurrentiels sur le marché des câbles, estimant que l'amélioration continue des matériaux donnera un nouvel élan aux câbles en caoutchouc pour les applications spécifiques.

La première étape de cette approche a été le développement de solutions EPDM sans plomb, présentées en 2012 et actuellement disponibles sur le marché (voir *Figure 1*)[1]. En raison du fait que les sels de plomb sont insolubles dans l'eau et ils ne contribuent donc pas à aucun courant de fuite à travers la couche isolante, l'oxyde de plomb est l'un des additifs les plus efficaces dans les composés isolants MV. Cependant, l'oxyde de plomb est répertorié dans la norme Reach SVHC (substances extrêmement préoccupantes) pour son risque bien connu de bioaccumulation et pour ses effets durables, entraînant des dommages importants à l'environnement et à la vie[2].

Mixer SpA a réussi à remplacer l'oxyde de plomb par un système de captation à ions capable d'immobiliser des ions, réussissant à produire des composés isolants MV sans plomb à base d'EPDM avec une stabilité thermique et électrique supérieure.

À partir de ce point de départ, la société a développé un nouveau TPV entièrement thermoplastique pour l'isolation MV qui réticulent dynamiquement le composé isolant MV sans plomb dans une matrice PP. Mixer SpA présente trois versions améliorées de composés MV TPV afin d'obtenir un matériau capable de passer les essais thermomécaniques à une température d'exercice continue de 90°C et 105°C et de 250°C dans le cas d'urgence du court-circuit, conformément à la norme italienne CEI 20-86, qui est jusqu'à présent, la seule norme existante sur les composés thermoplastiques pour l'isolation MV.

Tout d'abord, on analyse la préparation et les propriétés macroscopiques des nouveaux composés TPV pour les applications MV. La société a ensuite étudié les nouveaux composés MV TPV au moyen de la technique DSC pour étudier le processus de vulcanisation dynamique. Dans la troisième partie, on analyse la rhéologie du composé MV TPV à faible vitesse de cisaillement pour simuler leur comportement à l'extrusion. Par la suite, les propriétés mécaniques des composés MV TPV avant et après le vieillissement thermique jusqu'à 150°C pendant 21 jours. Les propriétés électriques des composés ont été étudiées chez Imerys Laboratories, Par, Royaume-Uni. En particulier, on a mesuré le facteur de perte (Tanδ), la constante diélectrique (εr) et la résistivité en volume ont été mesurés jusqu'à 90°C dans des conditions sèches. En outre, les valeurs Tanδ et εr ont été étudiées après immersion des composés dans de l'eau à 90°C pendant 28 jours. Les résultats des tests ont été comparés au composé MV IS79 sans plomb standard et il a été démontré qu'il est possible d'obtenir un composé innovant avec des propriétés d'isolation électrique élevées qui associe les propriétés du composé XL-EPDM sans plomb et la possibilité de le traiter en tant que matériau thermoplastique.

2 Composés MV TPV sans plomb

2.1 *Préparation des composés MV TPV*

Le composé d'isolation pour moyenne tension sans plomb, le MV IS79 et les composés MV thermoplastiques vulcanisés, les MV TPV, ont été préparés dans un mélangeur interne équipé de deux rotors contrarotatifs et d'une chambre d'un volume de 8cm³. La composition des composés MV TPV est résumée dans le *Tableau 1*.

De toute évidence, les composés MV TPV79 A et B ont le même rapport entre la phase élastomérique et la phase thermoplastique. Toutefois, de différents co-agents ont été utilisés dans leur formulation. Cela a été effectué suite aux études sur les co-agents influençant les propriétés des composés TPV en empêchant la décomposition du PP via la ß-scission causée par les radicaux libres[3].

Le composé MV IS79 a été préparé en mélangeant tous les composants dans le mélangeur interne pour mélanger les ingrédients parfaitement.

Après avoir déchargé le composé, du peroxyde a été ajouté à basse température dans un broyeur à deux cylindres. Les échantillons pour l'essai ont été obtenus en pressant les feuilles dans une machine de moulage par compression à 180°C pendant 10 minutes.

Composition TPV	MV TP79 A	MV TP79 B	MV TP79 C
MV IS79	75%	75%	70%
PP-1	25%	25%	20%
PP-2	-	-	10%

[1]d = 0.891 gr/cm³, MFI (230°C; 2.16kg) = 8.0 gr/10min; [2]d = 0.900 gr/cm³, MFI (230°C; 2.16kg) = 10.0 gr/10 min

▲ **Tableau 1**: *Formulation des composés MV TPV*

Les échantillons pour les propriétés mécaniques ont été poinçonnés dans le sens longitudinal.

Les composés MV TP79 ont été préparés en mélangeant le composé sans plomb (MV IS79) avec du polypropylène thermoplastique (PP) selon le rapport indiqué dans le *Tableau 1*. Au cours du processus de mélange, lorsque la réaction des radicaux a lieu et pendant que la température augmente en continu, le couple suit un modèle caractéristique, représenté graphiquement dans la *Figure 2*[4,5].

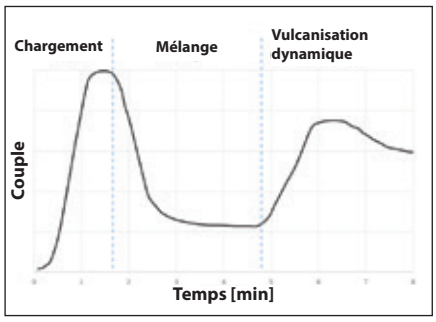
Après le chargement des ingrédients, le couple augmente en raison de la viscosité élevée des composants à basse température. En augmentant la température, les matériaux commencent à adoucir, le couple diminue pendant le mélange. À mesure que la réaction des radicaux commence, la réticulation simultanée de la phase caoutchouteuse et de la β-scission de la phase PP se produit, avec une inversion de phase conséquente conduisant à un accroissement rapide du couple. La température finale, à laquelle les composé TPV ont été déchargés après environ huit minutes de traitement, était entre 200°C et 220°C. Les composés encore chauds ont été calandrés dans un mélangeur à cylindres en obtenant ainsi des tôles; ensuite des plaques ont été obtenues en pressant les tôles dans une machine de moulage par compression à 180°C pendant une minute. Les échantillons pour les propriétés mécaniques ont été poinçonnés dans le sens longitudinal.

Comme illustré dans le *Tableau 2*, les composés présentent des propriétés mécaniques comparables, à savoir la résistance à la traction (TS), l'allongement à la rupture (EB) et la résistance à la traction à un allongement de 200%. Le choix du PP et du rapport correspondant ne semble pas influencer considérablement les propriétés mécaniques, qui sont proches du composé MV IS79 standard. Au contraire, la cristallinité du PP entraîne une augmentation remarquable de la dureté (HS), égale à 48 Shore D pour MV TP79 C, c'est-à-dire le composé ayant la plus haute teneur en PP. En raison de la viscosité élevée du composé MV TP79 A et B, l'indice de fluidité (MFI) a été mesuré à 190°C avec un poids de 21,6 kg.

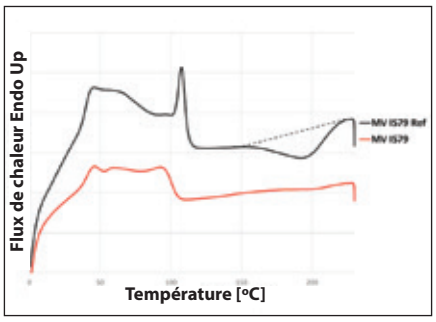
Leur faible débit peut être attribué à deux facteurs principaux: le rapport entre les phases thermoplastiques et élastomériques et le choix d'un PP avec un faible IMF à la température d'essai. Cependant, l'on peut remarquer qu'avec un équilibre soigneux du rapport entre les deux phases et un choix précis du PP, pour le composé MV TP79 C on a pu obtenir un IMF comparable au MV IS79 standard. Ces résultats sont confirmés par les études rhéologiques présentées dans la section 2.3.

Aux fins de comparaison et pour souligner la réussite des composés MV TPV, des matériaux de référence sans peroxyde ont été produits. Ainsi, dans ces composés, la vulcanisation dynamique n'était possible après le mélange des composants. Le composé de référence MV Ref AB présente la même composition du MV TP79 A et B (sans peroxyde et co-agents), le composé de référence MV Ref C a été formulé comme le composé MV TP79 C (sans peroxyde).

▼ **Figure 2**: *Représentation du modèle de couple en fonction du temps pendant la production des composés MV TPV, indiquant les trois étapes principales du processus*



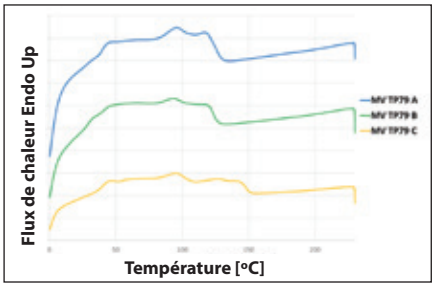
▼ **Figure 3**: *Analyse DSC de MV IS79 non vulcanisé (en haut) et vulcanisé (en bas). Ligne pointillée: représentation graphique de la ligne de base utilisée pour calculer l'enthalpie de réaction*



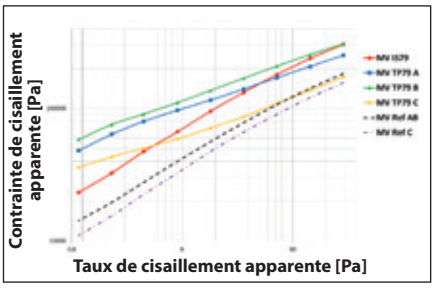
▼ **Tableau 2**: *Propriétés physiques typiques des composés isolants MV*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
TS[1] [N/mm²]	16.61	17.31	17.19	15.73
EB[1] [%]	321	360	310	341
TS @ 200% [N/mm²]	14.23	13.57	14.48	13.62
HS[2] [Shore A-D]	80-/	96-45	95-46	96-48
MFI[3] [gr/10min]	27.6[4]	4.4	4.2	21.3

[1]ASTM D412; [2]ASTM D2240; [3]ASTM D1238 (190°C, 21.6kg), [4]Mesuré sur le composé sans peroxyde



▲ **Figure 4**: *Analyse DSC des composés MV TP79 A (en haut), MV TP 79 B (au milieu) et MV TP79 C (en bas)*



▲ **Figure 5**: *Contrainte de cisaillement apparente en fonction de la mesure du taux de cisaillement apparent à 180°C des composés isolants MV. Lignes pointillées: composés de référence*

La rhéologie et les propriétés mécaniques des deux composés de référence ont été analysées par rapport aux composés MV TPV présentés dans cet article pour démontrer notre capacité d'obtenir des composés TPV de manière reproductible et contrôlée.

2.2 *Analyse DSC*

Afin de déterminer la quantité résiduelle de peroxyde non réactif dans les composés après le processus de vulcanisation, on a effectué l'analyse DSC. Les spectres ont été mesurés dans un Perkin-Elmer DSC 6000 dans une atmosphère d'azote inerte de 0°C à 230°C avec une vitesse de chauffage de 20°C/min, après chauffage, les échantillons ont été refroidis à 0°C avec une vitesse de 10°C/min. Ce cycle a été répété trois fois. Cependant, comme l'objectif de cette étude était de quantifier le rapport entre le peroxyde initial et résiduel (après durcissement ou vulcanisation dynamique), seul le premier cycle de chauffage est présenté et discuté ci-dessous.

Tout d'abord, le composé MV IS79 non vulcanisé contenant 100% de peroxyde non réactif a été analysé et utilisé comme référence. À partir de l'analyse DSC représentée à la Figure 3, l'enthalpie de réaction (ΔH) estimée résultant de la décomposition du peroxyde était de -8,97 J/g. La même figure représente également le graphique DSC du composé MV IS79 vulcanisé (10 minutes à 180°C). On a relevé une valeur ΔH de -1,16J/g, correspondant à un résidu d'environ 13% de peroxyde n'ayant pas réagi. Cela indique que le composé MV IS79 a été presque complètement vulcanisé.

De même, la quantité de peroxyde non réactif des composés MV TPV a été calculée, étant donné que l'MV TP79 A, B et l'MV TP79 C ont été formulés respectivement avec 75% et 70% du MV IS79 non vulcanisé.

À partir des données recueillies et montrées à la Figure 4, le peroxyde résiduel relevé dans le composé MV TP79 A était d'environ 4% (ΔH = -0,27 J/g) et dans le MV TP79 B était d'environ 5% (ΔH = -0,33 J/g). Pour le composé MV TP79 C, le peroxyde résiduel calculé était d'environ 11% (ΔH = -0,68J/g). Ces résultats confirment sans aucun doute la décomposition presque complète du peroxyde initial lors de la vulcanisation dynamique.

2.3 *Rhéologie*

Les études rhéologiques sont fondamentales pour prédire le comportement en extrusion des composés. Par conséquent, nous avons étudié la rhéologie à des vitesses de cisaillement apparentes de 200s^{-1} à 1s^{-1} dans un rhéomètre capillaire du type Göttfert Rheograph 2002. Le rapport L/D (longueur/diamètre) du capillaire était égal à 30 et les mesures ont été effectuées à 180°C. La température a été choisie pour permettre la fusion complète du PP. Normalement, les composés standard tels que le MV IS79 sont caractérisés à 125°C avant l'étape de vulcanisation; cependant, à cette température, le PP n'est pas fondu, ce qui conduit à des résultats trompeurs. En raison de la température d'essai élevée, pour empêcher la décomposition du peroxyde pendant l'analyse, le composé MV IS79 a été étudié sans peroxyde. Comme mentionné précédemment, les composés de référence MV Ref AB et C ont été inclus dans cette étude pour souligner le changement du comportement rhéologique résultant de la vulcanisation dynamique. Les diagrammes indiquant l'effort de cisaillement apparent en fonction de la vitesse de cisaillement apparente sont représentés à la *Figure 5*.

La réponse du MV IS79 est typique des composés à base d'EPDM/PE: l'effort de cisaillement diminue rapidement de manière presque linéaire au fur et à mesure que la vitesse de cisaillement diminue. De petits écarts par rapport à une linéarité parfaite peuvent être remarqués et sont généralement attribués aux caoutchoucs EPDM.

MV Ref AB et C présentent le même modèle avec l'effort de cisaillement traduit par des valeurs inférieures. Cet effet est causé par la phase thermoplastique, qui présente une viscosité plus faible à cette température.

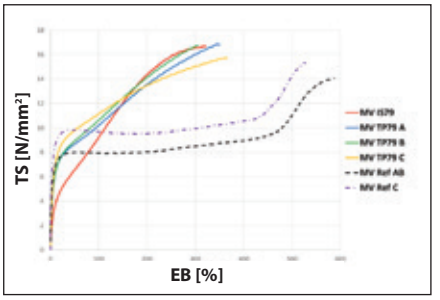
Il s'ensuit qu'en augmentant le contenu de PP, l'effort de cisaillement diminue. En raison de la nature différente des composés MV TPV, leur comportement rhéologique est plutôt différent[6,7].

Essentiellement, un tel caractère différent provient de la réponse élastique des particules réticulées élastomériques, qui est dominant à de faibles efforts de cisaillement. Au contraire, à des efforts de cisaillement élevés, le comportement des composés TPV est déterminé par la phase thermoplastique.

En conséquence, les trois composés MV TPV présentent un comportement similaire aux composés de référence à des vitesses de cisaillement élevées. Différemment, à de faibles vitesses de cisaillement, les courbes sont clairement divergentes.

En se concentrant uniquement sur les composés MV TPV, comme indiqué précédemment pour le MFI dans la section 2.1, en équilibrant soigneusement les composants et en choisissant correctement le PP, il est possible de "régler" le comportement rhéologique des composés MTV MV en conservant ou même en améliorant les propriétés thermomécaniques. À cet égard, le MV TP79 C présente des contraintes inférieures, c'est-à-dire une viscosité, jusqu'à des vitesses de cisaillement très faibles avec les meilleures propriétés thermomécaniques parmi les composés MV TPV étudiés.

