Precision speed reducers smooth servo motion

ALAN RUDT, Bayside Controls Inc.

Servomotor applications need precision speed reducers to ensure smooth and accurate operation along with high reduction ratios. These planetary gearheads are emerging as a way to fill the bill.

Servomotor selection usually begins with the designer seeking to reduce the motor size by using a gearbox to reduce speed and increase torque. Speed reduction allows rapid acceleration and deceleration of large loads using a small, less costly motor.

As a rule, the designer usually obtains the optimum speed reduction ratio by matching the inertia of the motor and gearbox with the inertia of the driven load. This inertia matching minimizes power loss in the motor, making it run more efficiently.

Several types of gear trains, including those with planetary gears, are commonly used to obtain this optimum reduction ratio. Planetary gear trains offer high stiffness and low backlash (needed for accurate operation), plus even load distribution (to obtain maximum torque). Some planetary versions combine external-tooth pinion-and-gear sets with planetary gear sections to simplify installation and boost speed. These hybrid gearheads are described later.

Planetary gear overview

In its simplest form, a planetary gear train comprises a central sun gear, several uniformly spaced planet gears, and a ring gear, Figure 1. The sun and planets are typically external-tooth spur gears and the ring gear is an internal-tooth spur gear.

The planets revolve around the sun gear, and each planet rotates on a spindle. A "planet carrier" (not shown) combines three or more planet spindles and an output shaft. The ring gear is stationary, causing the carrier to deliver torque to the driven load in the same direction as the sun gear, but at lower speed.

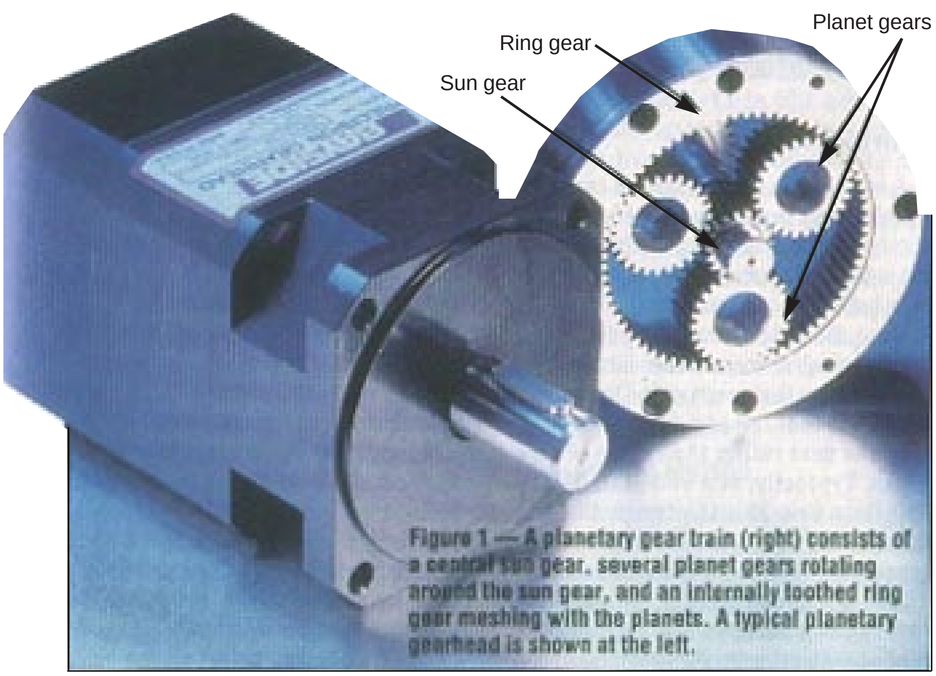

Figure 1 — A planetary gear train (right) consists of a central sun gear, several planet gears rotating around the sun gear, and an internally toothed ring gear meshing with the planets. A typical planetary gearhead is shown at the left.

Because the load from the motor or sun gear is shared among three or more planets, a planetary gear train typically offers higher load capacity (torque) and stiffness than equivalent pinion-and-gear sets (with external spur gear teeth), thereby ensuring high positional accuracy in servo applications. The increase in load capacity and stiffness is generally three times (or more) depending on the number of planets.

Now let's examine the sun gear's effect on the performance of a planetary gearhead.

Sun gear factors

A basic planetary gearhead has some limitations regarding ease of installation, load capacity, and speed, all of which are

Alan Rudt *is the sales and marketing manager at Bayside Controls Inc., Port Washington, N.Y.*

related to the sun gear.

