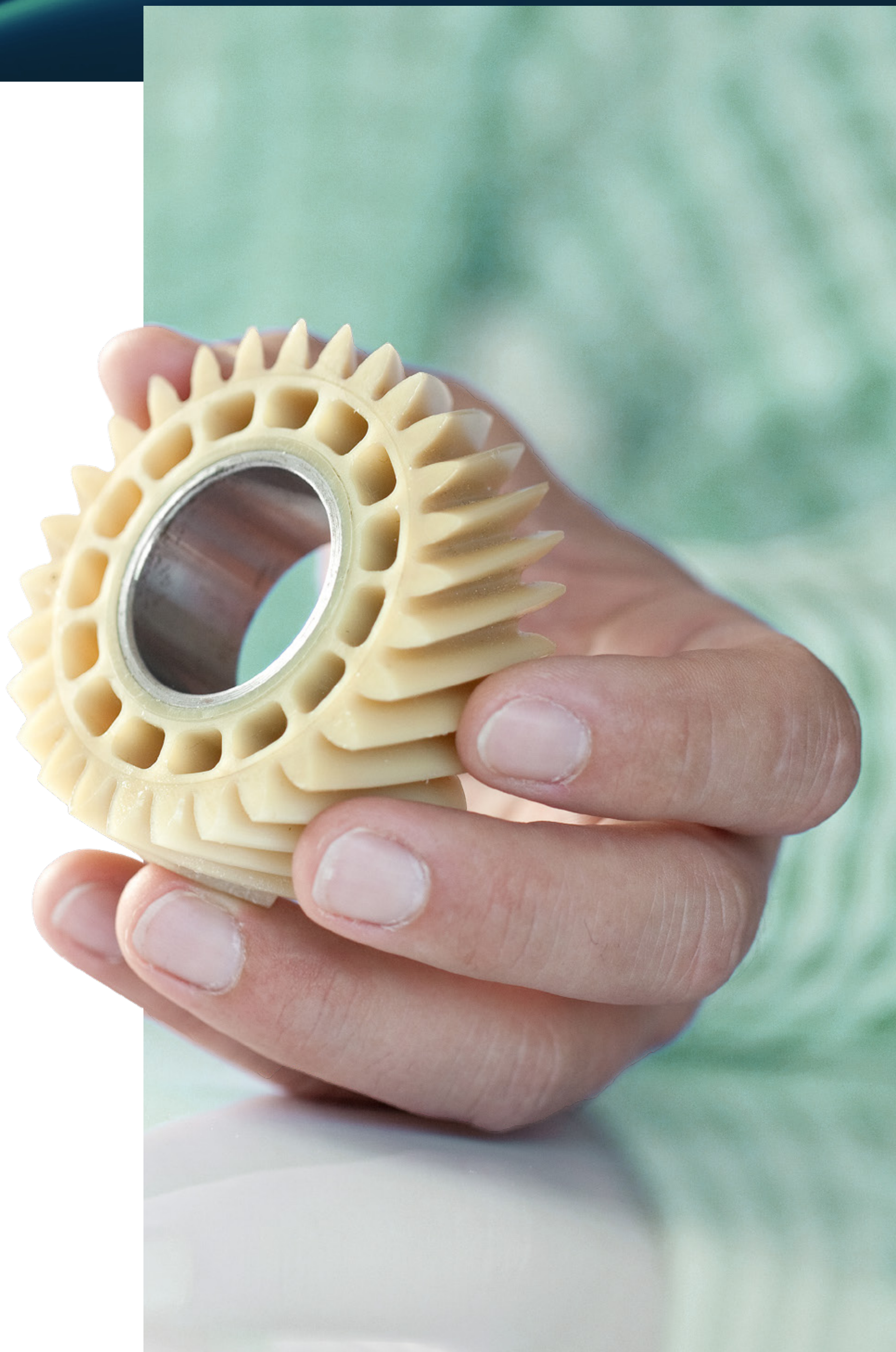
Whitepaper

DESIGNING FOR *PFAS–FREE TRIBOLOGY*

High–performance wear and friction starts with the right polymer foundation.

