INTECH Power-Core™
Power of Knowledge Engineering®

2021
WHITE PAPER

Used for painting cars, Intech's Power-Core™ robotic arm provides electrical insulation for paint charged with 100,000 volts.

Make Your Machines Faster

A Component-Based Approach to Boosting Line Speeds

When it comes to the economics of production machines, faster is always better. Every minute that it runs, a fast machine produces more goods—and more profits—than an otherwise similar slow machine. So why don't you simply crank up the speed on your existing production lines or design faster, new machines?

The answer is that speed, for all its economic advantages, has some steep costs from an engineering perspective. Faster production lines typically suffer from resonance and vibration problems. These fast machines tend to operate close to the critical speed of gears and other moving components, and they may have more violent reciprocating movements as well. As a result, they experience more wear and need more aggressive maintenance and lubrication schedules.

What's more, the technologies that can boost line speed do not come cheap. Faster lines typically require higher-bandwidth controls as well as larger motors, actuators and gearboxes. The machine frame will likely have to be beefed up as well. While these infrastructure upgrades may well pay for themselves if line speeds improve profitability, they also require a significant amount of engineering effort.

There is, however, a simple way to improve line speeds. By upgrading motion components—such as cam followers, track rollers, gears, cams or linear actuators—you can improve the line speeds of many machines by typically 15 to 20 percent and sometimes more. In one case, we were even able to double the output of a caplet making machine.

While it's easy to overlook the contribution of individual machine components to line speeds, upgrading these components doesn't require huge capital expenditures associated with infrastructure upgrades.

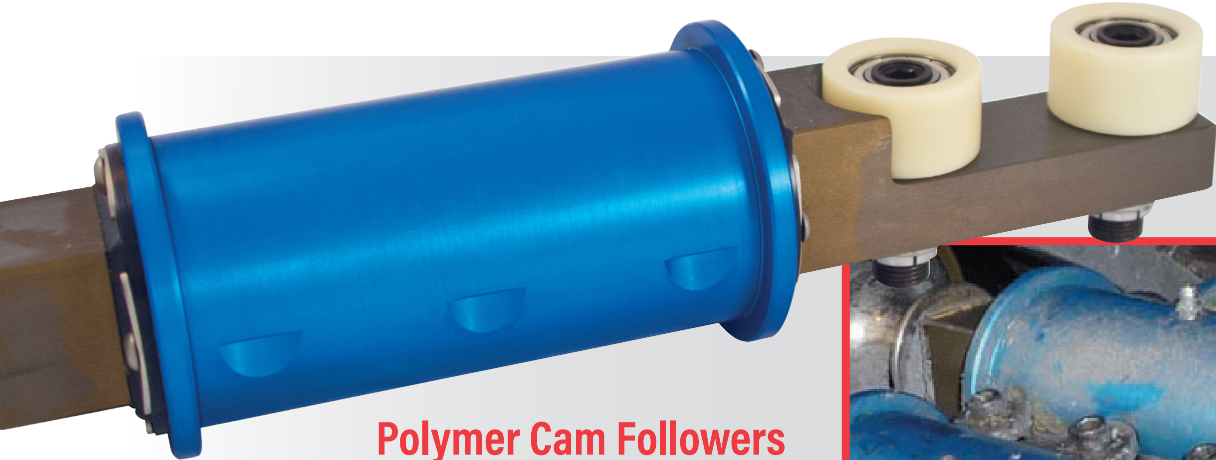
Not every cam follower, track roller or gear lends itself to speed. You'll need to pick components that offer reduced mass without sacrificing strength. You'll also want components that can resist abrasive wear without requiring excessive lubrication schedules.

Polymers Are Faster

One of the defining characteristics of advanced fast machines is that they tend to incorporate components made partially or entirely from high-tech polymers. When properly designed and made from the right material, polymer machine components weigh far less than comparable metal components. For example, our cam followers, which combine polymer-bearing surface with metal shafts and precision ball bearings, weigh about 40 percent less than all-metal cam followers of the same size. The weight savings reduces inertia, which, combined with low rolling resistance, allows for a more efficient high-speed operation. The same logic and weight savings applies to gears and track rollers too.

