Polyamide 6 and 66 (PA6 and PA66)

Demand for Polyamides is Determined by Asia and the Automotive Industry

With the growth of the major consumer markets, polyamide production is also growing. PA6 and PA66 predominate; the share of PA specialties is still small, despite relatively high growth rates. The biggest producer and consumer of PA6 was China. A key driver of polyamide growth is the global increase in automotive production. The consolidation and relocation of polyamide supply chains are progressing rapidly.

Global production of polyamide has been growing since 2013. In 2015, it was over 7 million t. As in previous years, the most important sales market in 2015 was still the manufacture of carpet and staple fibers, as well as textiles and industrial filaments (Fig. 1). About 46% of global demand was for technical compounds based on PA6 and PA66. The most important applications industries are automotive engineering, as well as the electrical and electronics sector (Fig. 2). Demand for finished products rose by 10% from 2013 to 2015 as a result of the increasing demand in the regions of Europe, North America and Asia, but chiefly, however, in China (Fig. 3). Besides fibers and compounds, films represent the third important market, though it is significantly smaller. Worldwide, consumption of PA6 and PA66 in 2015 reached a volume of 73 million t, compared to 7 million t in 2013 – corresponding to a growth of 4.7% (source: PCI Nylon, Yellowbook 2015). Supply and demand largely balanced one another (Fig. 3). PA6 and PA66 made up most of the PA market. The share held by PA specialties, such as long-chain polyamides (LCPA) and polyphthalamides (PPA) is still small, despite the continuation of relatively high growth rates. In Europe, it constitutes less than 5% of the market.

The current global market situation varies considerably for PA6 and PA66. The biggest share of PA6 in 2015 went to the production of fibers (58%), whereas most of the PA66 produced went into compounding (60%). The biggest producer (2.0 million t) and consumer (2.3 million t) of PA6 in 2015 was China. Growth here arose principally through the manufacture of PA fibers for textiles, and was 7.2% in the period from 2013 to 2015. The consumption of PA6 compounds increased, growing in all regions, principally through the positive expansion of the automotive industry. Compounds make up about a third of the overall global consumption of PA6. In the case of PA66, about 2.3 million t was produced and sold in 2015; about 1.5 million t of this was for compounds. The biggest producer and consumer of PA66 was North America, closely followed by Asia and Europe.

Market Consolidation

The consolidation and relocation of polyamide supply chains is progressing and will probably continue. Overcapacities of caprolactam, the precursor of PA6, are being reduced outside China, since local capacities, principally for the fiber market, but also for compounding, had been built up in China.

Large raw materials manufacturers, such as DSM, Heerlen, Netherlands, and Honeywell, Morris Plains, NJ/USA, have already divested parts of the supply chain, or are planning to do so.
early 2015, DSM transferred its caprolactam business into a joint venture with CVC Capital Partners, with the name ChemicalInvest. DSM has secured the global supply of its Engineering Plastics division through long-term delivery contracts with ChemicalInvest. Moreover, DSM entered a strategic partnership with Ascend Performance Materials, Houston, TX/USA, in the field of PA66. Ascend supplies DSM with PA66 base polymer, while DSM now also sells its partner’s PA66 compounds. Honeywell has announced that it will spin off its PA6 activities in a stand-alone company called Advansix. The merger of the US giant DuPont, Wilmington, DE/USA, and Dow Chemical, Midland, USA, to form DowDuPont, announced for the second half of 2016, and the splitting into three individual businesses, plastics, specialty chemicals and agrochemicals, intended for 2018, will also have an influence on the polyamide market.

** Capacities on Demand **

Besides new monomer and polymer capacities in the growth regions, the PA manufacturers are continuing to invest in the construction and expansion of plants for tailored compounds in order to participate in the growing market for compounds.

New PA6 polymerization plants have recently been commissioned in Shanghai, China, by BASF, Ludwigshafen, Germany, ...
in Antwerp, Netherlands, by Lanxess, Cologne, Germany, in Augusta, GA/USA, by DSM, in Tarnow, Poland, by Grupa Azoty, Tarnow, and in Chesterfield, VA/USA, by Honeywell. The start up of the new PA66 plant in Shanghai by Invista, Wichita, USA, is planned for this year, after the new plant for HMD had already been successfully commissioned.

