Polyvinyl Chloride (PVC)

Growth with Improved, Environmentally Friendly Solutions for a Large Number of Applications

The biggest market segments for PVC are still pipes and (window) profiles. The material is opening up new applications with printable and decorative films, e.g. for payment systems and in the furniture industry. An important specialty segment is paste PVC, e.g. for artificial leather, wallpapers and flooring. Substitution of short-chain phthalate plasticizers is continuing apace.

Worldwide PVC demand in 2013 was 38.5 million t (source: IHS) and was therefore 3% above the previous year. Since 2010, it has increased by 3.4% per year on average. PVC demand is thus continuing its growth following the crash due to the crisis in 2008/09. Growth of this order (3.5 to 4% p.a.) is still expected.

World demand for PVC is primarily determined by construction activities. Globally, the most important applications for PVC continue to be pipes and fittings (43%), profiles and tubes (18%), rigid film and sheet (17%) and cables (8%) (Fig. 1). Paste PVC has a share of 6%.

Global plastics production for PVC grew to about 61 million t in 2013 (source: Tecnon). Of this, China accounts for a half (Table 1). The enormous capacity growth since 2010 of about 13 million t, too, can be almost entirely attributed to China. The transformation of net importers into net exporters has been predicted for some years, however it has still not taken place.

Figure 2 shows the production capacities of the world’s biggest PVC manufacturers. There have been considerable changes due to mergers and acquisitions in recent years (see below).

Since construction activity in Europe is still historically very low and lagging behind the global average, growth is primarily driven by countries and regions such as North America, India, Asia and Turkey. However, the BRIC states (Brazil, Russia, India, China, South Africa) – the growth engine of the recent past – have weakened somewhat in an international comparison.

The capacity utilization of PVC manufacturers in the European Economic Area (EEA) is almost unchanged compared to 2012, at about 81%. The overcapacities here are over 1 million t of PVC. Since the demand in the EEA in 2013 has declined by 9% compared to 2010, exports have accordingly increased. With over 1.2 million t of exports from the EEA, 2013 set a new record. This corresponds to 22% of total production. Imports, on the other hand, have for years been at a relatively low level of between 3 and 4% of demand in the EEA (2013: 4%).

In 2013, the market for S-PVC (suspension PVC) fell by about 1% compared to 2012 in the EEA and was still not able to recover properly following the fiscal and economic crisis. Demand in 2013 was 4.3 million t, 0.4 million t lower than in 2010 and still 0.2 million t below the value during the worst crisis in 2009. How-
ever, since mid-2013, a slight upward trend has been registered month on month. The area of rigid profiles remains the biggest market segment at 1.3 million t. Now, almost all important profile extruders are represented with their own production sites in the Central and Eastern Europe region. This market is also served from the parent companies in Western Europe.

The price and profitability level for S-PVC is still unsatisfactory. Since the beginning of the financial and economic crisis, the price level has still been varying primarily by the order of the cost effects of the most important raw materials – principally ethylene.

PVC specialties temporarily showed a better trend. Demand for paste PVC was able to recover from the crisis very dynamically in 2010 and at the end of 2010 saw an availability bottleneck, which sustained a higher price level worldwide. This trend ebbed during 2011. The market for paste PVC has stagnated since 2011.

The consolidation of the PVC producers in the EEA, with a production capacity of 7.2 million t, has clearly gained impetus. The biggest planned joint venture, namely that by Ineos AG, Rolle, Switzerland, and Solvay AG, Brussels, Belgium, under the name Inovyn, was approved by the EU commission in May 2014 – conditional on the sale of a compensation package – and would take third place in the world capacity ranking. At the beginning of August 2014, the Mexican Mexichem S.A.B. de C.V., Tlalnepantla, Mexico, announced the sale of Vestolit GmbH, Marl, Germany, – conditional on antitrust approval. At the end of July 2014, the acquisition of Vinnolit GmbH & Co. KG, Ismaning, Germany, was concluded by Westlake Chemical Corp., Houston, TX/USA. Westlake/Vinnolit is thus moving up into the top ten PVC raw materials manufacturers, just like Mexichem/Vestolit (pro forma) (Fig. 2).

Processing

About 90% of global PVC production capacity is based on the suspension process, which on an industrial scale only operates discontinuously. Vinyl chloride, water, protective colloids and organic peroxides are charged into the reactor as initiators and then polymerized under pressure with stirring. The resulting heat of polymerization is dissipated via the cooled reactor wall, cooled fittings, e.g. baffles, and reflux condensers. By varying the choice of stirring conditions and the protective colloids used (e.g. polyvinyl alcohols or cellulose ether), the particle size and porosity, crucial for additive absorption, can be selectively controlled.

Paste PVC is produced on an industrial scale by emulsion polymerization, which operates discontinuously or continuously. There are different versions of the microsuspension process (discontinuous). The targeted use of surfactants and surfactant mixtures is of central importance to the process and the end product. Besides stabilization of the aqueous polymer dispersion, special emulsifier systems can be used to modify the viscosity of the plastisol (PVC/plasticizer dispersion) and the end product properties. The variety of manufacturing and processing
methods means that PVC has a uniquely diverse range of applications.