Growing PFAS (per– and polyfluoroalkyl substances) restrictions and evolving OEM requirements are reshaping how tribological components are engineered. As PTFE loses viability in many applications, performance can no longer rely on additive packages to compensate for limitations in the base polymer. The next generation of wear and friction solutions will depend on intrinsic material behavior—how the polymer itself manages heat, load, and long–term mechanical stress. Polymers engineered for high temperature, high load, and low wear provide a more reliable and future–oriented foundation than formulations built around PTFE modification.



PFAS–FREE IS BECOMING *A DESIGN CONSTRAINT*

EU SETS THE DIRECTION (ECHA)

- Broad PFAS restriction proposals
- Shift from substance–by–substance to class–based regulation

US ACCELERATES ENFORCEMENT (EPA)

- Increased reporting requirements
- Drinking water limits
- Stronger scrutiny of fluoropolymers

APAC ALIGNS WITH GLOBAL STANDARDS

- Japan Korea, China reference EU/US frameworks
- Export–driven compliance pressure

PFAS–FREE BECOMES THE DEFAULT

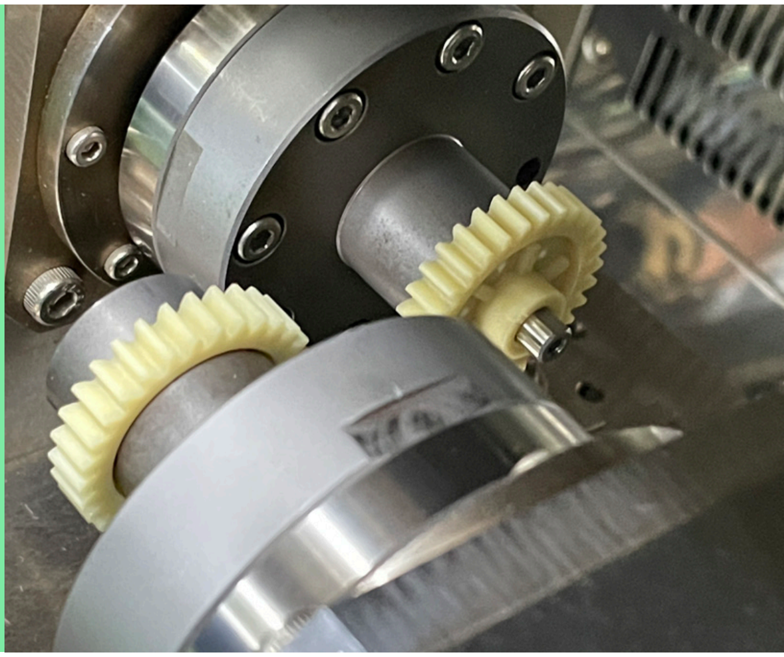
- Regulation baked into procurement
- OEMs demands PFAS–free materials
- Optional becomes expected

Regulators across Europe, North America, and Asia–Pacific are expanding PFAS restrictions to include a broader range of fluorinated chemistries, including PTFE. European proposals under ECHA outline one of the most comprehensive restrictions, extending from production to downstream use.

EPA actions in the United States are tightening reporting and compliance expectations, with similar measures emerging globally. As a result, any material system containing PTFE—whether as a base polymer or an additive—is increasingly exposed to future regulatory risk.

OEMs are setting PFAS elimination timelines of their own

Major automotive, industrial, and consumer OEMs are moving quickly to remove PFAS from components, processes, and material formulations. These mandates often run ahead of regulation and apply across full assemblies: polymers, additives, wear packages, and lubricants. At the same time, performance requirements continue to rise. Higher temperatures, higher loads, compact packaging, and longer lifetime expectations mean PFAS–free materials must match or exceed the durability previously achieved with PTFE–containing solutions.



