The Fundamentals of Specifying and Selecting Gear Drives

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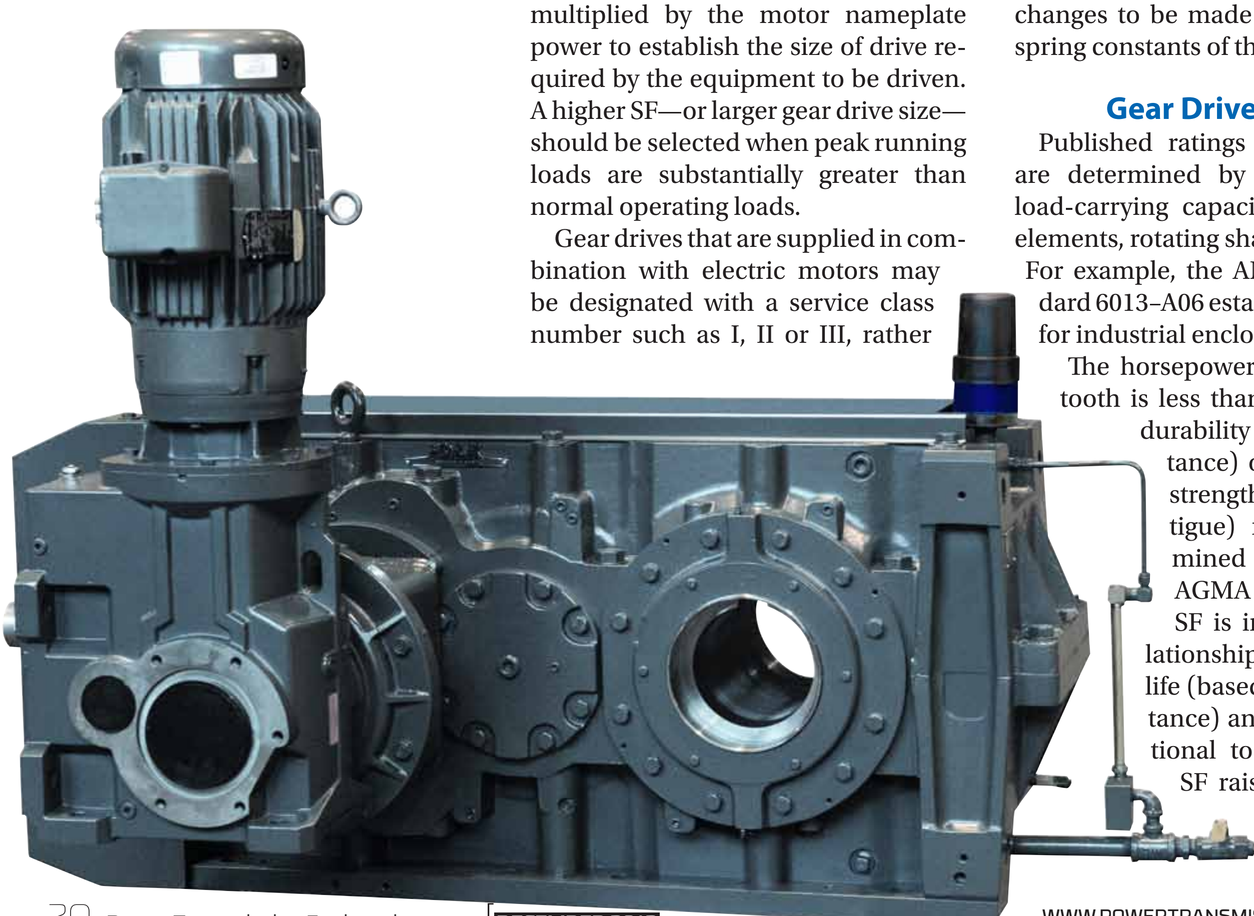
Introduction

Gear drives deliver power to industrial equipment such as bulk material conveyors, mixers, pumps and paper mills. The reliability that translates into greater uptime and profitability begins by specifying and selecting the proper drives for these critical applications. Many variables—such as service factor, gear drive rating, thermal capacity, speed variation and drive ratio—must be considered when sizing and selecting a gear drive. In addition, specific drive features may provide value-added benefits such as cooler operation or ease of serviceability that help reduce total cost of ownership over the life of the drive—a win for any organization. Here are several major areas of importance to consider when selecting a gear drive.



