

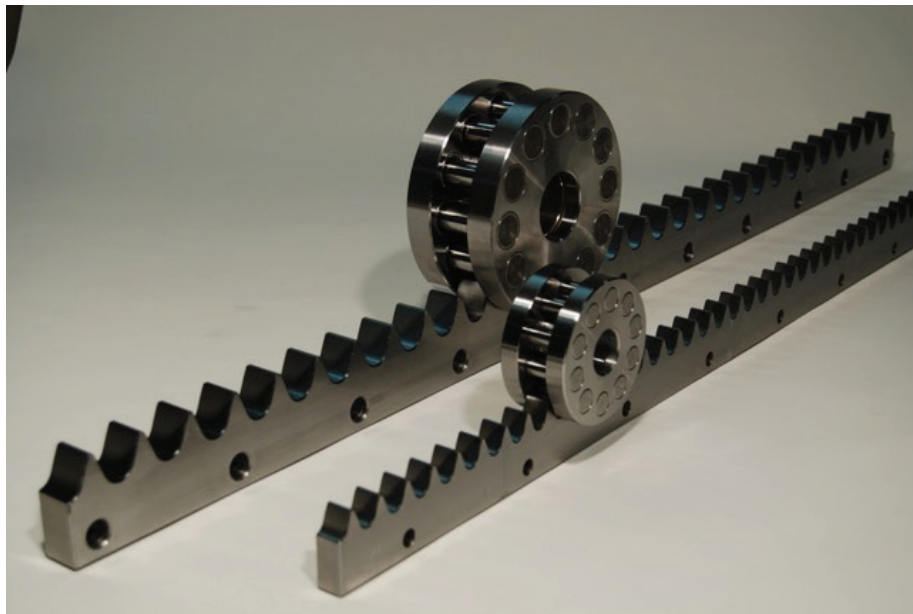
NEXEN WHITEPAPER

Roller Pinion System

Overcoming the Limitations of Traditional Linear Motion Technologies

Machinery engineers have many options for moving tools or parts in a straight line. These include belts, ballscrews, linear motors, conventional rack-and-pinion systems, and the latest technology—roller pinion systems.

A belt-driven system consists of a belt stretched around two pulleys of equal diameter. The pulleys are located at either end of the actuator. One pulley, the driver, is coupled to a servomotor. The other pulley, the idler, is unpowered. The carriage is attached directly to the belt and is supported by linear bearings. For applications requiring fast speeds, long travel lengths and high duty cycles, belt-driven linear positioning systems are an inexpensive option.



The Roller Pinion System advances the traditional rack-and-pinion concept by replacing the spur gear teeth with bearing-supported rollers that engage a unique tooth profile in the rack.

However, belt-driven systems have significant drawbacks. This technology works best in applications that require good repeatability, but not necessarily good accuracy. While the accuracy of a screw-driven system can be stated as, say, 1 millimeter per meter traveled, the same can't be said of belt-driven systems. Too many factors affect their accuracy, such as belt stretch or pulley alignment. Because maintaining belt tension is critical to ensure the transfer of torque, re-tensioning the belt is necessary at regular intervals. Belts are susceptible to shock loads, so very thick belts are needed for high-load or high-thrust applications. Travel length is limited with belt drives, too. Most are limited to about 14 meters. Finally, belt-driven systems cannot be used in vertical systems without a brake on the support rails, since the load could free fall if the belt breaks or if there's a power loss.