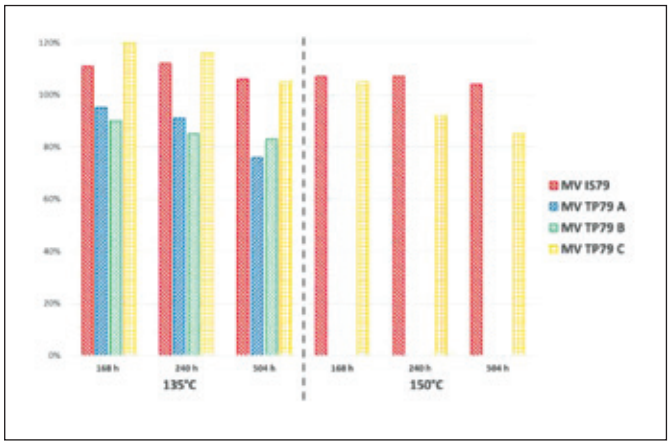
▼ **Figure 6**: *Diagrammes de contrainte-déformation des composés isolants MV. Lignes pointillées: composés de référence*



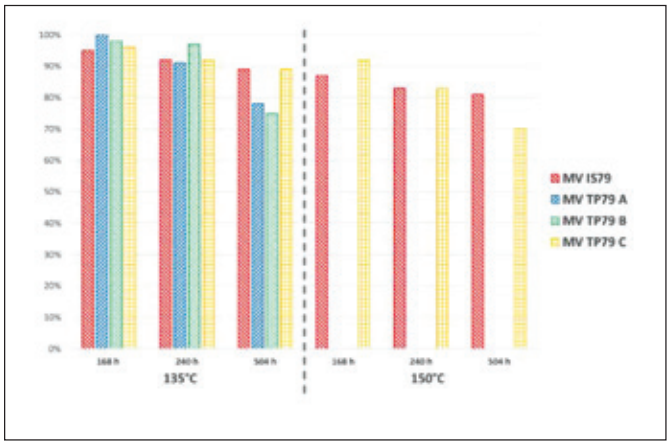
▼ **Tableau 3**: *Essai de pression à chaud et de contraction longitudinale à 130°C des composés de MV TPV*

	MV TP79 A	MV TP79 B	MV TP79 C
Essai de pression à chaud[1] [%]	n.a.[2]	27	3
Contraction longitudinale[1] [%]	14	11	2

[1]CEI 20-86; [2]Non applicable



▲ **Figure 7**: *Résistance à la traction retenue après vieillissement en air à 135°C et 150°C pendant 168, 240 et 504 heures*



▲ **Figure 8**: *Allongement de rupture retenu après vieillissement en air à 135°C et 150°C pendant 168, 240 et 504 heures*

2.4 Essais mécaniques

Les propriétés de contrainte et de déformation des composés isolants MV ont été mesurées selon la méthode ASTM D412 faisant la moyenne des résultats de cinq échantillons d'analyse type *dumb-bell* obtenus au moyen d'un dynamomètre électronique pour essais de traction. Les échantillons ont été poinçonnés le long de la direction de fraisage à partir de plaques obtenues dans une machine de moulage par compression à 180°C. Le composé MV IS79 a été pressé pendant 10 minutes pour compléter le processus de vulcanisation. Les composés MV TP79 A, B et C ont été soumis à pression pendant 1 minute et refroidis sous pression. Les composés MV Ref AB et C ont été traités de manière identique aux composés MV TPV pour obtenir les échantillons d'essai. La *Figure 6* illustre un exemple de la courbe de contrainte/déformation pour chaque composé.

À première vue, l'analyse des courbes de contrainte/déformation des matériaux révèle que les composés MV TPV ont des performances similaires au composé MV IS79 de référence en termes de TS et EB, comme l'on a remarqué dans la section 2.1. Outre les valeurs absolues, les courbes indiquées suivent un schéma similaire avec une forte réponse élastique à la contrainte appliquée. La différence principale qui peut être observée est le module de Young plus élevé dans les composés MV TPV. Cela est causé par la cristallinité de la phase thermoplastique. Cette différence et donc majeure pour le composé MV TP79 C. Le même comportement est reconnaissable dans le composé de référence MV Ref AB, qui présente un module de Young pratiquement identique à celui des composés MV TP79 A et B. Pareillement, le composé MV Ref C A présente un module de Young similaire à celui de MV TP79 C. Cependant, ces composés de référence n'étant pas vulcanisés et étant dépourvus de caractère élastique, cèdent jusqu'à la rupture finale.

En revanche, les composés MT TPV se comportent comme des matériaux réticulés avec un allongement élevé[8-10]. Ces résultats concordent avec les études rhéologiques, en confirmant ainsi la réussite des composés vulcanisables thermoplastiques.

Selon la norme CEI 20-86, pour évaluer la performance des composés MV TPV à haute température, on a effectué des essais de pression à chaud et de contraction longitudinale à 130°C (résumés dans le *Tableau 3*), qui sont obligatoires pour les matériaux isolants thermoplastiques classés pour 90°C et 105°C. Les résultats montrent une amélioration allant de MV TP79 A à MV TP79 C. Toutefois, cela n'est pas une conséquence du rapport entre la phase thermoplastique et la phase élastomérique, mais une amélioration résultant de l'ajout d'un PP (voir *Tableau 1*), qui peut résister à de telles températures élevées.

2.4.1 Résistance au vieillissement thermique

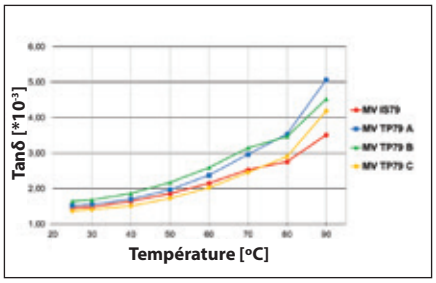
Les composés isolants MV ont été essayés à 135°C et à 150°C pendant 168, 240 et 504 heures, afin d'évaluer leur résistance au vieillissement accéléré. Les valeurs TS et EB retenues sont représentées graphiquement à la *Figure 7* et à la Figure 8. Les composés MV TP79 A et B n'ont pas pu être testés à 150°C, car la phase thermoplastique fond complètement à cette température. À cet égard, le composé MV TP79 C, qui contient du PP avec une température de fusion plus élevée, représente la seule alternative au composé MV IS79 à la température d'essai de 150°C.

Premièrement, il faut remarquer que tous les composés ont une excellente résistance à 135°C en termes de TS et EB maintenus, qui sont supérieurs à 70% après 504 heures. Les deux composés MV IS79 et MV TP79 C résistent parfaitement au vieillissement thermique à 135°C, tout en maintenant les valeurs TS et EB >90%. Bien que les performances de résistance thermique diminuent légèrement par rapport au composé MV IS79, le composé MV TP79 C présente un TS retenu >80% et un EB retenu d'environ 70% après 504 heures à 150°C. Les essais indiquent que le composé MV TP79 C peut résister aux mêmes conditions de vieillissement que le composé MV IS79.

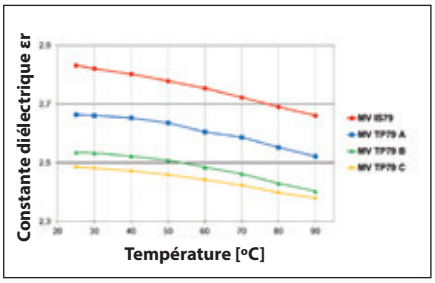
▼ **Tableau 4**: *Résistivité volumique mesurée à 25°C et 90°C avec un potentiel de 500 V*

Résistivité volumique [*10^{14}]	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
At 25°C [Ω-cm]	47.0	41.6	41.3	50.3
At 90°C [Ω-cm]	2.54	0.378	0.284	0.321

▼ **Figure 9**: *Facteur de perte (Tanδ) en fonction de la température à 500V et 50Hz*



▼ **Figure 10**: *Constante diélectrique (εr) en fonction de la température à 500V et 50Hz*



Il faut considérer que le composé MV TP79 C est classé pour une température d'exploitation de 105°C et donc régulièrement testé pendant 508 heures à 150°C avec des valeurs typiques de TS et EB retenues égales à 95% et 75%. Selon la norme CEI 20-86, les composés isolants MV doivent résister au vieillissement pendant 240 heures à 135°C et à 150°C pour une température d'exploitation de 90°C et de 105°C respectivement. Par conséquent, le composé MV TP79 C représente une alternative thermoplastique valable aux composés isolants MV en élastomère exempts de plomb standard.

2.5 Performances électriques

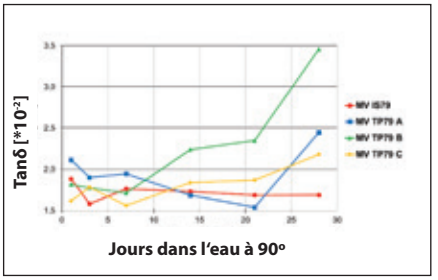
Les propriétés isolantes des composés ont été estimées en mesurant le facteur de perte (Tanδ), la constante diélectrique (εr) et la résistivité volumique en fonction de la température de 25°C à 90°C dans des conditions sèches. De plus, le facteur de perte et la constante diélectrique ont été mesurés après immersion des composés dans l'eau à 90°C pendant 28 jours. Les propriétés électriques ont été mesurées sur des échantillons pressés de 2mm d'épaisseur. Un système Omicron MI600 a été utilisé pour évaluer les valeurs Tanδ et εr; un modèle QuadTech 1868A a été réalisé pour vérifier la résistivité volumique. La totalité des propriétés électriques des composés ont été étudiées dans les laboratoires Imerys.

La *Figure 9* montre le diagramme du Tanδ de 25°C à 90°C dans des conditions sèches. Les quatre composés sont caractérisés par de faibles variations du facteur de perte, qui reste du même ordre de grandeur (10^{-3}) jusqu'à 90°C. En outre, tous les composés présentent une tendance similaire à celle de Tanδ au fur et à mesure que la température augmente. Plus précisément, le facteur de perte des quatre composés est pratiquement identique à la température ambiante, environ 1,5 x 10^{-3}, et augmente constamment avec une température comprise entre 3,5 x 10^{-3} e 5,0 x 10^{-3} à 90°C, respectivement pour les composés MV IS79 et MV TP79 A.

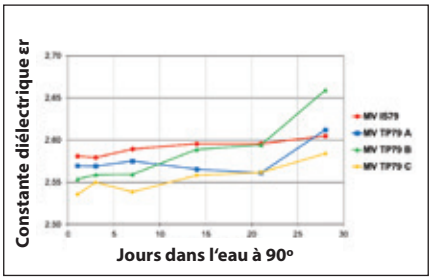
Comme décrit pour Tanδ, εr varie dans une gamme étroite pour tous les composés qui augmentent la température. Sur la *Figure 10*, l'on observe seul un petit abaissement de la constante diélectrique en augmentant la température. Comme εr est calculé selon la formule suivante:

$$\varepsilon_r = \left(\frac{C}{\varepsilon_0}\right)\left(\frac{t}{A}\right)$$

Où C est la capacitance mesurée par l'instrument et ε_0 est la permitivité du vide, alors que t et A sont des facteurs géométriques indiquant respectivement la séparation entre les plaques (électrodes) et la surface correspondante. La constante diélectrique inférieure des composés MV TPV par rapport au MV IS79 est donnée par leur teneur en PP, ce qui augmente les performances globales d'isolation du composé. En conséquence, le composé MV IS79 se caractérise par une constante diélectrique supérieure par rapport au composé MV TP79 C caractérisé par une constante diélectrique inférieure. Cependant, il faut souligner que la différence entre les composés est plutôt limitée à basse et à haute température.



▲ **Figure 11**: *Facteur de perte (Tanδ) en fonction des jours immergés dans l'eau à 90°C mesuré à 500V et 50Hz*



▲ **Figure 12**: *Constante diélectrique (εr) en fonction des jours immergés dans l'eau à 90°C mesuré à 500V et 50Hz*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
Absorption de l'eau[1] [mgr/cm²]	0.34	0.32	0.35	0.34

[1]Méthode gravimétrique, CEI EN 60811-402

▲ **Tableau 5**: *Absorption d'eau selon CEI 20-86*

Enfin, la résistivité du volume a été mesurée à 25°C et à 90°C avec un potentiel de 500V (voir le Tableau 4). À 25°C, tous les composés ont une résistivité volumique de l'ordre de 10^{15}Ω-cm, c'est-à-dire la valeur standard pour les isolants MV. À 90°C, la résistivité volumique des composés MV TPV est d'environ un ordre de grandeur inférieure à celle des composés MV IS79. Selon toute probabilité, cette différence résulte d'une fusion partielle de la phase thermoplastique des composés TPV, ce qui conduit à une plus grande mobilité des porteurs de charge dans le matériau. Cependant, en outre, la résistivité volumique des quatre composés MV TPV est supérieure à 10^{13}Ω-cm.

2.5.1 Performances électriques dans l'eau

Les propriétés électriques ont également été testées lors de l'immersion dans l'eau à 90°C pendant 28 jours. Au début, on avait estimé l'absorption de l'eau des composés MV TPV par rapport aux composés MV IS79, selon la norme italienne CEI 20-86. Les résultats résumés dans le Tableau 5 indiquent que les composés ont une absorption d'eau pratiquement identique après 14 jours d'immersion dans l'eau à 85°C, bien en dessous de la limite supérieure (5 mgr/cm²).

La faible absorption d'eau reflète la variation de Tanδ après immersion des échantillons dans l'eau à 90°C (voir la *Figure 11*). Les composés ne présentent une bonne rétention du facteur de perte, qu'après 28 jours dans l'eau, est d'environ 0,035 dans le pire des cas et de 0,017 dans le meilleur. Encore une fois, le composé MV TP79 C, grâce à sa stabilité supérieure, présente ses meilleures performances, proches de la performance de référence du composé MV IS79.

Ayant une faible absorption d'eau, également εr reste presque inchangé après l'immersion dans l'eau à 90°C. Comme représenté à la *Figure 12*, l'augmentation de la constante diélectrique est assez faible après l'immersion dans l'eau.

Parmi les composés MV TPV, le composé MV TP79 C affiche la meilleure stabilité au fil du temps avec un εr inférieur par rapport au composé de référence MV IS79 même après 28 jours d'immersion dans l'eau.

Conclusions

Cet article a présenté des composés MV TPV nouvellement développés. L'objectif consiste à produire des composés isolants MV avec des propriétés équivalentes à celles de l'isolement MV sans plomb standard courant et de simplifier le processus de traitement des thermoplastiques.

La préparation de ces composés a été également décrite avec leur caractérisation complète par rapport à l'isolant MV sans plomb standard. Grâce à l'analyse DSC, a été étudié le processus de vulcanisation dynamique. En fait, on a étudié la capacité à produire dans une usine pilote industrielle des composés TPV destinés à être utilisés comme isolant MV. Malgré la formulation complexe contenant des polymères, des charges, des co-agents et des antioxydants, les composés MV TPV ont été obtenus dans un processus entièrement reproductible et

fiable. Les résultats de la technologie sont les propriétés globales des composés MV TPV, qui ressemblent aux performances du composé MV IS79 standard sans plomb. Les études rhéologiques, en plus de confirmer la nature TPV des composés, simulent leur comportement en extrusion, démontrant que, grâce à un choix précis du PP thermoplastique, il est possible d'abaisser l'effort de cisaillement en maintenant inchangée la réponse élastique typique des composés TPV.

Une analyse détaillée des diagrammes contrainte-déformation des composés MV TPV confirme leur comportement élastique affecté seulement partiellement par la cristallinité de la phase thermoplastique, ce qui a pour résultat des propriétés mécaniques similaires à celles du composé de référence MV IS79. Après un vieillissement à 135°C, les composés MV TPV ont démontré leur résistance pendant 504 heures avec TS et EB retenus >70%. Après un vieillissement de 504 heures à 150°C, le composé MV TP79 C a conservé 80% de son TS et 70% de son EB, presque correspondant au composé de référence MV IS79. Enfin, les propriétés électriques dans des conditions sèches et humides ont été mesurées pour tous les composés à 500V et 50Hz. La valeur Tanδ dans des conditions sèches augmente avec la température jusqu'à une limite supérieure d'environ 5 x 10^{-3} à 90°C pour le composé MV TP79 A, qui est encore comparable à la valeur Tanδ du composé MV IS79 à la même température, 3,5 x 10^{-3}.