Service Factor

The service factor (SF), a variable that combines external load dynamics, reliability and life, is used to calculate equivalent horsepower. Application and service duty play an intricate role in determining the proper service factor. Acceptable values of SF are determined by field experience. The American National Standards Institute (ANSI)/American Gear Manufacturers Association (AGMA) Standard 6013–A06 (Metric 6113–A06) for enclosed speed reducers publishes a listing of applications with their recommended service factors.

Once an SF is chosen, the factor is multiplied by the motor nameplate power to establish the size of drive required by the equipment to be driven. A higher SF—or larger gear drive size—should be selected when peak running loads are substantially greater than normal operating loads.

Gear drives that are supplied in combination with electric motors may be designated with a service class number such as I, II or III, rather than a numerical SF. Classes I, II or III are equivalent to SF values of 1.0, 1.41 or 2.0. Service class and service factor are used interchangeably; however, numerical designations are preferred because service class does not accommodate intermediate SF values.

Note that published service factors are only the *minimum* recommended for a given application. Applications involving unusual or severe loading, or those requiring a higher degree of dependability, should be reviewed with the drive manufacturer. Typical values of SF will not accommodate systems that have serious, critical vibrations or repetitive shock loading. The system designer must identify vibratory or shock loading prior to gear drive selection. These conditions will require changes to be made in the inertia or spring constants of the drive system.

Gear Drive Rating

Published ratings of a gear drive are determined by the mechanical load-carrying capacity of gear tooth elements, rotating shafts and bearings. For example, the ANSI/AGMA Standard 6013–A06 establishes standards for industrial enclosed gear drives.

The horsepower rating of a gear tooth is less than or equal to the durability (pitting resistance) of the surface, or strength (bending fatigue) rating, as determined by established AGMA criteria. As the SF is increased, the relationship between gear life (based on pitting resistance) and load is proportional to the increase in SF raised to the 8.78th power. For ex-

ample, if SF is increased by 30 percent, the gear tooth life will increase 10 times.

Shafts support the gear tooth elements that transmit torque from the motor to the driven machine and also distribute the radial loads to the bearings. While shafts are designed for carrying torsional and bending stresses, they also minimize deflection by maintaining uniform contact across the gear face.

Roller bearings are selected according to bearing manufacturers' recommendations. Bearing life is defined as the number of hours of operation at a constant speed before the first evidence of fatigue develops on either the raceway or rolling elements.

Determining Thermal Capacity

Checking the thermal capacity of a gear drive is extremely important to ensure desired drive performance. Manufacturers' catalogs list thermal horsepower ratings based on a continuous duty cycle at an ambient temperature of 68°F (20°C) and an altitude of up to 2,460 feet above sea level. For other conditions, the thermal horsepower rating must be multiplied by factors provided by the manufacturer for the specific drive under consideration.

The maximum acceptable temperature for an oil sump is 200°F (93°C), according to AGMA standards. However, some manufacturers recommend lower temperatures to increase service life of the lubricant and extend operating life. These temperatures can be achieved with design features that improve cooling, as well as with auxiliary cooling methods.

Thermal capacity can limit selection of a drive if it is less than the nameplate rating of the motor—unless auxiliary cooling is provided. SF is not involved since heat dissipation is based upon average power consumed—not peak loads.

Gear drives are designed with a variety of internal features to minimize power losses, while yet assuring adequate splash lubrication. These include oil exclusion pans to reduce churning, wipers to collect oil from the rotating gear for distribution to the bearings, and dams to maintain a reservoir at the bearing. Sealing also is critical to dependability. Some manufacturers offer no-leak seals with purge-enabling grease chambers and contact seal designs that eliminate oil leaks while keeping dirt out.

If a gear drive generates heat faster than it can be dissipated, loss of operating life or severe damage can occur. This may take the form of surface distress on the gear teeth or hardening of the oil seals, resulting in leakage. Reducing operating temperatures will increase the oil film thickness at the gear teeth and bearings, thus increasing the life of the equipment.