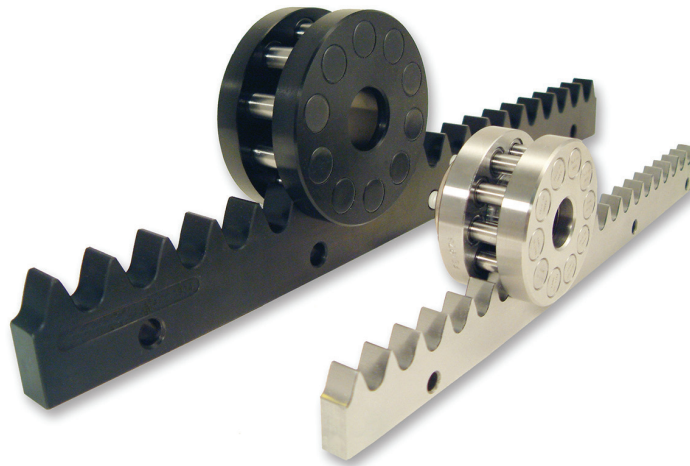
A ballscrew-driven system consists of a shaft and a nut, both of which have concave helical threads. Ball bearings ride between the screw and the nut in a recirculating raceway. The nut is attached to the carriage, which is supported by linear bearings. Bearings also support each end of the screw. Ballscrew-driven systems are fast, accurate and efficient.

However, ballscrew-driven systems have disadvantages, too. For one, back-driving can be an issue, especially if the ballscrew is in a vertical position. If the ballscrew is not held properly, the load could drop quickly. Travel length with ballscrews is limited to approximately 6 meters. Moreover, engineers must compromise between speed and travel length. To prevent the screw whipping like a jump rope, speed must decrease as travel length increases, or the screw diameter must be significantly increased. Ballscrews also require more frequent lubrication, and they can be compromised by contamination. Finally, ballscrews do exhibit a small amount of backlash (relative axial motion between the screw and the nut when the motor isn't turning). If ballscrews are preloaded to remove backlash, that increases wear on the screw and also decreases its efficiency.

A linear motor is like a rotary motor, except that the stator and rotor have been cut along a radial plane and unrolled. The two main parts of a linear motor are the primary and the secondary. The primary contains the motor windings. The secondary contains the steel and permanent magnets. In most cases, the secondary is fixed to the machine, while the primary is the part that moves, supported by linear bearings. Linear motors produce fast speeds, quick accelerations and high accuracies.

Linear motor systems are not without disadvantages. First, linear motors are the priciest option for linear motion, due to the high cost of rare earth magnets and sophisticated sensors and controls. That can make long travel lengths prohibitively expensive. Lead times can be long, due to the limited availability of rare earth elements. Another issue is that linear motors do not readily dissipate heat, so cooling may be necessary to maintain an acceptable operating temperature. Space can be an issue. Linear motors are fast, but they don't produce a lot of force for their size. Linear motor systems have no minimal friction. That's great for high speeds, but if there's a power loss, the carriage can reach the end of the line in a hurry. Thus, linear motors are not suitable for vertical lifting applications without external braking, such as profile rail brakes.

A less-expensive alternative for longer-length linear motion applications is a conventional rack-and-pinion system. Like ballscrews or belt drives, rack-and-pinion systems convert rotary motion into linear motion. The rack is a straight bar with teeth cut across it. The teeth are flat-sided and helical. The pinion is a round gear with mating teeth. If the motor is held in place, rotating the pinion moves the rack side to side. If the rack is fixed, rotating the pinion will move the motor (and carriage) up and down the rack.



Unlike belts and ballscrews, the Roller Pinion System can be implemented in any length.

But, conventional rack-and-pinion systems are not without flaws. The biggest is backlash. A small amount of clearance must be maintained between the pinion and the rack. While this clearance can be kept to a minimum (0.001 to 0.002 inch) over short travel lengths, the clearance required to maintain accurate positioning over great lengths makes conventional rack-and-pinion systems difficult and expensive to make and install. To reduce backlash, it's possible to use two preloaded pinions or an additional servo drive. However, this adds complexity and cost. In addition, the two pinions or drives work against each other, which reduces load capacity and increases wear. Maintaining clearance between the pinion and rack leads to other problems, too, such as vibration, noise and particulate generation caused by the teeth slapping into each other. Finally, conventional rack-and-pinion systems are prone to jamming, when a pinion tooth pushes off one side of a rack tooth and moves into the side of the following tooth.

A New Technology

Nexen's Roller Pinion System is a new, patented linear drive concept that combines the best attributes of existing technologies while eliminating most of their shortcomings.

