Worm gearhead handles servo demands

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Servo applications often impose severe demands on drive components, thereby ruling out the use of many geared speed reducers. However, advanced worm gearhead designs are changing this picture.

Conventional worm gearboxes generally do not meet the needs of servo applications such as low backlash, high speed, and resistance to shock loading. However, engineers have recently upgraded the design of worm gearheads to obtain high-precision units, Figure 1, that are competitive with other servo drive speed reduction methods.

Servo system demands

Most servo applications require more than just the continuous, single-direction motion that is typical of simple applications. Torque and direction reversal are common, causing shock loading that reduces gearhead life — possibly leading to failures. For this reason, operating cycles are usually hard to define, with only the peak acceleration values known. Also, servomotors can generate high peak torques — often many times the torque capacity of other system components.

Gearhead backlash must be minimized (less than 5 arc min for precision systems), to ensure accurate positioning and avoid system instability. The gearhead inertia also becomes an important factor in obtaining a good inertia match between the motor and driven load. To minimize the torque (and power) required to accelerate the gearhead, its inertia should be kept to a minimum.

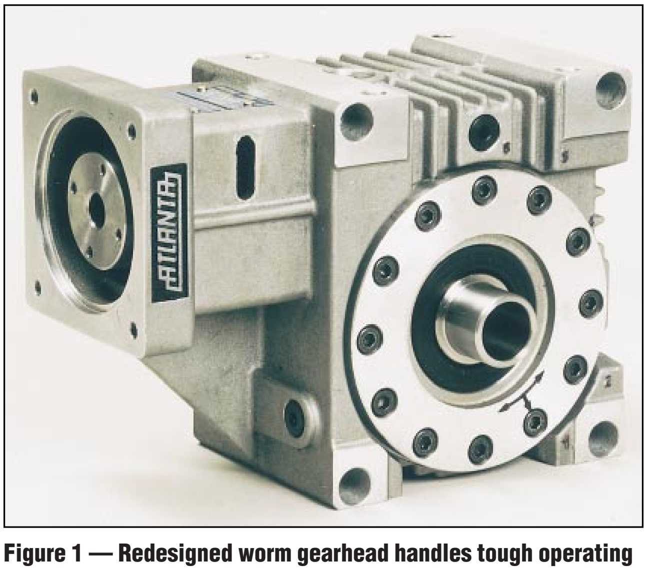

Figure 1 — Redesigned worm gearhead handles tough operating conditions found in servo applications.

Additionally, the gearhead should have a wide range of speed reduction ratios to enable minimizing the servomotor torque and to give more flexibility in selecting a servomotor size. Finally, the gearhead needs to handle input speeds over 3,000 rpm, which servomotors frequently generate.

Conventional worm gears

Standard (nonservo design) worm gearboxes offer a simple solution to many drive applications, allowing ratios from 5:1 to 100:1 in the same size box. The gearing often consists of only a single worm and worm-gear set. Because there is only one gear mesh, its torsional rigidity and velocity characteristics are almost linear, which makes it easier to match gearhead performance to application needs.

There are also drawbacks, such as the sliding-friction and high wear characteristics of worm gears. This accounts for their low starting and running efficiencies and high operating temperatures. Backlash is typically over 30 arc min, due mostly to the gear mesh and bearing clearances, and it can increase with normal wear. Some manufacturers offer low backlash gearing, but significant wear still develops because of the high sliding friction.

Redesigned gearhead

To design a worm gearhead that is suitable for servo operation requires overcoming the above obstacles.

