

Polyphenylene Sulfide (PPS)



Filter bag made from PPS
(photo: BWF)

Production Capacities Growing in Double Figures. Polyphenylene sulfide (PPS) is a semicrystalline high-performance plastic that is constantly opening up new fields of application due to its special range of properties. Rising demand for load-bearing materials has ensured, especially in the last few years, that the special properties of the polymer have increasingly attracted the attention of developers. In order to be in a position to meet continually rising demand in future, leading PPS suppliers are steadily expanding their capacities.

PPS is a semicrystalline high-performance plastic, that is to say it has a largely ordered structure with the formula $(SC_6H_4)_n$. Due to the linkage of aromatic monomer units via sulfur atoms particularly durable polymers are produced. Their very good mechanical properties are retained even at temperatures well above 200°C so that continuous use up to 240°C is possible. For short pe-

riods even exposure to 270°C is not a problem. The benzene-sulfur polymer has a melting point of about 288°C and is processed at approximately 320°C.

The specific properties of PPS include:

- Inherent flame resistance, accordingly no flame-retardant additives are needed,
- Chemical resistance to almost all solvents, many acids and alkalis and to some extent to atmospheric oxygen even at high temperatures,
- Very low water absorption,

- Excellent hardness, rigidity and dimensional stability,
- Very good electrical properties, for example as an insulator,
- Impermeable to a high degree to most liquids and gases,
- Only slight tendency to creep – even at elevated temperatures, as well as
- Excellent flowability: PPS is outstandingly suitable for processing by injection molding, even for long thin molded parts having complex mold geometries.

There are two types of polyphenylene sulfide: linear and cross-linked. While in cross-linked PPS the branched polymer chains are joined to one another via cross-linking points, the chains of the slightly branched linear materials bind together to form highly ordered superlattice structures. This special morphological structure is reflected primarily in its mechanical properties. Thus, viewed in chemical terms linear PPS is purer but at the same time it has a higher tear strength and elongation at break as well as

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greater flexural strength and notched impact strength than its cross-linked counterpart.

dustry – PPS plays an important role in metal substitution. PPS has captured market

in automotive engineering. The remainder goes into general industrial applications, the electrical and electronics sector and aircraft construction in which these durable polymers are now very important. Moldings made from PPS compounds are characterized by a metallic ringing sound when struck that is quite unusual for plastics.

Processing Methods and Examples of Applications

Linear PPS can be shaped into component parts by all common thermoplastic processing methods that are particularly valued for moldings subjected to high mechanical, electrical, thermal and chemical stresses in the electronics and automotive sectors and also in aviation. In contrast with this, cross-linked PPS has only limited processability. It can usually only be injection molded

and can be extruded only to a very limited extent.

Extrusion. From linear PPS fibers of the highest quality are produced in a multi-stage process. In processing the granular material is fused within a certain temperature range by means of a monofilament extruder and pressed through dies which determine the desired thickness of the individual filaments. In the subsequent processing stage stretching under controlled temperature conditions takes place to form a yarn. At the end a filament having outstanding mechanical properties is obtained. The high-strength fibers produced in this way are the starting material for textile reinforcing intermediates in the form of woven or nonwoven fabrics. The filaments can be further processed either on their own to form pure PPS fabrics or together with other fibers such as glass, carbon or polymer fibers to form blended fabrics. ▶

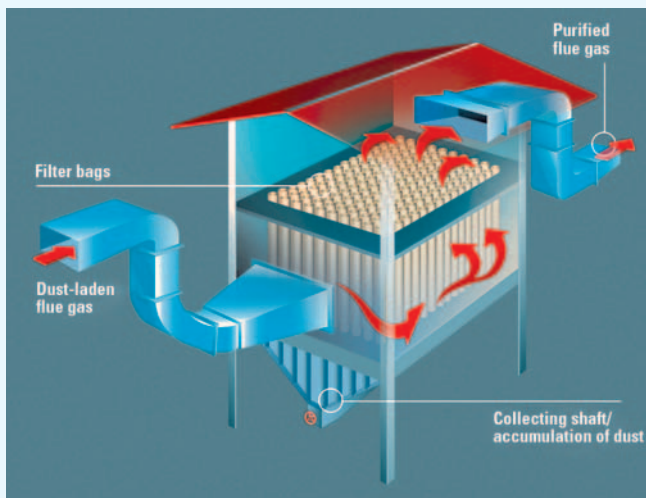


Fig. 1. Schematic illustration of a flue gas purification plant

(graphic: Ticona)