When a conventional planetary gearhead is mounted to a motor, the sun gear must be aligned to compensate for runout error of the servomotor shaft. Without proper alignment, load is unevenly distributed over the planetary gears and the drive train operates less smoothly. Also, gear life can be shortened. These alignment adjustments require skills that are not normally available in the field.

Achieving a larger speed reduction ratio requires a smaller sun gear diameter (or an exceptionally large ring gear). This smaller sun gear is usually integral with its shaft, which must be smaller as well, thereby reducing its strength and its torque or load capacity.

Further, because of the constraint on sun gear diameter, speed reduction ratios over 10:1 must sometimes be achieved by stacking several gear stages in series. This multiple stacking requires a larger, more costly housing.

Input speeds of conventional planetary gear trains range up to about 2,500-3,000 rpm, depending on the sun gear size. However, some applications may require servomotors that provide full torque at higher speeds, ranging up to 5,000-6,000 rpm (See box "Hybrids handle high speed").

To combat these limitations on installation, load capacity, and speed, you can get a hybrid planetary gearhead, which combines a pinion-and-gear set with planetary gears in one package.

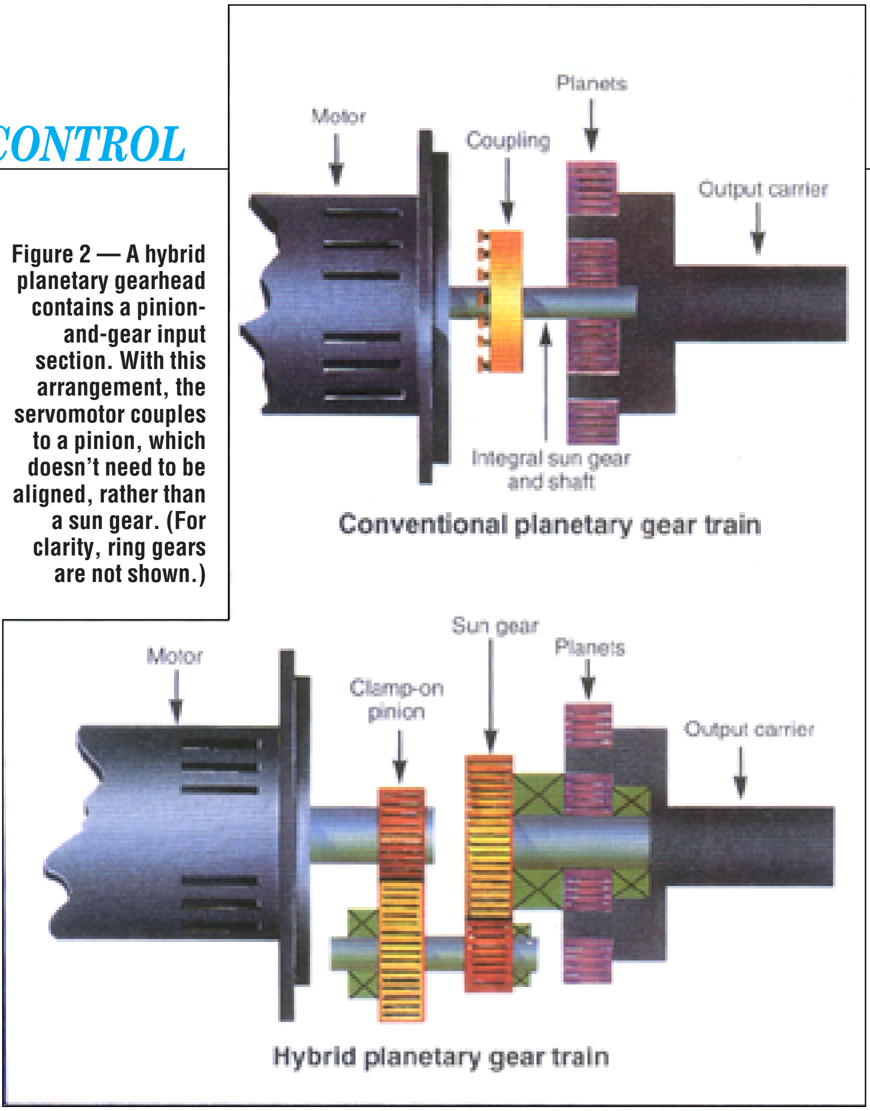

Figure 2 — A hybrid planetary gearhead contains a pinion-and-gear input section. With this arrangement, the servomotor couples to a pinion, which doesn't need to be aligned, rather than a sun gear. (For clarity, ring gears are not shown.)

