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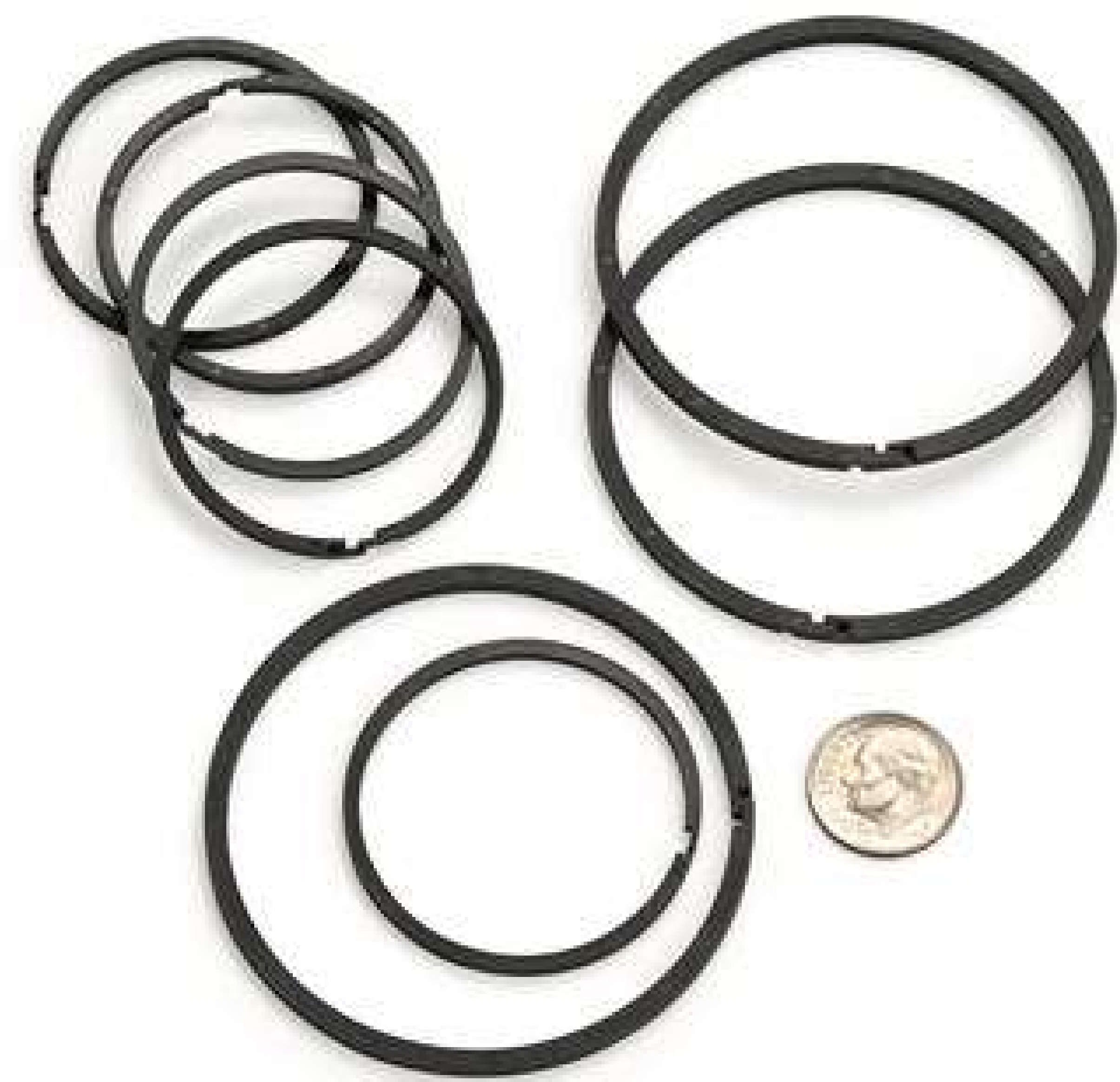
Understanding High-Performance Plastics and Their Applications

This class of materials provides high functionality in extreme conditions but poses challenges in design, manufacturing and preparation.

ENGINEERING RESINS   MATERIALS

Vincent Etchen, Manager of Technology and Innovation at Trelleborg

High-performance plastics (HPPs) excel in high-temperature environments, high-pressure applications and demanding mechanical settings. With their ability to reduce weight, improve energy efficiency and resist corrosion, HPPs are valuable in sectors such as automotive, aerospace, industrial automation, processing industries and semiconductors. As a a class of materials, they exhibit outstanding chemical resistance, low-friction characteristics and are well-suited for high pressure-velocity applications. They are ideal for rotating applications and applications where high precision and tight tolerances are needed. Finally, they can reduce noise, vibration and harshness, and provide electrical insulation or conductivity.



