Fluoropolymer Bearings Last Longer

THANKS TO POLYPHENYLENE SULFONE ADDITIVE

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Linear bearings and other wear parts are commonly made from fluoropolymers to take advantage of their low friction properties and chemical resistance. Based on recent laboratory tests with fluoropolymer bearing materials, adding polyphenylene sulfone ($PPS0_2$) to the resin blend improves long term performance, especially under high temperature and high load conditions. The additive helps fluoropolymer bearings last longer, handle higher loads at higher temperatures, and resist cold flow under higher preloads. Moreover, these gains are achieved without compromising the chemical resistance and/or lubricity of the bearing. Those properties often suffer with fiber reinforcements or costly additives such as polyarylate (PAR) or polyimide (PI). The same $PPS0_2$ additive also improves bonding of fluoropolymers to metallic reinforcement rings.

Implications for Bearings and Drives

■ The findings by researchers at the University of Erlangen-Nurenberg in Germany have important implications for designers of linear actuators, low-speed transmissions, or gearboxes that incorporate linear, thrust, or plain rotary bearings. The findings mean drive and bearing designers can take full advantage of the exceptional lubricity and chemical resistance of PTFE and other fluoropolymers in higher-load and preload situations.

From a friction/lubricity standpoint, neat fluoropolymers have long been accepted as an ideal nonlubricated bearing material for low speed applications at moderate temperatures. They are maintenance-free, offer extremely low coefficients of friction without lubrication, and are immune to virtually all chemicals. Those properties explain why fluoropolymers have shown up so widely in linear bearings such as push-pull cable jackets. The downside is that unsupported fluoropolymer deforms over time under sustained loads, a property known as cold flow. Fluoropolymer bearings are also prone to wear under continued use. These shortcomings have limited the wider use of PTFE and other fluoropolymers in higher load and more critical applications.

Figure 1. Ticona's Ceramer® $PPSO_2$ particles under a scanning electron microscope.

Past remedies have included reinforcing fibers and PAR or PI additives. Each has improved the life and expanded the operating envelope of fluoropolymer bearings, but each has shortcomings. Reinforcing fibers increase resistance to wear and cold flow, but only at the expense of lubricity. Fibers on the bearing surface can also mar metal parts that move against the fluoropolymer, increasing friction, heat and wear.

This explains why design engineers have sought a fluoropolymer bearing material offering greater resistance to both wear and cold flow while retaining the lubricity and chemical immunity of neat fluoropolymer.

$PPSO_2$ Close-Up

■ Polyphenylene sulfone is derived from the linear polyphenylene sulfide (PPS) polymer known for its thermal stability and chemical resistance. A closer look at this new additive will clarify why it offers such promise for improving fluoropolymer bearing performance.

$PPS0_2$ is a hard (Vickers hardness 28HV 1/60), partially crystalline resin with a glass transition temperature of 360°C (680°F). Compressive strength is 275 MPa and yield stress is 170 MPa. Chemical resistance is nearly equivalent to that of PTFE; there is no known solvent. As with PTFE, the melt temperature of $PPS0_2$ is higher than its decomposition temperature, so neat parts of $PPS0_2$ must be hot-press molded and not melt-processed.

Wear Testing

■ To find out whether $PPS0_2$ would fill its promise, scientists in Germany recently ran comparative wear and friction tests of PTFE specimens loaded with between 5 to 20 percent PAR, PI and $PPS0_2$. The same standard pin-on-disc friction/wear testing apparatus performed all the tests under identical conditions. A sample disc is spun under controlled conditions of temperature and velocity while a hard pin bears down on it under a known load. Loss of material due to the load is measured periodically to quantify a wear rate. Tests were run at 0.5 and 4.0 m/sec surface velocities and 1 and 5 MPa pin pressures.

All specimens were manufactured under processing parameters corresponding to those used to make commercial quantities of fluoropolymer bearing material with 10 percent additive levels. Figure 1 gives particle size distributions for the respective additives used in the test specimens and shows an inherently tighter size distribution of the $PPS0_2$ relative to the two other additives.

To measure the effect of surface roughness on service life, test materials were tested against two different levels of surface roughness: 1 and 2 μm R_Z.

Double the Wear Resistance

■ Figure 2 summarizes the results at loads of 5 MPa and velocities of 0.5 m/sec. Against smooth and rough specimens, the $PPSO_2$ demonstrated about twice the wear resistance of PAR. Against the smoother samples, wear resistance of $PPSO_2$ closely matched that of PI, but in contact with rougher specimens, PI outlasted it. Coefficients of friction, or lubricity, were comparable for all additives in all specimens. Note that, under these conditions, plain PTFE would wear so quickly that data could not even be collected.

