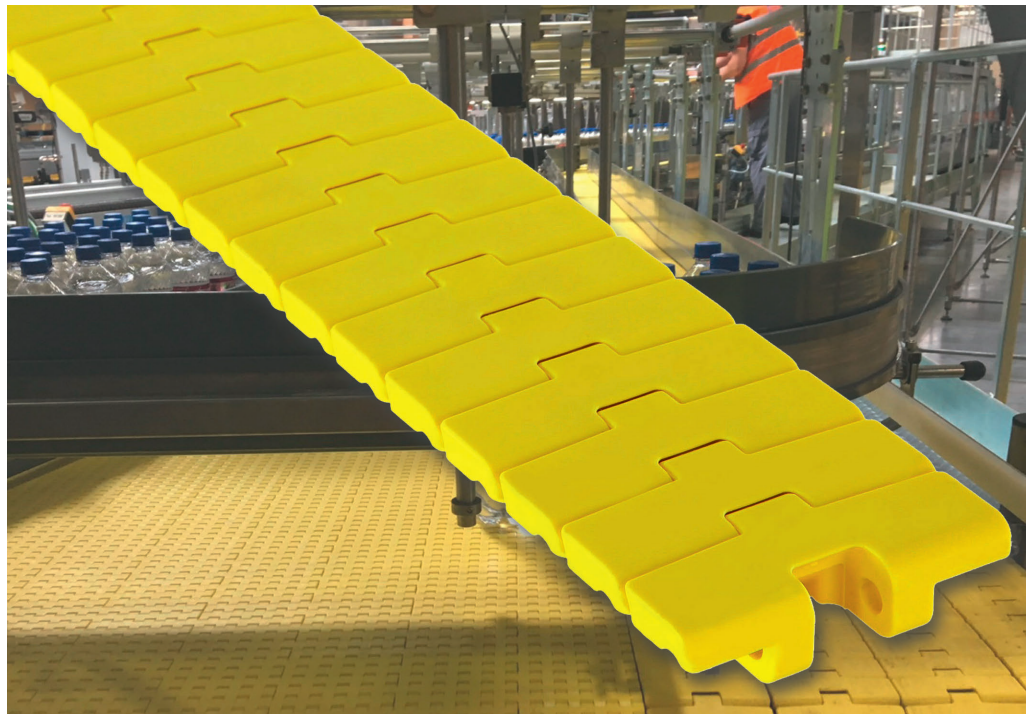


Polyoxymethylene (POM)

Moderate Growth in Traditional Applications and Ongoing Attractive Growth in Demand in Asia

Today, over 70 % of global POM production capacity is located in Asia. The market is growing strongly at around 4.5 % annually, totaling around 1350 kt in 2018. Main buyers are the automotive and the electrical/electronics industries. Development is focused on low emission, reduced friction or high impact grades or grades which are detectable with metal detectors or have been subjected to special quality control.

Conveyor chains and belts made from a custom developed POM homopolymer with reduced friction and wear from DuPont enable very high levels of productivity while simultaneously conserving resources thanks to water and energy savings (© DuPont)



Polyoxymethylene (POM) is a partially crystalline, injection moldable or extrudable thermoplastic which is available as a homo- or copolymer. The first POM homopolymers were invented by DuPont in 1956 and first commercially distributed 60 years ago under the trade name Delrin which is still in use today. Obtained by direct polymerization of formaldehyde, they typically reach relatively high degrees of crystallinity of 55 to 60%. POM copolymers (e.g. Hostaform from Celanese, Duracon from Polyplastics, Kepital from Korea Engineering Plastics JV, Koce-tal from Kolon Plastics and Ultraform from BASF) are synthesized by copolymerizing

trioxane with dioxolane and have lower degrees of crystallinity and lower melting points, depending on comonomer content and molecular weight.

Properties Bridge the Gap to Metals

POM's particular mechanical, chemical and tribological properties mean that it bridges the gap between plastics and metals. All grades have high hardness and good mechanical properties. POM offers the highest rigidity and strength of all unreinforced engineering polymers along with very good dimensional stability, a low coefficient of sliding friction and

very good wear resistance together with good dielectric properties. While copolymers additionally have high resistance to alkaline media and also to diesel fuels and exposure to hydrolysis, homopolymers are particularly distinguished by their very high rigidity, strength, creep performance and fatigue resistance and their elevated impact strength, specifically at relatively low temperatures.