Application Markets

The key consuming sectors for PPS are automotive engineering and general industry, where – as in the aviation in-

share especially in applications in the engine compartment of automobiles. According to estimates more than half of the processed materials now have some application

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Unmodified linear PPS is being used in increasing quantities for extruding inherently flame-resistant films and sheets. Typical points of use for materials having such a property profile are tanks for chemicals, under the hood in automobiles and in large thin-walled panels as found in aircraft, railroad cars and buses. The range of products on offer encompasses glass-fiber reinforced grades as well as grades that have been modified in other ways. Semifinished PPS products can be custom-made for specific purposes.

Due to their special mechanical performance fiber-reinforced composites with PPS as matrix are now ever more frequently demonstrating their potential. For the reinforcing materials that are responsible for the high mechanical strengths of the products and hence for their high load-bearing capacity glass, carbon and aramide fibers as well as stainless steel filaments are used. The fiber-reinforced high-tech plastics are suitable for almost all common downstream thermoplastic processing methods. Here the material is protected in that only one physical process takes place: cooling down to the demolding temperature. In comparison with this thermosets cross-link in the mold by means of a chemical process and in this way are cured. For environmental and handling reasons these processes are increasingly regarded as problematic.

Recently the material showed what it is made of in a routine examination of filter bags made from linear PPS fibers. For more than a decade the bags have successfully performed their duty in a garbage burning power station. Routine examination of a used filter bag confirmed the excellent retention power of the filter bags over the entire service life of the plant. When examined by microscope the bag exhibited no

appreciable mechanical or chemical wear. The cross section revealed largely surface-based separation of dust. The mechanical properties were still very good and lay in the average range of strength values for new product. What's more, the clean gas side was almost free of dust (title picture, Fig. 1).

PPS is also used successfully as a high-strength multifilament in hydraulic hoses for servocontrol. The filaments made of Fortron (manufacturer: Ticona GmbH, Kelsterbach, Germany) help effectively to reduce oscillations, vibrations and noises resulting from these. The use of these new PPS multifilaments (Diofor) as reinforcing material can also be transferred to other systems in vehicles in which high demands are im-

posed on pressure, temperature and above all on the mobility of the hoses, e.g. in fuel lines or supercharger systems. Veritas AG, Gelnhausen, Germany, for example, has developed elastomer hoses reinforced with Fortron multifilaments for the highly stressed supercharger segment. They are so flexible that they are comfortable to handle and at the same time are so strong and resistant that they defy great pressure and high temperatures. Above all the movements between the turbocharger fastened to the engine block and the supercharger intercooler anchored to the body are critical stress factors for the connecting hoses. In order to withstand these the new Veritas air charging hoses consist of three layers. Different elastomers are used according to requirements for the outer and inner layers. The decisive element for

the mechanics of the component, however, is the central pressure-bearing layer in which a fabric knitted from PPS multifilament yarn is used. This allows the pressure support, on the one hand, to be flexible so that it can yield to the movements imposed on it and absorb vibrations and torsional forces. At the same time it is rigid and hence affords the operational strength needed for great internal pressure and high temperatures. Accordingly, when choosing the material the high thermal and chemical resistance together with the fitting combination of strength and elasticity of the PPS yarn were decisive (Fig. 2).

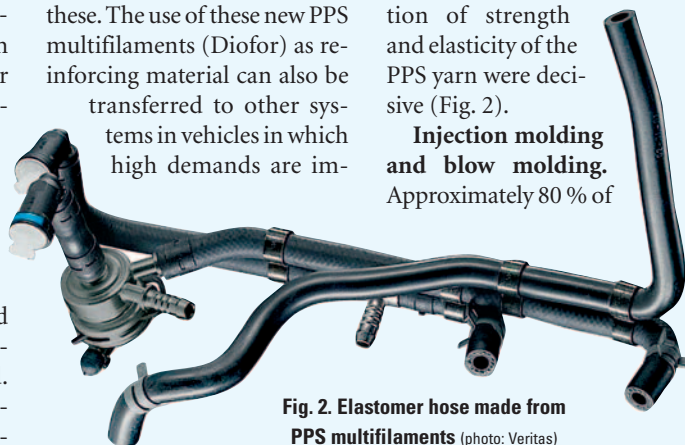


Fig. 2. Elastomer hose made from PPS multifilaments (photo: Veritas)