When comparing these results, remember that $PPSO_2$ exhibits superior chemical and temperature resistance to both PAR and PI, especially resistance to sulfuric acid. Also the smaller particle size of $PPSO_2$, relative to the PAR and PI material evaluated, creates a smoother bearing surface.

To compare heat resistance of bearings with various $PPSO_2$ loadings, test temperatures were varied between 25 and 250°C (77 and 482°F). As a reference, note that unfilled PTFE starts to flow and can no longer be studied at 150°C (302°F).

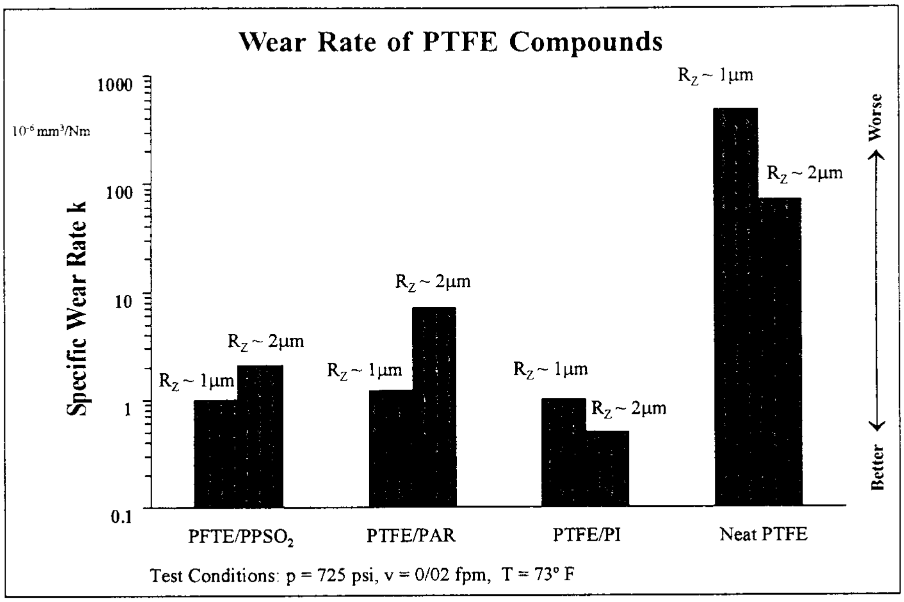


Figure 2 compares the specific wear rates of PTFE filled with $PPSO_2$, PAR and PI and neat PTFE.

Figure 3 on the next page summarizes the results. Polyphenylene sulfone increases the service temperature limits of PTFE bearing materials into the 200 to 250°C (392 to 482°F) range. The exact service temperature limit will depend on loads and $PPSO_2$ content.

Additive Guidelines

■ The study also provided these additional guidelines for $PPSO_2$ additives in fluoropolymer bearing materials:

For low-load applications, a 10 percent additive content by weight is probably adequate. For higher loads or contact velocities, a better starting point is 20 percent. ►

For operating temperatures in the 220 to 250°C range (428 to 482°F), $PPSO_2$ content should be about 10 percent.

For plastic-metal combinations, designers should keep hardness of the metal above R_c 50. With anything softer, roughness peaks can break off and embed themselves in the plastic and act as an abrasive in the bearing.

Adding as little as 5 percent $PPSO_2$ will significantly improve the life of a PTFE bearing when loads are in the 5 MPa range or higher.

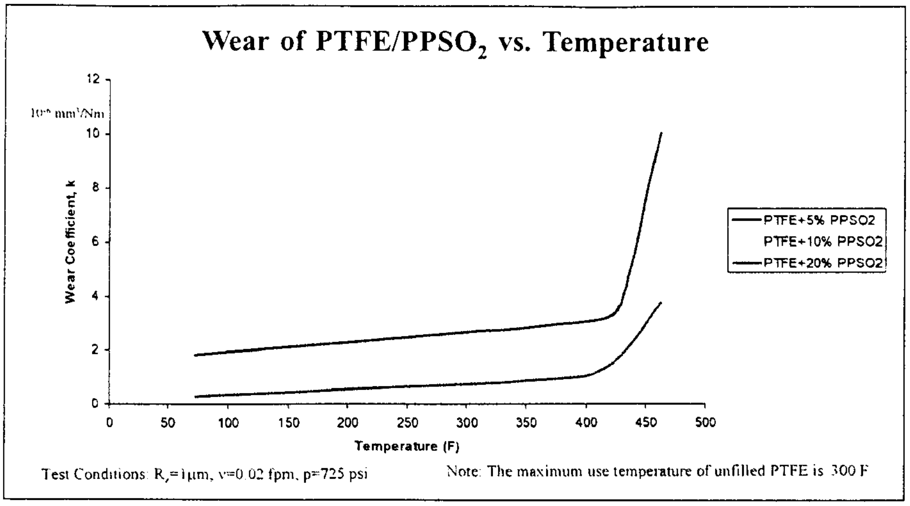


Figure 3. Specific wear rate K of the PTFE/$PPSO_2$ compounds is a function of sliding surface temperature. Polypheneylene sulfone increases the service temperature limits of PTFE bearing materials into the 200 to 250°C (392 to 482°F) range.

