NEXEN WHITEPAPER

Roller Pinion System
An Alternative to Traditional Linear Drive Systems

Introduction

Competitive market pressures are pushing machine builders to design machines that are faster, more precise, and require less maintenance so they are more productive for their end users. In pursuit of these goals, more servo controlled linear drive systems are being employed.

Linear drives are based several common technologies like ball screws, rack and pinion, belt drives, and linear motors. Each of these technologies have their strengths and weaknesses making none of them ideal for all applications due to shortcomings like backlash, low rigidity, cumulative error, thermal creep, limited length, low speeds, low force capability, vibration, noise, particle emissions, high maintenance, low life, and high cost\(^1\).

To address these linear drive systems limitations Nexen introduced the Roller Pinion System, a new, patented linear drive concept that combines the best attributes of the existing technologies while eliminating most of their shortcomings.


The Nexen Roller Pinion System (RPS) takes the traditional rack and pinion concept and advances it by replacing spur gear teeth with bearing supported rollers that engage a unique rack tooth profile. The bearing supported rollers eliminate the sliding friction of traditional rack and pinion with smooth rolling friction that give a 99% efficient rotary to linear motion conversion.

The above illustrations show rack tooth profile development.

In figure 1, the initial cord is drawn as the circle rolls forward and point P rotates to point P'.

Figure 2 shows several evenly spaced points going through the same process and developing basic tooth profiles.

In figure 3, the point is replaced with a roller modifying the tooth profile.

In figure 4, a further modification of the tooth profile causes the rollers to be loaded in opposition eliminating the backlash. With this meshing geometry, the roller glides into the tooth face following a tangent path resulting in no tooth slap that generates noise, vibration or tooth fatigue -- unlike traditional rack and pinion.
Positional Accuracy

The RPS rack uses a modular concept with only two standard factory lengths per size that are joined to create runs of any length. Full lengths are around one meter in length and half-lengths around ½ meter in length depending on tooth pitch. Shorter rack segments can be made by cutting the rack.

To transfer the positional accuracy to the following rack segments, a special tool was developed that uses the rack tooth profile to set the rack spacing rather than simply butting racks end to end. The alignment tool uses two teeth on each rack averaging out some of the transferred error. This small transferred error is ± each time and statistically trends to zero, so an infinitely long run would, in theory, have zero cumulative error. This allows runs of virtually any length without loss of system accuracy. In many cases, a linear encoder is no longer needed and the servo encoder can be relied on reducing cost and complexity.

This graph shows the positional accuracy based on very precise linear encoder and rotary encoder on the pinion shaft.

Looking at the wave pattern you will see individual spikes representative of individual pin and rack meshing error and a general periodic wave pattern representing the error in the pinion body that repeats with each revolution. As you can see, the error bar lines are horizontal showing no cumulative error. This would continue throughout any individual rack segment or run length.
The rack and pinion body are made from carbon steel. The rack teeth are heat treated to make an exceptionally wear resistant, long lasting product. In many applications, liquids and corrosive materials would pose a problem for an unprotected steel product. Stainless steel is not a viable option since it has less strength, and would compromise RPS performance.

Due to extremely tight manufacturing tolerances the RPS requires a coating that does not build up on the surface, or could quickly wear away. As a result, the RPS uses a protective surface treatment called Raydent. The Raydent surface treatment is a cryogenic process that permeates the metal surface and molecularly bonds with the steel forming a ceramic chrome layer while causing minimal surface buildup. It is extremely durable and highly resistant to acids, alkalis, and various solvents. It will not flake or rust if scratched. If a thin piece of metal is treated with Raydent and then sharply bent in half the coating will not be compromised.

This graph illustrates repeated returns to the same locations from one direction and both directions. As you can see repeatability from one direction is better than 2.6 μm and from both directions better than 5.8 μm. The difference between these two numbers is the backlash in the system and is less than 3.2 μm. This will hold true over virtually any length run.