Thanks to its particular combination of mechanical properties, POM is proving itself in an ever growing number of applications. Particularly in the automotive industry, where lightweight construction has already long been the spur for the re-

placement of metals, the trend towards electrification and further automation is expanding the range of applications for POM due to increased demand for small electric motors and gearwheels.

POM is only offered for sale in the form of compounds which are tailored to specific requirements. Homo- and co-polymers which are produced in particularly thoroughly monitored and documented processes are increasingly commonly used in the food and healthcare sectors.

Capacity and Consumption

Global production capacity for POM is currently slightly over 1900kt/a. China leads the world at 655kt/a, followed by South Korean manufacturing facilities at around 295 kt/a. Europe follows with a total of around 270kt/a, due to the fact that BASF ceased production in Ludwigshafen, Germany, in 2018 and Celanese slightly expanded its operations. The USA capacity is approx. 195kt/a (Fig.1).

Breaking capacity down by manufacturer reveals some distinct trends. As recently as the turn of the millennium, virtually two-thirds of global capacity was divided between the three largest manufacturers: Polyplastics, Celanese and DuPont. While these three do indeed still occupy the leading positions, their total share of global POM capacity has dropped to around 40%, although Celanese still operates the world's largest POM plant at Industriepark Höchst, Germany. These trends are explained in part by a new 60,000 t/a plant at Inner Mongolia Gulin Chemical Co. and a new 40,000t/a plant at Tangshan Zhonghao Chemical Co. Ltd., both of which went online in China in 2011. The Ibn Sina joint venture between Celanese, Sabic and Duke Energy (USA) also started up a new 50,000t/a POM production facility in Al Jubail, Saudi Arabia, in early 2018. The biggest expansion was in October 2018 in South Korea at the 50:50 joint venture between Kolon Plastics and BASF, BASF innoPOM, established in 2016, where capacity was boosted by 70,000t/a to approx. 150,000t/a. The BASF plant in Ludwigshafen, has since been shut down.

Global demand for POM has been virtually constant for years, reaching an estimated 1350kt/a in 2018 (Fig.2). This growth is, however, distributed very differently across the regions. While the growth rate is 1.5% in North and South America and 3% in EMEA, it is disproportionately high in China at over 6% and in Asia at over 7% because of the corresponding growth in electronics and automotive manufacturing there. At current levels of around 580kt/a, China is and has for years been by far the largest consumer, following by the remainder of the Asia-Pacific region and EMEA (both »

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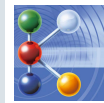
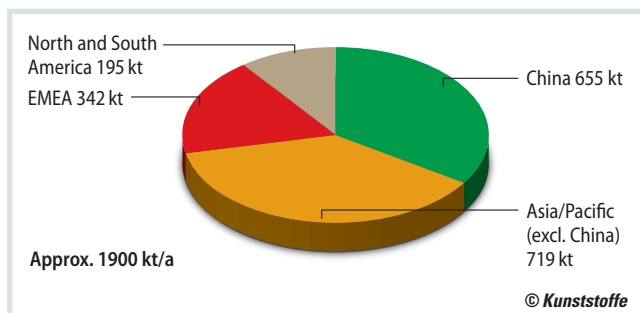


Fig. 1. Global production capacity for POM in 2018
(source: DuPont)



approx. 300t/a) and America (approx. 170kt/a). Germany is Western Europe's largest consumer, accounting for some one third of consumption (**Fig.3**).

Worldwide capacity utilization was around 75% between 2010 and 2017. It was initially higher in the first half of 2018 at around 85% in all regions due to increased demand. In the second half of the year, however, demand fell while at the same time new capacity came online, such as Kolon's facility, as a result of which utilization leveled out at just over 70%. Production capacity which will come online over the coming years means that no supply bottlenecks are anticipated in the short term. In fact, however, due to the expected further growth in demand, a balance is expected to be established from around 2023, which means that companies would already be well advised to enter into strategic alliances with suppliers to ensure security of supply.

