The WHAT'S NEW magazine

NOVEMBER 1984 $1.75

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Impossible squirm drive

—first real advance in gears in a century

A low-friction, zero-backlash gear system can provide pinpoint accuracy in laser-aiming devices, may be durable enough at high rpm for use in helicopter engines, and can produce two gear ratios simultaneously—a feat that seems to defy the laws of engineering.

By E. F. LINDSLEY
Photos by Greg Sharko

"Take this rubber band," Tom Murphy said, "and insert it between those two V-belt pulleys. I'll crank up the motor, and we'll see how long the band lasts attached to squirm gears."

The pulleys—one hooked to the shaft of a one-horsepower motor, the other to the input shaft of a cast-iron gearbox large enough to drive a golf cart—would usually require a ½-inch V-belt. Though I expected the band to snap immediately, I knew there had to be a catch: I hadn't been invited to Oradell, N.J., home of Murphy's company, MAXAXAM Corp., to watch a rubber band being chewed up.

Murphy started the motor, the gearbox hummed, and the rubber band—to my surprise—showed no sign of distress. The inherent friction of any other gears would have ripped the rubber band. But squirm drive, which resembles worm gear (see box), is more than just a low-friction gear system. This unique form of motion transfer can also aim a laser with pinpoint accuracy and drive a dual-motion robot's wrist. "It's natural to compare squirm with worm gear," Murphy said, "but squirm drive has capabilities that no other gear system in the world can match."

Murphy ticked them off for me:

- The ability to yield two gear ratios at once—giving a multispeed output from a single-speed input—which traditional mechanical engineering says is impossible.
- The ability to change gear ratios by replacing only one gear—not two as other gear systems require.
- A reverse, or speed-up, drive that turns the input—the worm—into an output and can step up a slower-speed motor to a high-speed motor.
- Zero-backlash drive, which gives the pinpoint accuracy and precision needed in such high-tech fields as robotics and aerospace.

These unmatched features stem from a unique design that is the first real advance on the worm gear in more than 100 years. It makes squirm drive versatile enough, Murphy believes, to be used not only as an alternative to worm gear but also in places where worm gear's inherent limitations render it impractical.

Squirm drive's unique design, according to its inventor, George Brackett, a Portland, Maine, tool-and-die maker, is based on: 1) the substitution of bullet-shape rollers for worm-gear teeth, and 2) the shape of the worm itself.

Each roller sits on a complement of thrust and roller bearings and springs, which force the roller out and into firm contact with the worm's grooves. Bearings allow the roller to rotate during contact.

These agile rollers engage the worm tangentially, not head-on as do the teeth in worm gear. To accommodate this unique orientation, Brackett redesigned the worm. In worm gear the worm is straight, like a regular screw, with spiral grooves, looking much like the coarse screw threads on a wine press or a bench vise. In squirm gear, however, the shape of the worm follows a double parabolic curve so that its profile resembles a thick-waisted hourglass.

Starting from scratch

Cutting threads to such contours just wasn't being done when Brackett began work on squirm drive. "It took me four or five years," he said, "to build the cutting machine from scratch."

Now, however, fabricating the novel worm is no problem. At MAXAXAM's plant in South Portland, Maine, computer-aided design takes over the job of designing just the right curves and tooth shapes. The output from the computer is programmed into a computer-assisted five-axis cutting machine that can swing and tilt freely to follow complex curves, so the worms can be turned out according to various specifications with great precision.

To achieve zero-backlash drive, the driven gear is split so that the rollers sit in a shallow V-shape indentation along the outer circumference of the gear. Rollers line both sides of the V and are staggered so that one roller at a time engages the worm (see drawings, opposite page).

Murphy believes that squirm gear's zero-backlash drive will fill a need in high-tech fields in which precision is paramount. To demonstrate this unique property, he used a table-top gear assembly with a small laser mounted on