Like belt-drives and ballscrews, the Roller Pinion System converts rotary motion into linear motion. The system advances the traditional rack-and-pinion concept by replacing the spur gear teeth with bearing-supported rollers that engage a unique tooth profile in the rack. Instead of the sliding friction of traditional rack and pinion systems, the rollers provide smooth rolling friction that converts rotary motion to linear motion with 99 percent efficiency.

The tooth profile of the rack causes the rollers to be loaded in opposition, which eliminates backlash. With this very precise meshing geometry, each roller glides smoothly into the tooth face following a tangent path. The roller does not slap into the teeth, so there's no noise, vibration or tooth fatigue due to tooth slap. In addition, the Roller Pinion System provides very high positional accuracy, virtually no cumulative error, low-velocity ripple, very high speeds, high rigidity, low maintenance, corrosion resistance and long life. Some grades can be run lubrication-free. Jams are not an issue because the pinion rollers simultaneously engage several tooth flanks in opposing directions.

Unlike belts and ballscrews, the Roller Pinion System can be implemented in any length. Depending on the model, racks are available in standard lengths of up to 1,000 millimeters. These standard lengths can be combined (using Nexen's RPS alignment tool) or cut to create any desired length. That makes Roller Pinion Systems much less expensive than linear motors for long-length applications. And, with a maximum speed of 11 meters per second, Roller Pinion Systems are faster than either belts or ballscrews and only marginally slower than linear motors.

Like any rack-and-pinion application, the rack in the Roller Pinion System is mounted to a flat surface, while the motor and pinion are attached to the carriage. As the motor turns the pinion and the rollers engage the teeth, the carriage is propelled up and down the rack.

Roller Pinion Systems have myriad applications in industrial machinery.

For example, Lumco Manufacturing Co. of Lum, MI, recently integrated the Roller Pinion System into a custom machine for drilling and cutting aluminum. The Roller Pinion System moves a drill head along a 16-foot track at speeds of up to 2 feet per second. Traditional linear motion systems wouldn't work in this application. A ballscrew wasn't feasible due to the length of travel needed, and a belt drive lacked the necessary accuracy. The Roller Pinion System met the application's load, speed and accuracy requirements. And, it is powerful and durable enough to move the drill head through all the aluminum chips that collect at the bottom of the machine.



Lumco Manufacturing Co. integrated Nexen's Roller Pinion System into a custom machine for drilling and cutting aluminum. The Roller Pinion System moves a drill head along a 16-foot track at speeds of up to 2 feet per second.

Kern Laser Systems of Wadena, MN, uses the Roller Pinion System in its line of large-format laser cutting and engraving machines. The work area on these machines can be as long as 10 or 12 feet. A ballscrew was not an option for moving the laser up and down the bed. It would sag. The Roller Pinion System provides stiff, precise positioning.

Roller Pinion Options

The Roller Pinion System features six rack models to meet a wide variety of application needs. Five are made of steel. One is made of thermoplastic. Maximum speeds for the steel racks range from 4 to 11 meters per second. Maximum speed for the thermoplastic rack is 2 meters per second.

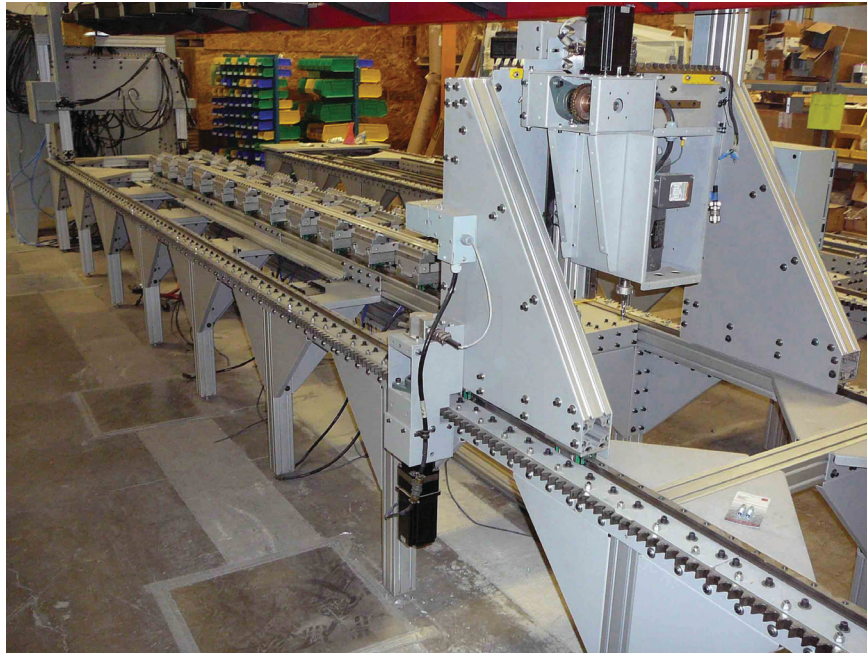
The Premium rack offers the highest positional accuracy (± 30 microns), the highest repeatability (± 5 microns), and a high load capacity. With a hard chrome coating, it resists corrosion and is suitable for dirty environments. It can run without lubrication if the speed is less than 30 meters per minute. Standard lengths range from 224 to 1,000 millimeters. The Premium rack is ideal for precision assembly equipment, machine tools, CNC mills, high-precision gantries and robotics.