Breaking down global demand by application reveals a three-way split between the automotive industry (approx. 36%), the electrical and electronics industry (approx. 27%) and other applications with general industry and consumer goods each consuming around 14% (**Fig.4**).

Application-Specific Material Development

Traditionally, it has been the all-purpose grades of POM, which are available in different viscosities, which have been the most widely used. They cover a broad range of processing characteristics and are thus suitable for applications from thin-wall injection molding to extrusion. DuPont Delrin POM homopolymers, for instance, range from the very high flow 900 series (MFR190/2.16 up to approx. 25g/10min), which are suitable for delicate parts, long flow paths and low wall thicknesses, to the higher viscosity 100 series (MFR190/2.16 approx. 2.5g/10min) and variants for extrusion (grade 150). Celanese, for example, also makes reference to grades for rotational molding, physical foaming or gas and water injection processes (GIT/WIT).

All manufacturers offer grades with different fillers and reinforcing materials or additives. Starting from the unreinforced grades, the offer extends via glass fiber reinforced up to impact and super impact-modified grades, variants with high thermal stability or media resistance and electrical conductivity, supple-

mented by matt, UV-stabilized, friction- and wear-optimized and low emission grades. Specific variants offer fuel resistance, detectability for metal detectors, metallic surfaces without coating or laser markability, while others offer an increased crystallization rate, dimensional stability or creep strength. The trend for special grades for medical technology applications also continues apace.

Emissions-Reduced for the Automotive Industry

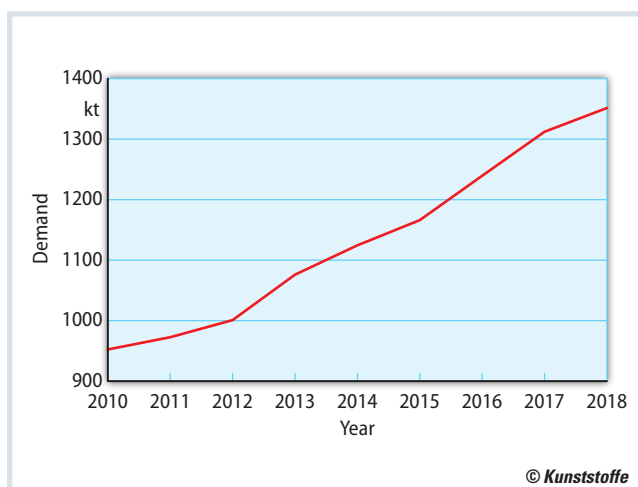
Formaldehyde emissions, with VDA275 stipulating a limit of 2 mg/kg, are a critical factor for automotive POM applications. All the leading POM manufacturers therefore include low emission grades in their range which comply with or even achieve values lower than this strict emission limit.

In connection with emission-reduced POM homopolymers, DuPont Delrin CPE grades presented at K2019 are distinguished by having additionally increased processing efficiency while maintaining the very high flexural fatigue strength and other mechanical properties of the standard grades. Above and beyond its low emission properties, the all-purpose grade 100CPE, as the successor to the Delrin 100 series which has been established for decades for gearwheels and other highly stressed applications, accordingly offers a wide processing window and reduced mold deposits (**Fig.5**) so considerably reducing maintenance costs.

Thanks to proprietary crystallization technology, the higher flow Delrin 511CPE provides short cycle times and high dimensional stability combined with high tensile strength and impact resistance. It is suitable for filling cavities with narrow cross-sections and long flow paths. This also opens up emissions-reduced thin-wall applications such as door lock housings and valves as well as processing in family and multi-cavity molds.