High-speed machines with all-metal components require continuous lubrication that's most often provided by central lubrication systems, oil-filled gearboxes or oil spray. An interruption of lubrication, like when a nozzle in a central lubrication system clogs, usually leads to catastrophic failure and downtime. Polymer machine components can solve the lubrication and wear problems and reduce attention to maintenance that's associated with metals. Wear and the resulting need to constantly provide lubrication slows down high-speed machines. Grease or oil can also contaminate the machine's final product, requiring product quarantine.

The best polymer motion components are typically made from self-lubricating materials so they eliminate the need for lubrication. They also resist various wear mechanisms—such as corrosive wear and galling—that affect metal machine components. The result is that polymer components can maintain smooth bearing surfaces over a long lifecycle.



Polymer Cam Followers Simplify Designs

The physical properties of polymer cam followers allowed us to simplify the design of high-speed rams*. When properly designed, polymer cam followers maintain full contact with the cam without the use of heavy springs in the rams they replace. Other benefits include greaseless operation, extended cam follower life and the elimination of cam wear. Low rolling resistance, along with lower weight, reduces drag and drive power requirements.

*See White Paper Redesign Improves High-Speed Can Making Machine on page 6.

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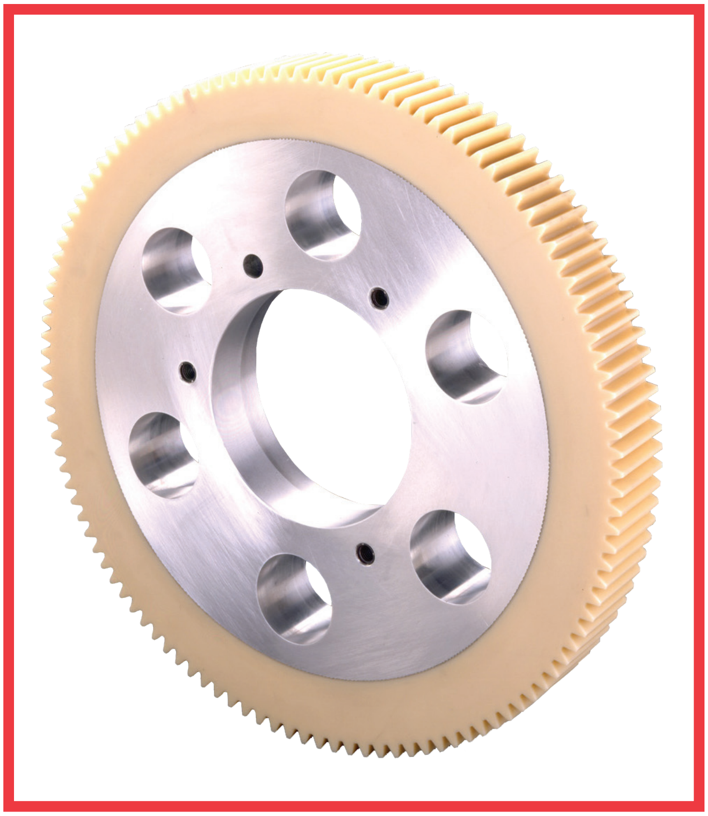

With an outside diameter of 19 inches, our 2.5-inch wide spur gear is the main drive of a diaper-making machine.

Keep in mind though that not all engineering polymers will perform equally in machine components. Some polymers lack the required tensile properties. Others can't meet the requirements for thermal, chemical or moisture resistance. Moisture, in particular, can be a problem since it's ubiquitous in many manufacturing locations, and it will cause most engineering polymers to lose tensile properties or change dimensions.

Making sure that your polymer machine components have the right properties for the job at hand is an essential ingredient for success. At Intech, we've found that a variety of polymers can make good motion components as long as the properties are carefully matched to the application requirement. So acetal, a go-to engineering polymer for gears and other motion components, can work well in many applications. We use it ourselves all the time. But if you want to push the performance envelope, you will need to consider other polymers.