Heat is generated by a gear drive through frictional loss. The gear lubricant is the carrier of this heat, which is then distributed to the housing and conducted to the outside surface, where it is dissipated. Housing design and configuration can improve heat dissipation.

If the thermal capacity of the gear drive is greater than the motor nameplate rating, and the ambient temperature is below 100°F (38°C), the operating sump temperature should remain below 93°C (200°F). If, on the other hand, the drive is in a confined area and is coated with dirt or waste material, a high probability of distress and a corresponding shorter operating life should be expected.

Effect of Speed Variations

Variable speed applications fall into two load categories: constant torque or constant horsepower. Constant torque occurs when load demand varies proportionally with a change in speed. Gear drives are basically constant torque machines requiring no selection modifications. For a constant horsepower application (load demand is constant regardless of speed) the gear drive must be selected for the slowest speed at which the motor will deliver its rated horsepower capacity. This also applies when a mechanical, electrical or hydraulic speed reduction device is used between a gear drive and a constant-speed AC motor. Variable or multi-speed applications also require special considerations to provide adequate splash lubrication at the slowest speed, but without excessive heating or churning at the higher speed.

Manufacturers' catalogs list input speeds for the high-speed shaft of each type of drive. These generally are based on standard motor speeds. Any input speeds above these limits should be discussed with the manufacturer, as they may exceed the design capabilities of the drive.

Finding the Ratio

To arrive at the specific gear ratio required, divide the motor full-load speed by the revolutions per minute (rpm) of the driven equipment. Exact ratios are determined by dividing the actual number of gear teeth by the mating pinion teeth—both of which are whole numbers. Deviation between AGMA nominal and exact ratios are ±3 percent for a single-reduction gear drive, and ±4 percent for a double-reduction. For applications with variable frequency drives, exact gear ratios become less important. In such cases it is best to select a manufacturer's standard ratios. These will provide lower costs and quicker delivery, with ready availability of off-the-shelf stock spare parts.

Choosing the Right Size

Manufacturers' catalogs provide input speed, ratio and horsepower rating for use in determining the size of the drive. Other factors that should be considered include: type of unit; initial cost vs. cost of maintenance (total cost of ownership); useful operating life; and spare parts if a marginal selection is made. For example, a 30 percent increase in the initial cost of specifying a gear drive that is one frame size larger could easily represent a 240 percent greater bearing life and 10 times greater gear tooth life. One additional consideration is ease of serviceability. Some drives have a horizontal split housing that makes them easier to disassemble and reassemble for maintenance of bearings and gearing.

Gear drives are available in a variety of sizes, with various shaft configurations to meet your space requirement. The most popular are parallel-shaft, concentric, and right-angle, with low-speed shaft either horizontal or vertical to the input shaft centerline. Some drives are available with special features such as backstops, which prevent reverse rotation. The manufacturer's selection procedure that applies to these features should be followed.

Under normal circumstances, reliability is evaluated as part of the SF, which accounts for the effect of the normal statistical distribution of failures found in material testing. Gear teeth designed to AGMA standards are based upon a statistical probability of less than one failure in 100. Most designers recognize that using a higher-than-minimum SF is cheap insurance compared to the costly downtime that results when a process is interrupted due to the failure of a single component. Because drive designs may vary considerably, past experience can only be a guide in determining the proper service factor for a new drive, and the manufacturer's recommendations should be followed.

Maintaining the proper level of oil in the sump, or a steady supply of cool, filtered lubricant, is basic to achieving long service life. To further increase thermal capacity, a shaft-driven fan can be mounted on the drive. This increases air flow along the exterior of the housing to improve heat dissipation. Cool operation also can be achieved through housing designs that improve this dissipation and ensure optimum bearing lubrication. Some manufacturers also offer optional cooling systems to control oil temperatures in the most extreme conditions.

Factors that can affect performance and wear, such as operation in an elevated temperature, can be managed with a consistent, preventive maintenance program followed by immediate corrective action. Manufacturers offer various condition monitoring packages to monitor bearing temperatures, vibration and other measurements, as well as convenient oil sampling ports that allow for lubrication analysis.

For specific details and rating information when researching a gear drive, always refer to the manufacturer's catalogs and technical support advisors to ensure that the drive you select will provide the optimum reliability, ease of service and uptime—with the lowest total cost of ownership. **PTE**

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