DuPont Delrin TE grades combine heat-stabilized, high impact-modified and low emission properties, with formaldehyde emissions of 1.0mg/kg for 300TE. Its applications for example include vehicle seating parts which have to be capable of withstanding severe impact loads. A further advantage of impact modification is increased absorption of both acoustic and mechanical vibration, which is becom-

Fig. 2. Global demand for POM, 2010 to 2018 (source: Dupont)



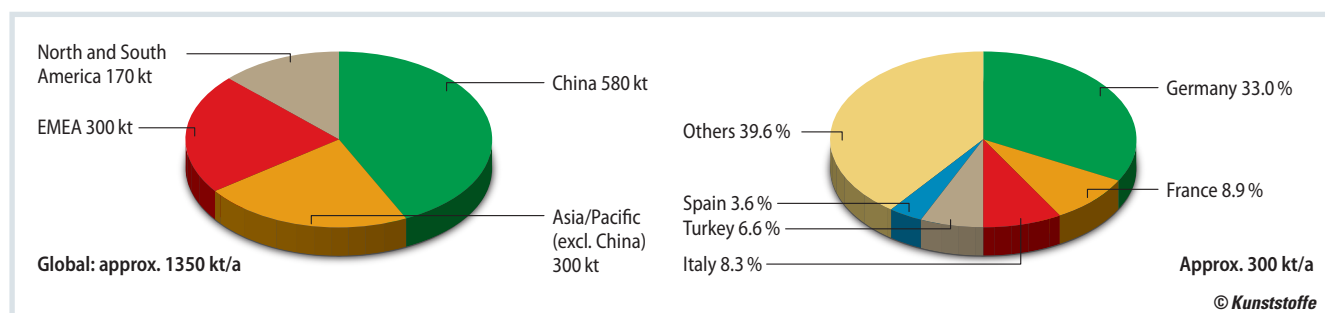


Fig. 3. Demand for POM, 2018, broken down by region (source: DuPont)

ing an increasingly significant factor in the light of ever lower levels of interior noise.

Asahi Kasei's Tenac POM homopolymers and Tenac C copolymers also include low VOC grades of which the China Automotive Technology & Research Center (Catarc) has recently certified their C Z4520 grade as an environmentally friendly green material. Other low-emission POM copolymers include Polyplastics' range of Duracon low VOC grades, which are available inter alia not only in low friction and low wear modifications but also with elevated UV resistance and low gloss. Celanese's range includes the emissions-reduced Hostaform/Celcon XAP2 product family for automotive interior parts. BASF's emissions-reduced grades are denoted by the suffix LEV. Examples from the Asian market are Kolon Plastics' Kocetal LO2 POM new generation copolymers which have very low emissions even at higher melt temperatures and for which the manufacturer also highlights their very low levels of mold deposits.

Reduced Friction and Wear for Conveyor Technology

One major potential application for POM is in conveying systems for the food or pharmaceuticals industry. Typical applications include quiet running slat and mat top chains which, thanks to their low weight, consume less drive power or permit higher conveying performance than metal designs.

In addition to the unreinforced Delrin 511P standard grade, suitable grades include the specially modified lubricant 500AL for multipurpose use and the new emissions-reduced 100ALE grade. Two grades which are proving themselves in this field are the PTFE micropowder-modified grade 500TL and the likewise new FG100TL which is adapted to food technology. Both offer a low coefficient of friction and increased wear resistance in a steel/POM or POM/POM tribological system. The high viscosity 100KM grade, which is modified with DuPont Kevlar brand fibers and is particularly abrasion-

resistant, is another member of this family of low-Wear-Low-Friction (LW-LF) grades.

If unlubricated smooth running is the aim, DuPont's low friction and low wear family of Delrin SLF (Super Low Friction) POM homopolymers introduced in 2019 offers further extended scope for improved performance. For instance, the e-fast conveyor chains and belts from Regina, Cernusco Lombardone, Italy, are made from an application-specific SLF grade for high-speed PET bottle filling (Title figure). These chains contribute to boosting productivity while simultaneously conserving resources because they reduce tensile forces in the chains reducing energy consumption, and because the operator can completely dispense with the lubrication with water, silicones or fluoropolymers which is otherwise required.