How to Reduce Temperature Development in Polymer Gears

Temperature development is another important consideration that should be addressed in high-speed polymer gears. We've developed a three-step approach:

1. Design a low friction tooth form.
2. Design a gear blank with a large enough metal or aluminum core to dissipate the heat from the tooth mesh.
3. Use a metal or aluminum mating gear with a low-friction coating to reduce friction in the mesh and help dissipate the heat.

Our choice for the most demanding motion applications is Power-Core™, a material based on butadiene. It has a combination of physical and mechanical properties that makes it uniquely well-suited for use in motion components, particularly at high speeds:

- **Stability and Strength.** Power-Core maintains its tensile properties and dimensional stability in persistent humidity or even total immersion. By contrast, most engineering polymers absorb moisture. These hygroscopic polymers can weaken by up to 50 percent and no longer carry their design loads. Or they can swell by 3 percent or more, making them incompatible with any mating components.
- **No lubrication required.** Power-Core parts have self-lubricating properties and smooth machined surfaces so they eliminate the need for lubrication—and associated viscous drag.
- **Vibration damping.** Like many plastics, Power-Core offers inherent damping capabilities that metals won't provide. Unlike many plastics, Power-Core's damping capabilities reach their maximum point close to typical operating temperatures of high-speed manufacturing lines. The damping capabilities of plastics let polymer motion components reduce noise and vibration as line speeds increase.

Plastics Have Limits

There's a good reason metals still make up the majority of highly loaded gears, cam followers, track rollers and similar components. In these applications, even a well-designed plastic part of equal size may not offer enough structural strength to meet the application requirements.

While polymers and other composite materials don't have the tensile or compressive strength of metals, there are many applications where metal components are not used to their full load capacity. These applications are where polymers shine. They're lightweight, which means lower inertia, kinetic energy and forces, as well as a host of self-lubricating characteristics for reducing or eliminating lubrication and wear. Lightweight, low-friction components also help to reduce drive power requirements and energy cost.

To get the best of both worlds, we often take a hybrid approach that uses plastics and metals together—casting plastic bearing surfaces over structural steel or aluminum elements. For example, we can apply polymer-bearing surfaces over high-speed roller ball bearings, which is a natural fit for applications slowed down by the greased needle bearings used in most metal cam followers. We also employ metal shafts and gear hubs.

These hybrid systems do require some extra design attention. Using advanced stress analysis, we can determine the right ratio of plastic to metal. A well-designed component will take the best of what each type of material has to offer—structural strength from the metal, such as using metal core for safe gear attachment to a metal shaft, and beneficial surface properties from the polymer.

Analyze and Redesign

To calculate forces and simulate the resulting stresses in lightweight polymer components, it pays to understand the load characteristics of an entire system, bearing in mind that a plastic component the same size as the metal component it replaces may not carry the load.

When designing for higher speeds, you'll often need to meet the requirements of larger component sizes. As long as there's enough room, you can design a component to carry the load by increasing the width or outside diameter, for example.

Intech's composite cam followers and guide rollers combine a high-tech polymer tire with precision ball bearings. The use of polymers eliminates rail and cam wear, as well as the need for lubrication. In addition, the precision-machined polymer's outer race absorbs shock and vibration and makes these components significantly quieter than their all-metal counterparts.

Of course, gear tooth mesh and cam follower tire designs also play a crucial role. The design process requires close cooperation with the engineers in charge of designing the equipment.

One example involves a paint robot arm. For carrying the payload and evenly distributing the stresses throughout its 1000 mm length, we change the original 100 x 100 mm square aluminum tube cross section to a tapered shape with a 260 x 150 mm cross section at the wide end. The purpose of the change to plastic material was to provide electrical insulation to the robotic arm in the electrostatic paint process.

Another example is a 19 inch OD anti-backlash Power-Core gear in a diaper-making machine. This gear must withstand the forces associated with an e-stop, which is equivalent to the full torque of 10 HP motor for 30 ms, plus the shock load of the machine's gear train mass. Our calculations showed that if we increased the gear width from 2 to 2.5 inches, the gear would carry this high e-stop load. The increase in width was possible because the application had enough room on the drive end of the machine to accommodate the thicker gear.