Design choices now start with the polymer, not the additive

As PFAS–free design becomes a fundamental requirement, the limitations of many base polymers become more visible. The real engineering challenge is not finding a one–to–one PTFE–additive replacement, but selecting polymers with intrinsic thermal stability, mechanical strength, and wear resistance. This shift is reshaping how engineers approach material selection, moving the focus from lubrication workarounds to polymer systems designed to carry the tribological load from the start.

What Engineers Should Look for in PFAS–Free Tribology Materials

PFAS–free design places greater emphasis on the base polymer's capability to manage heat, load, and continuous motion. Intrinsic material behavior now shapes friction and wear performance, with long–term stability far more than PFAS–containing systems. The following criteria define what engineers should evaluate when selecting materials for next–generation PFAS–free tribological components.

CORE REQUIREMENTS FOR *PFAS–FREE TRIBOLOGY*

Stable low friction in dry and grease and oil lubricated conditions

High wear resistance under load and sliding speed

Thermal stability at operating and peak temperatures

Dimensional stability in thin–wall geometries with minimal deformation or warpage

Predictable lifetime behavior across duty cycles

PFAS–free formulation at both polymer and wear and friction modifier level

Scalable manufacturability with reliable processing and cycle times

Why Many Common Base Polymers Fall Short

Without PTFE, the limits of several widely used polymers become more apparent:

PA66

Good all–purpose engineering polymer, but wear and friction degrade quickly at elevated temperatures; historically dependent on PTFE for durability.

POM (ACETAL)

Low initial friction but limited thermal stability and strength and fatigue performance; performance drops under continuous cycling – particularly at real contact temperatures above 80°C (note that the contact temperature for moving parts can be up to 40°C higher than the application temperature due to the frictional heat generated between the moving parts).

PPS

Strong heat resistance but brittle; PFAS–free versions often show higher wear rates without PTFE.

PPA

Performs well at temperature, but brittle and typically requires PTFE reinforcement to manage wear resistance under demanding duty cycles.

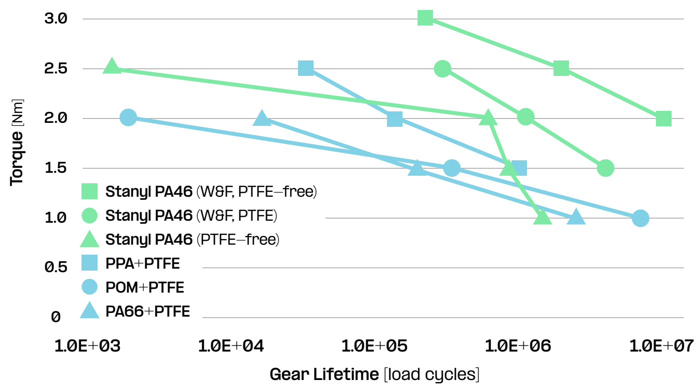
PTFE

Widespread use in many tribological applications with very good wear and friction performance and flexibility, yet no longer considered a safe and sustainable solution.

Across all families, once PTFE is removed, intrinsic polymer limitations surface—especially for heat, load, sliding speed, and long lifetime expectations.

Gear durability performance

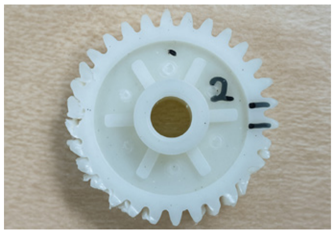
(spur gears/30 teeth/module 1/80°C/500 RPM/dry–running)



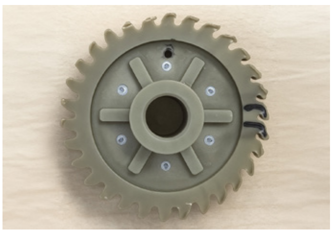
Failures observed dry–running gears

(Gears after testing, 2 Nm torque, 80°C)