**Speed**

The RPS system is capable of speeds up to 11 meters (36.1 ft) per second making it the fastest mechanical linear drive system second only to linear motors. Even at these speeds, the extremely-low friction design creates minimal heat and wear on components.

**Durability**

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Due to the smooth way the rollers engage the rack teeth the RPS system generates very low noise and vibration. It does not suffer from the noise caused by tooth slap or recirculating balls that other linear drive systems have. The system is whisper quiet at low speeds and less than 75 db at full speed. Typically, the guiding system, servomotor, and reducer generate more noise than the RPS system. Less noise and vibration is always desirable since it reduces inaccuracy in precision sensors and encoders and creates a better working environment for personnel who may have to work near the machinery.

<table>
<thead>
<tr>
<th>Noise</th>
<th>Average Decibels (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whisper</td>
<td>30</td>
</tr>
<tr>
<td>Average home noise</td>
<td>40</td>
</tr>
<tr>
<td>Normal conversation</td>
<td>60</td>
</tr>
<tr>
<td>Office noise</td>
<td>70</td>
</tr>
<tr>
<td>Average radio</td>
<td>75</td>
</tr>
<tr>
<td>Heavy traffic</td>
<td>80-89</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>96-100</td>
</tr>
<tr>
<td>Chainsaw</td>
<td>106-115</td>
</tr>
<tr>
<td>Gun shot</td>
<td>140</td>
</tr>
</tbody>
</table>

Source: WebMD.com

The RPS system is low maintenance while providing a very long life. The pinion consists of 10 or 12 needle-bearing, supported rollers that are sealed and lubricated for life and is therefore maintenance free. The rack is lubricated with a high performance light grease at installation and then every six months or 2 million pinion revolutions. In special applications the RPS system can be run lubrication free as long as the speed is less than 30 m/min. Other mechanical linear drive systems require more frequent lubrication or maintenance. Only a linear motor requires less.

Since the lubrication requirements are very low or nonexistent, the RPS system has very low particle emissions making it ideal for applications such as clean rooms, food processing, coating operations and pharmaceutical production. Even with very low maintenance the RPS system provides 60,000,000 pinion revolutions of life at its rated performance. That’s 9.6 – 28.8 million meters (3.2 – 95.5 million feet) when properly installed and maintained! The RPS system continues to operate beyond this point with diminishing accuracy.

No lubrication can also be very beneficial in dirty applications such as cutting, milling and routing. Contaminants are less likely to stick to the rack, reducing the creation of an abrasive paste that accelerates wear in mechanical systems.
Many linear drive technologies are sized by starting with a life consideration with the product size increasing with the life requirements. The RPS system selection process does not take life into consideration and is primarily based on load. No other mechanical linear drive system comes close to this performance and is only exceeded by a linear motor.

**Installation**

Installing the RPS system is comparable to the installation of precision profile guide rails. The rack should be placed on a step in the machine bed to provide full bottom support and a back plane for bolting it in place and to ensure straightness especially when joining rack sections.

Once the pinion is mounted, and its axis is properly positioned parallel to the rack tooth faces and fully engaged in the rack, a small preload is applied to take up the clearance in the pinion roller bearings. A high degree of rack mounting surface flatness is desirable, but more important is the parallelism between the guiding system and the RPS so pinion preload is neither lost nor becomes excessive.

**Summary**

Nexen’s Roller Pinon System offers a new linear drive solution that combines the best features of traditional linear drive systems like ball screws, rack and pinion, belt drives and linear motors while eliminating many of their short comings. The RPS provides high positional accuracy, speed, rigidity and life.

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**About Nexen**

Nexen is a leading manufacturer of brakes, clutches, linear motion control devices, torque limiters, and web tension control systems for a variety of industrial applications ranging from motion control and robotics to packaging and material handling. With headquarters in Vadnais Heights, Minn., Nexen has sales offices and distributor sales outlets throughout the world.