Backlash. The biggest concern in most servo applications is high backlash

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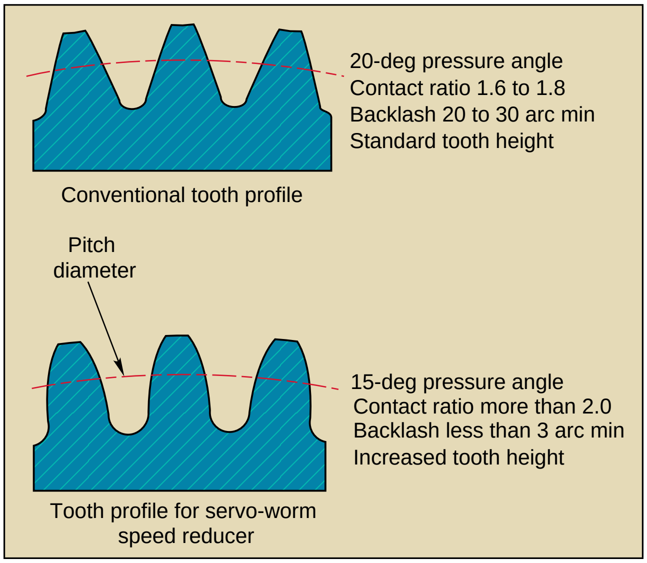

Figure 2 — New tooth profile cuts backlash (space between worm and worm gear teeth) and increases tooth bending strength.

because it affects positioning accuracy. To minimize backlash, engineers redesigned both the worm and gear tooth profiles, Figure 2, to obtain a taller tooth with a lower pressure angle (15 deg) and higher contact ratio (over 2.0), which decreases tooth-to-tooth clearances between the gears. Also, a larger fillet at the tooth base reduces stress concentration. This increases its bending strength and, along with the higher contact ratio, allows higher peak torques.

This new tooth profile also makes it easier to minimize backlash by adjusting the gearset center distance. This is accomplished with two output bearing covers in which the bearing seats are slightly eccentric, Figure 3. Rotating these covers before bolting them to the housing causes the worm gear centerline to move up or down, thus making minute adjustments in the gearset center distance. A reduced center distance decreases the tooth-to-tooth clearance between worm and gear, thus reducing the backlash between them . The housing has six rotation settings, which enables adjusting the backlash level to less than 3 arc min. Even lower backlash levels (less than 1.5 arc min) can be obtained by increasing the number of rotation settings.

Another advantage of this design: users can reset backlash to the original factory specification in the field by simply re-adjusting the bearing covers. This ability to adjust backlash in-the-field prolongs the useful life of the gearhead, and is especially useful for applications that require maintaining precise positioning over the life of the servo system.

Some additional backlash occurs because of axial clearance in the bearings supporting the input worm shaft. To remove this backlash, the conventional tapered roller bearings are replaced by a pair of precision angular-contact ball bearings, Figure 4. These bearings are mounted back-to-back to achieve zero axial clearance and eliminate axial movement of the worm relative to the worm gear. The angular contact bearings can

