Non-Metallic Bearings: An Alternative Worth Considering

ALT-MATERIAL BEARINGS NOW SUPPLYING BOTH MATURE AND NEW-GROWTH MARKETS, APPLICATIONS

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Bearings make the world go 'round. Much like gears, bearings are used in practically anything you can think of—from toys to titanic machinery and beyond. Another similarity to gears: they've been around since the beginning of recorded history, as Timken Process Industries' Steve Johnson, director–process technology, explains. (*Ed.'s note: Statements from Timken in this article pertain to rolling element bearings only—ball, cylindrical roller, spherical roller and tapered roller. Other friction management systems such as fluid film bearings, magnetic bearings etc., were not considered.*)

An SKF bearing cage produced with Victrex-supplied materials (courtesy Victrex).

"I believe the first non-metal bearings were wood. The ancient Egyptians/Greeks, etc., used wooden logs as simple roller bearings to move large objects. During the industrial revolution, early rolling element bearings were also wooden. In modern times, certainly low-cost plastic bearings have been used in toys, household appliances, etc., for many years."

So there you go—this article is a look at alternative-material, non-metal bearings, and it turns out the first bearings of that type—wood, in this case, were the norm—not an alternative.

But there are indeed alternatives out there today. We now have bearings made from—or coated with—ceramics, reinforced and non-reinforced polymers, carbons and graphite, for example, with other, next-generation engineered materials almost sure to follow. And given the ever-fluctuating cost, quality and availability of steel worldwide, it is no wonder that non-metallic bearings have made tremendous gains in many markets and applications.

"Full non-metal (ceramic) bearings are used in some space flight and semiconductor applications," says Johnson. "Metal bearings with non-metal components such as polymer cages or ceramic rollers are used extensively in markets such as rail, light-vehicle systems and machine tools. The use of hybrid ceramic bearings in high-speed machine tool spindles as the standard has occurred over the last 15 years or so."

Tom Miller, Igus Inc. bearings unit manager/North America, adds this:

"Plastic bearings can be used in many different industries and applications. Just some of the industries in which plastic bearings are being used include automotive, medical, food and drug, farming, solar, bikes, packaging, textile, offshore, marine, aerospace and office furniture.

"Over the past few decades, the applications for self-lubricating plastic bearings have become almost endless. Some design engineers do not believe plastic—a material that most people equate with a disposable commodity like a plastic fork or spoon—will deliver superior performance. If you are using high-performance plastic bearings, they can be used in almost any application—from packaging machines and medical equipment to environments with chemicals, extreme loads or high temperatures."

Looking at things from a leading material supplier's perspective, Victrex technical manager Patrick Clemensen adds, "The largest markets for non-metal bearings are automotive transmissions, followed by industrial pumps, compressors and material handling applications."

Speaking of automotive, one can safely assume that industry has been among the greatest consumers of bearings—of all kinds.

"The auto industry has driven the use of non-metal bearings in some of the largest volume applications," says Clemensen. "Victrex's PEEK material advantages in automotive applications include high resistance against aging and creeping at high operating temperatures and high circumferential speeds."

At Igus, Miller adds that "The automotive industry has certainly contributed to the increased use of self-lubricating plastic bearings, as they are an ideal choice for this sector. They are lightweight, dry-running, dirt and dust-resistant, maintenance-free and corrosion-resistant. Plastic bearings also deliver extremely quiet operation and eliminate vibration, which is a key concern for many operators. In many instances, plastic bearings are replacing metal roller bearings in axle journals and can be used in place of metal bearings in shock absorbers thanks to their low static and dynamic friction properties.

Alt-material NBR needle roller bearings (courtesy Victrex).

"Plastic bearings can be found in numerous automotive applications, including convertible tops, door hinges, seats, headrests, shock absorbers, brakes, control arms, windshield wipers, steering systems, foot pedals, gear boxes and engine compartments."

And while Timken's Johnson acknowledges there is "very limited (usage) in engine and driveline applications," he adds, "Polymer cages are used in several automotive applications. In addition, the increasing use of turbochargers and the drive to reduce turbo lag and increase operating pressure ratios for higher efficiency are driving a fundamental change in turbocharger bearings. The move is from fluid film bearings to rolling element bearings which are typically employing a hybrid ceramic solution—ceramic balls with high-temperature metal rings.

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Other major markets for non-metal bearings are toys, household products, the food industry, semi-conductors and computer equipment.

Says Victrex's Clemensen, "Besides automotive, other industries benefiting from (our) PEEK polymer bearings include aerospace/defense, food and beverage, material handling, recreational vehicles and the energy industry including oil, gas and wind energy."

