Rack and pinion Drives

What do today's motion system designers need to know about rack and pinion drives? Where are they best employed, and what are their strengths and shortfalls? See what industry gurus have to say about the modern day version of this age-old drive technology.

» R&P basics

How do rack and pinion drives contribute to productivity?

John • Atlanta: By allowing machines to run faster, rack and pinion drives increase throughput and efficiency. The quicker a machine can process a part, the sooner it can begin working on the next one, and the one after that. Helical rack and pinion drives, which have teeth at a slight angle across the face width, can handle very high linear speeds. This can be useful on production machinery to reduce time between cycles, or the time it takes a machine to return "home." Helical drive systems also provide smooth operation, which can produce better products.

Al • Nexen: Rack and pinion is a tried and true technology that offers reasonable performance over unlimited distances at a modest cost. It is limited, however, when it comes to accuracy, backlash, noise, and vibration; tooth fatigue, maintenance demands, and particle emissions present other issues. Using split or dual pinion systems can work around some of the issues, but these fixes drive up system cost and aggravate the other problems. A better solution, one that addresses the issues head on, replaces the traditional spur or helical toothed pinion with a rotary drive element consisting of bearing-supported rollers that engage a linear rack with a modified tooth profile. The roller pinion system thus formed operates with no mechanical clearance and ensures that two or more rollers are always loaded in opposition to eliminate backlash. And by minimizing friction, it converts rotary to linear motion with greater than 99% efficiency.

David • Andantex: Two words explain how rack and pinion drive systems contribute to productivity — speed and precision. Rack and pinion drives can reach linear speeds of 1,000 ft/min. with simple grease lubrication and this speed can be maintained over any axis length. Racks and pinions come in different materials and quality levels, offering an optimum balance of power, precision, and price for most applications. A complete drive system consists of a rack and pinion, speed reducer, servomotor, and an automatic lubrication system that extends rack life. Since more racks can be added to an existing axis, this modular design allows for simple changes in machine lengths and configurations.

For systems requiring zero backlash, drive gears must be mechanically or electrically preloaded. Achieving precision, in general, demands high stiffness, which minimizes torsional and radial pinion deflections as well as subsequent position errors and vibration. The optimum solution is to cut the pinion into the motor shaft, creating a solid drive element. This allows for the smallest pinion pitch diameter while providing maximum stiffness and minimum deflection.

Mike • Bosch: Rack and pinion drives come in a variety of materials, tooth arrangements and pitch types (including metric), and modular packages. One of the most common

types uses helical teeth to transmit high thrust forces with relatively low noise. Rack and pinion drives are typically used in applications that require long stroke lengths and high speeds. Ball rail linear guides are the primary choice for linear guidance where and when it's required. Lubrication is typically performed by a matched felt pinion, in which grease is metered through the felt and laid down on the gears.

» Good ideas

What's your best advice on specifying, sizing, and applying rack and pinion drives where productivity is the main goal?

John • Atlanta:

- Match the quality level of the rack to the application: Use a soft rack for light loads, medium accuracy; a quenched and tempered rack for medium loads, medium accuracy; an induction-hardened rack for heavy loads, low accuracy; and a hardened and ground rack for heavy loads, high accuracy.
- For high-speed applications requiring smooth and quiet operation, use helical rack and pinion drives.
- Size the rack and pinion drive based on peak cycle forces.
- Use an automatic lubrication system with felt gear applicator to maintain gearing quality and longevity.
- For smooth, accurate operation, use an integrated rack that mounts directly to a linear guide and eliminates the need for separate alignment.
- To remove backlash and produce higher quality products, use a preloaded system consisting of a hardened, ground rack and split-pinion and servo-worm reducer.

Al • Nexen: Roller pinion systems are specified primarily on thrust, making sizing relatively easy.

For a given size, there's only one pitch; teeth and rollers are large and strong, and by their meshing action, provide high precision. Roller pinion systems also eliminate lifetime considerations and the tradeoff between lifetime and size. Besides thrust and length, the only other design decision is which of two positional accuracies to use and whether or not to include a corrosion-resistant surface treatment.