De même, la valeur εr présente une variation dans une gamme très étroite (entre 2,8 et 2,4) à 25°C et jusqu'à 90°C pour tous les composés. Les mesures de la résistivité volumique confirment d'excellentes propriétés isolantes à 25°C (10^{15} Ω-cm) légèrement décroissantes à 90°C (10^{13} Ω-cm). Les propriétés électriques dans des conditions humides ont été mesurées en immergeant les échantillons dans de l'eau à 90°C pendant 28 jours. La valeur de Tanδ dans des conditions humides augmente jusqu'à un maximum de 3,5 x 10^{-2} pour le composé MV TP79 B. Les composés MV TP79A et C ont montré une meilleure résistance à l'eau; ce dernier proche de la performance du composé MV IS79 après 28 jours dans l'eau à 90°C, respectivement de 2,2 x·10^{-2} et 1,3 x 10^{-2}. La même tendance a été observée pour εr, qui augmente lentement après l'immersion des échantillons dans l'eau. Toutefois, les fluctuations sont pratiquement non pertinentes, se situant entre 2,53 et 2,66 en tenant compte de l'erreur associée à la mesure.

En conclusion, une étude complète sur les composés TPV comme matériaux d'isolation pour les applications MV a été présentée. L'approche graduelle a montré comment les propriétés des composés peuvent améliorer progressivement, en obtenant un matériau sans plomb complètement thermoplastique, à savoir le MV TP79 C, avec des performances mécaniques, rhéologiques et électriques comparables à celles du standard de marché sans plomb MV IS79.

Selon la norme CEI 20-86, le composé MV TP79 C a le potentiel d'être réalisé comme isolation MV avec une classification pour une température d'exploitation continue de 105°C et un court circuit d'urgence de 250°C. En développant davantage la stratégie, Mixer SpA s'attend à développer prochainement des composés MT TPV avec une résistance supérieure et de meilleures propriétés électriques à haute température et dans l'eau. ■

Remerciements

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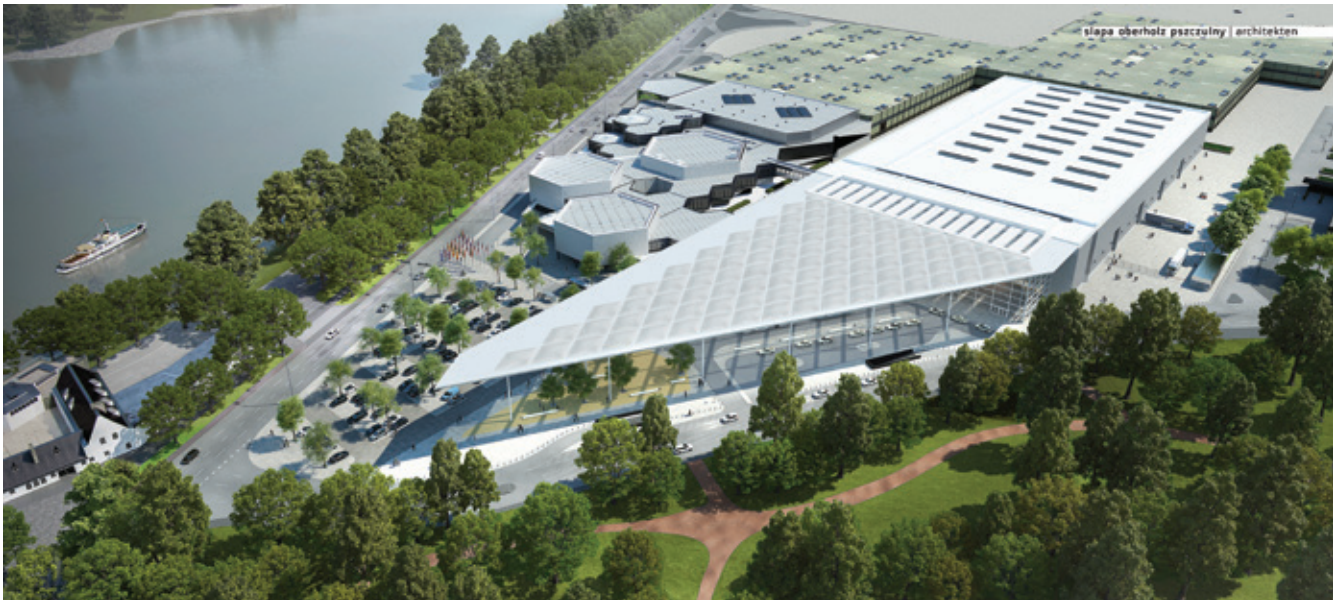


▲ *Il progetto di un architetto per il nuovo ingresso sud nel complesso fieristico di Düsseldorf*

Nuova sezione sud di Messe Düsseldorf: wire 2018 e Tube 2018 beneficiano della ristrutturazione

È INIZIATA la ricostruzione integrale dell'ingresso sud e del padiglione 1 adiacente presso il centro espositivo di Düsseldorf.

Il consiglio di vigilanza e gli azionisti di Messe Düsseldorf GmbH hanno dichiarato la loro approvazione ed è stato così raggiunto il punto di partenza per uno dei progetti di costruzione più ambiziosi della storia della società.

"Ora possiamo attuare il nostro piano generale per il completo ammodernamento e rinnovamento del nostro centro espositivo, la nostra base", ha dichiarato Werner M. Dornscheidt, presidente e amministratore delegato di Messe Düsseldorf, che ha aggiunto: "Come al solito, tutto sarà fatto senza sovvenzioni".

Il volume di investimenti per la sezione sud ammonta a 140 milioni di euro. Nel complesso, Messe Düsseldorf investirà circa 636 milioni di euro nel proprio centro espositivo entro il 2030. I lavori sono iniziati nel mese di maggio 2017 e il completamento è previsto entro l'estate del 2019. Il progetto dei lavori è stato realizzato dallo studio di architettura slapa oberholz pszczulny architekten di Düsseldorf.

Il nuovo ingresso sud conferirà a Messe Düsseldorf un aspetto moderno sulle rive del fiume Reno, che si affaccia sulla città di Düsseldorf. I visitatori della fiera e i delegati del congresso saranno accolti sotto una nuova tettoia illuminata e traslucida di 7.800m^2 e con un'altezza di circa 20m.

La struttura sarà una forte icona architettonica in questa posizione ben visibile del complesso fieristico. Jurek Slapa, socio amministratore presso lo studio sop architecten, ha dichiarato: "La tettoia fornirà a Messe Düsseldorf una nuova facciata e una collocazione inconfondibile in questa posizione unica tra il Reno e il Nordpark. "

La facciata dell'entrata sud si apre verso la tettoia attraverso una facciata costruita interamente in vetro della lunghezza di 93 metri. I servizi richiesti, come cassa e guardaroba, saranno collocati in quest'area di 2.000m^2. Il primo piano ospiterà una sala riunioni con pareti in vetro che esce nel foyer, offrendo una vista sull'entrata e sul piazzale antistante. Inoltre, l'intero foyer potrà essere usato come luogo per gli eventi. Il piazzale antistante ospiterà anche l'ingresso al parcheggio sotterraneo con 300 posti, fermate d'autobus e posteggi taxi.

La ristrutturazione dell'entrata sud comprende anche la ricostruzione del padiglione 1. A tal fine, Messe Düsseldorf prevede di demolire gli attuali padiglioni 1 e 2, che sono più piccoli, e di sostituirli con una nuova costruzione. Il padiglione 1, che misura 158m x 77m, con una superficie di oltre 12.000m^2, avrà circa la stessa dimensione dei padiglioni 8a e 8b.

Il nuovo padiglione soddisferà gli elevati standard tecnici ai quali è soggetto l'intero centro espositivo . Sarà accessibile attraverso sette cancelli, e le sospensioni dal soffitto dei padiglioni saranno facili da disporre così come le alimentazioni degli stand dal pavimento del padiglione.

I pedoni potranno utilizzare il ponte al primo piano per passare fra il padiglione e il Centro Congressi Düsseldorf (CCD). Oltre ad essere collegati ai padiglioni 3 e 4, ci sarà un percorso principale che conduce dall'ingresso sud direttamente al resto del complesso fieristico.

Nel 2017 e nel 2018, gli anni di transizione durante i quali avranno luogo i lavori di costruzione, agli espositori di Tube precedentemente ospitati nei padiglioni 1 e 2 verranno offerte delle attraenti opzioni alternative di stand nei padiglioni 16 e 17. Così Tube 2018 si terrà nei padiglioni da 3 a 7 e nei padiglioni 16 e 17. Gli espositori di wire 2018 presenteranno le loro innovazioni nei padiglioni da 9 a 16.

Messe Düsseldorf GmbH – Germania
Website: www.messe-duesseldorf.de

Sistemi di produzione di cavi di trasmissione dati e conoscenza dei processi

▲ *Linea di trefolatura di cavi di trasmissione dati con trefolatrice a doppia torsione tipo DSI 631 combinata con uno svolgitore a detorsione a monte e uno svolgitore longitudinale a nastro*

I CAVI per i veicoli, sistemi informatici, il settore energetico e altri settori di applicazione devono soddisfare requisiti sempre crescenti.

Per tenere il passo con questa tendenza, i costruttori di cavi necessitano di macchinari che possano produrre cavi dalla progettazione complessa, in grado di lavorare in modo efficiente per quanto riguarda l'energia, le materie prime e i costi e che si possano adattare in modo flessibile alle nuove esigenze produttive.

I macchinari per cavi sviluppati e fabbricati da Niehoff soddisfano tutti questi requisiti. Un esempio è dato dalla trefolatrice a doppia torsione tipo DSI 631 che è stata progettata per la trefolatura di conduttori isolati in coppie e bicoppie e per la trefolatura di quattro coppie di conduttori in cavi LAN.

La macchina è in grado di produrre in modo affidabile cavi LAN di tutte le categorie, anche di generazioni future, così come coppie con schermatura a nastro, cavi bus e altri cavi di telecomunicazione.

Grazie ai numerosi accessori ausiliari aggiuntivi, il sistema di trefolatrici DSI consente di creare e ricostruire rapidamente linee di produzione personalizzate per il cliente in base alla situazione degli ordini.

Rispetto ad altre macchine e tecnologie di processo, le possibilità di combinazione di questo sistema apportano notevoli vantaggi finanziari per la produzione di determinati prodotti o per determinate prestazioni produttive.

Un ulteriore vantaggio per gli utenti di questi e altri sistemi di Niehoff è che l'azienda, grazie a decenni di esperienza nella progettazione dei macchinari per filo e cavo, supporta i clienti con una conoscenza approfondita dei processi e un servizio professionale di assistenza post-vendita.

Maschinenfabrik Niehoff GmbH & Co KG – Germania
Website: www.niehoff.de

Nuovo direttore vendite

Arnold Büscher ha assunto il ruolo di direttore delle vendite per la Germania presso U I Lapp GmbH, una società di/del gruppo Lapp.

Büscher, per formazione ingegnere meccanico, ha precedentemente svolto diversi incarichi dirigenziali in aziende industriali molto note. Ha acquisito un'esperienza internazionale nel suo ruolo di amministratore delegato di Rittal Corp negli Stati Uniti, per citarne solo un esempio. Più recentemente è stato responsabile delle operazioni commerciali in Germania e in Europa centrale come amministratore delegato di Weidmüller GmbH & Co KG.

"Siamo lieti di avere a bordo il sig. Büscher, poiché è un manager esperto che conosce molto bene il nostro mercato e favorirà la nostra trasformazione in fornitore di sistemi", ha dichiarato Andreas Lapp.

Büscher intende rafforzare tutti i canali di vendita e concentrarsi sui mercati in crescita nel settore ferroviario e dell'industria alimentare e robotica. Le sue attività comprendono inoltre la creazione e l'espansione verso soluzioni di sistema sotto il nome di Ölflex® Connect con una vasta gamma di prodotti e servizi relativi ai cavi preassemblati.

"Lapp intrattiene solide relazioni con i clienti e ha un notevole potenziale di crescita. Vorrei intensificare il nostro approccio verso i clienti attraverso tutti i canali, aumentare la nostra attenzione sul loro potenziale e promuovere l'attività con nuovi clienti," ha dichiarato Büscher, parlando del suo nuovo ruolo.

Lapp Group – Germania
Website: www.lappgroup.com

▲ *Arnold Büscher*

Isolamento a base di TPV per applicazioni di media tensione

A cura di Andrea Galanti, Stefano Dossi e Andrea Magri di Mixer SpA, Ravenna, Italia, e Camillo Cardelli, iPool Srl, Pistoia, Italia

Riassunto

Il presente articolo tratta dello sviluppo di tre composti isolanti completamente termoplastici di media tensione (MV) senza piombo basati sulla tecnologia dei vulcanizzati termoplastici (TPV). I composti isolanti MV TPV sono stati preparati a partire da un isolamento di media tensione senza piombo vulcanizzato con perossido, che rappresenta lo standard di riferimento attuale. Per questa ragione sono stati ampiamente studiati rispetto all'isolamento MV standard senza piombo.

Per valutare i risultati del processo di vulcanizzazione dinamica, i composti sono stati studiati mediante la calorimetria differenziale a scansione (DSC). Per simulare il comportamento di estrusione, è stata analizzata la loro reologia. Sono state inoltre misurate le proprietà meccaniche prima e dopo l'invecchiamento a 135°C e 150°C fino a 21 giorni. Infine, viene presentato uno studio completo sulle relative caratteristiche elettriche, in condizioni asciutte (da 25°C a 90°C) e umide (a 90°C in acqua fino a 28 giorni).

1 Introduzione

Venti anni fa, per le applicazioni di cavi di media tensione venivano utilizzati entrambi i sistemi d'isolamento a base di XLPE ed EPDM in molte parti del mondo. Il Nord America rimane un mercato molto attivo per gli isolanti per media tensione a base di EPDM, mentre in altre parti del mondo è preferito l'XLPE.

Ultimamente, nel mercato globale stiamo assistendo a un rinnovato interesse per gli isolanti MV a base di EPDM dovuto alle impareggiabili prestazioni nella durata dei cavi per le applicazioni a lungo termine (>20 anni).

▲ **Figura 1**: *Isolamento MV contenente piombo (arancio) e senza piombo (bianco), da pellet a cavi*

Dal 1996 Mixer SpA produce composti isolanti MV a base di EPDM e miscele EPDM/LDPE: la sua strategia consiste nell'offrire materiali innovativi e competitivi al mercato dei cavi, supponendo che il continuo miglioramento dei materiali rilancerà i cavi in gomma per applicazioni speciali.

Il primo passo di questo approccio è stato lo sviluppo di soluzioni EPDM senza piombo, che furono presentate nel 2012 e sono ora disponibili in commercio (si veda la *Figura 1*)[1]. A causa del fatto che i sali di piombo sono insolubili in acqua e quindi non contribuiscono ad alcuna dispersione di corrente attraverso lo strato isolante, l'ossido di piombo costituisce uno degli additivi più efficaci nei composti isolanti MV. Tuttavia, l'ossido di piombo è elencato nella normativa Reach SVHC relativa alle sostanze estremamente problematiche per il suo noto rischio di bioaccumulo e per gli effetti di lunga durata, che comportano gravi danni per l'ambiente e per la vita[2].

Mixer SpA ha sostituito con successo l'ossido di piombo con un sistema captatore a ioni inorganici, capace di immobilizzare gli ioni, riuscendo a realizzare la produzione di composti isolanti MV senza piombo a base di EPDM con una stabilità termica ed elettrica superiore.

Da questo punto iniziale, la società ha sviluppato un nuovo TPV completamente termoplastico per l'isolamento MV, che reticola dinamicamente il composto isolante MV senza piombo in una matrice PP. Mixer SpA presenta tre versioni migliorate dei composti MV TPV al fine di ottenere un materiale in grado di superare i test termomeccanici ad una temperatura di funzionamento continuo di 90°C e 105°C e di 250°C nel caso di emergenza del cortocircuito, conformemente alla norma italiana CEI 20-86 che è, finora, l'unica norma esistente per i composti termoplastici per isolamenti MV.

In primo luogo, vengono discusse la preparazione e le proprietà macroscopiche dei nuovi composti MV TPV. La società ha quindi esaminato i nuovi composti MV TPV mediante la tecnica DSC per studiare il processo di vulcanizzazione dinamica. Nella terza parte, viene analizzata la reologia del composto MV TPV a bassa velocità di taglio per simularne il comportamento di estrusione. Successivamente, sono state testate le proprietà meccaniche dei composti MV TPV prima e dopo l'invecchiamento termico fino a 150°C per 21 giorni.