In Asia’s growth markets – principally China – new compounding plants are being set up by the European raw materials manufacturers. South Korea, too, has developed into an investment focus. In 2015, BASF commissioned the expansion of its biggest production plant for polyamide and PBT compounds at its Pudong, China, site and has thereby increased the initial capacity from 45 kt to 100 kt. In Korea, the chemical group expanded its compounding capacity for polyamides and PBT by 36 kt in 2016. At the Jiaxing site in the Eastern Chinese province of Zhejiang, Domon Chemicals, Leuna, Germany, built a new 10 kt-capacity plant for PA6 compounds in 2013. This year, the Radici Group, Bergamo, Italy, brought the second expansion on stream, and can now produce 20 kt/a of compounded polyamides at its Suzhou site.

Additional capacities are being created in Brazil and in the traditional markets of North America and in Europe. For example, the Radici Group has strengthened its PA activities in Mexico by acquiring Resinas, a Mexican compounder. The plant there has a production capacity of 8 kt/a. Mexico’s attractiveness, with its proximity to the USA, is also reflected in the commitment of other manufacturers, such as Toray, Tokyo, Japan, which have also brought production plants on stream (10 kt), or are planning to do so. Last year, Lanxess increased the capacity for production of PA and PBT by 20 kt at its Porto Feliz, Brazil, plant. Since 2015, the new plant has mainly met demand for products for automotive construction in Latin America. In 2016, Lanxess opened the second production line for high-performance compounds based on PA and PBT at its plant in Gastonia, USA. The compounding capacity there has thereby doubled to 40 kt. In the USA,besides other European manufacturers, such as Domon Chemicals (takeover of Technical Polymers), the big US producers Ascend and Invista expanded by developing their plants at the sites of Pensacola, by 30 kt, and Chattanooga, by 22 kt respectively; the same applies to Asahi Kasei of Japan, which opened a second compounding operation in Athens, AL/USA.

Investment continues to be made at the German sites. To meet increasing demand, mainly from the automotive industry, DuPont boosted production of its PA66 and PA6 grades by 20% at the Hamm-Uentrop plant in Germany in summer 2016. In Schwarzheide, Germany, BASF increased compounding capacity for PA and PBT by 70 kt this year. Operations are planned to start in 2017. The Chinese compounder Kingfa, Guangzhou, China, intends to build its first production site in Europe at Wiesbaden, Germany. The new plant, where Kingfa is investing EUR 10 million, is to come on stream in 2016. Because of the manufacturer’s broad portfolio, however, the machines will not only be available for the manufacture of PA compounds.

**The Car as a Growth Driver**

The global increase in car production is crucial to the growth of polyamide. The share of the PA market was 38% in 2014 in Europe (Fig. 2). Polyamide applications range from parts for the engine compartment, via structural and decorative elements in the interior through to body parts and electronic components. Advanced, tailored compounds with improved performance can be used as replacements for metal and other materials, and thereby continually expand the potential applications. The most important growth drivers are weight saving to reduce emissions, higher continuous service temperatures close to modern supercharged IC engines, miniaturization, design and, of course, cost reduction.

Particularly in the engine compartment, polyamides have a long tradition, where, for years, they have replaced more and more parts that were hitherto made of metal. Their lower weight compared with metals, and the possibility of functional integration and greater design freedom make this material an attractive, economic alternative. In the automotive industry, the megatrend of downsizing is continuing. Engines with a smaller cylinder capacity and ever more effective turbocharging allow charge air temperatures to be increased to 210°C constant load or 290°C peak temperature and charge-air pressures to over 3 bar. All the major polyamide manufacturers have responded to this trend. In recent years, they have developed heat-resistant and oil-resistant PA compounds, which can be found today in a wide variety of car models. For example Ultramid Endure, a glass...
fiber-reinforced PA66 from BASF has very good heat aging resistance. The material resists continuous thermal loads of up to 220 °C and peak loads up to 240 °C. The good processability permits parts under the hood, which are exposed to very hot air, to be made of plastic at reasonable system costs, and thereby to save weight (Fig. 4).

Lightweight construction, structural design and functional integration with polyamides continue to be in vogue in the chassis and in the interior. Glass-fiber, and increasingly carbon-fiber, based compounds specially tailored to the application are now available to the automotive industry. A vivid example of the viability of this concept is the grille opening reinforcement for the 2016 Ford Mustang Shelby GT350 developed by Magna International. It is injection molded from Ultramid A3WC4, a PA66 reinforced with 20% carbon fibers. The use of the compound reduces the weight of the original plastic-metal hybrid part by a further 25% (Title figure).