Thermoplastic Applications

Worldwide, approx. 95% of the processed quantities of PVC are used in different thermoplastic applications. The biggest market segments are still pipes and (window) profiles. The K values 65 to 68 used for these applications are typical commodity products, and as such are largely interchangeable. Processors expect high constancy of quality, reliability of delivery and a favorable price. Here, the markets are facing high pressure on margins. Cost optimization of the formulations is in particular performed by increasing the filler content or by using recyclates. Correspondingly, coextrusion is becoming increasingly important. Besides S-PVC, acrylate copolymer is also used for window profiles (Fig. 3). In this case, additional impact modification is not necessary. Such copolymers are available in low concentration with acrylate contents of around 7%. They are processed in pure form or as blends with S-PVC. However, 50% concentrates are also commercially available, which are used as impact modifiers and allow customers wider flexibility in material selection. In technical profiles, lower K values are also used, in particular for producing thin bridges or complicated geometries. E-PVC (emulsion PVC) with K values of 70 is used in extrusion as an inexpensive and effective processing aid to improve gelling and enhance gloss.

For rigid sheet manufacture, S-PVC with K values of 57 to 60 is used. For improved melt flow behavior and increased thermof ormability, vinyl chloride – vinyl acetate copolymers are employed, chiefly for the fields of packaging and pharmaceuticals. VAc copolymers also introduce additional polarity into PVC and thereby improve the processing in many processes in which PVC is combined with other materials, such as printing, or lamination and bonding to PVC itself or other materials. Examples are the production of complex cards for (contactless) access or payment systems (Title figure), but also high-quality decorative films for furniture and profile surfaces. E-PVC also has sales markets for thermoplastic processing, particularly in film applications. In the highly specialized Luvitherm process, PVC with K values from 78 to 80 is processed into thin, tear-resistant adhesive tapes, which are still superior to the available alternatives as regards tear-off behavior, unwinding noise and printing. In many standard calendaring formulations, the low particle size of E-PVC (K value 59 to 60) is exploited to increase the bulk density and improve the flow and gelling behavior. For these aspects, the effect is the result of the fact that E-PVC particles only a few micrometers in size lodge between the 100 to 150µm large S particles, and thereby fill the free space and homogenize the energy input. This has a positive effect on the higher emulsifier content, which improves the antistatic properties of the film.

A new promising segment that has been growing in the flooring sector in recent years is luxury vinyl tiles (LVT), which are usually termed “design vinyl” in Germany. LVTs are easier to lay than conventional laminates, but feel warmer and are characterized by advantages in footstep sound insulation. There are various systems, all based on decorative films of very realistic appearance, for example embossed wood design surfaces made of PVC film. The base layer, too, is usually of PVC formulated with different hardnesses.

Thermoplastic soft PVC products are usually produced with K values between 64 and 80. The PVC particle must readily absorb the plasticizer. Rigid PVC grades of the same K value are not suitable because of the lower porosity. The higher the K value, the better are the mechanical properties such as elongation and yield properties. An important innovation driver is the need to avoid undesirable plasticizer migration. The required amount of plasticizer can be reduced by means of suitable acrylate-based graft copolymers, since the acrylates already reduce the hardness of the compound. On the other hand, the plasticizer still required is also more effectively incorporated into the copolymer matrix, so that additional migration reduction is obtained. With these graft copolymers, soft PVC products can also be manufactured entirely without monomeric plasticizers. Thanks to blends with suitable terpolymers, lower Shore hardn esses can also be achieved.

The very high K values of about 100 used for high-quality gaskets, particularly in the automotive field and for dynamic window gaskets, provide outstanding rubberlike and tactile properties, and, in contrast to the alternatives, are also employed for light colors for outdoor use. Here, too, the aforementioned graft copolymer improves the migration and recovery properties (compression set) of the end product. In a new development, the porosity of these high K values could be strongly increased, facilitating processing with new plasticizer systems.

PVC for Paste Processing

The paste process represents an important segment in the technical techniques for PVC processing. The PVC, plasticizer and other additives provide a liquid medium that can be processed by a number of techniques. For example, textiles, paper or nonwovens can be coated by means of doctor blades or immersion baths. As a result, multilayer structures, used for example in high-quality artificial leathers for automotive interiors (Fig. 4) or
resistant floor coverings, can be manufactured in a simple method. By the addition of blowing agents to the paste, many types of foam layer can be produced in a relatively easy way. They perform important functional tasks in wallpapers (design), flooring (footstep sound insulation, softness) and artificial leathers (tactile, sound insulation in automotive interiors). Rotational casting and dipping also allow complex geometries to be produced e.g., gloves, toys and massage balls.

This diversity means there are serious demands on the formulations, and therefore on the paste PVC used. That explains why there is a large bandwidth of PVC products for this application field. Along with standard grades with a balanced property profile for a wide spectrum of uses, the manufacturers’ portfolios also contain specialty products with optimized properties. The requirements for these specialized PVC products are continually developing, requiring continual innovations from PVC manufacturers. For example, there are regularly new grades with improved properties in the field of paste PVC. Efficient research and development and application technology is essential for manufacturers of paste PVC to be able to keep pace with technical requirements and developments in the market.