In comparison with corresponding standard grades of PBT and POM, its coefficient of friction is around 60% lower and consistently remains at this low level over extended periods of service in pro- »

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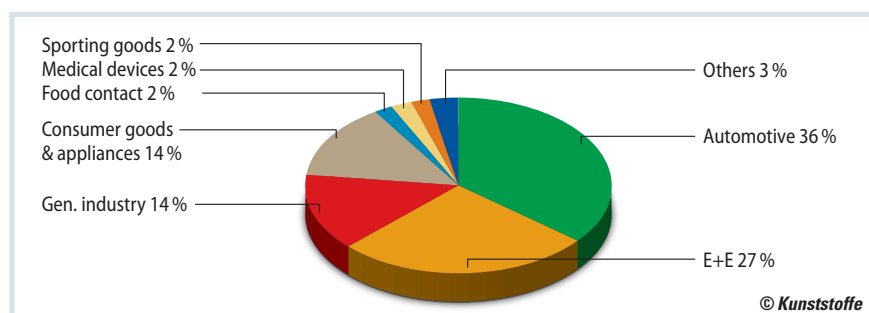
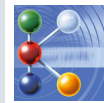


Fig. 4. Demand for POM, broken down by application (source: DuPont)

duction. The modification retains the typical high levels of rigidity and strength, very low water absorption and low distortion. The material's elevated abrasion resistance and very good surface slip permit virtually contamination-free, low-maintenance use without lubricant. Furthermore, the high level of corrosion resistance also makes it possible to use highly effective cleaning media, the use of which either makes it impossible to use metal chains or entails high maintenance costs. On the basis of this successful application at Regina, DuPont is currently developing further Delrin POM grades for conveying applications which have massively reduced friction and wear.

In terms of friction- and wear-reduced POM copolymers, which include specific Ultraform grades from BASF and Hostaform grades from Celanese, Polyplastics has recently presented a high-viscosity Duracon grade of POM. Typical applications stated by the manufacturer include components which require a long service life under continuous high loads and high weight while being thin-walled in order to permit lower weight. An additional characteristic highlighted by the manufacturer is the low-noise properties of the parts produced from it. Kolon also offers numerous Kocetal LW-RT grades over a wide range of viscosities.

Strictly Controlled for Pharmaceutical and Medical Technology

As with all plastics for medical technology, polyacetals are also subject to stringent quality assurance requirements. They are produced on separate production lines and their availability is ensured over the long term. DuPont offers these POM grades in two variants. Very high standards in terms of product uniformity apply to the production of SC (Special

Control) grades. They are globally available and suitable for conventional sterilization methods including treatment with ethylene oxide (EtO), are produced in accordance Good Manufacturing Practice (GMP), are authorized for food contact (EU/FDA) and are biocompatible to USP Class VI and 10993-5 and -11. DuPont provides 60 days notice of any changes in formulation that may become necessary. The manufacture and properties of PC (Premium Control) grades are still more closely controlled and they have a Drug Master File (DMF) listing. Both series include medium to high flow grades, in either nucleated or friction- and wear-modified variants.

The coefficient of friction of polyacetals against themselves and against other plastics and metals can be significantly reduced by adding either specific internal lubrication additives or PTFE fibers or micropowders, aramid fibers or silicone oils. As a result, it is possible to dispense with external lubricants, which is crucial for example in pharmaceutical and food applications. At the same time, such polymer compounds can extend the service life of tribologically loaded components.

Components made from conventional highly friction-reduced POM grades may, however, exhibit surface defects in the form of delamination if the polymer and lubricant segregate due to high shear forces during processing. Colored visible parts of drug administration systems are thus often made from different polymers, primarily intended to provide ease of movement and durability, than the internal mechanical working parts, so increasing design and manufacturing costs. In Delrin SC698SLF (super low friction), DuPont has now provided an internally lubricated POM which is suitable for use in any drug administration systems such as insulin pens or insulin pumps because it com-

bines reduced friction with high surface quality (Fig. 6).

A crucial factor here is the use of a specifically selected friction-reducing additive package which, even under critical processing conditions, such as high injection speeds and use in hot runner systems, does not segregate and so permits visually faultless component surfaces. Delrin SC698 is thus just as suitable for colored housing parts as for the internal mechanical working parts. Thanks to the very low coefficient of friction, insulin pen components produced from it ensure, for example, that the dose can be accurately and silently adjusted and dispensed with little effort and without judder.

There are many further applications in medical technology including clips, springs, levers and clamps together with free-running gearwheels and toothed racks capable of handling high loads which combine high productivity with high performance. Good fluidity here assists with filling cavities with narrow cross-sections and long flow paths in the production of thin-wall parts and processing in family and multi-cavity molds. Delrin SC698 is also laser markable which means that sharp, high contrast graduation scales can be applied.