The world’s first plastic transmission crossbeam in the rear axle subframe has been developed for the Mercedes-Benz S-Class by ContiTech Vibration Control and BASF from Ultramid A3WG10 CR, a specialty polyamide from BASF which is particularly highly reinforced and optimized to withstand high mechanical loads. Compared to the previous beam made from die-cast aluminum, this highly durable component offers a weight saving of 25%. A comparable reduction in weight allows the material to be used in a top mount. By combining with the microcellular polyurethane elastomer Cellasto, an advanced NVH solution (NVH: noise, vibration, harshness) was created. BASF developed the top mount for serial production using the Ultrasim simulation tool and received the Automotive Innovations Award 2016 for the most innovative supplier in the “chassis, body and exterior” category.

Despite vigorous development activities by the OEMs, suppliers and raw materials manufacturers such as Lanxess (Tepex) and BASF (Ultracom), parts based on endless fiber-reinforced composites are slow in becoming established. One of the few serial applications in the automotive industry is the rear bumper beam of Honda’s new “Clarity Fuel Cell” car. It is made of Tepex, a fiber-reinforced composite, and PA6.
It becomes even more challenging when not only mechanical properties, but the surface quality and design also play an important role in the material selection. BASF was able to realize the complex and slimline design for the backrest of the driver and front passenger seat in the BMW i3 electric car by using the UV-resistant Ultramid B3ZG8 UV. It precisely reproduces the grain, has good scratch resistance and does not need to be painted.

The piano black decorative elements for the car interior no longer need to be expensive painted if they are manufactured from the newly developed unreinforced Ultramid A3L BK779 from BASF. The material is used for the door switch bezel of the Ford Fusion (Fig. 5).

**Strong in Electrical Systems and Electronics**

The second most important market for polyamides is the electrical and electronics industry. The market share in Europe was about 21% in 2014 (Fig. 2). As halogen-free, flame-retardant products, polyamides are used in almost all areas of switchgear and connection technology, electronics and household appliances. The flame retardant polyamide Ultramid A3U42G6, reinforced with 30% glass fibers, from BASF is used in plugs and applications subject to high temperatures in industrial automation, for example in switchgear and contactors. The material meets flammability class V-0 as per UL94 from a wall thickness of 0.4 mm and, because of its RTI value of 150 °C, is especially suitable for use at high temperatures. The halogen-free flame-retardant system does not show any migration effects, even in critical climatic change tests, and allows high-quality part surfaces to be manufactured.

Because of their high mechanical strength and toughness, proven media resistance and good insulation properties, as well as excellent processing properties, polyamides are used in almost all areas of automotive electrical systems and electronics. For reliable microelectronics in sensitive car applications, such as control units and sensors, BASF has developed a portfolio of different polyamide 6 and 66 grades, which help to prevent damage to the circuits due to electrical corrosion. Ultramid EQ grades (EQ = electronic quality) have glass fiber contents of 30 and 35%, and show high purity and low-ion formulation (specified residual halogen content in the range of trace amounts).

Heat-conducting polyamides are increasingly in demand in LED technology. For example, Lanxess recently presented a PA6 compound newly developed for this purpose. The highly mineral-filled Durethan TP 723-620 has good thermal conductivity together with high light reflection and extensive flame resistance. Potential applications include LED heat sinks and carriers, as well as electronic devices that need heat-conducting housings and covers because of their high power consumption. BASF has expanded its Ultrasim integrative simulation tool, and now offers users the opportunity to design and optimize heat conducting parts made from the new Ultramid B3EGM65 HM, which was developed at the Innovation Campus in Shanghai (Fig. 6).

**Ecology and Sustainability**

Although there is interest in bio-based PA6 and PA66 in many important customer industries for improving the sustainability of polyamide fibers and parts, the development of the required monomers is still in its infancy. Such processes are being developed by companies such as Genomatica, San Diego, CA/USA, and Rennova, Santa Clara, CA/USA. However, no commercially viable alternatives to the traditional manufacturing processes can be expected in the short term. Polyamide manufacturers and processors are therefore looking for alternatives such as recyclates, in some cases already commercially available bio-based polyamides (e.g. PA610, PA410 or PA4T copolymers) or new base polymers (e.g. PAS10).

Often, these approaches are pursued not only to improve the sustainability of a product. The bio-based material is rather chosen because of its better properties for a particular use, which may also justify a higher price. It should also be noted that just the conversion to a renewable raw material does not necessarily lead to a better environmental footprint. Rather, the entire lifecycle of an application (cradle to grave approach) must be taken into account, and thereby also, e.g., the growing conditions (generation of monocultures, competition with food production or over-fertilization of the soil) and disposal.

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