Sustainable Growth

Polyurethane (PU)

The central issue in all polyurethane applications is the conversion from the past linear economy into a circular economy, and the use of sustainable raw materials in manufacturing. To do so, manufacturers are taking measures such as using bio-based raw materials, chemical recycling, and CO_2 as a synthesis component. Digitalization, electromobility, autonomous driving and the construction industry are also driving PU development.

Insulation boards and metal composite elements are the primary applications for PU in the construction industry. Since buildings are responsible for 40% of global energy consumption, more efficient materials in this area can generate big savings, such as through improved insulations © Covestro

In 2019, global demand for polyurethane (PU) saw a significant boost above the long-term average growth of approx. 5% per year. This resulted in record sales of approx. 22 million t. Growth was particularly strong in China, although sales also increased greatly in other Asian-Pacific countries and in the EMEA region (Europe, Middle East, Africa). Growth in North and Latin America, in contrast, cooled notably. The very large growth in sales year over year in Asian-Pacific countries has resulted in the APAC region (Asia Pacific) being responsible for over half of global PU consumption for the first time in 2019, with around 11 million t. The EMEA region followed in second place with around 30%, and North and Latin America with almost 20%.

One reason for the positive development in the global PU market was that weaker vehicle sales impacted PU less than other plastics. The PU market encompasses the total quantities of all isocyanates and polyols used in PU production. The drawback to this positive growth was that the pricing erosion which began in 2018 continued in 2019, and was worsened this year once again due to the coronavirus crisis. This is currently having a major impact on margins for PU raw materials providers. The Covid-19 pandemic caused PU demand to drop during the first few months of 2020, first in China, then in Europe and then in the USA. However, economic activity began increasing in China in May, once again increasing demand on local PU raw material providers. We expect this recovery to begin in Europe and the USA as well on a time lag. Hopes are primarily based on the construction industry: »

Fig. 1. With the opening of the new MDI plant, the Brunsbüttel is one of Europe's three largest production sites worldwide for this PU preliminary product © Covestro

for instance, PU thermal insulation applications could help moderate the significant drop in demand within the automotive and furnishings industries. In the medium term, Covestro AG, Leverkusen, Germany, expects to see robust growth in the global PU market of around 4% per year.

Capacities for the two PU preliminary products diphenylmethane diisocyanate (MDI) and toluene diisocyanate (TDI) will be expanded worldwide. In early 2020, for instance, Covestro doubled its MDI capacity in Brunsbüttel, Germany, to 400,000 t/a (**Fig. 1**). The company's planned expansion in MDI production for 2023 in Taragona, Spain, by 50,000 t/a to 220,000 t/a, is also going to plan. Covestro did delay the construction of a new world-scale MDI system in the Texas city of Baytown with a capacity of 500,000 t/a, but does plan to continue expanding MDI capacities in the USA. BASF SE, Ludwigshafen, Germany, has commenced the second phase of its gradual expansion of MDI production from 300,000 t/a to 600,000 t/a as planned in Geismar, LA/USA. In contrast, Wanhua, Yantai, China has withdrawn a planned investment in an MDI system with 400,000 t annual capacity in Convent in the US state of Louisiana, indicating a sharp increase in costs as the reason for the withdrawal. In China, however, Wanhua continues to pursue ambitious expansion plans. For example, it intends to expand MDI capacities in Yantai and Ningbo by a total of 800,000 t/a. Furthermore, Wanhua took over a project planned in Fuzhou for a new MDI system with 400,000 t/a capacity as part of a joint venture founded in March 2020 with local partner Fujian Petrochemical, Quanzhou. The cooperation also includes the takeover of a TDI system, including planned capacity expansion from 100,000 to 250,000 t/a from Fujian Southeast Electrochemical in Fuzhou. This acquisition could be the start of a consolidation among TDI providers in China.