For some years now, BASF has been offering various grades from the Ultra-

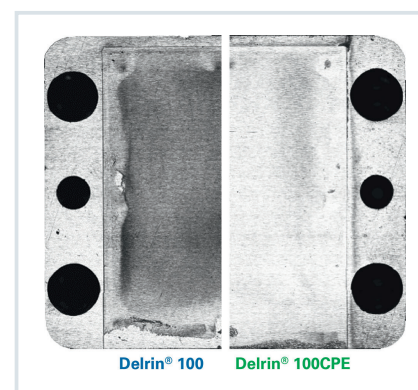


Fig. 5. One special feature of the new CPE family is the low level of mold deposits, shown here for 100CPE after 21,000 shots under accelerated test conditions (© DuPont)

form PRO range of POM copolymers for medical technology applications. The grades designated SC and PC at DuPont and PRO at BASF have the suffix MT at Celanese, which denotes the Celanese Medical Technology service package. The

new lubricated grade Hostaform MT SlideX provides excellent friction and wear behavior, for example in internal components of insulin pumps. New from Polyplastics is the Duracon POM PM series for pharmaceutical and medical technology.

Detectable for the Food Processing Industry

Most POM grades from all leading manufacturers are authorized for food contact. Products here range from unreinforced standard grades with different viscosities up to special grades for specific applications. These include, for example, many FG (Food Grade) variants of Delrin, such as FG150 for extrusion and FG100 and FG511DP, which are also authorized for drinking water contact, and now (for Europe) also Duracon M90-57 and M270-57 from Polyplastics. Such materials generally meet many regional and international regulatory requirements, such as FDA, European Regulation (EU) No. 10/2011 (Food Contact for Plastics) and European Regulation (EU) No. 2023/2006 (GMP). Typical applications include conveyor belts and dispensing systems used in the food processing industry, blades, paddles and scrapers or also chocolate molds etc.

Detectability is one focus of development for POM applications which are intended for contact with foodstuffs. The requirement for detectability is increasingly being felt due to the progressive replacement of metal components with components made from lightweight, corrosion-resistant, low-noise POM with its low friction and low wear properties even when unlubricated. Operators want to be able to go on using the conventional metal or X-ray detectors found in quality control and there is consequently demand for appropriately modified POM grades.

DuPont has recently introduced Delrin FG500MXD, a medium viscosity POM for injection molding applications which, for the first time, is detectable both with metal detectors and by means of X-ray detectors and so replaces two previous products. In both cases, particles from a cube edge length of 3mm can be detected by conventional equip-

ment. The first applications for this universally detectable DuPont POM homopolymer include trays for transporting portioned dough or cereals which are being used in food production and portioning (Fig. 7). Reasons for the choice of materials are not only the detectability but also the very good impact resistance.

Impact Strength and Easy Processing for Automotive Safety Systems

Safety systems, specifically automotive restraint systems, have for many years

been the domain of polyacetals. Typical applications include unlocking buttons for seat belt locks and a series of critical parts in the retraction mechanism, for which elevated impact resistance over a wide temperature range from -40°C up to 90°C is vital.

DuPont has now added four new grades to its range for such applications. Delrin 100TE, which combines high strength and impact resistance (T = tough) with low emissions (E), has been in the range since K2016. Grade 100STE additionally provides very high impact re- »




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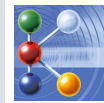
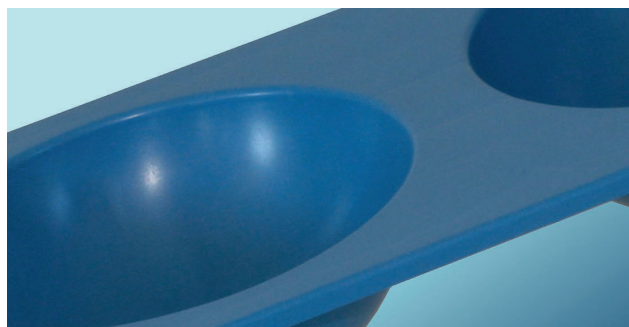