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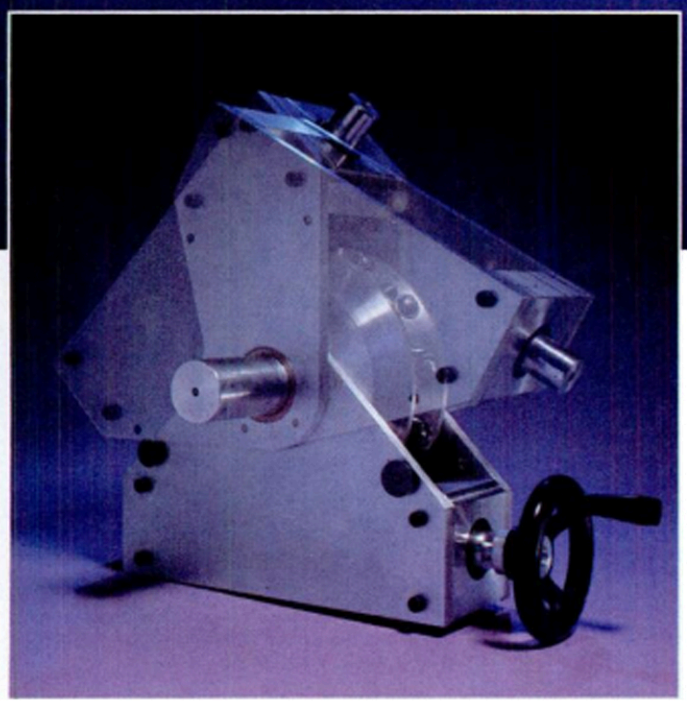
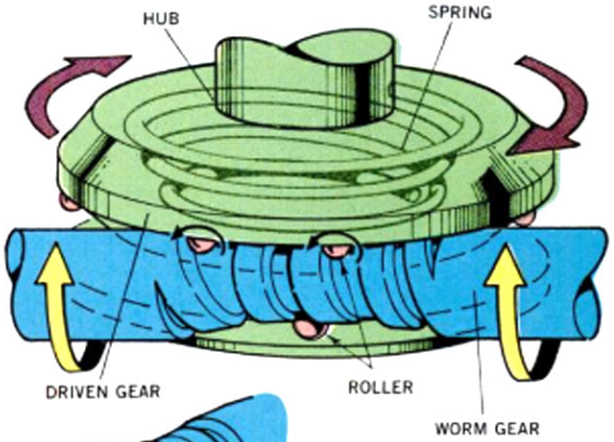
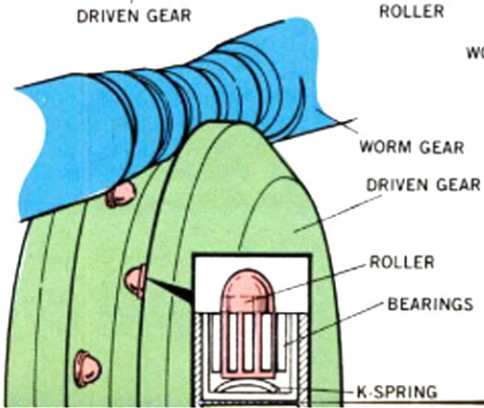
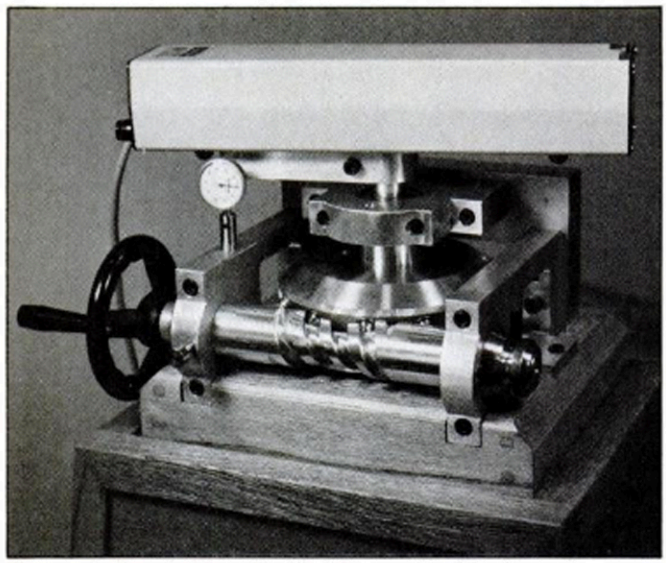




DRAWINGS BY ED LIPINSKI

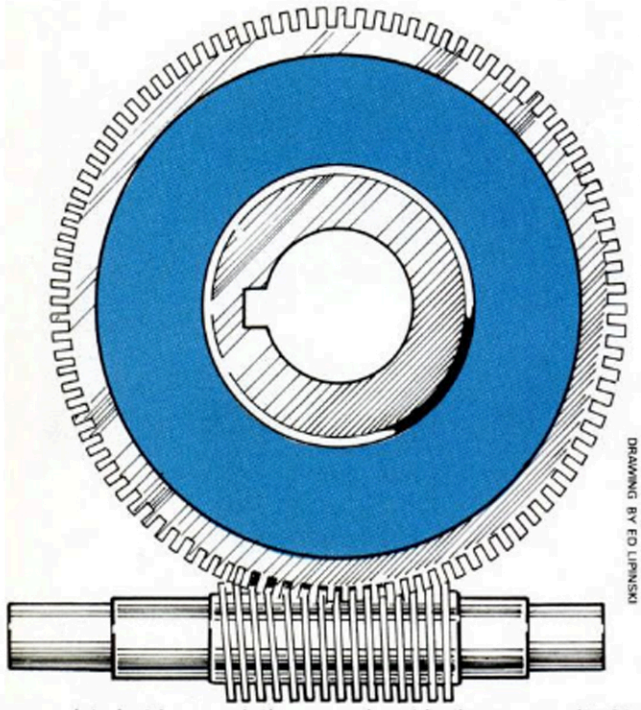


Radically different, hourglass-shape worm was designed to engage bullet-shape rollers (top). For zero backlash, driven gear is split and spring loaded (drawings), causing flanges to rotate against each other and forcing consecutive rollers to find different contact faces within worm's grooves. Driven gear can be attached to clutch mechanism, giving squirm gear ability to rotate in two directions at same time (above). This rotational elasticity can give robot's wrist flexibility similar to that of a human wrist.