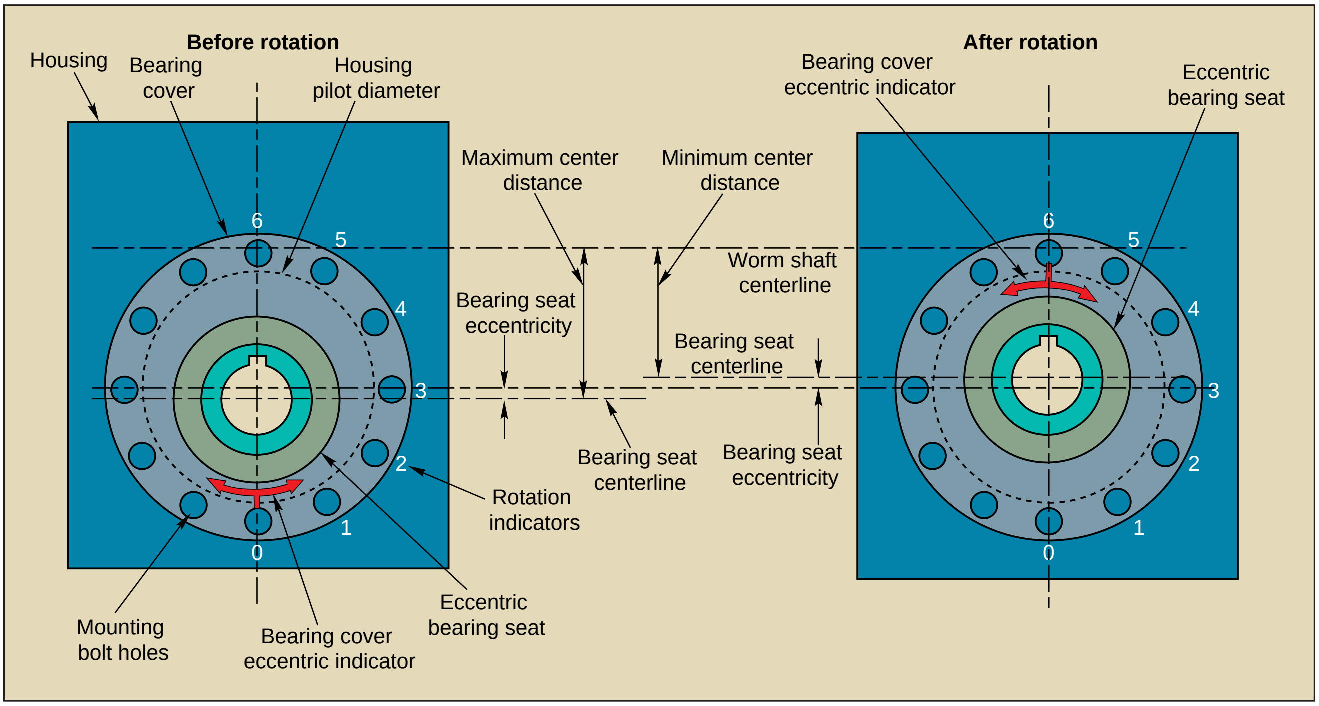

Figure 3 — Bearing covers move the worm gear shaft up to reduce backlash. For lower backlash, rotate each cover so its indicator moves from its original position to the next higher position on the housing. This moves the worm gear up into a tighter mesh with the worm, thus minimizing backlash between them.

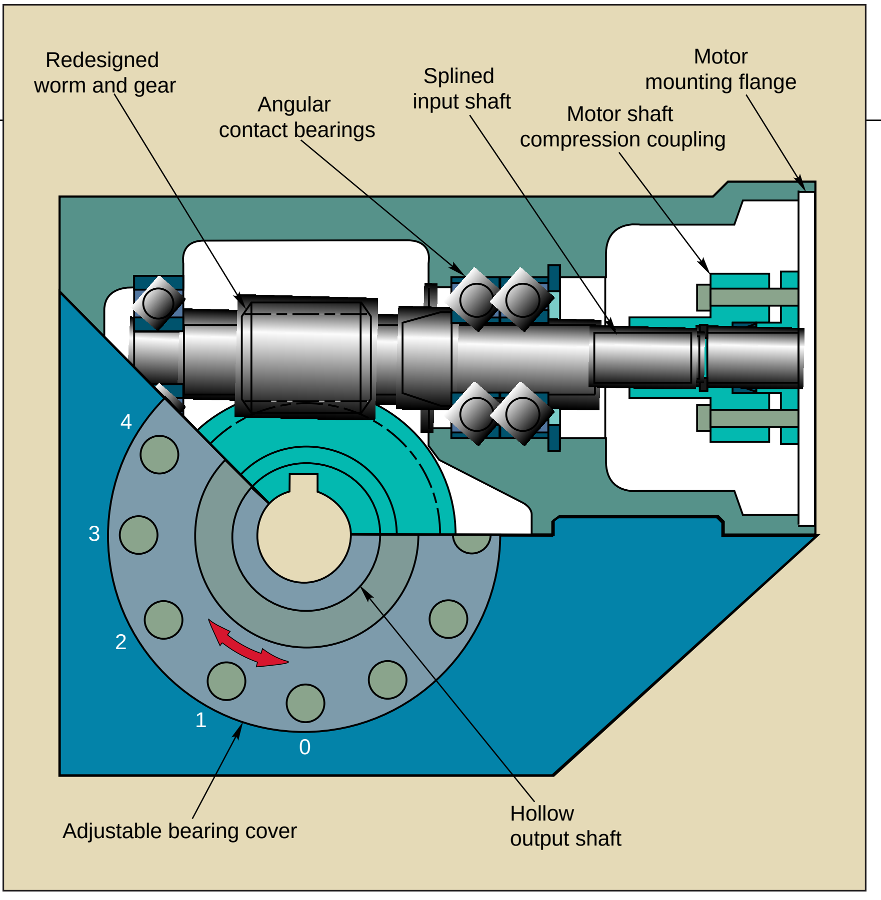

Figure 4 — To reduce backlash, new gearhead combines improved gear tooth profiles, adjustable eccentric bearing covers, and precision angular contact bearings. Other features include an input mounting flange for most servomotor types and a hollow output shaft to accommodate various driven load connections.

accommodate operating speeds over 3,000 rpm, which are typical of servo applications.