HPP-based seal rings shown with a dime for scale. Source (all images): Trelleborg

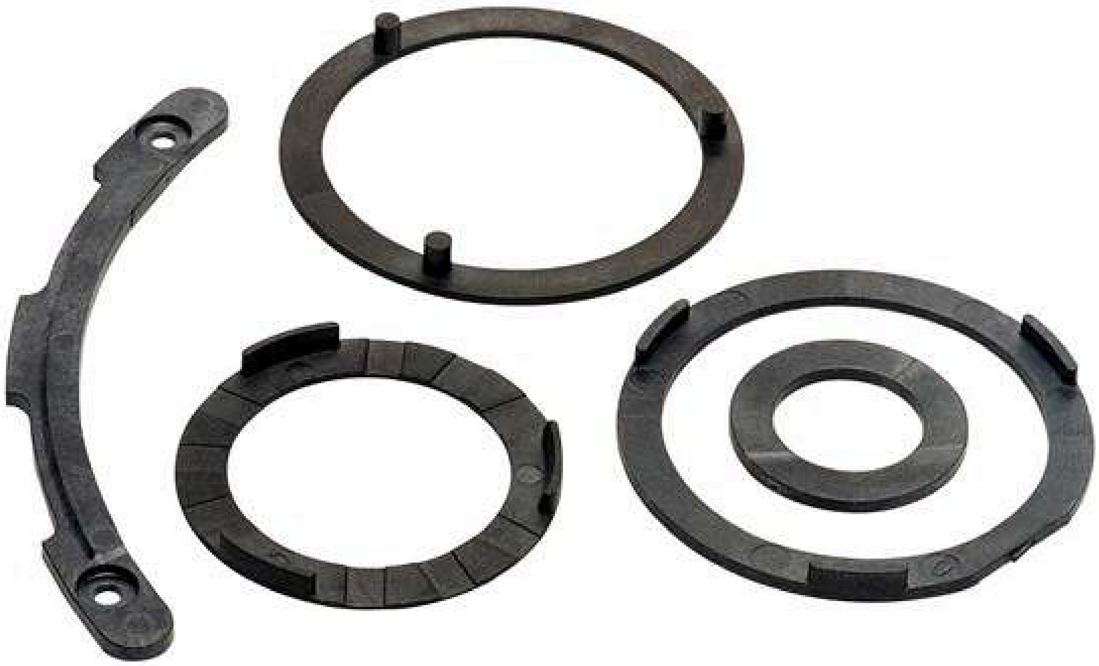
However, only supplier partners with the right equipment and expertise can help customers create value using HPPs. This article delves into the unique properties, manufacturing processes and real-world applications of HPPs, showcasing their impact on engineering and design.

Q: What are HPPs and their advantages over other materials?
HPPs can be explained in two different ways. They can refer to a group of polymers that retain their mechanical, thermal or chemical characteristics even in harsh environments. Alternatively, HPPs can mean engineered polymers modified to improve their performance (e.g., adding carbon fiber to polyphthalamide (PPA) for strength or molybdenum disulfide (moly) to polyamide (PA) for wear and durability).

Many HPPs are made with oriented fibers, plastics impregnated with fillers that increase their strength and/or reduce friction in the application. These fillers can be polytetrafluoroethylene (PTFE) added to polyetheretherketone (PEEK) materials to reduce friction and improve wear characteristics or moly added to nylon leads for a more wear-resistant surface. HPP combinations require the right balance between the base resin and the appropriate filler loadings.

Q: Can HPPs replace metal in structural components?

Yes. HPPs make applications lighter and more durable, replacing traditional metal components. For example, a traditional steel washer can be replaced with a lightweight polymer alternative, improving functionality by reducing wear on the mating hardware. Decreasing weight with these lighter parts improves the efficiency of the system because less mechanical energy is required to power the application. HPPs also help prevent corrosion seen with metal components in contact with water. Finally, HPPs are inherently insulative and do not transmit as much noise or vibration as traditional metal components.



Thrust washers

Q: Can HPPs perform in high-temperature environments?

Yes. Traditional metals can be replaced with HPPs that can withstand high-temperature environments. Materials like PEEK, polyphenylene sulfide (PPS) and polyamide-imide (PAI) can meet the demands of such harsh environments.