So what are the benefits of alternative-material bearings over metal?

"There are benefits such as lower mass—which supports operating at higher speeds—chemically inert, high thermal stability, high strength, higher temperature performance and low friction," says Johnson. (*Ed.'s note: Please see sidebar for additional benefits.*)

But despite the increasingly widening use of alt-material bearings, the question must still be asked: What dictates whether to use metal or non-metal bearings in a given application?

"Application requirements such as load, speed, temperature, lubrication, weight etc.," says Johnson.

"There are many factors that contribute to choosing the right bearing for an application," Igus's Miller explains. "With the advancements in plastic materials over the past few decades, plastic bearings have proven to be a cost-effective, maintenance-free alternative for bronze and metal bearings. They can endure extreme temperatures, heavy loads and high speeds. However, it is important to understand both the advantages and disadvantages of the options available."

At Victrex, Clemensen points out that "High-corrosive environments require polymers such as the company's PEEK offering. In addition, if there is minimal lubrication, PEEK may be a better choice. Operating temperatures may limit the use of polymer bearings, but Victrex polymers can handle continuous-

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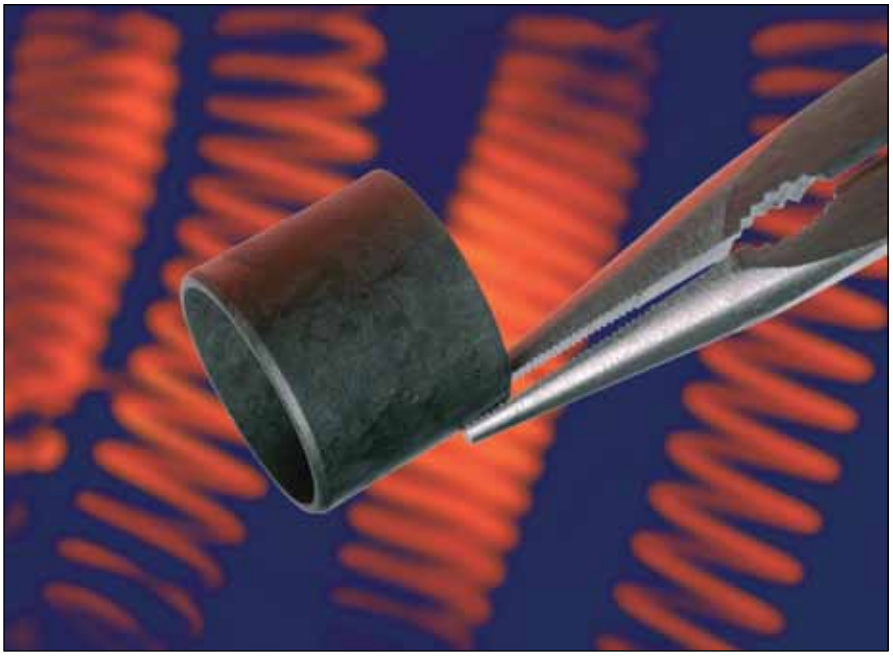
The Timken Company offers a variety of synthetic material bearings and bearings components (courtesy The Timken Company).



A high-temp, non-metal offering from Igus, Inc. (courtesy Igus, Inc.).

use temperatures up to 260° C," he says.

And then there are lubrication issues to address. But while proper lubrication is a must-have component of metallic bearings, its use in alt-material bearings is not as clear-cut. In many cases—while certainly not all—lubrication is not a factor with non-metallic bearings. Or, at minimum, synthetic bearings often provide a reduction in lubrication.

As Timken's Johnson explains, "Running hybrid bearings, i.e.—ceramic rolling elements with metal rings or full-ceramic bearings—can offer significant advantages in reducing/removing traditional lubrication requirements."

At Igus, Miller points out that "In most cases it is acceptable to use lubrication, as it does not affect plastic bearings. However, one of the major benefits of using self-lubricating bearings is the elimination of lubrication and maintenance. If lubricant is used, once it wears out, the self-lubricating properties of the plastic bearing will start working and transfer dry lubricant onto the shaft."

And if the bearings are full-polymer, such as, for example, Victrex's PEEK products, "Lubrication is not an issue for non-metal bearings," says Clemensen. "Polymers are typically better than metal in un-lubricated environments."

Predictive lifetime for alt-material bearings is another part of the mix. And as with their metal counterparts, it can get complicated, given the lack of international standards coupled with other factors, such as application and specification of synthetic to be used.

But in many cases, lifetime is determined "the same way as for metal bearings," says Johnson—"stress analysis of the application compared with strength and fatigue endurance limit of the material(s) being considered to predict system life."