The Standard rack offers similar performance to the Premium rack, but lacks the corrosion-resistant coating. With slightly lower accuracy (± 50 microns) and repeatability (± 10 microns), the Standard rack still delivers dependable performance in many of the same applications as the Premium rack, but at a lower cost. Standard lengths range from 500 to 1,000 millimeters.

The Endurance rack is the workhorse of the product line, combining both high load capacity and good corrosion resistance. It has a nitride finish and can run without lubrication if the speed is less than 30 meters per minute. Standard length is 1,000 millimeters. It has a positional accuracy of ± 80 microns and repeatability of ± 20 microns. The Endurance rack is suitable for general assembly equipment, machine tools and gantry systems.

With better accuracy (± 50 microns) and repeatability (± 10 microns) than the Endurance rack, the Universal rack is a great option for lower load applications when corrosion resistance is not required. Standard lengths range from 500 to 1,000 millimeters. The Universal rack is appropriate for material handling equipment, gantry systems, packaging equipment and general motion control applications.

The Universal Stainless rack offers the same performance as the Universal rack, but with the added benefit of corrosion resistance. It is available in uncoated stainless steel or stainless steel with a thin, dense hard chrome coating. Standard lengths range from 300 to 1,000 millimeters.



With a maximum speed of 11 meters per second, Roller Pinion Systems are faster than either belts or ballscrews.

Made from a self-lubricating thermoplastic, the Versa rack can go places no other racks can go. It's great in dirty environments, clean rooms, or food and pharmaceutical production, since it can operate without lubrication. Standard lengths are 992 and 1,000 millimeters. It has a positional accuracy of ± 500 or 580 microns, depending on the pinion, and repeatability of ± 20 microns. Backlash is less than 3.2 microns.

Two pinions are available: the Premium and the Value. The Premium pinion offers very high precision and high torque capacity. The pinion can be made from alloy steel with a thin, dense hard chrome coating; alloy steel with nickel plating; or stainless steel, with or without a hard chrome coating. The Premium pinion comes in eight sizes, ranging from 10 to 14 rollers. Distance per revolution ranges from 100 to 560 millimeters, and maximum speed ranges from 643 to 1,820 rpm. The Premium pinion comes in shaft coupling and flange mounting versions.

The Value pinion is suitable for lighter load and general accuracy applications. Made from aluminum, it can be used in harsh environments. It comes in three sizes, each of which has 10 rollers. Distance per revolution ranges from 160 to 250 millimeters, and maximum speed ranges from 480 to 750 rpm. The mounting style is shaft and keyway.

Flange-mounted Premium pinions can be paired with a Pinion Preloader for easy integration into a machine. Preloaders feature an adjuster that allows the pinion to be moved up or down into the rack while keeping the pinion properly oriented to the rack. The pilot in the adjuster plate accommodates common servo gearhead sizes.

For more information on the Roller Pinion System, call the Nexen Group 800-843-7445 or visit www.nexengroup.com.