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Maximizing Speed

Whether you have a new or existing production line, it turns out that metal motion components can impose speed limitations in four ways: metal components can limit motion systems by virtue of their sheer mass—heavier components have more inertia, lower critical RPM and require more force to accelerate. Metal components require lubrication, and worn components must be replaced, which often causes prolonged downtimes.

Finally, and most importantly, metal motion components have no damping capabilities. And many production lines can no longer meet increased production requirements due to problems with shock, vibration and noise.

With these limitations of metals in mind, here's a look at some examples that illustrate how plastic motion components helped increase the line speed of production lines:

- Metal cam followers, as well as the cams or rails they're running on, are subject to metal-on-metal wear. Over-greased needle bearings in metal cam followers can lead to skidding and extra wear. Cam followers on high-speed machines are often pressed against the cam with heavy spring loads to prevent skidding. High spring loads only accelerate both cam and cam follower wear. Fitted with pre-lubricated for life ball bearings, polymer cam followers eliminate the need for lubrication of both the bearing and the cam surface. And when properly designed, they maintain full contact with the cam without any springs, simplifying design. Most importantly, they don't wear the cam surface, preventing costly downtimes.
- Making gears out of maintenance-free polymers—which can be up to seven times lighter than metal— eliminates vibration from same-size metal gears, increasing both RPM and machine output. In the case of a caplet-making machine, we replaced a heavy 3.5 inch-wide cast iron gear with an outside diameter of 17 inches and weighing about 170 pounds, with a Power-Core gear containing a metal hub that weighs less than 40 pounds. This increased the machine output from 400 to 800 cpm. The customer came to us with the request to eliminate grease in the caplet production and ended up with a machine that produced double the output of prevailing industry standards. Polymer components often produce unexpected benefits.

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Power-Core™ Gear Calculations

Power-Core gears often serve as lubrication-free replacements for metal gears, but only after an extensive design process. Here's an overview of the gear calculation process we use to design polymer gearing that will last.

CRUNCH THE NUMBERS

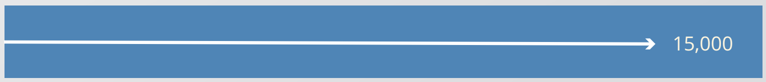
We start with more than 20 different gear design parameters, including the dimensional, operational and tooth modification data. We use that info for a complex lifecycle simulation that we've validated against hundreds of real-world applications.

Application Data	
No. of teeth pinion (STEEL)	z_1 = 118
No. of teeth gear (Power-Core)	z_2 = 118
Face width	b, in, = 2.500
Diametral Pitch	NDP = 6.2832
Circular Pitch	CP, in. = 0.5000
Nominal center distance	ao, in. = 18.7803
Operational center distance	a_1, in. = 18.7803
Transm. ratio	i = 1.00
Torque Pinion shaft	T_1, lbf, in = 5044.1
Torque Gear shaft	T_2, lbf, in. = 5044.1
Pitch line velocity	V, m/sec = 3.12
Normal PA	α, deg = 20.00
Normal Operating PA	αw, deg = 20.0000
Contact ratio	εa = 1.87

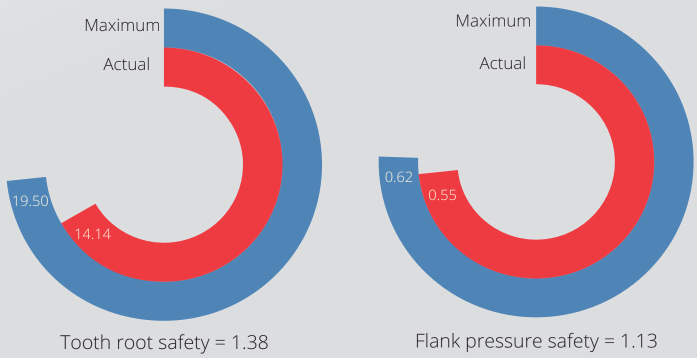
GET RESULTS

Our lifecycle simulation yields a reliable prediction of gear life, as well as detailed information about gear geometry, tooth loads and safety factors. For continuous operation, we recommend tooth root and flank pressure safety factors above one.