Q: How do HPP components handle high pressure-velocity (PV) applications?

For HPPs to handle high PV applications, consider several factors like operating temperature, chemical exposure, cooling and thermal management to optimize performance. The selection and design process involves evaluating the entire application environment to ensure the material's PV limit is not exceeded and integrating design features to maintain optimal performance. The use of fillers in HPPs can further optimize friction and wear characteristics for high PV or different lubrication conditions. The choice of counter surface and whether the application is dry or lubricated are also critical factors in determining HPP performance in PV applications.

Q: What is the benefit of using HPPs?

The use of HPPs can significantly reduce time and expense during design, prototyping and manufacturing. They can be recycled, reprocessed or downcycled, which can reduce waste. Their ability to bond to differing materials enables the creation of hybrid structures. Additionally, HPP parts are lighter than steel counterparts, so applications like automotive require less energy to function.

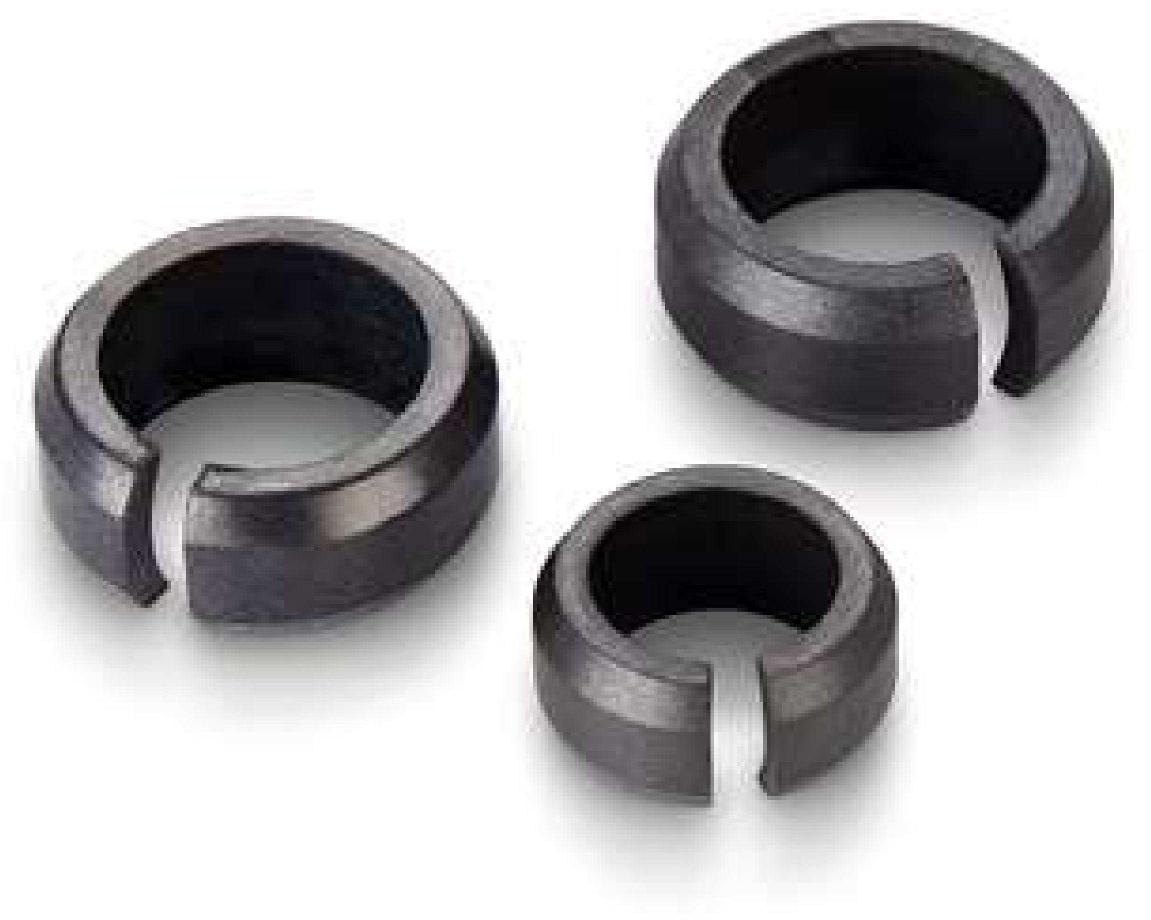
Additives further enhance the performance of HPPs based on application needs. For example, carbon or glass fibers stiffen materials, while PTFE and graphite lower friction levels and improve wear resistance. This makes HPPs ideally suited for use in the aerospace, automotive, chemical transportation, industrial automation, medical and semiconductor industries.

