Harmonic Concepts Jazz Up Planetary Design

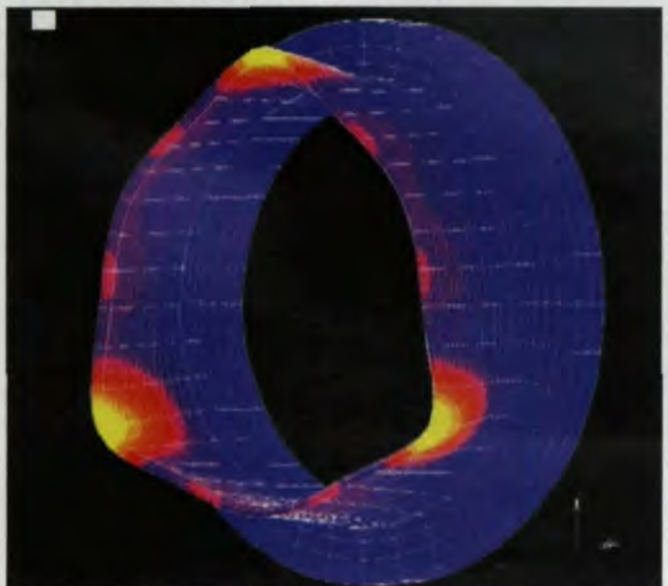
In the world of planetary servo drives, precision is everything. Advertisements abound for servo gear drives with extremely low or even zero backlash. With that type of drive in high demand, manufacturers have done everything they can to tighten their designs—through more exacting tolerances, tighter assembly and better materials.

Instead of tightening, one manufacturer of planetary servo drives has tried loosening in order to provide the low backlash that manufacturers of robotics and other precise positioning equipment require.

That loosening has nothing to do with the manufacturing tolerances or assembly. Precision manufacturing is still required. It has to do with a type of flexibility borrowed from a related technology: harmonic drive gearing.

Harmonic drive gearing has long been known for its low backlash, high precision and compact design. Harmonic drive systems use a circular spline, a flex spline and wave generator to create extremely high ratios in a single reduction. One of the advantages of the harmonic drive system is that the flex spline deforms as it rotates to keep its teeth fully loaded against the circular spline at all times.

Cut-away view of the HPG gear drive from HD Systems.



The HPG drive includes a flexible outer ring gear to control backlash (deformation exaggerated for illustrative purposes).

Engineers at HD Systems of Hauppauge, NY, have figured out how to apply the deformation concept of harmonic drive systems to planetary gears as well. Instead of a flexible inner spline, the HPG "harmonic planetary" gearheads use a flexible outer ring gear to preload the gearset.

The flexible outer ring gear of the HPG gearhead creates a continually adjusting backlash compensation method. The ring gear is thinner in the radial direction than a typical ring gear. This makes it radially flexible, yet torsionally stiff, says HD Systems' marketing manager, Brian St. Denis. "As normal gear wear occurs, any increase in space between the teeth is immediately compensated by the preload in the ring gear. The concept is as if the ring gear is a spring in the radial direction."

The system employed by HD Systems has a huge advantage over those commonly employed by other manufacturers, says St. Denis. The backlash of the HPG drive won't deteriorate over time.

One method commonly employed to provide "low" or "zero" backlash in planetary gear systems is to create a "tight fit" between all of the gears. However, this method is subject to gear tooth wear, and over the life of the gearbox, the backlash can increase significantly.

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Another method is to use preloaded bevel gears as part of the mechanism. Shims force the bevel gears together axially, which forces a radial preload in the planetary gears. Backlash in this type of system also increases over time because of gear tooth wear.

Because of the flexible deformation of the planetary ring gear, the HPG gearhead automatically compensates for gear tooth wear, St. Denis says. This helps ensure consistent backlash throughout the rated life of the gearbox.

The HPG Series planetary gearheads have standard backlash of less than 3 arc-minutes, and they can be ordered with 1 arc-minute of backlash as an option. They are available in ratios from 5:1 to 33:1.

Circle 301

Microgears: For Use In The Human Machine?

In a Hungarian lab, using a microscope's laser, researchers are creating gears and rotors thinner than a human hair. And, while hair grows out of the body, the researchers want to put their gears and rotors into the body, in microscopic machines for conducting experiments.