applications involving PPS are manufactured by injection molding. This includes switches and plug connectors in the electrical and electronics sector and engine compartment applications in automotive engineering, e.g. components for the cooling water circuit or fuel system. In an electric cooling pump for instance the rotor of the electric motor is placed in a can hermetically sealed with respect to the outside, the so-called canned motor. Thus, parts subject to wear such as slide ring seals and V-belts have had their day. Apart from the costly electronics, PPS as an innovative material meeting the high requirements was important for implementing the approximately 7.5 cm long canned motor. Here the high-performance plastic Fortron withstands operating temperatures in the range of -40 to +140°C and internal pressures

of up to 3 bar. The circulation of water containing glycol additionally requires high chemical resistance even at temperatures up to 130°C. Due to the use of the canned motor principle the new electric pump from Pierburg GmbH, Neuss, Germany, is very reliable in operation with low wear. Since it operates independently of the speed of the vehicle engine and responds only to the actual cooling demand it is also very economical with a power consumption of 200 W in comparison with the customary 2 kW. The bottom line is that the electric cooling pump saves up to half a liter of fuel per 100 km.

Other specially developed PPS grades are suitable for blow molding and so contribute to reducing weight. Supercharger pipes are a good example of this. For a long time they were manufactured from lightweight metal (aluminum). Due to the use of PPS, however, they are over 40 % lighter today and, furthermore, they have become more flexible and more resistant to stresses (Fig. 3). Promising new developments will soon be launched on the market.

In the new generation of engines Mercedes, for instance, has put its trust in PPS. In the SLK V6 and V8 engines the vehicle manufacturer is employing an innovative air intake module based on a combination of PA 46 and PPS. This entails less weight, increases power yield while reducing emissions and at the same time provides opportunities for further rationalization in production. The air intake module is eye-catching technically due to its air management and the use of what are called tumble valves. The module for Otto engines (with four-valve technology and aluminum crank housing and cylinder head) consists of eight parts: frame with seal, shafts with bearing, charge movement flaps with bearing, and seal as well as shafts, lever with seal, sealing ring and so-



lenoid disk. Here, the bearing pillows and shafts have a particularly important function since they have to bear the greatest mechanical loads. The shaft must be permanently sealed and in continuous operation withstand a maximum torque of 7.5 N/cm without damage. In the production of the exacting new intake module assembly injection molding together with multicomponent injection molding is employed. In doing so production costs have been lowered by about 30 % in comparison with conventionally assembled solutions. The eight components of the SLK engines are injected simultaneously and assembled fully automatically. Manual after-treatment and assembly are rendered unnecessary.

Market Forecast

It is expected that at least 50,000 t of the two types of the high-tech polymer will be con-



Fig. 3. For the highly stressed supercharger segment elastomer hoses reinforced with PPS multifilaments have been developed (photo: Ticona)

sumed worldwide in 2007. For the coming years continuously rising growth rates and a sustained upward trend in consumption are assumed. Accordingly, the manufacturers of the polymer will invest correspondingly, especially due to the high demand from the automotive, electrical engineering, electronics, aerospace and

filtration sectors as well as from other industrial and consumer applications.

PPS will benefit from the steadily rising demands that all sectors of industry impose on materials with regard to design freedom, ease of processing, reduction in weight and a wide range of properties. As before the automotive industry pro-

vides the best example: its demands on materials employed under the hood are not only enormous but are also continuously escalating. Thus, on the one hand, materials should be light and flexible but at the same time they must survive exposure to aggressive lubricants and fuels. Moreover, in pressure applications for example, the high-tech materials have to defy the ever rising demands stemming, inter alia, from turbocharging and also withstand higher temperatures. Since this trend will continue, market experts proceed on the assumption that at least until 2009 average global PPS growth of 5 to 10 % p.a. should be expected. For China and other Asian markets scenarios are being developed that forecast even higher growth rates. To keep pace with this production capacities must grow in double figures. ■

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