Le proprietà elettriche dei composti sono state studiate presso i Laboratori Imerys, Par, Regno Unito. In particolare, sono stati misurati il fattore di perdita (Tanδ), la costante dielettrica (εr) e la resistività di volume fino a 90°C in condizioni asciutte. Inoltre, sono stati studiati i valori Tanδ ed εr dopo aver immerso i composti nell'acqua a 90°C fino a 28 giorni. I risultati dei test sono stati confrontati con il composto standard MV IS79 senza piombo ed è stato dimostrato che è possibile ottenere un composto innovativo ad elevate proprietà di isolamento elettrico, che combina le proprietà del composto XL-EPDM senza piombo e la possibilità di trattarlo come un materiale termoplastico.

2 Composti MV TPV senza piombo

2.1 Preparazione dei composti MV TPV

Il composto isolante MV senza piombo, MV IS79, e i composti MV termoplastici vulcanizzati, MV TPV, sono stati preparati in un miscelatore interno dotato di due rotori controrotanti e di una camera con un volume di 8cm^3.

La composizione dei composti MV TPV è riassunta nella *Tabella 1*. Evidentemente, i composti MV TPV79 A e B hanno lo stesso rapporto tra la fase elastomerica e la fase termoplastica. Tuttavia, sono stati utilizzati diversi coagenti nella loro formulazione. Ciò è stato eseguito in seguito agli studi sui co-agenti che influenzano le proprietà dei composti TPV impedendo la decomposizione del PP mediante beta scissione causata dai radicali liberi[3].

Il composto MV IS79 è stato preparato miscelando tutti i componenti nel mixer interno per miscelare perfettamente gli ingredienti. Dopo aver scaricato il composto, è stato aggiunto il perossido a bassa temperatura in un mescolatore a due cilindri.

Icampioni da esaminare sono stati ottenuti premendo le pellicole in una macchina di stampaggio a compressione a 180°C per 10 minuti. I campioni per le proprietà meccaniche erano punzonati nella direzione longitudinale.

Composizione del TPV	MV TP79 A	MV TP79 B	MV TP79 C
MV IS79	75%	75%	70%
PP-1	25%	25%	20%
PP-2	-	-	10%

[1]d = 0.891 gr/cm^3, MFI (230°C; 2.16kg) = 8.0 gr/10min; [2]d = 0.900 gr/cm^3, MFI (230°C; 2.16kg) = 10.0 gr/10 min

▲ **Tabella 1**: *Formulazione dei composti MV TPV*

I composti MV TP79 sono stati preparati miscelando il composto senza piombo (MV IS79) con polipropilene termoplastico (PP) in base al rapporto indicato nella *Tabella 1*. Durante il processo di miscelazione, mentre avviene la reazione dei radicali e la temperatura aumenta continuamente, la coppia segue un modello caratteristico, che è rappresentato graficamente sulla *Figura 2*[4,5].

Dopo aver caricato gli ingredienti, la coppia aumenta a causa dell'elevata viscosità dei componenti a bassa temperatura. Aumentando la temperatura, i materiali iniziano ad ammorbidirsi, la coppia diminuisce, mentre ha luogo la miscelazione. All'inizio della reazione dei radicali, si realizzano simultaneamente la reticolazione della fase gommosa e la beta scissione della fase PP, con conseguente inversione di fase che determina un rapido aumento della coppia.

La temperatura finale alla quale sono stati scaricati i composti TPV dopo circa otto minuti di lavorazione, variava da 200°C a 220°C. I composti ancora caldi sono stati sottoposti a calandratura in un mescolatore a due cilindri ottenendo delle lamiere; successivamente sono state ottenute delle placche pressando le lamiere in una macchina di stampaggio a compressione a 180°C per un minuto. I campioni per le proprietà meccaniche sono stati punzonati nella direzione di fresatura.

Come illustrato nella *Tabella 2*, tutti i composti presentano proprietà meccaniche confrontabili, vale a dire la resistenza alla trazione (TS), l'allungamento a rottura (EB) e TS al 200% di allungamento.

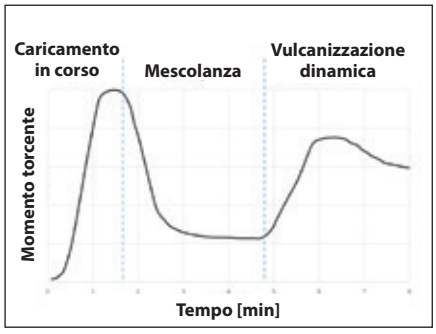
La scelta del PP e del rapporto corrispondente non sembrano influenzare notevolmente le proprietà meccaniche, che sono prossime a quelle del composto standard MV IS79. Al contrario, la cristallinità del PP determina un cospicuo incremento della durezza (HS), che è pari a 48 Shore D per MV TP79 C, cioè il composto con il più alto contenuto di PP. Data l'elevata viscosità del composto MV TP79 A e B, l'indice di fluidità (MFI) è stato misurato a 190°C con un peso di 21,6kg.

La loro ridotta portata può essere attribuita a due fattori principali: il rapporto tra le fasi termoplastiche ed elastomeriche e la scelta di un PP con un basso MFI alla temperatura di prova. Tuttavia, si può notare che con un attento bilanciamento del rapporto tra le due fasi e un'accurata scelta del PP, per il composto MV TP79 C è stato possibile ottenere un MFI paragonabile all'MV IS79 standard. Questi risultati sono confermati dagli studi reologici presentati nella sezione 2.3.

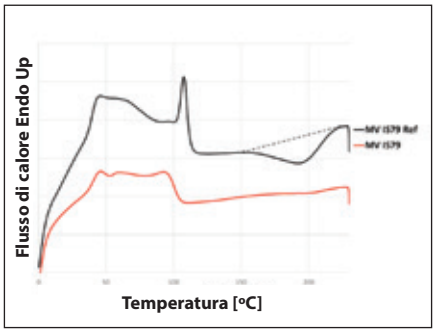
Ai fini di un confronto e per evidenziare il risultato positivo dei composti MV TPV, sono stati prodotti dei materiali di riferimento senza perossido.

Perciò, in tali composti, la vulcanizzazione dinamica non poteva avvenire dopo la miscelazione dei componenti. Il composto di riferimento MV Ref AB, presenta la stessa composizione dell'MV TP79 A e B (senza perossido e co-agenti), il composto di riferimento MV Ref C è stato formulato come il composto MV TP79 C (senza perossido). Sono state analizzate la reologia e le proprietà meccaniche di entrambi i composti di riferimento rispetto

▼ **Figura 2**: *Rappresentazione del modello di coppia in funzione del tempo durante la produzione dei composti MV TPV. Sono indicate le tre fasi principali del processo*



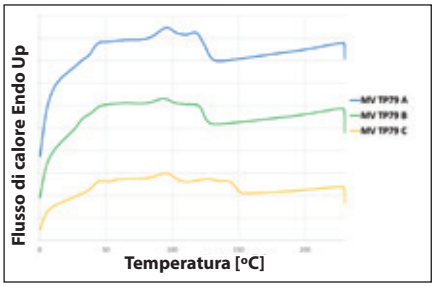
▼ **Figura 3**: *Analisi DSC del composto MV IS79 non vulcanizzato (sopra) e vulcanizzato (in basso). Linea tratteggiata: rappresentazione grafica della linea di base utilizzata per calcolare l'entalpia della reazione*



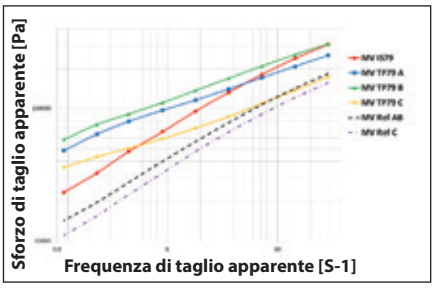
▼ **Tabella 2**: *Proprietà fisiche tipiche dei composti di isolamento MV*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
TS[1] [N/mm^2]	16.61	17.31	17.19	15.73
EB[1] [%]	321	360	310	341
TS @ 200% [N/mm^2]	14.23	13.57	14.48	13.62
HS[2] [Shore A-D]	80-/	96-45	95-46	96-48
MFI[3] [gr/10min]	27.6[4]	4.4	4.2	21.3

[1]ASTM D412; [2]ASTM D2240; [3]ASTM D1238 (190°C, 21.6kg), [4]Misurato sul composto senza perossido



▲ **Figura 4**: *Analisi DSC dei composti MV TP79 A (sopra), MV TP 79 B (centro) e MV TP79 C (in basso)*



▲ **Figura 5**: *Sforzo di taglio apparente in funzione della velocità di taglio apparente a 180°C dei composti di isolamento MV. Linee tratteggiate: composti di riferimento*

ai composti MV TPV presentati in questo articolo per dimostrare la nostra capacità di ottenere dei composti TPV in modo riproducibile e controllato.

2.2 Analisi DSC

Per determinare la quantità residua di perossido non reattivo nei composti dopo il processo di vulcanizzazione, è stata effettuata l'analisi DSC. Sono stati misurati gli spettri in un Perkin-Elmer DSC 6000 in atmosfera inerte di azoto da 0°C a 230°C con una velocità di riscaldamento di 20°C/min; dopo il riscaldamento i campioni sono stati raffreddati fino a 0°C con una velocità di 10°C/min. Questo ciclo è stato ripetuto tre volte.

Tuttavia, poiché lo scopo di questo studio era di quantificare il rapporto tra il perossido iniziale e quello residuo (dopo la vulcanizzazione o vulcanizzazione dinamica), verrà presentato e discusso di seguito solo il primo ciclo di riscaldamento.

In primo luogo, è stato analizzato e utilizzato come riferimento il composto MV IS79 non vulcanizzato contenente il 100% di perossido non reattivo. Dall'analisi DSC illustrata nella *Figura 3*, l'entalpia di reazione (ΔH) stimata risultante dalla decomposizione del perossido era pari a -8,97J/g.

Nella stessa figura è rappresentato il grafico DSC del composto MV IS79 vulcanizzato (10 minuti a 180°C). È stato rilevato un valore ΔH di –1,16J/g, corrispondente ad un residuo di circa il 13% di perossido non reattivo. Ciò indica che il composto MV IS79 è stato quasi completamente vulcanizzato.

Analogamente, è stata calcolata la quantità di perossido non reattivo dei composti MV TPV, considerando che l'MV TP79 A, B e l'MV TP79 C sono stati formulati rispettivamente con il 75% e il 70% dell'MV IS79 non vulcanizzato.

Dai dati raccolti e indicati nella *Figura 4*, il perossido residuo rilevato nel composto MV TP79 A era pari a circa il 4% (ΔH = -0,27J/g) e nell'MV TP79 B era pari a circa il 5% (ΔH = -0,33J/g). Per il composto MV TP79 C il perossido residuo calcolato era di circa l'11% (ΔH = -0,68J/g). Questi risultati confermano senza ombra di dubbio la decomposizione quasi completa del perossido iniziale durante la vulcanizzazione dinamica.

2.3 Reologia

Gli studi reologici sono fondamentali per prevedere il comportamento di estrusione dei composti. Pertanto abbiamo studiato la reologia a velocità di taglio apparenti da 200s^{-1} a 1s^{-1} in un reometro capillare del tipo Göttfert Rheograph 2002. Il rapporto L/D (lunghezza/diametro) del capillare era pari a 30 e le misurazioni sono state effettuate a 180°C. La temperatura è stata scelta per consentire la completa fusione del PP. Normalmente, i composti standard come l'MV IS79 sono caratterizzati a 125°C prima della fase di vulcanizzazione; tuttavia, a questa temperatura il PP non è fuso con conseguenti risultati fuorvianti.

A causa dell'elevata temperatura di prova, per evitare la decomposizione del perossido durante l'analisi, il composto MV IS79 è stato studiato senza perossido. Come precedentemente accennato, i composti di riferimento MV Ref AB e C, sono stati inclusi in questo studio per sottolineare il cambiamento di comportamento reologico come conseguenza della vulcanizzazione dinamica. I diagrammi indicanti lo sforzo di taglio apparente in funzione della velocità di taglio apparente sono illustrati nella *Figura 5*.

La risposta di MV IS79 è tipica dei composti a base di EPDM/PE: lo sforzo di taglio diminuisce rapidamente in modo quasi lineare al diminuire della velocità di taglio. Si possono notare delle modeste deviazioni da una perfetta linearità che sono generalmente attribuite a gomme EPDM. MV Ref AB e C presentano lo stesso modello con lo sforzo di taglio tradotto in valori più bassi.

Questo effetto è causato dalla fase termoplastica, che esibisce una viscosità inferiore a questa temperatura.

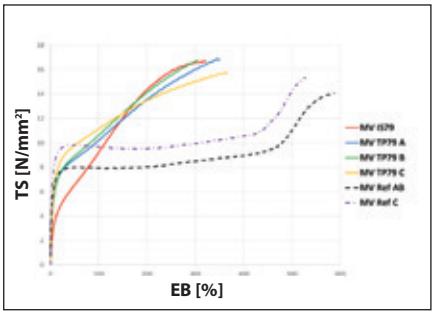
Ne consegue che aumentando il contenuto di PP lo sforzo di taglio diminuisce. Data la differente natura dei composti MV TPV, il loro comportamento reologico è alquanto diverso[6,7]. In sostanza, tale carattere dissimile deriva dalla risposta elastica delle particelle reticolate elastomeriche, che è dominante con sforzi di taglio bassi. Al contrario, ad elevati sforzi di taglio, il comportamento dei composti TPV è determinato dalla fase termoplastica. Di conseguenza, i tre composti MV TPV presentano un comportamento simile ai composti di riferimento a velocità di taglio elevate. Diversamente, a velocità di taglio ridotte, le curve sono chiaramente divergenti.

Concentrandosi esclusivamente sui composti MV TPV, come notato in precedenza per l'MFI nella sezione 2.1, con un accurato bilanciamento dei componenti e una corretta scelta di PP, è possibile "regolare" il comportamento reologico dei composti MV TPV mantenendo o addirittura migliorandone le proprietà termomeccaniche. A questo proposito, il composto MV TP79 C presenta sollecitazioni inferiori, cioè viscosità, fino a velocità di taglio molto basse nonché le migliori proprietà termomeccaniche tra i composti TPV MV studiati.

2.4 Prove meccaniche

Le proprietà di sforzo e deformazione dei composti isolanti MV sono state misurate secondo il metodo ASTM D412 che fa la media dei risultati dei cinque provini tipo *dumbbell* ottenuti con un dinamometro elettronico per prove in trazione e compressione (*Tensor Check Profile di Gibitre*).

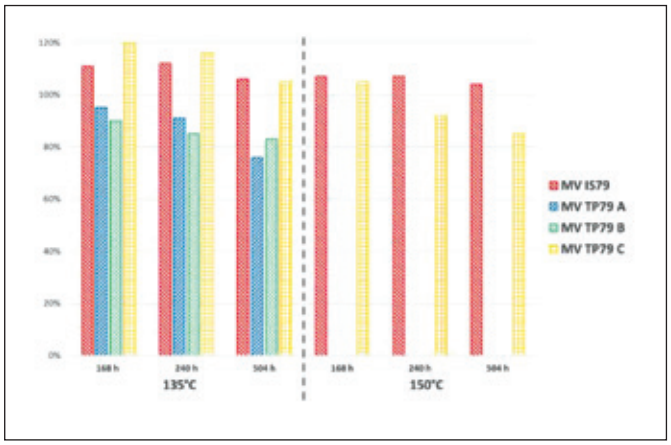
▼ **Figura 6**: *Diagrammi di sforzo-deformazione dei composti di isolamento MV. Linee tratteggiate: composti di riferimento*



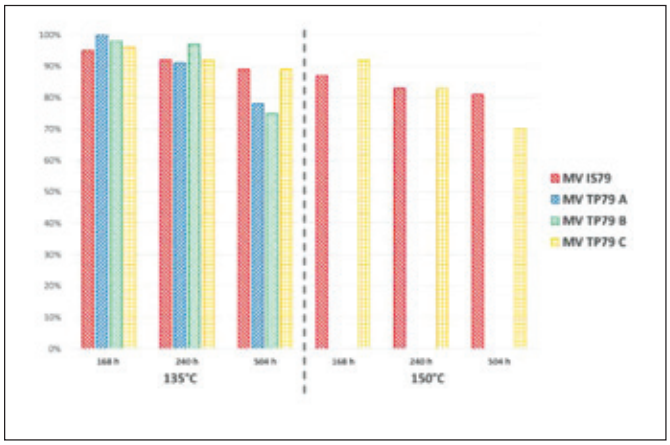
▼ **Tabella 3**: *Prova di pressione a caldo e di contrazione longitudinale a 130°C dei composti MV TPV*

	MV TP79 A	MV TP79 B	MV TP79 C
Prova di pressione a caldo[1] [%]	n.a.[2]	27	3
Contrazione longitudinale[1] [%]	14	11	2

[1]CEI 20-86; [2]Non applicabile



▲ **Figura 7**: *Resistenza alla trazione mantenuta dopo l'invecchiamento in aria a 135°C e 150°C per 168, 240 e 504 ore*



▲ **Figura 8**: *Allungamento a rottura mantenuto dopo l'invecchiamento in aria a 135°C e 150°C per 168, 240 e 504 ore*

I campioni sono stati punzonati lungo la direzione di fresatura da placche ottenute in una macchina di stampaggio a compressione a 180°C. Il composto MV IS79 è stato pressato per 10 minuti per completare il processo di vulcanizzazione. I composti MV TP79 A, B e C sono stati sottoposti a pressione per 1 minuto e raffreddati sotto pressione. I composti MV Ref AB e C sono stati trattati in modo identico ai composti MV TPV per ottenere i campioni di prova. La *Figura 6* illustra un esempio della curva della sforzo-deformazione per ciascun composto.