Stanyl PA46 (W8F, PTFE–free)

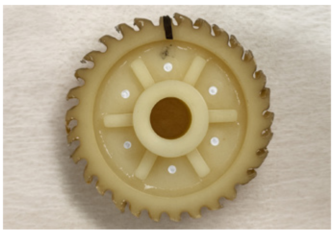


PPA+PTFE



Stanyl PA46 (W8F, PTFE)

POM+PTFE



Stanyl PA46 (not W8F, PTFE–free)

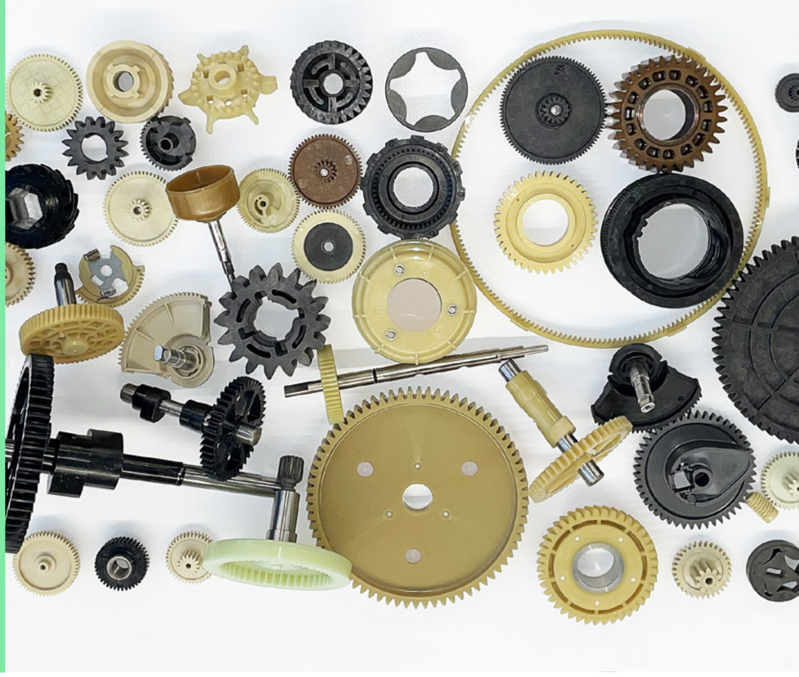
PA66+PTFE

What an Effective PFAS–Free Tribology Material Must Deliver

A viable PFAS–free tribology material should combine:

- **Intrinsic thermal stability**
- **High crystallinity, mechanical stability, and fatigue strength**
- **Low, stable friction without PFAS additives**
- **Strong wear resistance under continuous load**

This defines the baseline for materials engineered for next–generation PFAS–free tribology.