Hybrids handle high speed

Servomotors deliver nearly constant torque over speeds typically ranging up to 6,000 rpm. However, conventional planetary gearheads are limited to about 3,000 rpm. Thus, it could take a larger motor to do the same job that a smaller motor operating at higher speed could do.

For example, an application requiring 100 lb-in. torque at 600-rpm output speed can be driven by a servomotor delivering 10 lb-in. torque and 6,000 rpm, coupled with a 10:1 gearhead. But if the gearhead can't accommodate this speed, a larger motor, delivering perhaps 20 lb-in. torque at 3,000 rpm and using a 5:1 gearhead, is required.

Hybrid gearhead

A hybrid planetary gearhead contains a pinion-and-gear set on the input side, Figure 2, and planetary gears on the output side. The input and output gears typically both have spur gear teeth.

Here, the servomotor shaft is fitted to a pinion, which accommodates larger shaft runout errors than a sun gear. One reason for this is that the pinion meshes with only one gear rather than three planet gears. Typically, sun and planets are American Gear Manufacturers Association (AGMA) Number 12 precision class gears, which can accommodate less than 0.0005-in. runout. Most motor manufacturers can't achieve this low level of runout without preselecting motors for accuracy, an expensive process. In a hybrid gearhead, the input pinion typically accommodates 0.001 to 0.002 in. runout. Because the pinion accommodates more runout, it generally doesn't need to be aligned during mounting.

Part of the overall speed reduction of a hybrid gearhead is achieved in the pinion-and-gear section and part in the planetary section. Designers incorporate various speed reduction ratios in the pinion-and-gear section, so the sun gear diameter need not be changed. Thus, the torque rating of the gearhead doesn't vary with the ratio. Also, this arrangement eliminates the need for multiple stacks to achieve high ratios.

For reduction ratios of less than 10:1 at speeds of 3,000 rpm or lower, a conventional single-stage planetary gearhead is more compact than a hybrid gearhead. Therefore, where space is at a premium, the all-planetary gearhead may serve best. For reduction ratios above 10:1,

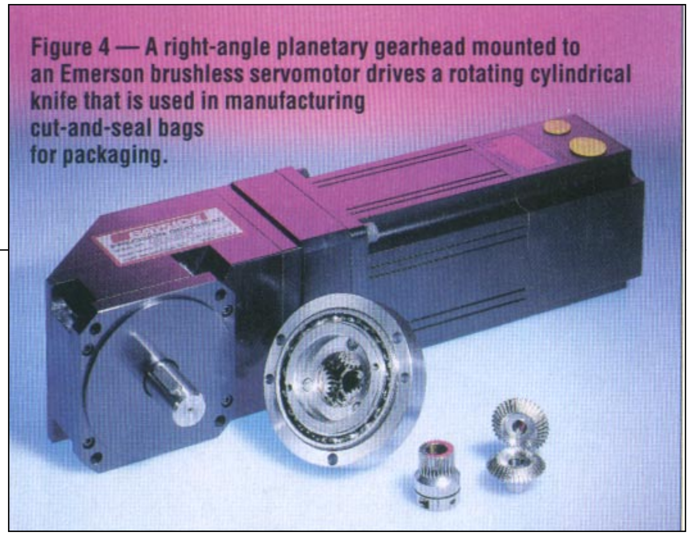

Figure 4 — A right-angle planetary gearhead mounted to an Emerson brushless servomotor drives a rotating cylindrical knife that is used in manufacturing cut-and-seal bags for packaging.

however, dual stages are generally required for conventional planetary gearheads, so the hybrid type may be a better choice.

Because a pinion is not subject to the same size and alignment constraints as a sun gear, it can be designed for higher speeds. Thus, users can take advantage of the full 5,000 to 6,000-rpm speed range of servomotors.