"It's like the movie *Inner Space* with Dennis Quaid," says researcher Pál Ormos. The machines could be built so small that they would fit into blood vessels, for analyzing blood.

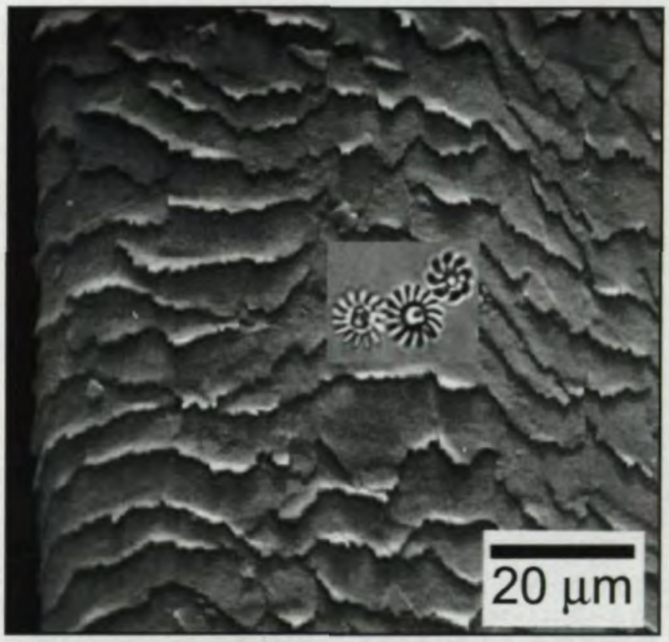
To create the gears and rotors, Ormos uses hardened liquid photopolymer. But, unlike the microparts and their possible use, the material isn't nearly as exotic.

"Dentists use it a lot," Ormos says. The material is the same as what's used for tooth fillings hardened with ultraviolet light.

Ormos developed the technique with Péter Galajda in a little more than a year—"Just now, we are perfecting it." Ormos adds that he'd like to use the technique in less than a year to build several types of machines.

With a doctorate in physics, Ormos belongs to the Hungarian Academy of Sciences and works at its Biological Research Centre, located in Szeged. Ormos is director of the centre's Institute of Biophysics. Galajda is his doctoral student.

"We study the physics of living systems," Ormos says. He adds that there's a strong drive in biology toward miniaturizing, which has "a lot of promise in it."



Created under a microscope, three rotors appear in front of the oak-like trunk of . . . a human hair.

Ormos and Galajda's gears and rotors could be used in that study as parts in microscopic biochemical devices. The micromachines would be used to investigate living systems at a cellular level, permitting the movement of individual cells—"even individual large molecules," Ormos says. "It's a very precise tool that can be used in biology."

With such machines, scientists could introduce chemicals into cells, manipulate their reactions, and maintain those cells' environments, pumping different solutions to different regions. They could measure cell properties to select certain cells, create a channel for transporting those cells and transport the cells individually. They could also remove compounds from cells, even destroy cells.

The gears' and rotors' diameters can be as small as two microns. A human hair's diameter is about 100 microns. At two microns, the parts can weigh as little as 10^{-10} grams.

Ormos and Galajda make their microparts by placing liquid photopolymer under a microscope, then moving a computer-controlled laser focus into the microscope. Wherever the focus moves, the liquid becomes hardened. If it moves in a gear shape, the focus makes a hardened gear.

"We can create a three-dimensional object that is as complicated as we want," Ormos says.

But, there's a wrinkle in the technology that needs to be ironed out.

The microgears are rotated by the microrotors. The microrotors are rotated by light.

"It's not easy to introduce light into the blood vessels," Ormos says.

But, he adds there may be a solution to that problem. Ormos explains that the machines in the body could be powered by light, if it were introduced effectively—via a thin optic fiber, for example.

In similar research, Sandia National Laboratories in New Mexico has used chemical etching to create microgears and experimental micro-engines, electric motors no larger than a grain of sand.

Ormos started his research to understand how light causes different trapped particles to rotate. But, he later realized such light-induced rotation could have useful applications.

"It was not really the area in which we were deliberately moving," he says.

Ormos is unsure about the technique's future—"Whether this can be commercialized or not, isn't clear." Still, he and Galajda are testing resins to decide which works best for creating their gears and rotors.

"I think the possibilities are really unlimited," Ormos says. "Anything that can be done with larger machines can be done with smaller ones, too."

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