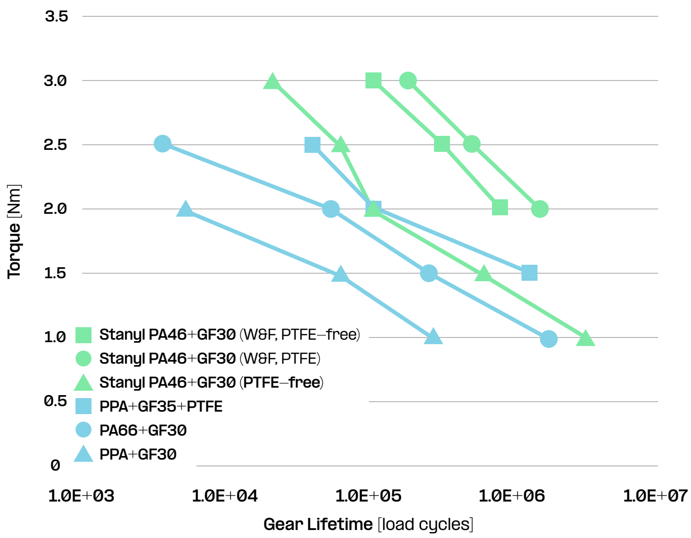


PA46: A POLYMER ENGINEERED *FOR PFAS–FREE TRIBOLOGY*

Meeting the requirements of PFAS–free wear and friction applications consistently, and without relying on PTFE, requires a polymer with a fundamentally different structure. PA46 offers that foundation. Its high crystallinity, fast crystallization rate, and ability to retain mechanical properties at elevated temperatures distinguish it from other polyamides and many traditional engineering polymers. These material–structure characteristics enable PA46 to carry more of the tribological load through the polymer matrix itself.

Gear durability performance

(spur gears/30 teeth/module 1/130°C/500 RPM/dry–running)



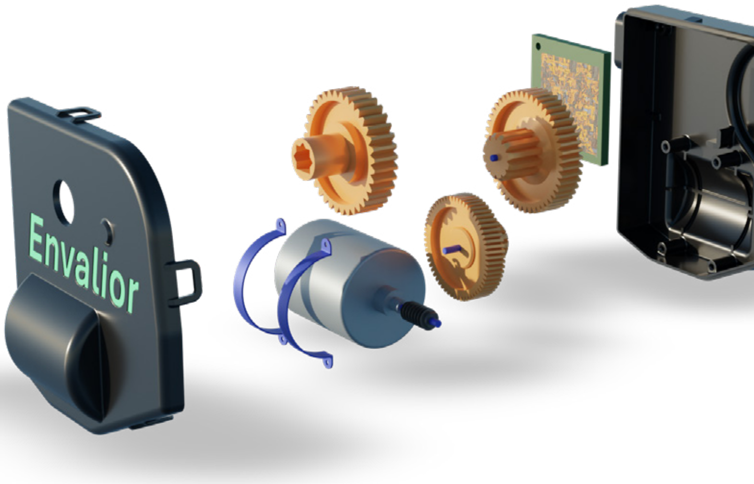
PA46 can be further optimized with advanced PFAS–free wear and friction technologies, producing low friction and high wear resistance in both dry and grease or oil lubricated environments. Together, the polymer structure and additive system create a balanced PFAS–free solution capable of performing under the demanding conditions seen in modern gear trains, bearings, seals, and timing components.

PFAS–free PA46 grades now enable material replacement not only for PTFE–containing engineering polymers such as PA66, POM, PPS, and PPA, but also for selected sealing applications where ductility, durability, and low friction are required and where typically PTFE compounds were used. In addition, PA46's rapid crystallization supports efficient, scalable production and thin–wall component designs that reduce weight and material use.

This combination positions PA46 as a strong foundation for PFAS–free tribology in next–generation applications.

APPLICATION LANDSCAPE AND *DESIGN CONSIDERATIONS*

The move to PFAS–free materials affects a wide range of components exposed to heat, load, and continuous motion. Designers now require polymer solutions that deliver stable friction, strong wear resistance, and reliable performance in compact, lightweight assemblies. PA46's intrinsic thermal stability, mechanical strength, and PFAS–free wear and friction technologies support these needs across multiple tribological applications.



GEARS

Gears require low friction, low wear behavior and structural integrity under continuous cycling. PA46's high crystallinity enables high stiffness, high strength and high fatigue performance at elevated temperatures. This allows for compact and durable geartrain designs, while PFAS–free wear and friction technologies ensure consistent performance in both dry–running and lubricated environments.

SLIDING BEARINGS AND BUSHINGS

PA46's heat resistance, low friction, and low wear, combined with PFAS–free wear technologies, deliver stable performance across variable lubrication conditions.