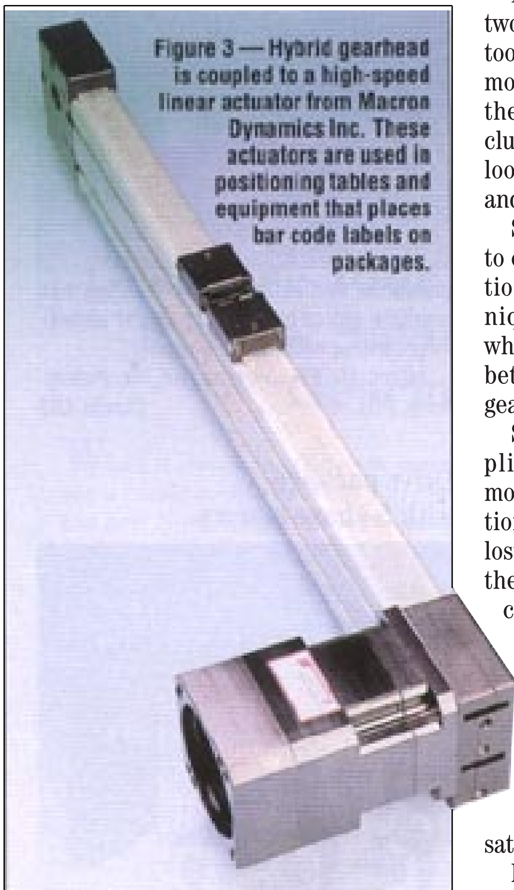

Figure 3 — Hybrid gearhead is coupled to a high-speed linear actuator from Macron Dynamics Inc. These actuators are used in positioning tables and equipment that places bar code labels on packages.

Point-to-point motion

Servomotors are being used more often in new applications because of the easier installation and wider speed range of hybrid planetary gearheads. For example, these gearheads are suitable for point-to-point applications, such as pick-and-place robots, automatic tool changers, machine tool indexing heads, and package handling equipment, Figures 3 and 4.

Point-to-point motion involves accurate and repeatable movement of a tool or part from one point to another. Controlling backlash and lost motion are of prime importance in these applications.

Backlash is the excess space between two adjacent gear teeth and its engaging tooth; lost motion is the total looseness or motion at a reducer's output shaft when the input shaft is fixed. Lost motion includes backlash, plus losses from bearing looseness, tolerances and fits, and shaft and gear tooth compliance.

Servo controllers can be programmed to compensate for backlash and lost motion in planetary gearheads. This technique compensates for backlash even where an application requires accuracy better than the minimal backlash of the gearhead.

Software compensation is accomplished by commanding the motor to move beyond the apparently desired position by an amount equal to the system's lost motion, thereby bringing the load to the truly desired position. For example, consider a servomotor, gearhead, and leadscrew combination in a pick-and-place robot. If 100,000 encoder counts equals 1.0 in. of linear motion and the system has 0.1-in. lost motion, then the controller tells the motor to move 110,000 encoder counts to get 1.0 in. of motion, thus compensating for the 0.1-in. lost motion.

Many servo controllers use software compensation, and their success depends on knowing the lost motion of the entire system. This information is usually available from the gearhead manufacturer.

Contouring motion

Contouring applications usually involve end-effectors or tool-points that follow mathematically defined paths. Sealant and bonding machines, water and flame cutters, laser welders and cutters, motion controlled cameras, and CNC machine tools are good examples.

Smooth motion, which means the absence of torque and velocity variations (ripple), is important in contouring applications. But, it is difficult to consistently achieve smooth motion where the sun gear is mounted on the motor shaft. Even a slight misalignment in the sun gear (motor shaft runout or coupling inaccuracies) can cause rough operation and noise.

Because the sun gear in a hybrid unit is pre-aligned within the gearhead and not affixed to the motor shaft, these gearheads can be used in contouring applications such as a glue-dispensing nozzle for affixing a windshield to an automobile. Motion of the nozzle as it follows the seam between a windshield and its window frame must be perfectly smooth; otherwise a ripple in velocity alters the bead diameter and causes messy glue application.

Smoothness and absence of ripple are essential for the printing of elaborate color images on reusable plastic cups available at fast-food chains. The color image is made up of millions of tiny ink dots of many colors and shades. The entire cup is printed in one pass (unlike regular color separation where each color is printed separately). The gearheads must operate smoothly enough to synchronize ink blankets, printing plates, and cup rollers without introducing any ripple or inaccuracies that may smudge the image. In this case, the hybrid gearhead reduces motor shaft runout error, which reduces roughness. ■

For more information on hybrid planetary gearheads from Bayside Controls Inc., ***circle 403*** *on the reader service card.*

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