David • Andantex: Productivity is maximized when components do not fail, so it's critical to spend time developing the motion requirements:

1. Mass to be moved
2. Motion orientation — vertical or horizontal
3. Acceleration rate
4. Coefficient of friction (linear guides with rolling elements, box ways, hydrostatic ways)
5. Maximum linear speed
6. Move profile — acceleration + constant running speed + deceleration
7. Move type — pick and place or working while moving
8. External forces such as cutting force on a machine tool

It's also important to determine axis position, repeatability, and accuracy requirements. Provide the above data to a rack solution supplier along with the life requested for the application, and the correct module or pitch rack can be selected along with reducer type and precision. The motor should be sized by working from the rack and pinion backwards through the reducer to the motor shaft. It's not good practice to start with a motor and then size the rack, as this can result in a rack that's oversized for the requirement or a system unable to move the mass.

Mike•Bosch: Don't forget the guide. When sizing a rack and pinion application, the guide mechanism should be properly sized as well. Load, speed, and lubrication intervals need to be considered for both the rack drive and guide mechanism. Rack and pinion drives can exert high lateral forces on the linear guide mechanism they are paired with. It's important to understand and calculate these forces in order to size the linear guide mechanism appropriately and avoid early failure.

» Don't go there

What's can happen if a rack and pinion drive is not specified or installed correctly?

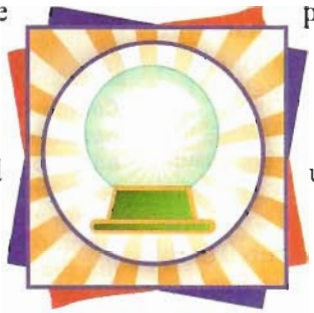
John•Atlanta: Most people don't realize just how critical lubrication is. Typically, gear drives are enclosed in a housing with an oil bath that provides continuous lubrication, but rack and pinion drives are open gearing and therefore need more attention to lubrication. Lubrication of rack and pinions is traditionally done manually, which can lead to problems if not done consistently or often enough.

If a thin film of grease or oil is not present on the tooth flanks when transmitting load, metal-to-metal contact can quickly lead to damage and/or failure of the tooth surface. Over time, this damage can cause complete drive failure. A brush can

Shown here is a classic example of a scoring failure, which occurs when there's not enough lubrication to create a film between the teeth of the rack and pinion. Careful!

be used to apply grease to the tooth flanks, but by far the best lubrication method is the use of a felt gear. These gears mesh with either the pinion or the rack and provide continuous lubrication to the tooth flanks.

Al • Nexen: Roller pinion systems are slightly more challenging to install than traditional rack and pinion since it operates with no mechanical clearance and requires a small pinion preload. Parallelism between the guiding system and rack is critical. If they diverge, the pinion preload will be lost, causing inaccuracy, backlash, and shorter system life. If they converge, on the other hand, the pinion needle bearing will wear out faster and the system might even bind.



David • Andantex: The primary problem we encounter is with lubrication. Once a lubrication failure occurs, the system is down and automation stops. We've developed automatic lubrication systems to avoid these problems, but we still occasionally run into failures. The teeth get so hot that they begin to intermittently weld together, creating "scoring lines" in the direction of pinion rotation. Scoring failures are a direct result of inadequate lubrication.

Mike • Bosch: Alignment issues are one of the leading causes of early gear failure. If multiple racks are joined together for long stroke applications, it's critical that the sections be properly aligned. Poor alignment can cause early failure of one or more gear teeth. Once one tooth is damaged, the entire system typically needs to be replaced. Some manufacturers install the linear guide to the rack to help alleviate or limit the possibility of misalignment.

» What's to come

If you could create the ideal rack and pinion drive, what would it look like? What would it do?

John • Atlanta: An ideal rack and pinion drive would have no errors in tooth form or tooth spacing, providing ultra-precise positioning and repeatability. Tooth surfaces would be treated at the molecular level to provide extreme durability, providing corrosion resistance and eliminating the need for lubrication.

David • Andantex: Today's dream is to make a high capacity rack and pinion system that does not require lubrication. **MSD**

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