A prima vista, l'analisi delle curve di sforzo-deformazione dei materiali rivela che i composti MV TPV hanno prestazioni simili al composto standard MV IS79 di riferimento in termini di TS ed EB, come già osservato nella sezione 2.1. Oltre ai valori assoluti, le curve indicate seguono uno schema simile con una forte risposta elastica alla sollecitazione applicata. La differenza principale che si può osservare è il modulo di Young più elevato nei composti MV TPV. Ciò è causato dalla cristallinità della fase termoplastica ed é quindi maggiore per il composto MV TP79 C. Il medesimo comportamento è riconoscibile nel composto di riferimento MV Ref AB, che presenta un modulo di Young praticamente identico a quello dei composti MV TP79 A e B. Analogamente, il composto MV Ref C presenta un modulo di Young simile rispetto a quello di MV TP79 C. Tuttavia, tali composti di riferimento non essendo vulcanizzati e mancando della caratteristica elastica, cedono fino alla rottura definitiva. Per contro, i composti MV TPV si comportano come materiali reticolati con elevato allungamento[8-10]. Questi risultati sono in accordo con gli studi reologici, confermando il risultato positivo dei composti vulcanizzati termoplastici.

Conformemente alla norma CEI 20-86, per valutare le prestazioni dei composti MV TPV ad alta temperatura, sono state eseguite le prove di pressione a caldo e di contrazione longitudinale a 130°C (riassunte nella *Tabella 3*), mentre queste sono obbligatorie per materiali isolanti termoplastici classificati per 90°C e 105°C. I risultati mostrano un miglioramento dal MV TP79 A al MV TP79 C. Tuttavia, questa non è una conseguenza del rapporto tra fase termoplastica e la fase elastomerica, bensì un miglioramento risultante dall'aggiunta di un PP (vedi *Tabella 1*), che può resistere a tali temperature elevate.

2.4.1 Resistenza all'invecchiamento termico

I composti isolanti MV sono stati testati a 135°C e 150°C per un periodo di 168, 240 e 504 ore, per valutare la loro resistenza all'invecchiamento accelerato. Il valori TS ed EB mantenuti sono graficamente illustrati nella *Figura 7* e nella *Figura 8*.

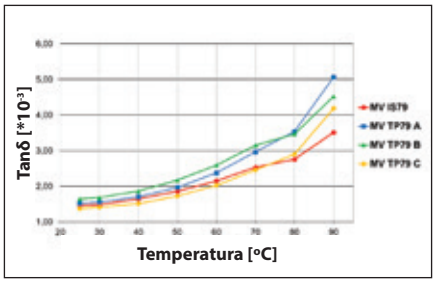
Non è stato possibile provare i composti MV TP79 A e B a 150°C, poiché la fase termoplastica fonde completamente a questa temperatura. A questo proposito, il composto MV TP79 C, che contiene PP con una temperatura di fusione più elevata, rappresenta l'unica alternativa al composto MV IS79 alla temperatura di prova di 150°C.

In primo luogo, va rilevato che tutti i composti presentano da una buona ad un'eccellente resistenza a 135°C in termini di TS e EB mantenuti, che sono superiori al 70% dopo 504 ore. Entrambi i composti MV IS79 ed MV TP79 C presentano un'ottima resistenza all'invecchiamento termico a 135°C, mantenendo i valori TS ed EB >90%. Sebbene le prestazioni di resistenza termica decadono leggermente rispetto al composto MV IS79, il composto MV TP79 C presenta una TS mantenuta >80% e un EB mantenuto di circa il 70% dopo 504 ore a 150°C. Le prove indicano che il composto MV TP79 C può resistere alle stesse condizioni di invecchiamento del MV IS79. Si deve considerare che MV IS79 è classificato per una temperatura di esercizio di 105°C ed è quindi regolarmente testato per 508 ore a 150°C con i valori tipici di TS e EB mantenuti pari al 95% e 75%. Secondo la norma CEI 20-86, i composti isolanti MV devono resistere all'invecchiamento per 240 ore a 135°C e 150°C rispettivamente ad una temperatura di esercizio di 90°C e 105°C. Pertanto il composto MV TP79 C rappresenta una valida alternativa termoplastica ai composti isolanti standard MV elastomerici senza piombo.

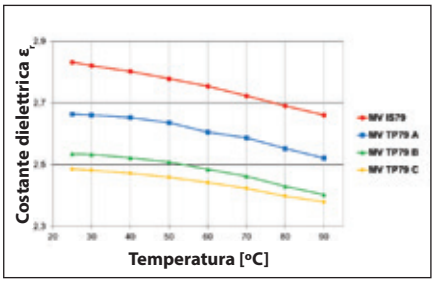
▼ **Tabella 4**: *Resistività del volume misurata a 25°C e 90°C con potenziale di 500V*

Resistività di volume [*10¹⁴]	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
At 25°C [Ω-cm]	47.0	41.6	41.3	50.3
At 90°C [Ω-cm]	2.54	0.378	0.284	0.321

▼ **Figura 9**: *Fattore di perdita (Tanδ) in funzione della temperatura a 500V e 50Hz*



▼ **Figura 10**: *Costante dielettrica (εr) in funzione della temperatura a 500V e 50Hz*



2.5 Prestazioni elettriche

Le proprietà isolanti dei composti sono state calcolate misurando il fattore di perdita (Tanδ), la costante dielettrica (εr) e la resistività di volume in funzione della temperatura da 25°C a 90°C in condizioni asciutte. Inoltre, il fattore di perdita e la costante dielettrica sono stati misurati dopo aver immerso i composti nell'acqua a 90°C per un massimo di 28 giorni. Le proprietà elettriche sono state misurate su campioni pressati dello spessore di 2mm. È stato utilizzato un sistema Omicron MI600 per valutare i valori Tanδ ed ε_r; è stato realizzato un modello di QuadTech 1868A per verificare la resistività di volume. Tutte le proprietà elettriche dei composti sono state studiate presso i laboratori Imerys.

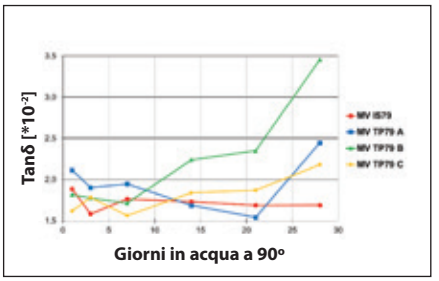
La *Figura 9* illustra il diagramma del Tanδ da 25°C a 90°C in condizioni asciutte. I quattro composti sono caratterizzati da lievi variazioni del fattore di perdita, che rimane nello stesso ordine di grandezza (10^{-3}) fino a 90°C. Inoltre, tutti i composti presentano una simile tendenza di Tanδ aumentando la temperatura. Più in dettaglio, il fattore di perdita dei quattro composti è praticamente identico a temperatura ambiente, circa 1,5 x 10^{-3} e cresce costantemente con la temperatura ai valori compresi tra 3,5 x 10^{-3} e 5,0 x 10^{-3} a 90°C rispettivamente per MV IS79 e MV TP79 A.

Come descritto per Tanδ, εr varia in una gamma ristretta per tutti i composti che aumentano la temperatura. Nella *Figura 10*, si osserva solo un lieve abbassamento della costante dielettrica all'aumentare della temperatura. Essendo εr calcolato con la seguente formula:

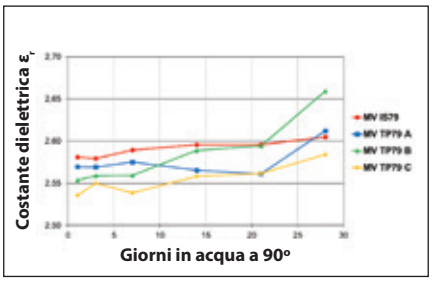
$$\varepsilon_r = \left(\frac{C}{\varepsilon_0}\right)\left(\frac{t}{A}\right)$$

In cui C è la capacitanza dallo strumento e ε_0 è la permittività del vuoto, mentre t ed A sono fattori geometrici che indicano rispettivamente la separazione tra le piastre (elettrodi) e l'area corrispondente La costante dielettrica inferiore dei composti MV TPV rispetto a MV IS79 è data dal rispettivo contenuto di PP, che aumenta le prestazioni isolanti complessive del composto. Di conseguenza, il composto MV IS79 è caratterizzato dalla costante dielettrica superiore contrariamente al composto MV TP79 C caratterizzato dalla costante dielettrica minore. Tuttavia, va sottolineato che la differenza tra i composti è piuttosto limitata sia a bassa sia ad alta temperatura.

Infine, è stata misurata la resistività di volume a 25°C e a 90°C applicando un potenziale di 500V (si veda la *Tabella 4*). A 25°C, tutti i composti presentano una resistività di volume nell'ordine di grandezza di 10^{15}Ω-cm, che è il valore standard per gli isolanti MV. A 90°C la resistività di volume dei composti MV TPV è circa un ordine di grandezza inferiore a quella dei composti MV IS79. Con ogni probabilità, questa differenza deriva da una fusione parziale della fase termoplastica dei composti TPV, che determina una maggiore mobilità dei vettori di carica nel materiale. Tuttavia, oltre a ciò, la resistività di volume dei quattro composti MV TPV è superiore a 10^{13}Ω-cm.



▲ **Figura 11**: *Fattore di perdita (Tanδ) in funzione dei giorni di immersione in acqua a 90°C misurati a 500V e 50Hz*



▲ **Figura 12**: *Costante dielettrica (εr) in funzione dei giorni di immersione in acqua a 90°C misurati a 500V e 50Hz*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
Assorbimento dell'acqua [1] [mgr/cm²]	0.34	0.32	0.35	0.34

[1]Metodo gravimetrico, CEI EN 60811-402

▲ **Tabella 5**: *Assorbimento dell'acqua secondo la norma CEI 20-86*

2.5.1 Prestazioni elettriche in acqua

Le proprietà elettriche sono state anche testate dopo l'immersione in acqua a 90°C fino a 28 giorni. In un primo momento, è stato calcolato l'assorbimento d'acqua dei composti MV TPV rispetto ai composti MV IS79, secondo la norma italiana CEI 20-86.

I risultati riassunti nella *Tabella* 5 indicano che i composti presentano un assorbimento d'acqua praticamente identico dopo 14 giorni di immersione in acqua a 85°C, ben al di sotto del limite superiore (5mgr/cm²).

Il basso assorbimento d'acqua si riflette sulla variazione del Tanδ dopo aver immerso i campioni in acqua a 90°C (si veda la *Figura 11*). I composti presentano una buona ritenzione del fattore di perdita, che dopo 28 giorni in acqua, nel peggiore dei casi è pari a circa 0,035 e nel migliore a 0,017. Ancora una volta, il composto MV TP79 C, grazie alla sua stabilità superiore, presenta le migliori prestazioni, prossime alle prestazioni di riferimento del composto MV IS79.

Avendo un basso assorbimento d'acqua, anche εr rimane pressoché invariato dopo l'immersione in acqua a 90°C. Come illustrato nella *Figura 12*, l'aumento della costante dielettrica è piuttosto ridotto dopo l'immersione nell'acqua.

Tra i composti MV TPV, il composto MV TP79 C mostra la migliore stabilità nel tempo con una εr inferiore rispetto al composto di riferimento MV IS79, anche dopo immersione in acqua per 28 giorni.

Conclusioni

In questo articolo sono stati presentati dei composti MV TPV di nuova concezione. L'obiettivo è produrre composti isolanti MV con proprietà equivalenti a quelle dell'isolamento MV senza piombo standard di mercato e semplificare il processo di lavorazione dei termoplastici.

È stata inoltre descritta la preparazione di tali composti e ne è stata fornita la completa caratterizzazione rispetto all'isolante MV standard senza piombo.

Grazie all'analisi DSC è stato studiato il processo di vulcanizzazione dinamica. È stata infatti studiata la capacità di produrre composti TPV in un impianto pilota industriale per l'applicazione come isolamento MV.

Nonostante la complessa formulazione contenente polimeri, riempitivi, co-agenti e antiossidanti, i composti MV TPV sono stati ottenuti mediante un processo completamente riproducibile e affidabile. I risultati della tecnologia sono le proprietà complessive dei composti MV TPV, che assomigliano alle prestazioni del composto MV IS79 standard senza piombo.

Gli studi reologici, oltre a confermare la natura TPV dei composti, ne simulano il comportamento di estrusione, dimostrando che grazie ad una scelta accurata del PP termoplastico è possibile abbassare lo sforzo di taglio mantenendo inalterata la tipica risposta elastica dei

composti TPV. Un'analisi dettagliata dei diagrammi di sforzo-deformazione dei composti MV TPV ne conferma il comportamento elastico condizionato solo parzialmente dalla cristallinità della fase termoplastica, con conseguenti proprietà meccaniche simili al composto MV IS79 di riferimento. In seguito a invecchiamento a 135°C, i composti MV TPV hanno dimostrato la loro resistenza fino a 504 ore con TS e EB mantenuti >70%.

In seguito ad invecchiamento per 504 ore a 150°C, il composto MV TP79 C ha mantenuto l'80% del proprio TS e il 70% del proprio EB, quasi corrispondente al composto di riferimento MV IS79.

Infine, sono state misurate le proprietà elettriche in condizioni di ambiente asciutto e umido per tutti i composti a 500V e 50Hz. Il valore Tanδ in condizioni asciutte aumenta con la temperatura fino ad un limite superiore di circa 5·x·10^{-3} a 90°C per MV TP79 A, che è ancora paragonabile al valore Tanδ del composto MV IS79 alla stessa temperatura, 3,5 x· 10^{-3}.

Analogamente, il valore εr presenta una variazione in una gamma molto ristretta (fra 2,8 e 2,4) a 25°C e fino a 90°C per tutti i composti. Le misure di resistività del volume confermano delle eccellenti proprietà isolanti a 25°C (10^{15}Ω-cm) con una lieve diminuzione a 90°C (10^{13}Ω-cm).

Sono state testate le proprietà elettriche in condizioni di ambiente umido dopo l'immersione dei campioni in acqua a 90°C fino a 28 giorni. Il valore Tanδ in condizioni di ambiente umido aumenta fino ad un massimo di 3,5 x 10^{-2} per il composto MV TP79 B. I composti MV TP79A e C hanno mostrato una migliore resistenza all'acqua; quest'ultimo vicino alla prestazione del composto MV IS79 dopo 28 giorni in acqua a 90°C, rispettivamente di 2,2 x 10^{-2} e di 1,3 x 10^{-2}.

La stessa tendenza è stata osservata per εr, che aumenta lentamente dopo l'immersione dei campioni in acqua. Tuttavia, le fluttuazioni sono praticamente irrilevanti, attestandosi tra 2,53 e 2,66 e considerando l'errore associato alla misurazione.

In conclusione è stato presentato uno studio completo sui composti TPV come materiali isolanti per applicazioni MV.

L'approccio graduale ha dimostrato come possano migliorare in maniera incrementale le proprietà dei composti ottenendo un materiale completamente termoplastico e privo di piombo, ovvero il MV TP79 C, con prestazioni meccaniche, reologiche ed elettriche paragonabili a quelle dello standard di mercato senza piombo MV IS79.

Secondo la norma CEI 20-86, il composto MV TP79 C ha le potenzialità per essere realizzato come isolamento con classificazione per una temperatura continua di funzionamento di 105ºC e un cortocircuito di emergenza di 250°C.