In the desire for cost saving and process optimization, there are requirements for low viscosity or higher filler tolerances of the PVC paste formulations. A lower viscosity also permits a generally more flexible formulation scope, or in some cases higher plant throughputs. The requirement to minimize VOC (volatile organic compounds) and emissions can also be easily met with low-viscosity PVC grades, since the need for diluents or other liquid components can be reduced. Fillers (particularly chalk) are widespread for reducing formulation costs, however they have a negative influence on the processing (higher viscosity) and the properties of the end product (mechanical properties, foam structure in the case of foams). With new developments, some of these issues can be better addressed, so that a higher filler content is possible without sacrificing important properties.
in the end product. It is also important with this new generation of foam grades to allow direct contact gelation, so that energy efficient processing is ensured. Such products will probably gain further importance in future.

There are currently changes in additives that have an effect on the requirements on the PVC. The trend towards alternative primary plasticizers (see below) leads to a changed gelling behavior, which must be offset by means of rapid gelling plasticizers or PVC grades with improved gelation. Special copolymers have a higher gelling rate and help further with these issues. These copolymers can be added as paste PVC or else in the form of extenders. Both variants are available in the market.

PVC stabilizers must also be adapted to new ecological and/or regulatory requirements. Many tried-and-tested substances can no longer be used, or only with restrictions. Higher demands are therefore now made on the initial color and thermal stability of PVC grades. Topics such as color fastness during use, light or weather exposure are increasing in importance.

However, the effects of the current REACH (registration, evaluation, authorization and restriction of chemicals) debate regarding azodicarbonamide are still unclear. This blowing agent, which is generally very important for paste processors and the plastics industry, partly determines the properties of the end product. If this blowing agent cannot be used, or only with restrictions, in future, it can be expected there will be considerable effects on foam formulations. The demands on the PVC foam grades could also change fundamentally. This development is therefore being closely watched by PVC manufacturers and processors.

**Plasticizers**

The trend, which was unbroken until the crisis of 2009, of a slow but steady increase in the proportion of hard PVC applications is not continuing at present. Due to the relative weakness of the large construction applications, the share of soft applications in Europe has since risen from almost 31 to 33%. Substitution of the plasticizer DEHP (bis(2-ethylhexyl)phthalate) by the longer-chain phthalate DINP (diisononylphthalate) and DIDP (dibutylphthalate) and alternative plasticizers is continuing. The market share of DEHP in 2012 in the EU was only 10%, while that of DINP and DIDP had further increased to 74%. Alternatives such as cyclohexane dicarboxylic acid diisononlyester (best known trade name: DINCH), terephthalates and citrates are also continuing to gain in importance and, together, hold a market share of 16%. DEHP is subject to authorization under REACH and may not be used after February 21, 2015, without special approval.

**PVC and Sustainability**

VinylPlus, the now second 10-year program of the European PVC industry for sustainable development, was successfully continued by the companies and associations of the supply chain involved (www.vinylplus.eu). The aims are to further increase the PVC recycling rate, help to avoid the buildup of persistent chemicals in the environment and further reduce emissions, ensure the use of additives according to acknowledged sustainability criteria, increase the use of renewable energies and renewable raw materials in PVC production, and advance awareness of sustainable development in the PVC supply chain. For example, in 2013, a total of 444,000 t of PVC was recycled as part of VinylPlus and the share of lead-containing stabilizers in the EU 27 was reduced by 81% from 2007 to 2013. The latter should be completely replaced in EU 28 by the end of 2015. The new VinylPlus product label as part of BES-6001 “Responsible sourcing of construction products” in cooperation with BRE Global and The Natural Step (TNS) has now been launched.

The program voluntarily promoted by EuroChlor members to convert chlorine production in the EU from the mercury to the environmentally friendly and energy-efficient membrane process has continued. Consequently, the mercury process retreated further in 2013 to its current 26%. This trend, which can also be observed globally, is receiving a further boost in the EU with the BAT conclusions published at the end of 2013: according to which, the use of mercury technology will no longer be permissible in the EU after December 2017 (Fig. 5). This means a considerable financial challenge for the remaining chlorine manufacturers and sites that have not yet completed the conversion.

**Dr. Peter Attenberger**

is head of Thermoplastics Applications Technology at Vinnolit GmbH & Co. KG, Burghausen, Germany.

**Thomas Kufner**

is head of the Business Analysis and Regional Management department at Vinnolit GmbH & Co. KG, Ismaning, Germany.

**Dr. Oliver Mieden**

is head of Environmental Affairs & Corporate Communications at Vinnolit GmbH & Co. KG, Ismaning, Germany.

**Dr. Andreas Winter**

is a technical marketing adviser for paste PVC at Vinnolit GmbH & Co. KG, Burghausen.

**Digital Version**

A PDF file of the article can be found at www.kunststoffe-international.com/919365

**German Version**

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