Q: What are some of the challenges in producing HPP components?

Producing components in HPPs, especially when they incorporate additives, present challenges related to tooling, temperature and part shrinkage. HPPs may be highly abrasive on press components, so presses are often fitted with custom-designed screw and barrel systems to reduce wear and extend life for improved process capability. Due to the molecular chemistry of HPPs, material flow is challenging in multicavity tools. To successfully produce components, molding needs to be at very high temperatures. A press molding a component in standard polymers runs at a melt temperature between 392-527°F (200-275°C). Presses for HPPs, meanwhile, reach up to 797°F (425°C). Maintaining the temperature of all mold components is difficult, so programmable thermal management systems using treated soft water can be installed to successfully run water at 440°F (227°C).

The mechanics of thermal management for thermoplastic molding are also complex. Controlling the temperature of the tool helps ensure that the material has the correct mechanical characteristics and that part crystallinity and cycle times are not negatively affected. Proper cooling is especially critical for high-precision parts that are flat because they are prone to warpage. Another challenge related to temperature is part shrinkage. When a part cools to room temperature, it changes volume. Designing a tool with optimum cooling while considering part shrinkage takes in-depth knowledge by experienced engineers to overcome multiple challenges.

Formulating HPPs is more complex than with standard plastics due to limited choices of additives and fillers that must have high thermal stability and be compatible with the HPP matrix. This requires advanced technical expertise and close collaboration with suppliers to create custom formulations for specific applications.



Injection molded PEKEKK turbo part

Tool design, processing simulation and optimization of designs for manufacturability are essential qualification criteria for a competent polymer engineering solutions partner.

Q: Tell me about the manufacturing process for HPPs.

HPPs are often manufactured using injection molding, compression molding or extrusion. These processes allow for very precise control over the shape and size of the final product. The plastic components can be precision molded to achieve tight tolerances or machined for further refinement and unique specifications. The goal is to improve the overall performance of the assembly and reduce the total stack up of tolerances in the system, leading to reliable performance.

Precision molded or extruded plastics can help absorb some tolerancing in other parts of the system. They remove the need to grind and modify mating parts in secondary processes, reducing overall system costs. In other words, HPPs are often more durable in applications compared to metallic components. They have greater flexibility to conform to mating hardware.

Overmolding and welding are also used to combine HPPs with other materials, enabling multicomponent parts with reliable bonding.

Q: What materials does a competent supplier partner work with?

Thermoplastics, HPPs and engineered molded plastics including:

- **PAEK –** polyaryletherketone
- **PEEK** – polyetheretherketone
- **PEKK** – polyetherketoneketone
- **PEKEKK** – polyetherketone etherketone ketone
- **PBI** – polybenzimidazole
- **PA** – polyamide
- **PEI** – polyetherimide
- **PPS** – polyphenylene sulfide
- **PPA** – polyphthalamide
- **PPSU** – polyphenylsulfone
- **POM** – acetal homopolymer
- **PBT** – polybutylene teraphthalate

Q: How do HPPs contribute to the PFAS conversation?

HPPs can be PFAS-free replacements. Component partners should actively respond to customer demands for PFAS alternatives, driven by regulatory and market pressures. They should collaborate with material suppliers to develop and test custom formulations that replace PFAS, including PFAS-free wear additives.

Q: What are some application examples of HPP?

Plastic guide rings can be designed to absorb side-load forces in pistons and rods in hydraulic cylinders while eliminating metal-to-metal contact. They also provide a low coefficient of friction, a long service life, good chemical resistance and high load capacity, as well as a lower wear-rate than metal. The guide rings can be purchased with an angled cut for linear motion, a straight cut for rotary motion or a step cut for special applications.

Bearings and bushings of plastic also prevent metal-to-metal contact and reduce friction, extending the life of non-hydraulic systems. Finally, back-up rings installed in grooves protect and support elastomeric seals and stop them from being pushed into the sealing gap. They are often used in hydraulic cylinders for excavators and agricultural machines.

ABOUT THE AUTHOR: Vincent Etchen is an expert at Trelleborg's River Falls facility, which specializes in advanced engineering capabilities and custom material formulations for high-volume, tight-tolerance products from highly engineered polymers. Vincent and the River Falls team focus on high-end, specialized production, investing in both equipment and expertise, including clean water systems for high-temperature molding, AI-powered all-electric machines, and ceramic heaters and high-wear screw and barrels to handle abrasive fillers and high temperatures.

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