Fig. 6. As testing with pilot customers has revealed, Delrin SC698 combines low friction with a faultless visible part surface and is consequently just as suitable for housing parts as for functional parts, for example of insulin pens (© DuPont)



Fig. 7. First applications for the new Delrin FG500MXD, detectable with both metal and X-ray detectors, include food production and portioning trays (© DuPont)



sistance (ST = super tough), while the provisional development grade 100MTE, currently undergoing customer trials, has a particularly well balanced ratio between impact resistance (MT = medium tough) and strength. Reducing wall thickness to shorten cycle times is also a theme for push-buttons and DuPont, building on the previously available Delrin 127UVE, has developed the higher flow grade 327UVE for such applications. Both are UV resistant, low emission and available in natural color or for coloring by the customer using a tailored masterbatch.

Current applications for the 100 series include the mounting plate, belt guide and control wheel in Autoliv belt retractors, where, due to their water absorption, polyamides would not allow the very tight tolerances to be met (Fig. 8). In addition to dimensional stability, the good damping properties of the impact-modified grades also offer advantages as they help to minimize noise, something which is of great significance in rear seat areas (head height) and specifically in very quiet e-vehicles.

Also suitable for wall thickness reduction is a new, high flow POM from Kolon with an improved combination of stiffness, ductility and toughness. This grade is also available as LO2 version. At K2019, Polyplastics is presenting a Duracon POM for the production of small and particularly thin-walled parts which

combines high rigidity, good flow and high fuel resistance. Celanese's new MetaLX series, for example, is particularly suitable for components with a metallic surface.

Growth Remains Steady

The drivers of growth in the POM market will remain in place over the coming decades. The changeover from internal combustion engines to alternative hybrid or fully electric powertrain systems is not anticipated to have any significant negative impact on use. Indeed, quite on the contrary, their advantages will increasingly come to the fore in electrically

driven vehicles. Ongoing electrification and automation of industrial processes will also further boost demand for POM. This applies equally to homopolymers with their excellent mechanical properties and to copolymers with their strength combined with chemical resistance. POM materials will in future continue to be modified to meet customer requirements and to suit them for innovative applications.

While short-term growth rates might well be affected by the current slowdown in the global automotive industry, growth will remain at 3% to 4% over the medium- to long-term. On the basis of current knowledge, the highest growth at >4% is expected in Asia, followed by EMEA (3%) and North America (2%). Particularly high growth rates in the upper single digit range are to be expected in the relatively small medical technology market, while growth can currently be assumed to be over 3% in the relatively large electrical and electronics, consumer electronics and domestic appliances markets. The lowest growth rates of around 2% are to be expected in the sporting goods market.

Given anticipated growth rates in these markets, it is highly probable that existing production capacity will be at full utilization within the coming five years. When it comes to selecting a raw materials supplier, POM users will therefore in future have to pay attention not only to whether the material meets quality requirements but increasingly also to security of supply. ■

Andreas Zöller, Stefan Greulich, both Geneva, Italy, and Valéry Rebizant, Luxembourg

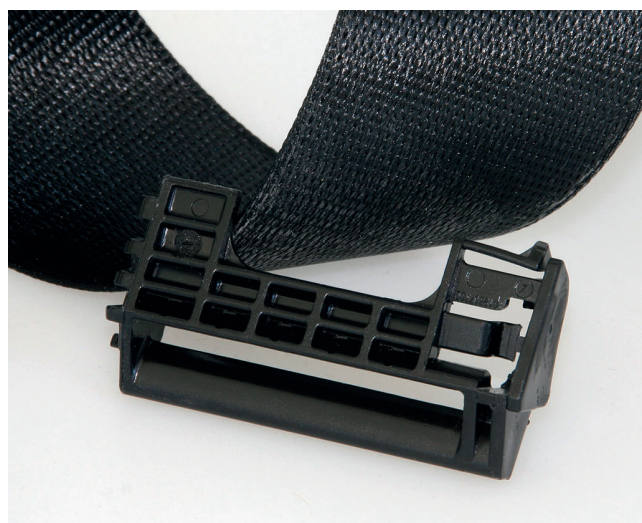


Fig. 8. Belt guide for an Autoliv belt retractor – one current application of Delrin 100TE

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