Proseguendo lo sviluppo della strategia, Mixer SpA prevede di sviluppare nel prossimo futuro dei composti MV TPV con maggiore resistenza e migliori proprietà elettriche ad alta temperatura e in acqua. ■

Ringraziamenti

Gli autori desiderano ringraziare Imerys quale fornitore delle materie prime utilizzate nel presente studio.

Gli autori desiderano inoltre ringraziare il laboratorio di Imerys a Par, Regno Unito, per le misurazioni elettriche eseguite sui suoi composti.

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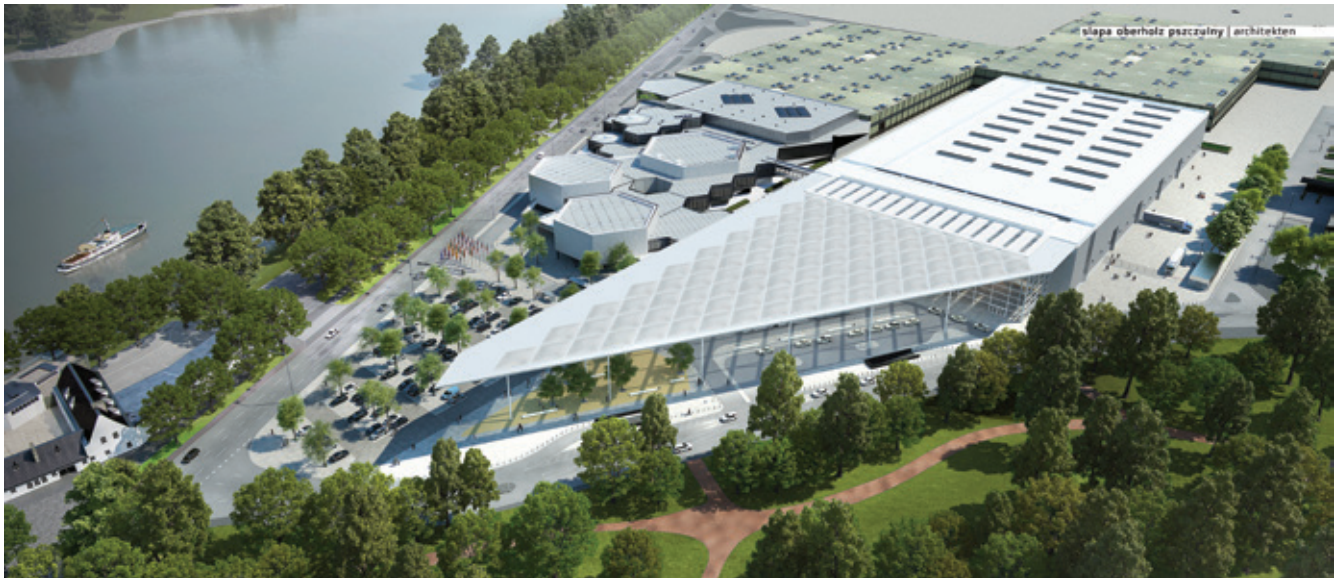


▲ *Proyecto de un arquitecto para la nueva entrada sur del centro de exposiciones de Düsseldorf*

Nueva ala sur de Messe Düsseldorf: wire 2018 y Tube 2018 se benefician de la renovación

SE ha iniciado la reforma completa de la entrada sur y del Pabellón 1 contiguo del centro de exposiciones de Düsseldorf.

La junta directiva y los accionistas de Messe Düsseldorf GmbH han dado su aprobación y así se ha iniciado uno de los proyectos de construcción más ambiciosos de la historia de la empresa.

"Ahora podemos llevar a cabo nuestro plan maestro para la modernización y renovación completas de las instalaciones de nuestro centro de exposiciones y nuestra base", dijo Werner M. Dornscheidt, presidente y CEO de Messe Düsseldorf, que añadió: "Como siempre, todo será realizado sin subvenciones."

La inversión para la ala sur es de 140 millones de euros. En total, Messe Düsseldorf invertirá alrededor de 636 millones de euros en su centro de exposiciones de aquí al año 2030. La obra iniciará en mayo y se prevé que finalice en el verano de 2019. El diseño fue realizado por el estudio de arquitectos slapa oberholz pszczulny architekten de Düsseldorf.

La nueva entrada sur dará a Messe Düsseldorf un aspecto moderno a orillas del Rin y con vistas hacia la ciudad de Düsseldorf. Los visitantes de la feria y los delegados de la convención harán su entrada por una nueva marquesina translúcida iluminada y de 7.800m² y de aproximadamente 20m de altura.

Esta estructura constituirá un punto emblemático en un lugar tan visible del centro de exposiciones. Jurek Slapa, socio administrador de sop architecten, dijo: "La marquesina dará a Messe Düsseldorf una nueva fachada y una ubicación inconfundible en esta posición tan especial entre el Rin y Nordpark."

La fachada de la entrada sur se abre hacia la zona exterior a través de una fachada toda de vidrio de 93 metros de longitud. Los servicios necesarios, como cajas y guardarropas, serán ubicados en este área de 2.000m². La primera planta albergará una sala de reuniones con paredes de vidrio que da al vestíbulo y ofrece una vista de la entrada y de la zona exterior. Además, se podrá usar todo el vestíbulo como lugar para eventos. La zona exterior también albergará la entrada del aparcamiento subterráneo de 300 plazas, paradas de autobús y aparcamientos de taxis.

La renovación de la entrada sur comprenderá también la reconstrucción del pabellón 1. Para ello, Messe Düsseldorf prevé demoler los pabellones 1 y 2 actuales, que son más pequeños, y cambiarlos por una nueva construcción. El pabellón 1, de 158m x 77m, con una superficie de más de 12.000m², tendrá aproximadamente el mismo tamaño que los pabellones 8a y 8b.

El nuevo pabellón cumplirá los elevados estándares técnicos de todo el centro de exposiciones. A los pabellones se accederá a través de siete puertas y estarán equipados con un sistema de suspensiones en el techo tan fáciles de realizar como las alimentaciones desde el suelo de los pabellones.

Los peatones podrán usar el puente del primer piso para pasar del pabellón al Centro de Congresos de Düsseldorf (CCD). Además de estar comunicado con los pabellones 3 y 4, habrá un camino que llevará desde la entrada sur directamente hasta el resto de las instalaciones de la feria.

En 2017 y en 2018, los años de transición durante los cuales se realizarán los trabajos de construcción, a los expositores de Tube que anteriormente se habían alojado en los pabellones 1 y 2 se le ofrecerán opciones alternativas atractivas para exponer en los pabellones 16 y 17. Por tanto, Tube 2018 se celebrará en los pabellones de 3 a 7 y en los pabellones de 16 a 17. Los expositores de wire 2018 presentarán sus novedades en los pabellones de 9 a 16.

Messe Düsseldorf GmbH – Alemania
Website: www.messe-duesseldorf.de

Sistemas de fabricación de cables de datos además de conocimiento de los procesos

▲ *Línea de cableado para cable de datos con cableadora de doble torsión tipo DSI 631 combinada con un desenrollador de detorsión cuesta arriba y un desenrollador de cinta longitudinal*

LOS cables de vehículos, los sistemas IT, el sector de la energía y otros sectores de aplicaciones deben cumplir requisitos cada vez más numerosos.

Para mantenerse al día con esta tendencia, los fabricantes de cables necesitan de máquinas que puedan producir cables con diseños complejos, capaz de trabajar de manera eficaz por lo que se refiere a energía, materias primas y costes y que puedan adaptarse de manera flexible a las nuevas exigencias productivas.

Las máquinas para cables desarrolladas y fabricadas por Niehoff responden a todas estas exigencias. Un ejemplo es la cableadora de doble torsión tipo DSI 631 que ha sido diseñada para trenzar conductores aislados en pares y cuadretes y para el trenzado de cuatro pares de conductores en cables LAN.

La máquina puede producir de manera fiable cables LAN de cualquier categoría, incluso de generaciones futuras, como también pares con blindaje de cinta, cables bus y otros cables para telecomunicaciones. Gracias a los numerosos equipos auxiliares adicionales disponibles, el sistema de las cableadoras DSI permite crear o reconstruir rápidamente líneas de producción personalizadas para el cliente de acuerdo con la situación de los pedidos.

Respecto a otras máquinas y tecnologías de procesamiento, las posibilidades de combinación del sistema llevan ventajas económicas significativas para la fabricación de ciertos productos o ciertas prestaciones productivas.

Otra ventaja para los usuarios de estos y otros sistemas de Niehoff es que la compañía, gracias a decenios de experiencia en el diseño de máquinas para el alambre y el cable, da soporte a los clientes con amplios conocimientos de los procesos y un servicio de asistencia postventa profesional.

Maschinenfabrik Niehoff GmbH & Co KG – Alemania
Website: www.niehoff.de

Nuevo jefe de ventas

Arnold Büscher se ha adjudicado el cargo de jefe de ventas de Alemania para U I Lapp GmbH, compañía del grupo Lapp.

Büscher, ingeniero mecánico, tuvo varios cargos directivos en empresas bien conocidas del sector industrial. Adquirió experiencia internacional con su cargo de director general de Rittal Corp en Estados Unidos, por citar un ejemplo. Más recientemente, fue encargado de operaciones comerciales en Alemania y Europa Central como director general de Weidmüller GmbH & Co KG.

"Estamos muy contentos de tener con nosotros al señor Büscher, porque es un gerente experto que conoce muy bien nuestro mercado y favorecerá nuestra transformación en un proveedor de sistemas", dijo Andreas Lapp.

Büscher desea reforzar todos los canales de venta y centrarse en los mercados en crecimiento en el sector de ferrocarriles y en la industria alimenticia y robótica. Sus actividades comprenden también la creación y expansión de soluciones de sistemas bajo la marca Ölflex® Connect con una amplia gama de productos y servicios relacionados con los cables preensamblados.

"Lapp tiene sólidas relaciones con los clientes y también un potencial de crecimiento notable. Quiero intensificar nuestra relación con los clientes a través de todos los canales, aumentar nuestra atención hacia su potencial y promover los negocios de los clientes nuevos", declaró Büscher, hablando de su nuevo cargo.

Lapp Group – Alemania
Website: www.lappgroup.com

▲ *Arnold Büscher*

Aislamiento a base de TPV para aplicaciones de media tensión

Por Andrea Galanti, Stefano Dossi y Andrea Magri, de Mixer SpA, Ravenna, Italia, y Camillo Cardelli, iPool Srl, Pistoia, Italia

Resumen

Este artículo presenta el desarrollo de tres compuestos aislantes para media tensión (MV) sin plomo completamente termoplásticos producidos mediante la tecnología de termoplásticos vulcanizados (TPV). Se prepararon los compuestos aislantes TPV para media tensión (MV TPV) a partir de un aislamiento de media tensión sin plomo curable con peróxido, que es el estándar de referencia actual para el mercado. Por esta razón, se estudiaron los compuestos detenidamente comparándolos con el aislamiento de media tensión sin plomo estándar. Para evaluar los resultados del proceso de vulcanización dinámica, se analizaron los compuestos mediante calorimetría diferencial de barrido (DSC). Para simular su comportamiento durante la extrusión, se estudió su reología. Se midieron las propiedades mecánicas antes y después del envejecimiento a 135°C y150°C durante 21 días. Por último, se presenta un estudio completo de las características eléctricas en seco (de 25°C a 90°C) y en húmedo (hasta 28 días a 90°C en agua) de dichos compuestos.

1 Introducción

Veinte años atrás se usaban los dos sistemas aislantes a base de XLPE y EPDM para los cables de media tensión en muchas partes del mundo. Norteamérica sigue siendo un mercado muy activo para los aislamientos de media tensión a base de EPDM, mientras que en otras partes del mundo se prefiere el XLPE. Recientemente, se ha observado un nuevo interés por los aislamientos de media tensión a base de EPDM en el mercado global debido a su inigualable rendimiento en términos de duración para aplicaciones a largo plazo (>20 años).

▲ **Figura 1**: *Aislamiento de media tensión con plomo (naranja) y sin plomo (blanco), de pellets a cables*

Desde 1996, Mixer SpA produce compuestos aislantes de media tensión a base de EPDM y mezclas de EPDM/LDPE: su estrategia es ofrecer materiales innovadores y competitivos al mercado del cable, con la idea de que mejorando continuamente los materiales, se puede dar vida nueva a los cables de caucho para aplicaciones especiales.

El primer paso de este enfoque fue el desarrollo de soluciones EPDM sin plomo, que fueron presentadas en 2012 y ya están disponibles en el comercio (véase la *Figura 1*)[1]. Dado que las sales de plomo son insolubles en agua y, por lo tanto, no intervienen en las pérdidas de corriente a través de la capa de aislamiento, el óxido de plomo es uno de los aditivos más eficaces en los compuestos aislantes de media tensión. Sin embargo, el óxido de plomo se encuentra en la Lista de Sustancias Candidatas Extremadamente Preocupantes (Reach SVHC) debido a su bien conocido riesgo de bioacumulación y efectos duraderos que dañan gravemente el medioambiente y la vida[2].

Mixer SpA ha reemplazado con éxito el óxido de plomo por un sistema barredor de iones inorgánicos capaz de inmovilizar los iones, pudiendo así producir compuestos aislantes de media tensión sin plomo a base de EPDM de estabilidad térmica y eléctrica superior.

A partir de aquí, se ha desarrollado un nuevo TPV completamente termoplástico para el aislamiento de media tensión reticulando dinámicamente el compuesto aislante de media tensión sin plomo en una matriz de PP. Mixer SpA presenta tres versiones revisadas de los compuestos MV TPV para lograr obtener un material capaz de pasar las pruebas termomecánicas a temperaturas de funcionamiento continuo de 90°C y 105°C y de emergencia de cortocircuito a 250°C según la norma italiana CEI 20-86 que es, hasta ahora, la única norma para compuestos termoplásticos para aislamiento de media tensión.

Primero, se analizaron la preparación y las propiedades macroscópicas de los nuevos compuestos MV TPV. Luego, se examinaron los nuevos compuestos MV TPV mediante DSC para estudiar el proceso de vulcanización dinámica. Seguidamente, se analizó la reología de los compuestos MV TPV a bajos valores de corte para simular su comportamiento durante la extrusión. A continuación, se probaron las características mecánicas de los compuestos MV TPV antes y después del envejecimiento por calor hasta 150°C durante 21 días. Las propiedades eléctricas de los compuestos fueron estudiadas en los Laboratorios Imerys, Par, Reino Unido. En particular, se midieron el factor de pérdida (Tanδ), la constante dieléctrica (εr) y la resistividad de volumen hasta 90°C en seco. Además, se estudiaron el Tanδ y la εr después de sumergir los compuestos en agua a 90°C durante 28 días. Los resultados de las pruebas fueron comparados con el MV IS79 sin plomo estándar y se demostró que se puede ofrecer un compuesto innovador, con altas propiedades de aislamiento eléctrico, que combina las propiedades de un compuesto XL-EPDM sin plomo con la posibilidad de procesarlo como material termoplástico.

2 Compuestos MV TPV sin plomo

2.1 *Preparación de los compuestos MV TPV*

El compuesto aislante para media tensión sin plomo, MV IS79, y los compuestos termoplásticos vulcanizados MV TPV, fueron preparados en un mezclador interno equipado con dos rotores contrarrotatorios y una cámara de 8cm³ de volumen. La composición de los compuestos MV TPV está indicada en la *Tabla 1*.

Obviamente, los compuestos MV TPV79 A y B presentan la misma relación entre la fase elastomérica y la termoplástica, a pesar de que se usaron distintos coagentes en su formulación. Esto fue realizado siguiendo los estudios sobre los coagentes que influencian las propiedades de los compuestos TPV evitando la descomposición del PP mediante escisión β causada por los radicales libres[3].

El MV IS79 fue preparado mezclando todos los componentes en un mezclador interno hasta mezclar perfectamente los ingredientes. Después de descargarlo, se le añadió el peróxido a baja temperatura en un mezclador de dos cilindros. Se obtuvieron muestras para las pruebas prensando las hojas en una máquina de moldeo por compresión a 180°C durante 10 minutos. Las muestras para las propiedades mecánicas fueron troqueladas en la dirección longtudinal.