Fig. 2. Mattresses create a large amount of soft foam waste at the end of their service life. Because of this, many PU manufacturers are working for options for chemically recycling mattresses so they can be used again to manufacture PU © Covestro

Digital Business Models

Digitalization is advancing rapidly in the manufacturing and processing of PU raw materials and systems, in customer communication, as well as in sales. Covestro is cooperating with universities and other companies, for instance, on these developments. Recently, the company launched a conference for data science in the chemistry sector called "Chemalytix" alongside Bayer AG, Leverkusen, and Evonik AG, Essen, Germany. The participants discussed issues at the conference like how digitalization can be utilized across the entire chemical supply chain to improve research, production and customer contact and create more sustainable products.

Covestro is also already using integrated data management to make its processes, for instance for manufacturing soft foam raw materials, more efficient and to increase system utilization through mobile maintenance. The company recently set up a digital recipe finder for visco-elastic PU foams, which manufacturers can use to calculate suitable raw materia formulations for their planned physical foam properties. The tool can also be used to determine foam properties for specified recipes. The tool helps save time, materials and costs in development.

Digital business models are also becoming more and more important. Now, Covestro customers can do business around the clock and with just a few clicks via the Covestro Direct Store on a new web platform (covestro.asellion.com). The sales channel runs on the "Asellion" platform, which is also designed for additional web shops. In addition, Covestro is now marketing PU raw materials and systems for foams through its own web shops on other B2B sales platforms from third-party providers – such as "1688.com" from Alibaba.

Chemical Recycling Projects

The Circular Economy is developing into a guiding principle for industry worldwide. Manufacturers of PU products and raw materials have developed technologies and processes to use the material in a more environmentally-friendly way. Covestro, for instance, is working intensively to use more sustainable raw materials

Fig. 3. Covestro has developed a material and production solution for efficiently producing wind energy rotor blades alongside industrial partners. This allows for longer, lighter weight rotor blades. They are already being produced commercially in China © Covestro

such as recycled products, waste, biomass and CO_2, to focus on long-lasting, recyclable products, and above all to use chemical recycling processes that allow for the reuse of plastics, particularly from post-consumer waste (PCR).

One example of the latter is the Europe-wide project PUReSmart, which involves nine companies and academic institutions. The goal of the project is to turn PU soft foam waste materials which accumulate in large quantities, for instance, in the form of mattresses (**Fig. 2**) and padding into high-quality raw materials through a chemical process, in order to then be used again in PU systems. In addition to spectroscopy-based technologies used to efficiently sort different types of PU foam, the industry is developing new monomers for PU systems that enter into thermally reversible chemical bonds, and therefore can be recycled through a purely thermal process, similar to thermoplastics (CAPU, Covalent Adaptable Polyurethanes). In addition, the participants are working on chemolysis processes that can be used for mass-balanced recovery of pure PU raw materials from foams. One of Covestro's tasks in the project is to develop an efficient industrial process for this chemical recycling.

Using CO_2 as Raw Material

Other manufacturers are likewise working intensively on chemolysis of soft foam. For example, during June of this year Dow, Midland, USA, invested in a production system for this purpose as part of the "Renuva Mattress Recycling Program."

CO_2 is a good example of an alternative, more sustainable raw material that reduces dependency on fossil resources as part of the circular economy. Alongside the RWTH Aachen, Germany, Covestro has developed a technology that uses the normally inert gas to create plastics (see ***Kunststoffe*** 1/20, p. 68 – 71). Covestro is already producing the polyol cardyon polytex on an industrial scale at its plant in Dormagen, Germany. It contains up to 20% chemically bonded CO_2, and is already used in the commercial manufacturing of soft foams for mattresses, as well as in other applications. Covestro and the RWTH Aachen's CO_2 technology recently landed them a spot as one of the three finalists for the major German Future Prize for 2019.

Using PU as a lamination matrix for rotor blades on wind energy systems has been the subject of intensive development work for many years. Interest in this application was sparked primarily by the trend towards longer, lighter, and more powerful rotor blades and the attempt to make wind energy even more competitive through lower manufacturing costs for wind power systems. Currently, commercialization of PU for rotor blades is advancing particularly rapidly in China (**Fig. 3**). A PU resin system is used for this purpose, for instance, based on the isocyanate components Baydur 78BD085 and Desmodur 44CP20 from Coves- »