TIMING SYSTEM COMPONENTS

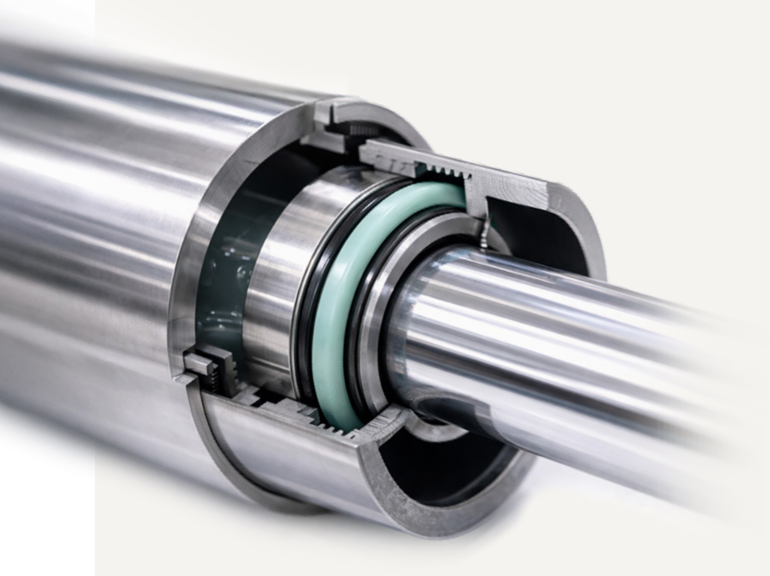
Chain guides and tensioners depend on materials that maintain friction stability and resist wear under continuous contact at elevated temperatures. PA46 meets these demands while supporting system efficiency and component life.

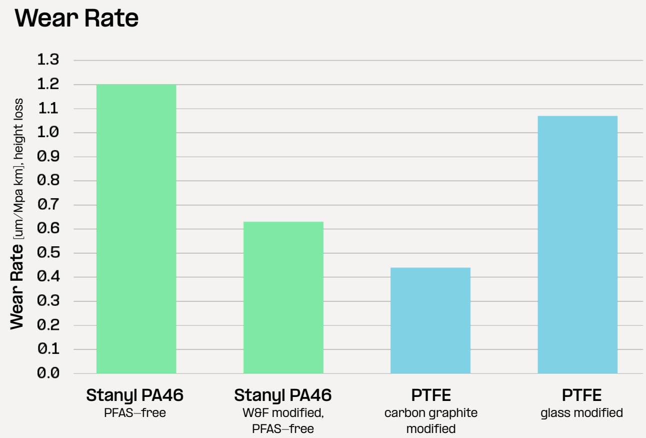
MANUFACTURING CONSIDERATIONS

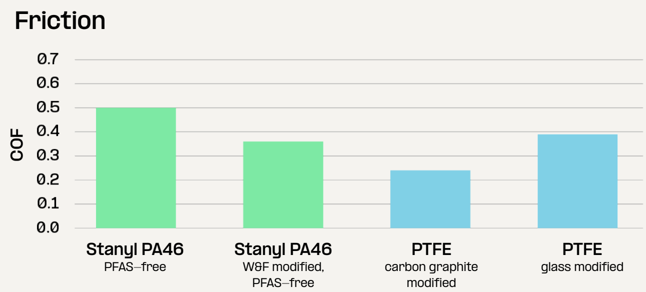
PA46 enables efficient production through rapid crystallization and dimensional stability, supporting shorter cycle times, consistent quality, and reliable thin–wall performance.

SEALS

Sealing components need low wear and friction with high ductility. PA46 offers PFAS–free sliding performance with excellent toughness and fatigue, helping seals resist cracking and assembly stresses while maintaining performance in motion.







SELECTING THE RIGHT *PFAS–FREE GRADE*

Key Decision Factors

Choosing the right PFAS–free grade starts with understanding the dominant operating stresses on the part. These core factors guide grade selection within PA46–based solutions.

1

Friction or wear—which dominates?