Composición del TPV	MV TP79 A	MV TP79 B	MV TP79 C
MV IS79	75%	75%	70%
PP-1	25%	25%	20%
PP-2	-	-	10%

[1]d = 0.891 gr/cm³, MFI (230°C; 2.16kg) = 8.0 gr/10min; [2]d = 0.900 gr/cm³, MFI (230°C; 2.16kg) = 10.0 gr/10 min

▲ **Tabla 1**: *Formulación de los compuestos MV TPV*

Los compuestos MV TPV79 fueron preparados mezclando el compuesto sin plomo (MV IS79) con polipropileno termoplástico (PP) según la relación indicada en la *Tabla 1*. Durante el proceso de mezclado, a medida que ocurre la reacción radical y la temperatura aumenta continuamente, el par sigue un modelo característico que está representado gráficamente en la *Figura 2*[4,5].

Después de cargar los ingredientes, el par aumenta debido a la alta viscosidad de los componentes a baja temperatura. Al aumentar la temperatura, los materiales inician a reblandecerse y el par disminuye a medida que se van mezclando los ingredientes. Al iniciar la reacción radicalaria, se realizan simultáneamente la reticulación de la fase caucho y la escisión β del PP, con la consiguiente inversión de fase que lleva al rápido aumento del par.

La temperatura final a la que se descargaron los compuestos TPV después de aproximadamente ocho minutos de procesamiento, era de entre 200°C y 220°C. Los compuestos todavía calientes fueron calandrados en un mezclador de dos cilindros en forma de hoja; luego se obtuvieron placas prensando las hojas en una máquina de moldeo de compresión a 180°C durante un minuto. Las muestras para las propiedades mecánicas fueron cortadas en la dirección longitudinal.

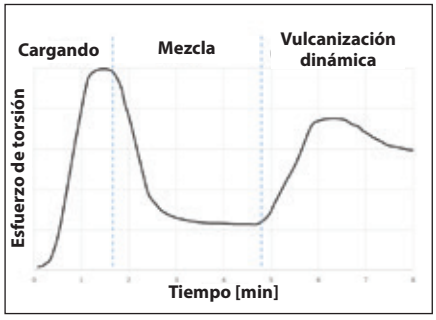
Como se puede ver en la *Tabla 2*, todos los compuestos muestran propiedades mecánicas similares, en particular, la resistencia a la tracción (TS), el alargamiento a la rotura (EB) y el TS a un 200% de alargamiento.

La elección del PP y su relación no parece influenciar mucho las propiedades mecánicas, que están próximas a las del MV IS79 estándar. Al contrario, la cristalinidad del PP lleva a un aumento considerable de dureza (HS) que es 48 Shore D para el MV TP79 C, es decir, el compuesto con el contenido más alto de PP. Debido a la alta viscosidad del MV TP79 A y B, el caudal del material fundido (MFI) fue medido a 190°C con un peso de 21,6Kg.

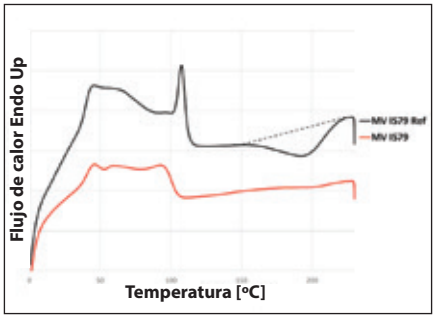
Su bajo caudal puede ser debido principalmente a dos factores principales: la relación entre las fases termoplástica y elastomérica y la elección de un PP con MFI bajo a la temperatura de prueba. Sin embargo, se puede notar que, equilibrando atentamente la relación entre las dos fases y seleccionando correctamente el PP, se pudo obtener un MFI para el MV TP79 C comparable al MV IS79 estándar. Tales resultados son confirmados por los estudios reológicos presentados en la sección 2.3.

Para la comparación y para destacar la importancia del éxito a la hora de obtener los compuestos MV TPV, se produjeron materiales de referencia sin peróxido. Así que, en aquellos compuestos, la vulcanización dinámica no podía ocurrir después del mezclado de los componentes. El compuesto de referencia MV Ref AB, presenta la misma composición del MV TP79 A y B (sin peróxido ni coagentes), el compuesto de referencia MV Ref C fue formulado como MV TP79 C (sin peróxido). La reología y las propiedades mecánicas de ambos compuestos de referencia fueron analizadas comparándolas con los compuestos MV TPV presentados en este artículo para demostrar nuestra capacidad de obtener compuestos TPV de modo reproducible y controlado.

▼ **Figura 2**: *Representación del modelo de par en función del tiempo durante la producción de los compuestos MV TPV. Se muestran los tres pasos principales del proceso*



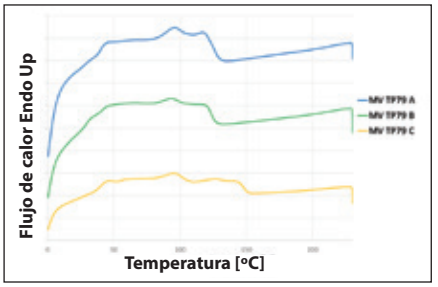
▼ **Figura 3**: *Análisis DSC del MV IS79 no curado (arriba) y curado (abajo). Línea punteada: representación gráfica de la línea de base usada para calcular la entalpía de la reacción*



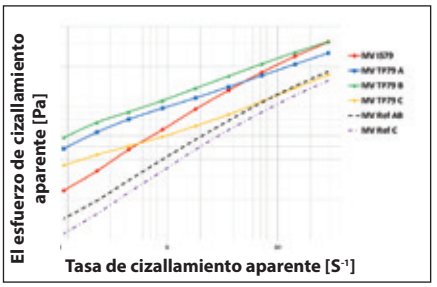
▼ **Tabla 2**: *Típicas propiedades físicas de los compuestos aislantes de media tensión*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
TS[1] [N/mm²]	16.61	17.31	17.19	15.73
EB[1] [%]	321	360	310	341
TS @ 200% [N/mm²]	14.23	13.57	14.48	13.62
HS[2] [Shore A-D]	80-/	96-45	95-46	96-48
MFI[3] [gr/10min]	27.6[4]	4.4	4.2	21.3

[1]ASTM D412; [2]ASTM D2240; [3]ASTM D1238 (190°C, 21.6kg), [4]Medido en el compuesto sin peróxido



▲ **Figura 4**: *Análisis DSC del MV TP79 A (arriba), MV TP79 B (centro) y MV TP79 C (abajo)*



▲ **Figura 5**: *Esfuerzo de corte aparente en función de la velocidad de corte aparente medido a 180ºC de los compuestos aislantes de media tensión. Líneas punteadas: compuestos de referencia*

2.2 Análisis DSC

Para determinar la cantidad de peróxido restante que no ha reaccionado en los compuestos después del proceso de curado, se realizó el análisis mediante calorimetría diferencial de barrido (DSC). Los espectros fueron medidos en un Perkin-Elmer DSC 6000 en atmósfera de nitrógeno inerte de 0°C a 230°C con velocidad de calentamiento de 20°C/min; después del calentamiento, las muestras fueron enfriadas a 0°C a una velocidad de 10°C/min.

Este ciclo fue repetido tres veces. Sin embargo, dado que el objetivo de este estudio era cuantificar la relación entre el peróxido inicial y final (después del curado o vulcanización dinámica), a continuación se presenta y examina solamente el primer ciclo de calentamiento.

Primero, el MV IS79 no curado que contenía 100% de peróxido que no había reaccionado fue analizado y usado como referencia. El análisis DSC ilustrado en la *Figura 3* muestra que la entalpía de reacción calculada (ΔH) resultante de la descomposición del peróxido era -8,97 J/g. En la misma figura está representado el gráfico DSC del MV IS79 curado (10 minutos a 180°C). Se observó un ΔH de -1,16 J/g que correspondía a un residuo de aproximadamente un 13% del peróxido que no había reaccionado. Esto indica que el MV IS79 estaba casi completamente vulcanizado. De la misma manera, se calculó la cantidad de peróxido que no había reaccionado en los compuestos MV TPV considerando que el MV TP79 A, B y MV TP79 C fueron formulados respectivamente con un 75% y 70% de MV IS79 no curado.

De los datos recogidos e indicados en la *Figura 4*, el peróxido residual detectado en el MV TP79 A era aproximadamente un 4% (ΔH = -0,27 J/g) y en el MV TP79 B era aproximadamente un 5% (ΔH = -0,33 J/g). Para el MV TP79 C el peróxido residual detectado era aproximadamente un 11% (ΔH = -0,68 J/g). Estos resultados confirman, sin duda alguna, la casi completa descomposición del peróxido inicial durante la vulcanización dinámica.

2.3 Reología

Los estudios reológicos son fundamentales para predecir el comportamiento de extrusión de los compuestos. Por tanto, hemos examinado la reología a velocidades de corte aparentes de 200 s^{-1} a 1 s^{-1} en un reómetro capilar Göttfert Rheograph 2002. La razón longitud/diámetro (L/D) del capilar era 30 y las medidas se efectuaron a 180°C. Se seleccionó dicha temperatura para permitir la fusión completa del PP. Normalmente, los compuestos estándares como el MV IS79 se caracterizan a 125°C antes de la fase de curado; sin embargo, a esta temperatura el PP no está fundido y esto lleva a resultados engañosos. Debido a la alta temperatura, para prevenir la descomposición del peróxido durante el análisis, se estudió el MV IS79 sin peróxido. Como se ha dicho antes, se incluyeron los compuestos de referencia MV Ref AB y C en este estudio para subrayar el cambio de comportamiento reológico a consecuencia de la vulcanización dinámica. Los gráficos del esfuerzo de corte aparente en función de la velocidad de corte se ilustran en la *Figura 5*.

La respuesta del MV IS79 es típica de los compuestos a base de EPDM/PE; el esfuerzo de corte disminuye rápidamente de manera casi lineal al disminuir la velocidad de corte. Se pueden notar ligeros desvíos respecto a una linealidad perfecta, que normalmente son atribuidos a los cauchos EPDM. MV Ref AB y C muestran el mismo modelo con el esfuerzo de corte trasladado hacia valores más bajos. Este efecto es causado por la fase termoplástica que muestra una viscosidad más baja a esta temperatura.

De la misma manera, aumentando el contenido de PP, el esfuerzo de corte disminuye. Debido a la diversidad de los compuestos MV TPV, su comportamiento reológico es bastante diferente[6,7].

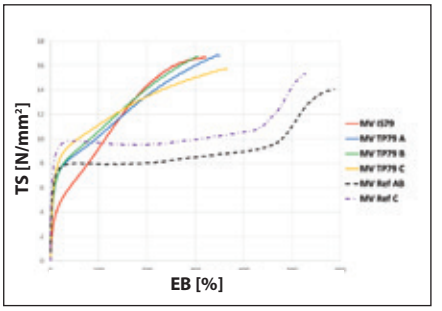
Esencialmente, este carácter distinto se origina a consecuencia de la respuesta elástica de las partículas elastoméricas reticuladas que es dominante sometidas a bajos esfuerzos de corte. Al contrario, con altos esfuerzos de corte, el comportamiento de los compuestos TPV es determinado por la fase termoplástica. Por consiguiente, los tres compuestos MV TPV tienen comportamientos similares al de los compuestos de referencia a altas velocidades de corte. Al contrario, a velocidades de corte bajos, las curvas son claramente divergentes.

Si se centra la atención en los compuestos MV TPV, como se ha notado antes para el MFI en la sección 2.1, equilibrando atentamente los componentes y seleccionando correctamente el PP, es posible „regular" el comportamiento reológico de los compuestos MV TPV manteniendo e incluso mejorando las características termomecánicas. En ese sentido, el MV TP79 C manifiesta esfuerzos más bajos, es decir, viscosidad, hasta velocidades de corte muy bajas junto con las mejores propiedades termomecánicas de entre los compuestos MV TPV estudiados.

2.4 Pruebas mecánicas

Se midieron las propiedades de esfuerzo y deformación de los compuestos aislantes de media tensión según el método ASTM D412, haciendo la media de los resultados de cinco muestras de tipo *„dumb-bell"* obtenidos en un Gibitre Tensor Check Profile (dinamómetro electrónico para pruebas en tracción y compresión). Las muestras fueron troqueladas en la dirección longitudinal a partir de placas obtenidas en una máquina de moldeo por compresión a 180°C. El MV IS79 fue prensado durante 10 minutos para

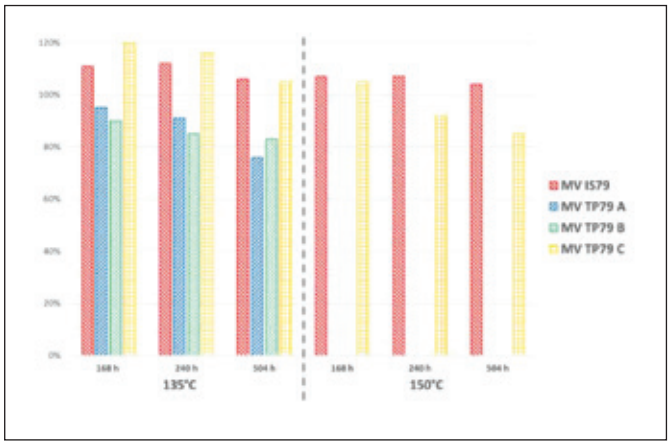
▼ **Figura 6**: *Esquemas de esfuerzo-deformación de los compuestos aislantes de media tensión. Líneas punteadas: compuestos de referencia*



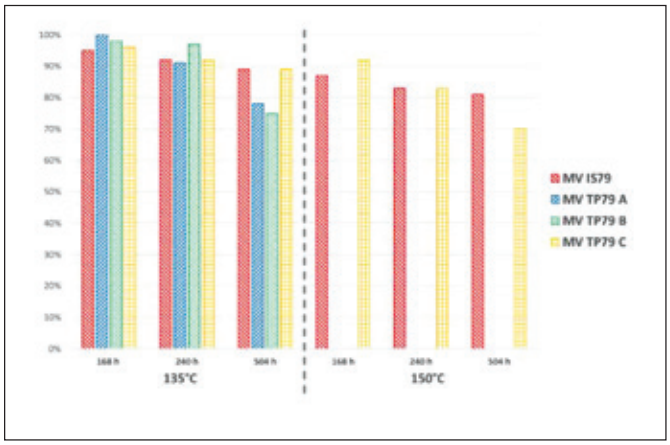
▼ **Tabla 3**: *Prueba de presión a alta temperatura y contracción longitudinal a 130ºC de los compuestos MV TPV*

	MV TP79 A	MV TP79 B	MV TP79 C
Prueba de presión a alta temperatura[1] [%]	n.a.[2]	27	3
Contracción longitudinal[1] [%]	14	11	2

[1]CEI 20-86; [2]No aplicable



▲ **Figura 7**: *Resistencia a la tracción retenida después del envejecimiento a 135ºC y 150ºC durante 168h, 240h and 504h*



▲ **Figura 8**: *Alargamiento de rotura retenido después del envejecimiento a 135ºC y 150ºC durante 168h, 240h and 504h*

completar el proceso de curado. Los MV IS79 A, B y C fueron prensados durante un minuto y enfriados bajo presión. Los compuestos MV Ref AB fueron tratados de manera idéntica al compuesto MV TPV para obtener las muestras de prueba. La *Figura 6* ilustra un ejemplo de la curva esfuerzo-deformación de cada compuesto.

A primera vista, el análisis de las curvas esfuerzo-deformación de los materiales muestra que los compuestos MV TPV presentan prestaciones similares al estándar de referencia MV IS79 en términos de TS y EB, como se ha afirmado antes en la sección 2.1. Además de los valores absolutos, las curvas delineadas siguen un modelo similar con una fuerte respuesta elástica al esfuerzo aplicado. La diferencia principal que se puede observar es el módulo de Young, que es más alto para los compuestos MV TPV. Esto se debe a la cristalinidad de la fase termoplástica y, por lo tanto, es más elevado en el caso del MV TP79 C. Se puede observar el mismo comportamiento en el compuesto de referencia MV Ref AB, que tiene un módulo de Young virtualmente idéntico al MV TP79 A y B. De la misma manera, el compuesto MV Ref C comparándolo con el MV TP79 C, presenta un módulo de Young similar. Sin embargo, estos compuestos de referencia, dado que no están vulcanizados y no tienen características elásticas, resisten hasta la rotura final. De lo contrario, los compuestos MV TPV se comportan como materiales reticulados con alargamiento elevado[8-10]. Estos resultados concuerdan con los estudios reológicos, convalidando el éxito de los compuestos vulcanizados termoplásticos.