At Victrex, "In lubricated environments we are comfortable looking at the PV and operating temperature," says Clemensen. "In un-lubricated environments we look at PV and wear factors."

But there can be major distinctions to be made, dependent once again on the application at hand and the synthetic specified for it.

"It is important not to confuse high-performance plastic bearings with plastic bearings from a local injection molder," says Miller. "With (Igus's) Iglide plastic plain bearings, you can accurately calculate the life of a bearing according to wear rates, actual testing results and specific application parameters.

"(We also) provide the Expert System—a complimentary database where users enter the maximum loads, speeds, temperatures and shaft and housing materials, which then prompts the system to calculate the appropriate plastic bearing and its expected lifetime based on decades of real-world testing."

As one might expect—at least for now—there are indeed limitations to when alt-material bearings may be used. Johnson points to "application, market requirements and regulation factors" such as extreme loading, temperature and dimensional stability as determinants in whether non-metallic materials may be safely used.

But conversely, in some cases, as Igus's Miller explains, "When using plastic bearings, some safety concerns can actually be eliminated. Since they do not require lubrication, there are less instances where a maintenance worker could be injured while re-lubricating a bearing system or taking apart a machine. Also, Igus offers decades of empirical test data that enables us to predict how it will perform

and if certain safety considerations need to be kept in mind."

Speaking of decades, one wonders how much time and R&D are required in developing these highly engineered materials.

"Developing a reliable, high-performance polymer material blend can take years of research and testing," says Miller.

Victrex's Clemensen offers that "Twelve to 24 months is typical to go from concept to production. Overall development time is dependent on design complexity, typical operating environment and the range of testing required for qualification. Our early involvement can reduce the application development time by sharing material test data, reviewing part and tooling designs before cutting, interpreting FEA/mold-filling results and referring experienced molding/machining sources."

Another question comes to mind—How "green" are non-metal bearings? The short answer—As green as they can be at this stage of development. They are, for the most part, a petroleum-based product. But advantages do exist.

"Some materials are low coefficient of friction, which reduces parasitic loss in mechanical systems and enhances energy efficiency," says Timken's Johnson. "In addition, certain material systems require less lubrication, which has a number of benefits in reducing the lubricant quantity as well as the size of the lubricant delivery system and resulting energy utilization."

And, Igus's Miller points out, "Self-lubricating plastic bearings do feature some 'green' attributes. Nearly every time plastics are mentioned, the fact that they are petroleum-based is brought up, but they still use considerably less oil to produce than steel or aluminum parts. Also, since they do not require external lubrication, they will not contaminate the environment when, for example, being used in farming equipment, lawn mowers or off-road vehicles."

So what's next for the alt-material bearings industry? Who can say for certain? But consider that in just the past 15 years or so, says Johnson, "The use of hybrid ceramic bearings in high-speed machine tool spindles (has become) the standard" material of choice. But, "Simple polymers only are applicable for very lightly loaded, low-speed, low-precision applications such as toys. This market is mature."

Yet on the other hand, he continues, "High-speed mechanical systems and turbo machines can benefit from the use of ceramics/hybrids. This will be driven by cultural acceptance in various markets (aerospace, for example) as well as ongoing improvements in the performance/cost equation that will result from volume increases, as has already been seen in the machine tool industry. For other applications, alternative material systems such as ceramics and reinforced polymers have niche applications based on product attributes, but there is no indication that any of these will make major inroads into the traditional metal bearing markets."

At Victrex, Clemensen states that "The wind turbine market is expected to grow significantly over the next decade, so this could fuel growth of non-metal bearings for longer life and lower maintenance. Aerospace engineers are also highly motivated to replace metal in order to hit weight-reduction goals, so this could increase the adoption of non-metal bearings in aircraft engines and mechanical actuators."

Why Use Alternative-Material Bearings?

There remains no doubt that in some cases, only metal bearings will do. But there are many exceptions. Among them are:

- **Cost**. Commodity-type plain bearings can reduce costs up to 25 percent and can replace more costly alternatives in a variety of applications.
- **Extended life.** Plastic bearings are designed to maintain a low coefficient of friction (COF) consistently over the lifetime of the bearing. Compared to metal-backed bearings, which can become scratched and increase the COF, plastic bearings often last longer.
- **Energy savings.** Reduced energy consumption via lighter weights and lower friction.
- **Maintenance-free.** Plastic plain bearings can replace bronze, metal-backed and custom injection-molded bearings in many applications and provide resistance to dirt, dust and chemicals.
- **Corrosion and chemical resistance.** Plastic bearings can be used in wash-down applications, salt water and harsh chemicals without compromising performance.

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