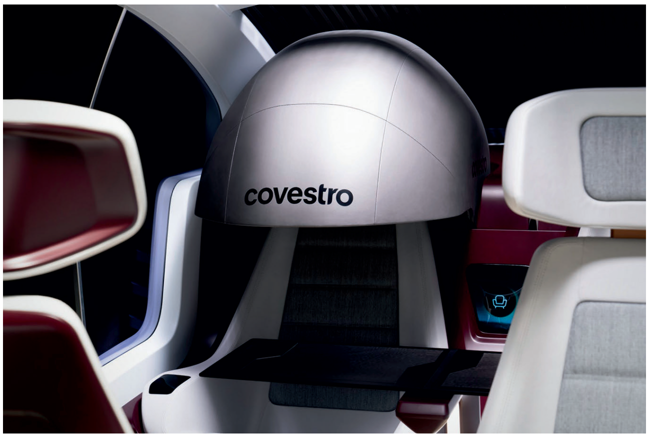

Fig. 4. The Baynat PU system from Covestro provides effective sound insulation in the PrivacyDome, an extendable dome. Noise production plays a vital role for electrical and autonomous driving vehicles © Covestro

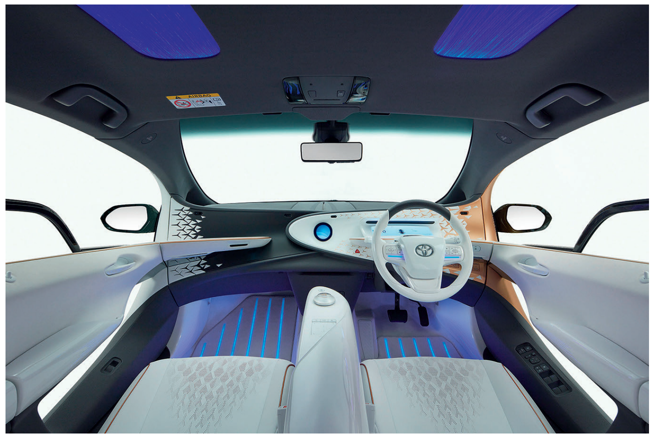

Fig. 5. A PU from Covestro reinforced with Kenaf fibers was used in the door panel of the "LQ" concept vehicle. As such, it is 30 % lighter than the previous models © Toyota

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Database and Sources

All market information is based on Covestro's surveys and estimates, as well as additional information on investments and technical developments from Covestro or from press releases from the companies mentioned.

tro, which have certifications including a DNV-GL certification (Det Norske Veritas – Germanischer Lloyd). This industrial standard for the safety, reliability and performance capability of wind energy systems is a key global criterion for using such resins in rotor blades.

Exchange of Epoxy Resin for PU in Wind Energy Systems

PU resins are processed in vacuum infusion processes, and significantly reduce infusion due to their low initial viscosity in comparison to commonly used epoxy resins. In addition, PU resins pre-cure and harden more quickly, both of which result in more efficient production. Covestro and Windnovation, Berlin, Germany, evaluated the advantages PU has for rotor blade properties in a study of rotor blade design SR552–2. Even a simple 1:1 exchange of epoxy resin for PU resin results in a slight weight savings, paired with lower deflection in the rotor blade and higher stability, as well as a lower likelihood of interfiber failure (IFF). If the rotor blade is furthermore structurally improved using the mechanical advantages of PU, then the weight saving is 5 %. This results in lower fatigue loads, meaning not only the rotor blade but also other system components such as the hub can be designed to be more lightweight, and the rotor blade length can be increased.

The development of PU systems for automobiles is part of the trends towards electromobility, autonomous driving and sustainable materials. The interior of the vehicle of the future will turn into a mobile living and working space where passengers will not be disrupted by noise from the road, wind or the vehicle's gears. In the future, sound insulation will become more and more important, for instance in the front wall, trunk, and doors. Semi-firm PU foams with optimized acoustic insulation properties offer a weight-optimized solution.

Almost all PU providers have these materials in their product range (**Fig 4**). They offer self-supporting PU foams, for instance, which can have shapes precisely adapted to complex installation sites. They are free from phenols, produce low emissions and low odors, and can be processed economically with short cycle times. They fulfill fire test UL94 from the US testing institute Underwriters Laboratories, Northbrook, IL, USA, with the best classification of V-0. In addition, they serve as not only acoustic, but also thermal insulation.