- **Friction control priority:** standard PFAS–free PA46 grades and PFAS–free PA46 grades that include wear and friction technologies for demanding friction performance, both available as either unreinforced or fiber reinforced, dependent on application requirements.
- **Wear under load:** grades tuned for durability in gears, bearings, and continuous sliding.

2

Stiffness, strength and dimensional performance.

- **Unreinforced grades** for moderate stiffness and strength needs, but long life requirements
- **Glass fiber grades** for moderate to high stiffness, strength and dimensional requirements.
- **Carbon fiber grades** for highest stiffness and strength requirements and/or in the case of wear–sensitive counter surfaces.

3

Thermal environment.

- **Temperature performance** is one of PA46's key intrinsic properties. Stanyl® works exceptionally well over a very broad range of temperatures, from –40°C to 180°C. Grade selection to consider complete application requirements.
- **Intermittent peaks + sliding:** formulations optimized for friction stability across cycles.

4

Lubrication conditions.

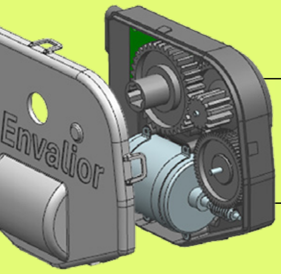
- **Dry running conditions:** PFAS–free wear and friction–optimized Stanyl® grades.
- **Grease or oil lubricated conditions:** Standard Stanyl® grades without wear and friction optimization will often work well enough. PFAS–free wear and friction optimized grades can be used if the quality of grease or oil lubrication cannot be guaranteed by the engineer over the application's full lifetime.

5

Manufacturing requirements.

- **Thin walls / complex geometry:** grades with fast, predictable crystallization.
- **High–volume molding:** formulations with stable shrinkage and short cycle times.

FULL–SYSTEM SUPPORT FOR PFAS–FREE *TRIBOLOGY DESIGN*



Concept Design → Detailed Design → Component Optimization → Process Optimization → Functional Validation → Production Optimization

EXPERT SUPPORT AT EVERY STAGE

Moving to PFAS–free materials can impact product design, testing, and manufacturing processes. Envalior supports this transition seamlessly by providing application development expertise from early concept development through full–scale production. This helps manufacturers adopt PFAS–free solutions while maintaining durability, performance, and high–volume manufacturability.

FROM CONCEPT TO OPTIMIZED DESIGN

Combining materials science and tribology performance expertise with virtual engineering capabilities, our teams help with optimal material selection, and part and design optimization. This integrated approach helps address performance requirements early, reducing design iterations and accelerating development.

VALIDATION THROUGH HANDS–ON PROCESSING AND TESTING EXPERTISE

In parallel, our hands–on expertise in processing, testing, and analysis enable earlier validation of PFAS–free solutions. This ensures mechanical, thermal, and lifetime requirements are met, while reducing risk and accelerating time to production.

CONTINUOUS INNOVATION IN PFAS–FREE PERFORMANCE

Envalior continues to advance PFAS–free wear and friction technologies across the PA46 portfolio, expanding performance.

The Advantage of Starting at the Polymer Level

The shift to PFAS–free design is reshaping tribology across industries, bringing the performance of the base polymer to the forefront. As PTFE is regulated, reliable wear and friction behavior must come from thermal–mechanical stability supported by advanced, non–PFAS technologies. This reframing moves design decisions away from additive substitution and toward polymer systems engineered to withstand the combined demands of heat, load, and continuous motion.

PA46 provides a strong foundation for this new approach. Its inherent thermal stability, mechanical strength, and tribological performance—enhanced with PFAS–free wear and friction technologies—enable durable components that meet evolving regulatory and OEM requirements. By starting at the polymer level, manufacturers can develop PFAS–free tribology solutions that remain robust today and adaptable to the demands of tomorrow's applications.

To learn more about our materials for PFAS–free wear and friction applications, contact us via Envalior.com.

Envalior
Imagine the Future