Laser-aiming device attached to zero-backlash squirm gear attains a precision impossible with other gear drives. Squirm gear's unique zero-backlash capability could fill a need in such high-tech fields as robotics and aerospace, in which extraordinarily precise mechanical drive is sought in everything from assembly-line robots to telescopes.

An age-old system of motion transfer—worm gear



DRAWING BY ED LIPINSKI

To appreciate just how revolutionary squirm drive is, compare it with worm gear, a mechanical drive almost as old as the wheel itself. Worm gear consists of a worm, a screw-like helical gear, and a second, driven, gear with teeth. These gears do not mesh together closely, and the small space between them—backlash—is both necessary and the source of the gear's imprecision and inherent wear. Backlash allows for gears to engage and disengage with some degree of ease, lubricating oil to slide in, expansion due to heat, and minor manufacturing variations. Because of the backlash, however, the gears scrape and shear each other, affecting the life of the gear system and restricting the speeds at which it can operate. Nevertheless, worm gear has many applications, from race cars to hand mixers; it is used where gears are designed to be at right angles to each other and where a high-speed motor's output must be reduced before being transferred to a mechanical drive.

it. By cranking the drive, he could aim the laser. "Look up there," he said, pointing to a tiny dot on a wall about 60 feet away. He used the squirm drive to point the laser so its red beam fell exactly on the dot target. Then he set a gauge on the squirm drive to read zero. Next he moved the laser beam randomly, well off the mark.

"Now watch," Murphy said. "Without even looking at the dot, I'm going to return the laser beam dead on target simply by cranking the gears back to where the gauge reads zero." Standing with his back to the wall, he tweaked the drive until the gauge returned to zero. He turned around and pointed triumphantly to the wall. "With the backlash typical of conventional gear drives," he explained, "you'd never be able to do that."

Zero-backlash drive is handy if you're designing a robot arm for an assembly line to spray paint in exactly the same locations every time—gears with backlash may or may not hit the bull's-eye every time. And precision is of the utmost importance if you plan to send a telescope into space that will be mechanically aimed and re-aimed at exact coordinates.

In a demonstration of another of squirm drive's surprising abilities, Murphy picked up one of the hourglass-shape worms and placed it on his desk between two different-size driven gears. According to orthodox engineering practice, he said, a worm cannot simultaneously drive two gears with different mesh pitches—the space between meshing teeth—and different gear ratios (the number of teeth on a driven gear compared with the same on a driving gear). "But squirm drive can—it's the only gear system that can deliver a multispeed output from a single-speed input," he pointed out. Squirm drive can do so because the worm is able to mesh with a range of roller spacings. From this ability follows another unique trait of squirm drive: You can change a gear ratio by changing only one gear—not two gears as you would in other gear systems.

High-speed applications

Squirm drive's durability and efficiency could allow this gear to be used both in place of worm gear and where that old standby simply can't perform. According to Murphy, squirm gear's low-friction drive makes it suitable for use in high-speed drives that would overheat and wear out worm gear. Murphy has tested one set of squirm gears, which will be used in a golf cart, up to 13,000 rpm. "Of course you don't need that speed for a golf cart," he admitted, "but there are other drives, such as those in helicopters, where I can foresee squirm drive performing at 30,000 to 50,000 rpm."

As for efficiency, worm gear is capable of transferring 50 percent of the rotary power fed into it, but that percentage jumps to 98 with squirm drive, according to Murphy. This degree of mechanical efficiency could be of great use in electric vehicles, for example, where there is little energy to waste.

In some reference books you'll find worm gear under the heading of "speed reducers." Worm gear is designed to run forward, linking a high-speed motor with a slower drive. But squirm drive can run in reverse as a speed increaser. Murphy is working on using it in wind-powered generators, where turbine blades turning at 40 rpm are linked to a 1,200- to 1,800-rpm generator.

Adding to squirm drive's versatility is the fact that Murphy can scale the gear size up or down. "The smallest gears we've designed so far have been for aerospace. The entire mechanism is one inch thick, 5½ inches long, and 3½ inches wide," he said. Murphy also estimates that the manufacturing cost of squirm drive will be five to 10 percent more than that of worm gear, although the price may fall in high-volume production. PS