Autonomous vehicles will also place increased demands on vehicle interior surfaces. Classic PU applications like headliners, door panels and cockpit areas like the dashboard and center console will be directly impacted. PU manufacturers are working in collaboration with OEMs and suppliers to create solutions that allow the seamless integration of displays, switches and ambient lights into headliners and door panels, while fulfilling high demands for comfort and design in combination with a high degree of functional integration. At the same time, the surfaces must have very good haptics when touched or pressed, which is achieved, for instance, with PU sprayed skin to cover foam.

Better sustainability can be achieved in automotive construction with partially bio-based PU materials. Using these materials conserves resources. One major challenge is that the properties of these materials must be at least comparable to those of conventional materials, if not better. In addition, it must be economical to integrate them into existing processes. Almost all major PU providers now have relevant PU systems in their product range. Often, some of the polyol components are bio-based. Companies offer highly elastic and semi-firm foams, for instance, for sound insulation applications like carpet inlays, wheelhouse and center tunnel coverings, semi-flexible foams for head rests, arm rest and center consoles, as well as semi-firm filler foams for soft touch dashboard and door panels. The use of partially bio-based reinforcing fibers has become an established option in automotive construction. For example, a PU foam composite based on Covestro's Baypreg-F-NF technology is used in the door panel on the "LQ" electric concept vehicle from Toyota Motor, Toyota, Japan, which is reinforced using fibers from the Hibiscus plant Kenaf (**Fig. 5**). The composite material was developed in collaboration with automotive component manufacturer Toyota Boshoku Corporation, which has extensive expertise in using Kenaf fibers. The component is around 30 % lighter than if it were manufactured from commonly used materials.

The two primary segments of the PU construction sector are the applications of insulation boards and metal composite elements (**Title figure**). Thanks to its very good thermal insulation properties, PU rigid foam has become an established material in the construction industry. In addition to easy handling and good mechanical properties, the energy efficiency that can be achieved using such foams is one reason demand for PU is growing in the construction sector. Because of this, Covestro expects to see above average market growth of 4 to 5 %.

The new approach from the EU Commission for a sustainable economy within the European Union – called the "Green Deal" has the goal of ensuring that no net greenhouse gas emissions are emitted starting in the year 2050. The EU wants to become climate neutral by 2050. The construction industry has a key role to play, because 40 % of global energy consumption and a third of greenhouse gas emissions are caused by buildings.

The second largest segment using PU rigid foams is thermal insulation for cooling equipment such as refrigerators and refrigerated counters. Development work is concentrated on improving equipment production efficiency, increasing the insulation properties of foams as wall thicknesses decrease, and making the PU raw materials and reaction systems used as well as equipment manufacturing more sustainable and energy efficient. Better productivity, for instance, is facilitated by Covestro's fast-demold system. It can be used to demold cooling devices up to 20 % faster with normal wall thicknesses.

Demolding Cooling Devices up to 20 % Faster

In addition to ongoing challenges to make insulation systems for thermal and cold insulation even more efficient and long-lasting, the current focus is on the circular economy, sustainability, and end-of-life solutions. This is why many manufacturers are working intensively on how to recycle their own products or use recyclable materials. One example of this is the ChemCycling project from BASF. The goal of the project is to use plastic waste such as packaging or refrigerator rigid foam, as well as waste generated from insulation boards to create pyrolysis oils. These are then used to recover raw materials from them such as ethylene and propylene in steam crackers. Other companies are investing in manufacturing polyester polyols from polyethylene terephthalate waste (PET) for the PU insulation industry, such as Soprema GmbH, Mannheim, Germany, with its product Sopraloop. However, they are also taking up the use of partially bio-based raw materials – Covestro developed a process for manufacturing bio-aniline alongside partners, for instance – or returning industrial waste gases into the material cycle. One example of the latter is the European Carbon4PUR project. CO_2 and carbon monoxide (CO), created as waste in steel production, are to be converted into polyols for rigid foams and other applications. All of these projects have the goal of developing energy-efficient technologies with a good CO_2-footprint. ■

Service

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