Wear. To reduce gear wear, engineers took several steps. They replaced the conventional bronze material used in the worm gear with centrifugally cast bronze, which has better material consistency, thereby increasing tooth pitting resistance and bending strength. The worm and worm gears are also ground to a precision matched set, thereby removing any inconsistencies at the tooth profiles, and increasing the gearset's quality level from AGMA 9 (typical) to AGMA 11. This further reduces backlash and noise.

To avoid concentrated wear areas on the gear teeth, a "hunting tooth" ratio is used. This ratio is formed when the number of teeth on the gear divided by the number of teeth on the worm is not an integer (e.g. $19 \div 4 = 4.75:1$). It produces a self-indexing action in which all of the worm teeth (threads) eventually mesh with all of the gear teeth in succession. This action reduces the number of common wear points and more evenly distributes wear across all of the tooth surfaces.

Lubrication is very important in servo applications because of their high performance demands. To provide reliable lubrication for the gears, bearings, and shafts of the gearhead — a high-performance synthetic oil is used. This oil has a high viscosity (ISO VG 220), wide operating temperature range (up to 300 F), and long service life. These characteristics help the unit achieve optimum thermal efficiency, as well as high wear resistance.

Other pluses. Engineers added a mounting flange to the housing to accommodate the variety of motor flanges available. Connecting the motor shaft to the gearhead input is achieved by a zero-backlash compression coupling, which compresses two wedge-shaped sleeves against the shaft, Figure 4. To allow for misalignment, the input shaft has an involute spline. This creates a tight fit with the coupling and minimizes fretting corrosion between parts due to frequent torque and direction reversals of servo applications.

To handle various output configurations, the output shaft is replaced with a hollow shaft. This allows for precisely connecting the driven load to the gearhead with a keyway or compression-type coupling. Accessories can be mounted via this hollow shaft, such as pinion shafts for rack-and-pinion drives, and straight output shafts for use with timing pulleys, gears, or couplings.

To improve thermal heat dissipation from the gearhead, engineers use an aluminum housing (rather than the usual cast iron), with convection fins. The aluminum also reduces weight, which makes the servo-worm gearheads suitable for overhead gantry applications, where system inertia should be minimized, Figure 5. ■

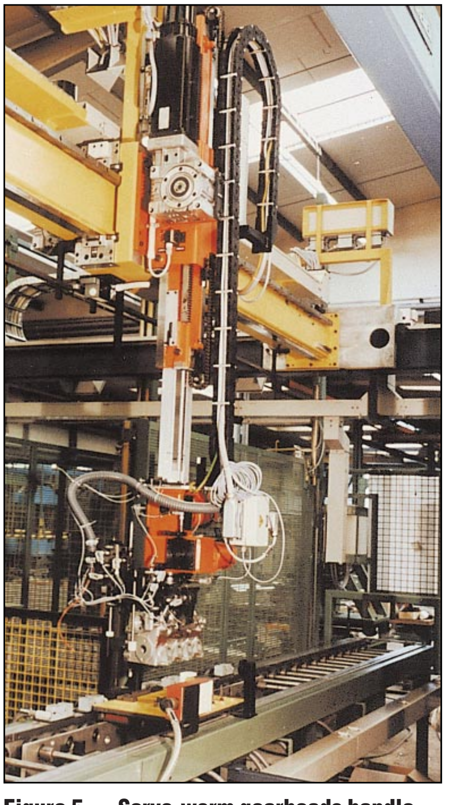

Figure 5 — Servo-worm gearheads handle the ups and downs of one or two-axis drives on material handling gantry robots that are commonly used in the automotive industry.