De acuerdo con la norma CEI 20-86, para evaluar las prestaciones de los compuestos MV TPV a alta temperatura, se realizaron las pruebas de presión en caliente y de contracción longitudinal a 130°C, que son obligatorias para los materiales aislantes termoplásticos clasificados para 90°C y 105°C, y que se ilustran en la *Tabla 3*.

Los resultados muestran una mejora de los resultados pasando del MV TP79 A al MV TP79 C. Sin embargo, esto no es una consecuencia de la relación entre la fase termoplástica y la elastomérica, sino que resulta de la adición de un PP (véase la *Tabla 1*), que puede soportar esas altas temperaturas.

2.4.1 Resistencia al envejecimiento térmico

Se probaron los compuestos aislantes para MT a 135°C y 150°C durante 168, 240 y 504h, para verificar su resistencia al envejecimiento acelerado. La resistencia a la tracción (TS) y el alargamiento de rotura (EB) retenidos están ilustrados gráficamente en la *Figura 7* y en la *Figura 8*. No se pudieron probar los MV TP79 A y B a 150°C porque la fase termoplástica se funde completamente a esta temperatura. En ese sentido, el MV TP79 C, que contiene PP con temperatura de fusión más alta, representa la única alternativa al MV IS79 a la temperatura de prueba de 150°C.

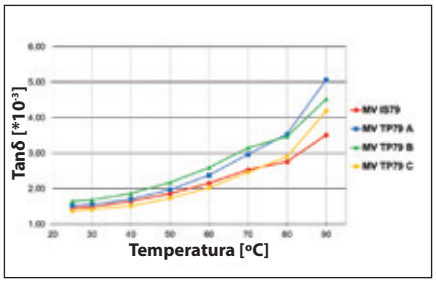
En primer lugar, se debe precisar que todos los compuestos tienen una resistencia de buena a excelente a 135°C en términos de TS y EB retenidos, que son superiores a un 70% después de 504h. Tanto el MV IS79 como el MV TP79 C soportan perfectamente el envejecimiento térmico a 135°C, manteniendo TS y EB > 90%. Aunque las prestaciones de resistencia térmica bajen ligeramente respecto al MV IS79, el MV TP79 C muestra una TS retenida > 80% y un EB retenido de aproximadamente un 70% después de 504h a 150°C.

Las pruebas indican que MV TP79 C puede soportar las mismas condiciones de envejecimiento que el MV IS79. Se debe considerar que el MV IS79 está clasificado para una temperatura de servicio de 105°C y, por lo tanto, se prueba habitualmente durante 508h a 150°C con valores típicos de TS y EB retenidos de un 95% y 75%. Según la norma CEI 20-86, los compuestos aislantes para MT deben soportar un envejecimiento durante 240h a 135°C y 150°C para una temperatura de servicio nominal respectivamente de 90°C y de 105°C. Por lo tanto, el MV TP79 C representa una válida alternativa termoplástica a los compuestos aislantes MT elastoméricos estándares sin plomo.

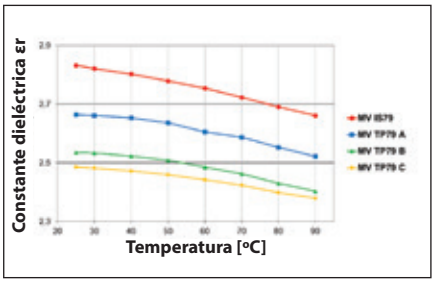
▼ **Tabla 4**: *Resistividad de volumen medida a 25°C y 90°C con un potencial de 500V*

Resistividad de volumen [*10¹⁴]	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
At 25ºC [Ω-cm]	47.0	41.6	41.3	50.3
At 90ºC [Ω-cm]	2.54	0.378	0.284	0.321

▼ **Figura 9**: *Factor de pérdida (Tanδ) en función de la temperatura a 500V y 50Hz*



▼ **Figura 10**: *Constante dieléctrica (Tanδ) en función de la temperatura a 500V y 50Hz*



2.5 Propiedades eléctricas

Se evaluaron las propiedades aislantes de los compuestos midiendo el factor de pérdida (Tanδ), la constante dieléctrica (ε_r) y la resistividad de volumen en función de la temperatura de 25°C a 90°C en seco. Además, se midieron el factor de pérdida y la constante dieléctrica después de sumergir los compuestos en agua a 90°C durante 28 días. Para la medición de las propiedades eléctricas se utilizaron muestras de 2mm de espesor moldeadas a presión. Para evaluar el Tanδ y la ε_r se utilizó un Sistema Omicron MI600; para; se implementó un QuadTech modelo1868A para estudiar la resistividad de volumen. Todas las propiedades eléctricas de los compuestos fueron estudiadas en los laboratorios Imerys.

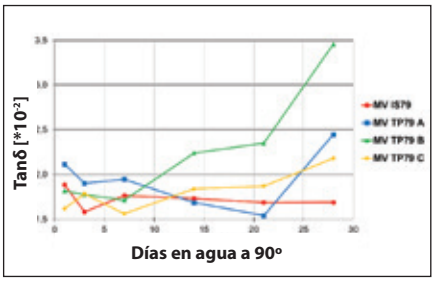
La *Figura 9* muestra los gráficos del Tanδ de 25°C a 90°C en seco. Los cuatro compuestos están caracterizados por pequeñas variaciones del factor de pérdida, que quedan en el mismo orden de (10^{-3}) hasta 90ºC. Además, todos los compuestos presentan una tendencia similar del Tanδ al aumentar la temperatura. Más detalladamente, el factor de pérdida de los cuatro compuestos es virtualmente idéntico a temperatura ambiente, aproximadamente $1{,}5x10^{-3}$, y crece constantemente con la temperatura hasta valores de entre $3{,}5x10^{-3}$ y $5{,}0x10^{-3}$ a 90°C respectivamente para MV IS79 y MV TP79 A.

Como se ha afirmado para Tanδ, ε_r varía en un campo estrecho para todos los compuestos al aumentar la temperatura. En la *Figura 10*, se puede observar solamente una pequeña reducción de la constante dieléctrica al aumentar la temperatura. Dado que ε_r se calcula mediante la fórmula siguiente:

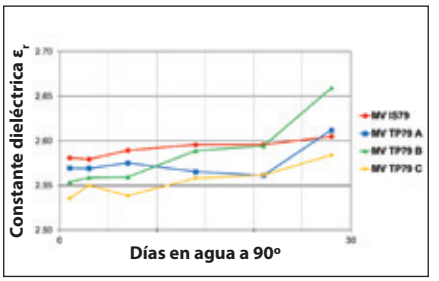
$$\varepsilon_r = \left(\frac{C}{\varepsilon_0}\right)\left(\frac{t}{A}\right)$$

en la cual C es la capacitancia medida por el instrumento y ε_0 es la permitividad del vacío, mientras que t y A son factores geométricos que indican la separación entre la placas (electrodos) y su área, respectivamente. La constante dieléctrica más baja de los compuestos MV TPV respecto a los MV IS79 es debida a su contenido de PP, que aumenta las prestaciones de aislamiento totales del compuesto. Por consiguiente el MV IS79 se caracteriza por la constante dieléctrica más alta a diferencia del MV TP79 C que se caracteriza por la constante dieléctrica más baja. Sin embargo, se debe precisar que la diferencia entre los compuestos es bastante limitada ya sea a baja ya sea a alta temperatura.

Por último, se midió la resistividad de volumen a 25°C y 90°C aplicando una diferencia de potencial de 500V (véase la *Tabla 4*).



▲ **Figura 11**: *Factor de pérdida (Tanδ) en función de días de inmersión en agua a 90ºC medido a 500V y 50Hz*



▲ **Figura 12**: *Constante dieléctrica (ε_r) en función de días de inmersión en agua a 90ºC medida a 500V y 50Hz*

	MV IS79	MV TP79 A	MV TP79 B	MV TP79 C
Absorción de agua [1] [mgr/cm²]	0.34	0.32	0.35	0.34

[1]Método gravimétrico, CEI EN 60811-402

▲ **Tabla 5**: *Absorción de agua según la norma CEI 20-86*

A 25°C, todos los compuestos tienen una resistividad de volumen del orden de 10^{15} Ω-cm, que es el valor estándar para los aislantes MT. A 90°C la resistividad de volumen de los compuestos MV TPV es aproximadamente un orden de magnitud más bajo que el MV IS79.

Muy probablemente, esta diferencia resulta de una fusión parcial de la fase termoplástica de los compuestos TPV, que lleva a una movilidad más alta de los portadores de carga en el material. Sin embargo, además de esto, la resistividad de volumen de los cuatro compuestos TPV de MT es superior a 10^{13} Ω-cm.

2.5.1 *Prestaciones eléctricas en agua*

Se probaron las propiedades eléctricas con inmersión en agua a 90ºC durante 28 días. En primer lugar, se calculó la absorción de agua de los compuestos MV TPV respecto al MV IS79, según la norma italiana CEI 20-86. Los resultados ilustrados en la *Tabla 5* muestran que los compuestos tienen virtualmente una absorción idéntica después de 14 días en agua a 85°C, muy por debajo del límite superior (5mgr/cm²).

La baja absorción de agua se refleja en la variación de Tanδ después de sumergir las muestras en agua a 90°C (véase la *Figura 11*). Los compuestos presentan una buena retención del factor de pérdida, que es, después de 28 días en agua, en el peor caso, aproximadamente 0,035 y en el mejor caso 0,017. De nuevo, el MV TP79 C, gracias a su estabilidad superior, muestra las mejores prestaciones mejores, próximas a las prestaciones de referencia del MV IS79.

Gracias a su baja absorción de agua, el ε_r también queda casi invariado después de la inmersión en agua a 90°C. Como se ilustra en la *Figura 12*, el aumento de la constante dieléctrica es bastante pequeño después de la inmersión en agua.

Entre los compuestos MV TPV, el MV TP79 C muestra la mejor estabilidad durante el tiempo teniendo una ε_r más baja respecto al IS79 de referencia, incluso después de 28 días en agua.

Conclusiones

Con este artículo se han presentado los compuestos MV TPV recién desarrollados. El objetivo es producir compuestos aislantes de media tensión con propiedades iguales al corriente aislamiento de media tensión sin plomo estándar de mercado, y el procesamiento fácil de los termoplásticos.

Se ha descrito la preparación de estos compuestos junto con su completa caracterización comparándolos con el aislante de media tensión sin plomo estándar. Se ha estudiado el proceso de vulcanización dinámica mediante DSC. De hecho, se ha estudiado la capacidad de producir los compuestos TPV en una instalación piloto para usarlos como aislamientos de media tensión.

A pesar de que la formulación compleja contenía polímeros, cargas, coagentes y antioxidantes, el MV TPV fue obtenido con un proceso completamente reproducible y fiable. Los resultados de la tecnología son las propiedades generales de los compuestos MV TPV que igualan las prestaciones del MV IS79 sin plomo estándar.

Los estudios reológicos, además de confirmar la naturaleza TPV de los compuestos, simulan su comportamiento durante la extrusión demostrando que, gracias a una selección cuidadosa del termoplástico PP, es posible bajar el esfuerzo de corte manteniendo inalteradas la respuesta elástica típica de los compuestos TPV.

Un análisis detallado de los esquemas de esfuerzo-deformación de los compuestos MV TPV confirma que su comportamiento elástico se ve afectado solo parcialmente por la cristalinidad de la fase termoplástica, dando propiedades mecánicas similares al compuesto de referencia MV IS79.

Durante el envejecimiento a 135°C, los compuestos MV TPV demostraron su resistencia hasta 504h con TS y EB retenidos > 70%. Después del envejecimiento durante 504h a 150°C, el MV TP79 C conservó el 80% de su TS y el 70% de su EB, llegando casi a igualar el MV IS79.

Por último, se midieron las propiedades eléctricas en seco y en húmedo de todos los compuestos a 500V y 50Hz. El Tanδ en seco aumenta con la temperatura hasta un límite superior de aproximadamente $5x10^{-3}$ a 90°C para el MV TP79 A, que se puede todavía comparar con el Tanδ del MV IS79 a la misma temperatura, $3,5x10^{-3}$.

Asimismo, la εr varía en un campo muy estrecho (de entre 2,8 y 2,4) a 25°C y hasta 90°C en todos los compuestos. Las mediciones de la resistividad de volumen confirman excelentes propiedades de aislamiento a 25°C (10^{15} Ω-cm) que bajan ligeramente a 90°C (10^{13} Ω-cm). Se probaron las propiedades eléctricas en húmedo sumergiendo las muestras en agua a 90ºC durante 28 días. El Tanδ en húmedo aumenta hasta un máximo de $3,5x10^{-2}$ para el MV TP79 B. Los MV TP79 A y C mostraron una resistencia mejor al agua de $2,2x10^{-2}$ y $1,3x10^{-2}$ respectivamente, con éste último que reveló prestaciones próximas a las del MV IS79 después de 28 días en agua a 90°C. La misma tendencia se registró en el caso de la ε_r, que aumenta lentamente después de la inmersión de las muestras en agua. Sin embargo, las fluctuaciones son virtualmente irrelevantes, de entre 2,53 y 2,66 y considerando el error asociado a la medición.

En conclusión, se ha presentado un estudio completo sobre los compuestos TPV como materiales aislantes para aplicaciones de media tensión. El enfoque paso a paso ha mostrado cómo se pueden mejorar progresivamente las propiedades de los compuestos y obtener un material completamente termoplástico sin plomo, el MV TP79 C, con prestaciones mecánicas, reológicas y eléctricas comparables a las del estándar del mercado sin plomo MV IS79.

De acuerdo con la norma CEI 20-86, el MV TP79 C tiene la potencialidad para ser implementado como aislamiento de MT con clasificación para una temperatura de funcionamiento continua de 105°C y cortocircuito de emergencia de 250°C.

Siguiendo adelante con la estrategia, Mixer SpA espera desarrollar compuestos MV TPV con resistencia más alta y mejores propiedades eléctricas a alta temperatura y en agua en un futuro próximo. ■

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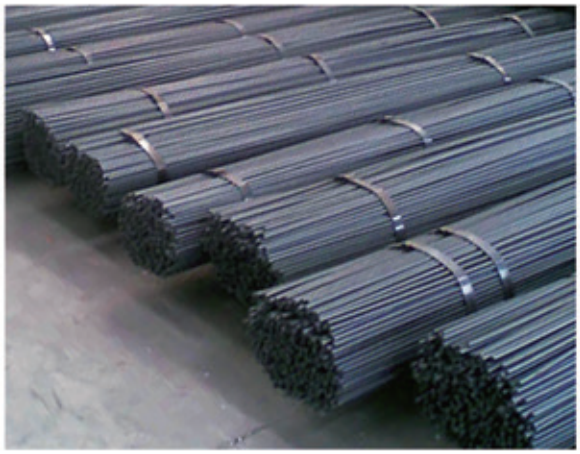

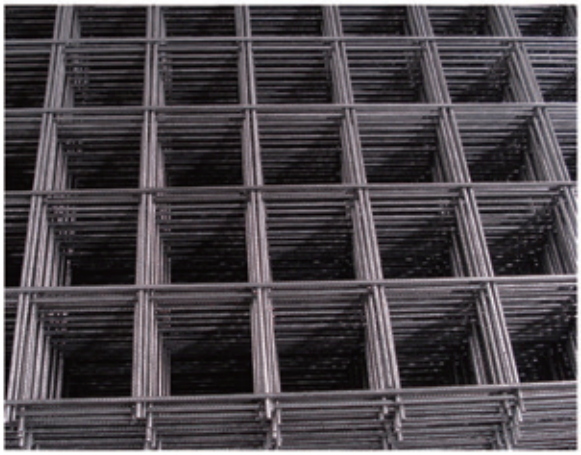

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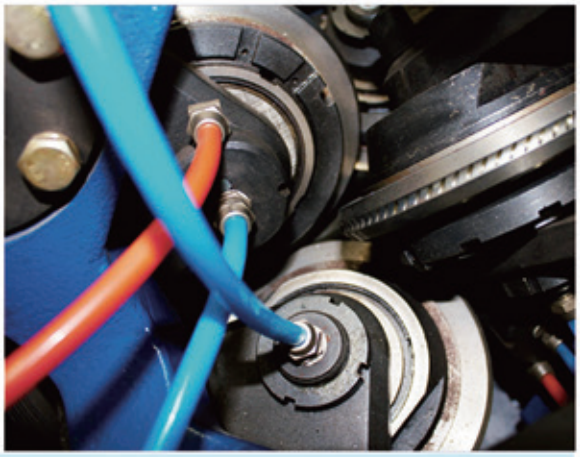

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