TOOTHTIPS

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Many may feel that the rack and pinion is the simplest of all existing gearing systems, but is that actually the case? Read on for an in-depth discussion of the many factors involved.

OF ALL THE GEAR SYSTEMS THAT EXIST, THE RACK AND PINION SEEM to be the simplest… but are they really? In comparison with other mechanisms for linear positioning, rack and pinion systems are robust, efficient, and economical. They can also be operated as fast as alternate methods, but not necessarily as accurately. If they are used for vertical motion, a brake is needed. Also with the rack there is virtually no limit to its length, while ball-screw and belt driven systems are limited in this regard. Another advantage over the two systems mentioned is that the rack can support multiple carriages that can move independently of one another.

The quality of the rack has to be matched to the application. The rack and pinion accuracy is influenced by three variables: backlash, tooth quality, and pitch deviation. The pitch deviation is the variation between actual and theoretical length. Racks can be made at great expense with zero cumulative pitch deviation over the required distance. The heat treatment, hardness, and material selection depend on the accuracy and load requirements. Ranging from soft to hardened and ground teeth, the pinion can have teeth that are rollers, spur, helical, worm, and even herringbone. Helical teeth may also be a requisite in providing a higher contact ratio with more tooth contact, thereby increasing load capacities and strength. The detrimental helical factor is that it produces axial forces. Racks are also subject to peak cycle forces such as the cutting process in a machine tool or during acceleration.

As a general rule, the limiting factor is the pinion's strength. Racks are calculated to be from 300-400 percent stronger for the same pitch and pressure angle when applying the normal rules for rack face and material. The thicker the depth of material below the tooth root, the better. There should be at least twice the tooth depth in material thickness. Installation is also critical, as is the resulting backlash. The pinion must be at the correct distance from the rack, providing contact across the full face width and the allowable backlash. When there is insufficient backlash, the smoothness of action is impaired and wear increases. On those rare occasions when zero backlash is specified, some pressure is placed on the pinion such as by spring loading. A split pinion, is used with an axial spring pack and is made to mesh with opposite tooth flanks. Alternatively, by trial and error testing the pinion is set to the closest fit that still allows for smooth running. If tighter limits than those provided by AGMA are required, the racks can be made to a special pitch and tighter tolerances on straightness.

The majority of racks are produced from cold-drawn material. This induces stresses, and the rack is never as straight after the teeth have been cut. Modern machines outperform the old method of clamping and hammering. Today a modern machine presses down to hold the material with thousands of pounds of pressure to provide the most perfect pitch line. Wide swings in ambient temperature can also result in the material's memory returning to the un-straight condition. It is also important that they are transported in a manner that minimizes the possibility of stress. A linear motion system requires the consideration of the complete system that converts rotational motion into linear motion. Mistakes occur when the components are selected piecemeal. Each influences the other, so selection not only includes the rack and pinion but also the motor, gear reducer, supporting slide, and bearing. The pinion size will affect the torque required to generate the linear force, ratio of the gear reducer, and the reflected inertia to the motor. The shaft of the reducer also has to sustain the gear mesh loads generated between the rack and pinion.

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Close tolerances are also required for the guiding system. Relying on assembly adjustments is a poor idea. Typical failures are due to tooth wear or fatigue in the tooth root. Abnormal sound indicates a misalignment problem. The contact pattern should be periodically checked. As with all metal contact, lubrication should not be ignored. Automatic systems with a felt applicator are available, as are various greases and lubricants that are especially suitable for open gear applications.

ABOUT THE AUTHOR:

William P. Crosher is former director of the National Conference on Power Transmission, as well as former chairman of the AGMA's Marketing Council and Enclosed Drive Committee. He was resident engineer-North America for Thyssen Gear Works, and later at Flender Graffenstaden. He is author of the book *Design and Application of the Worm Gear.*