Predicted Safe Life (hours)

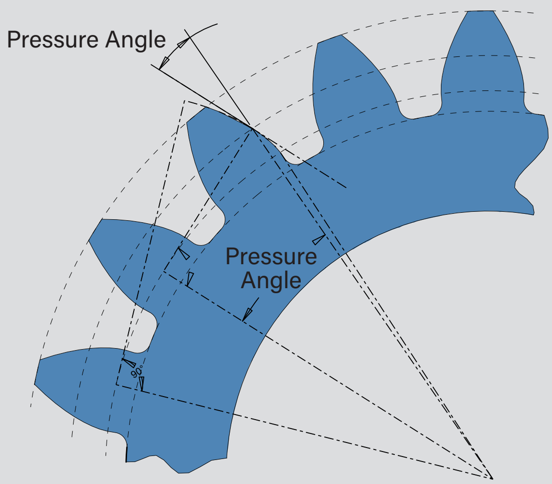


Gear Tooth Root Stresses (N/mm2) | Gear Flank Pressure (N/mm2)



OPTIMIZE TOOTH FLANK WEAR

Flank pressure is an important indicator of wear in plastic gears without lubrication. Using the life cycle simulation, we can optimize the safety factors, such as the Tooth Root Stress and Flank Pressure *(See Get Results above)*–for example, by increasing the gear's width or by tooth profile modification. One such modification is increasing the pressure angle from 20 to 23.5 degrees, for example. The resulting tooth form helps to reduce friction, heat development and wear in the tooth flank. Additionally, the tooth root width is increased, reducing the tooth root stress.



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About Intech

Intech Corporation specializes in the design and manufacture of lightweight, robust, low-noise machine components that eliminate the need for lubrication. Our self-lubricating products include gears, guide rollers, cam followers and custom-designed motion components. To meet your application requirements, we employ a variety of advanced polymers, low friction coatings, metal alloys, or polymer-metal hybrid structures. We have pioneered many design solutions and support each design with advanced durability calculations, including stress simulations.

For more detailed information on our engineering capabilities, check out our latest white papers and case studies.

Durable, Self-Lubricating Polymer Bearing Surface Excels in Motion Systems

Polymer-based hybrid track roller design overcomes the pitfalls of traditional metals and plastics in motion systems

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Redesign Improves High-Speed Can Making Machine

Solving a costly lubrication problem triggers unexpected productivity improvements

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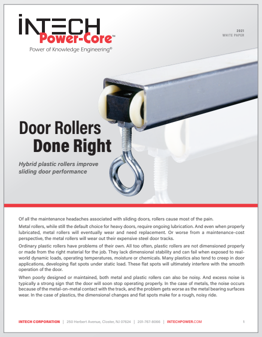

Door Rollers Done Right

Hybrid plastic rollers improve sliding door performance

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Make Your Machines Faster

A component-based approach to boosting line speeds

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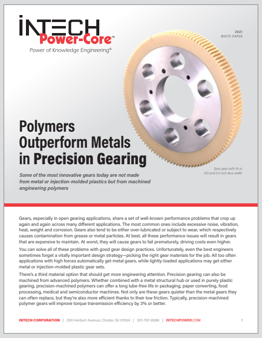

Polymers Outperform Metals in Precision Gearing

Some of the most innovative gears today are made from machined engineering polymers rather than metal or injection-molded plastics

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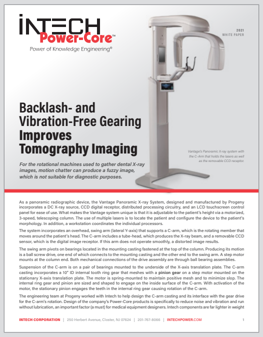

Backlash- and Vibration-Free Gearing Improves Tomography Imaging

For rotational machines used to gather dental X-ray images, motion chatter can produce a fuzzy image unsuitable for diagnostic purposes

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