a lot of noise, whereas bevel gears with other types of teeth operate much quieter and permit a higher degree of power transfer. It is important to remember that bevel gears always generate axial thrust.

Hypoid Gears

Hypoid gears are characterized by hyperbolic teeth, crossing shafts and a pinion axis offset to the center of the crown gear (Figure 7.6). The tooth traces are curved. Owing to the staggered axes, the hypoid pinion has a larger diameter than that of a bevel gear with the same crown diameter. Consequently, hypoid gears have a better load-carrying capacity, while ensuring the same transmission ratio. When the teeth are meshing, there is a point contact with an ellipsoid surface, which results in vertical sliding movements and an increased percentage of sliding in the horizontal direction. Owing to the increased contact ratio and the additional sliding motion, hypoid gears operate much smoother than bevel gears. Their disadvantage, however, is that the horizontal sliding movement reduces the scuffing load capacity the more the axes are offset, resulting in a lower gear efficiency. Special hypoid gear oils can help. As compared to bevel gears of the same size, hypoid gears have a better noise behavior, higher transmission ratio and increased power transfer capacity. Their efficiency, in contrast, is worse.

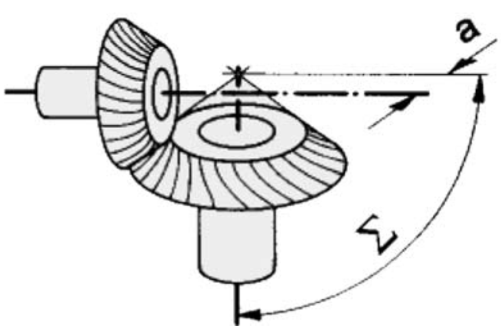

Fig. 7.6. Hypoid gear pair

Worm Gears

These gears are characterized by shafts crossing at an angle of 90° (Figure 7.7). Figure 7.8 shows the main worm and wheel types and the respective geometrical components. Cylindrical worm gears (Figure 7.8a) are most common. Having a high transmission ratio (i = 5–70), worm gears usually are of a single-stage design. They can transfer increased forces and are still small in size. As compared to all other gear units, they have the best noise behavior, but also a very high sliding percentage, which results in friction losses. Worm gears therefore operate hotter and have a lower efficiency.

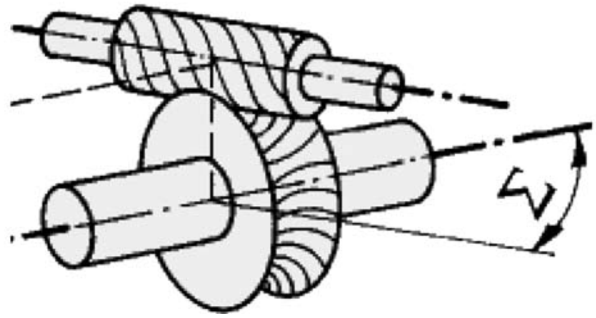

Fig. 7.7. Worm gear pair

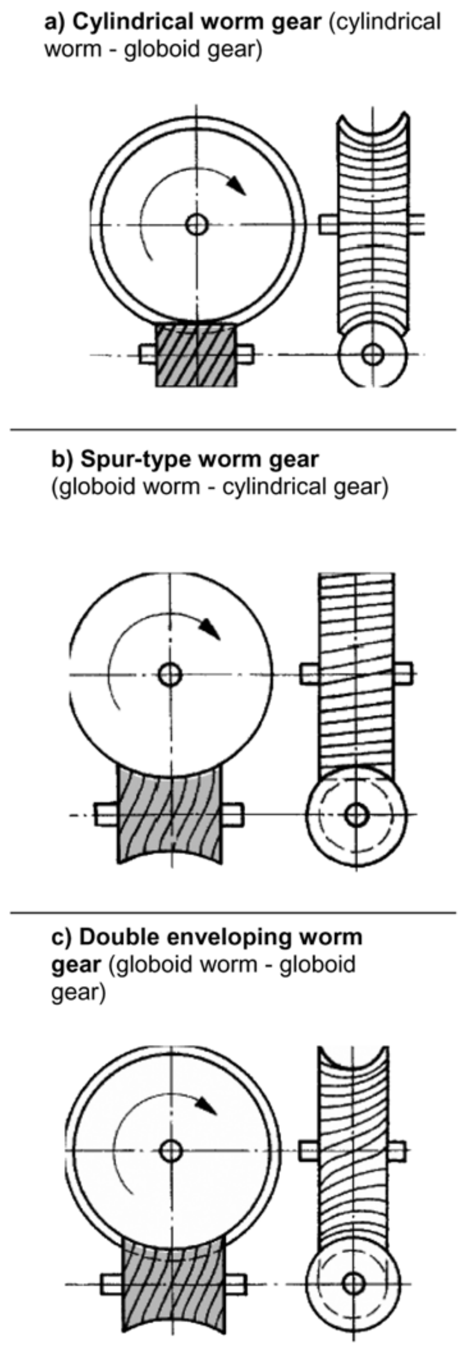

Fig. 7.8. Worm Gears

GEAR COMPONENTS

Gear systems are made up of wheels, shafts, bearings and housings. All components interact closely, and lubricants play an important role.