Typical Applications

■ Several manufacturers have already taken $PPSO_2$ – filled fluoropolymers beyond testing and into the commercial application stage. One example is the cover lining for a push-pull cable mechanism (see photo).

$PPSO_2$ is used in the PTFE outer cover for a push-pull cable mechanism. In effect, the fluoropolymer tube serves as a linear bearing to reduce friction between the stationary cover and moving cable.

In effect, the fluoropolymer tube serves as a linear bearing to reduce friction between the stationary cover and moving cable. In such cables, the addition of $PPSO_2$ to PTFE paste extrusion powders increases life dramatically. Unlubricated push-pull cable jackets in one test, filled with 7 percent branched polyphenylene sulfide (PPS), rubbed through after only about 30,000 cycles. Cables containing the same amount of $PPSO_2$ were still intact after one million cycles. Reliable, low-friction performance is essential in such applications. Push-pull cables are used in passenger cars, automatic welding machines and lawn mowers.

Another example is a pump housing made of the fluorothermoplastic destined for extremely corrosive service (see photo). PFA reinforced with 30 percent $PPSO_2$ improved both the structural strength and chemical resistance in a single component. The additive enhanced both hardness and yield strength of the housing.

Outlook

■ Linear drives, transmissions and actuator mechanisms have broad requirements for bearings capable of handling low speeds and high loads with zero maintenance. Examples are found in control linkages, clutch and shift mechanisms, shaft containment and housings. Self-lubricated fluoropolymer bearings have proven successful in thousands of such applications. With $PPSO_2$ improving wear resistance, dimensional stability and cold flow resistance, fluoropolymer bearings are ready to take on even more severe-service applications. ❑

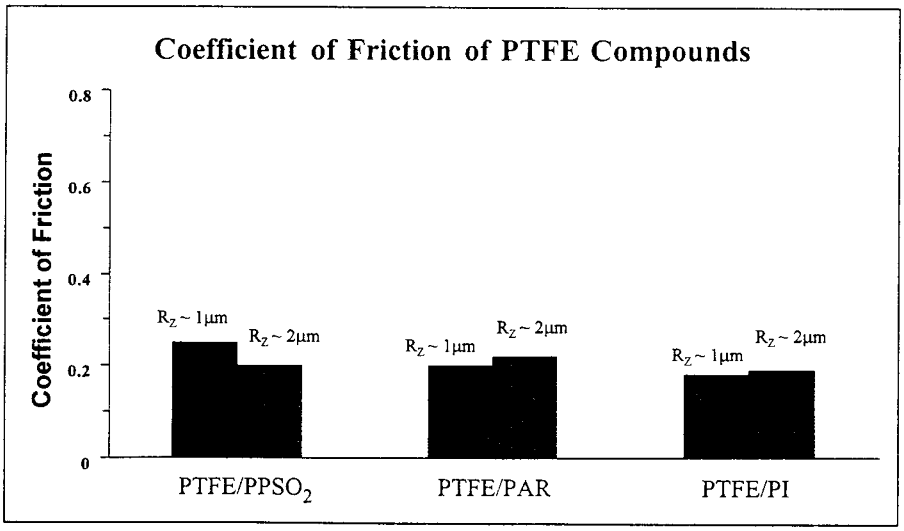
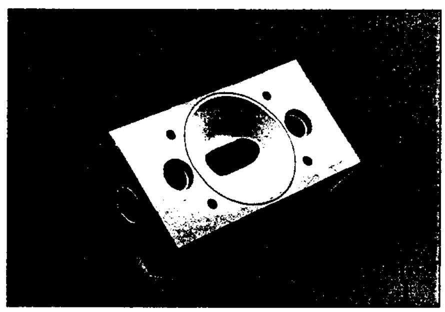


Figure 4 compares the coefficient of friction of PTFE filled with $PPSO_2$, PAR and PI.



A pump housing made of a fluorothermoplastic, reinforced with 30 percent $PPSO_2$, displays improved structural strength and chemical resistance. The additive enhanced hardness and yield strength of the housing.

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