Gear Wheels

A gear wheel is a machine element rotating around a shaft. It consists of a wheel body, contact surface and teeth. Depending on the position of the teeth relative to the wheel body, a distinction is made between internal and external gear wheels. A gear pair consists of two gear wheels separated by the center distance “a” (Figure 7.9). The smaller wheel is called the *pinion,* and the larger is called the *wheel*. The general terms relating to gear wheels, pairs and units are defined in ANSI-AGMA and ISO standards, which also explain the basic principles.

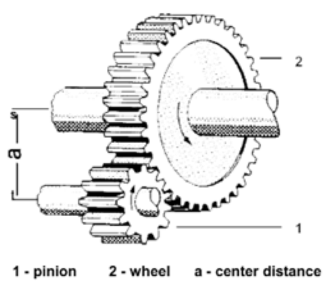

Fig. 7.9. Main components of a gear pair

Tooth Geometry

Involute gears are most widely used in machine construction. As compared to other gears, the tooth geometry has the following advantages:

- Simple and precise manufacturing.
- Exchangeable when used in spur gears.
- Uniform transfer of movements even with center distance variations.
- Uniform direction and amount of normal force.
- One tool with variable profiles can be used for various tooth geometries and center distances.

Positive and negative profile corrections are made by the gear designer in order to avoid undercutting when the number of teeth is low and to increase the root’s load-carrying capacity. They are also made to improve the flanks’ load-carrying capacity (larger curve radius). Profile corrections are also made to reduce the sliding percentage and thus decrease power losses. Figure 7.10 shows the nomenclature and dimensions for involute gears.

Even though cycloid gears operate more precisely than involute gears, they are much more sensitive to variations in the center distance, and are very expensive to manufacture.

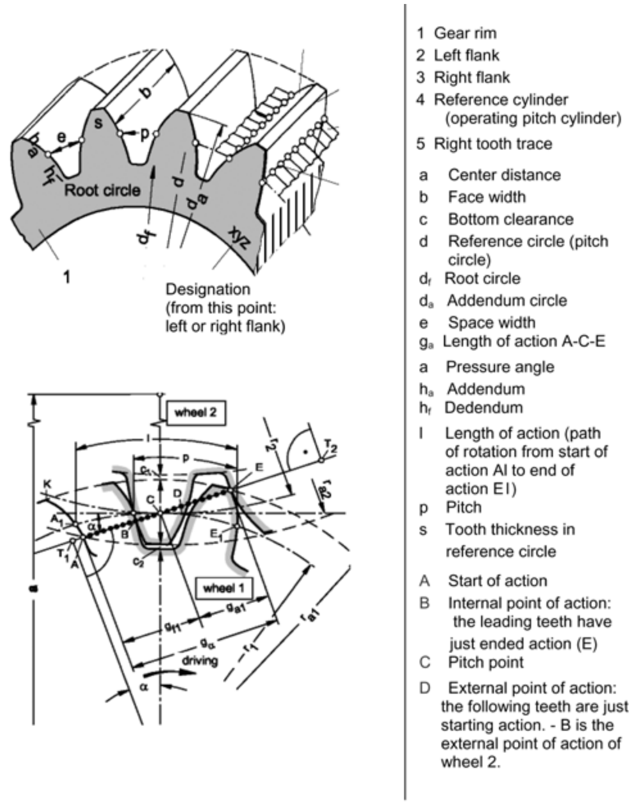

Fig. 7.10. Nomenclature and dimension of involute gears

BACKLASH defines the amount of clearance between adjacent mating teeth. In effect, it is a measure based on tooth thickness along the pitch circle. Backlash for small teeth (high diametral pitch) may be as low as 0.06–0.12 mm (0.004–0.008 inch); for large gears (1–3 diametral pitch) it ranges from 0.23 to 1.1 mm (0.009–0.040 inch). When the pinion and gear first engage to transfer force, the pinion tooth dedendum contacts the addendum of the mating gear. Since the travel distance of the addendum profile is greater than that of the dedendum profile, **SLIDING** occurs until the contact point reaches the pitch circles of both gears, at which point the contact action becomes pure rolling. As engagement continues, the addendum of the driving tooth contacts the dedendum of the driven tooth to cause more sliding action, but with the greater distance on the driving tooth.

This sequence of sliding, rolling and sliding is common to all types of gearing. Spur, helical, bevel and spiral bevel gears experience less sliding than hypoid and worm gears and generate lower heat. The different arc lengths come into contact until the mating gear surfaces reach the pitch point, at which both gears have the same angular velocity. The ratios of the contacting arc lengths determine the **SLIDING VELOCITY** of the dedendum across the addendum.

The extent of sliding varies greatly with **OPERATING SPEED**, which contributes significantly to heat generation along with oil viscosity and load. It can be shown