Land Speed Champion: The Turbinator III

The machine is called a streamliner. It is thirty-one feet in length and three feet wide. It weighs 3,400 lbs. and looks like something out of a science fiction movie. It's the Turbinator III and it's the machine that Don Vesco used when he broke the land speed record for wheel-driven, gas turbine automobiles (as opposed to thrust vehicles that use jet engines to reach speeds over 700 mph) out at Utah's Bonneville Salt Flats this year. Vesco's record-breaking speed was 417.529 miles per hour. To accomplish this, Team Vesco put an Avco Lycoming T-55-L 11A SA gas turbine helicopter engine in the car. The engine generates 3,750 horsepower at 16,000 rev/min—more than enough to push the Turbinator III to record-breaking speeds. In theory, the Lycoming could push the car past 600 miles per hour, 100 miles per hour or more over the tires' top rated speed!

Of course, speed isn't everything. There is also traction.

At speed, the tires are almost never firmly on the ground at the same time. According to Don Vesco, the driver, mechanic and co-designer of the Turbinator, the tires jump and skip over sections of the 11-mile course. This subjects the driver to vision-blurring vibrations and the drive train to varying loads as the car builds up speed and races for the finish line. That is in addition to the 9,000 lbs. of gear-stripping torque coming out of the Lycoming Turbine engine. That's enough to give any transmission designer night sweats.

The solution that Vesco and his gear designer, Bob Hodgkinson, came up with was to eliminate the transmission entirely. Instead, they built a gear reducer with three gears made from Carpenter's Aermet 100 steel. This, coupled with the locked 1:1 front and rear differentials, means that the Turbinator's drive train is actually a direct drive system. "We wanted to make the system as bullet proof as possible," Vesco explained. "The gears are AGMA 12 and were cut and ground from a single bar of Aermet 100 with the shafts integral to the gears." This allowed them to increase the strength of the parts and avoid the problems associated with shafts flexing and moving in their bearings.

What made this possible was the engine itself. According to Vesco, it is the turbine engine's blades, not the engine's power plant, that turn the driveshaft and the wheels. "It's basically an engine with a hollow output shaft running through the middle," said Vesco. "The output shaft comes out the front and has four fan blades in the back. The exhaust from the engine turns these fan blades. The fan blades, as they turn, drive the car." This means that the engine itself acts like a torque converter in an automatic transmission in that it builds up, yet never provides full power to the wheels due to a slight energy loss in the turbine itself. Therefore, it takes a little time for the wheels to catch up to the power plant.

The wheels aren't the only things that have to catch up to the power plant. It's taken Vesco himself a few runs to get used to driving that fast. "At first I was amazed, five miles gone and I didn't realize it," he said. "Now, I'm waiting for it. My mind is going as fast as the car." Today, that speed is 417.529 miles per hour. Next year, 500 miles per hour will be within their grasp. "With our highest ratio gear reducer and enough track, the car could probably go as fast as 700 miles per hour," said Vesco. "But right now, that's not realistic." Perhaps, but it is only a matter of time.

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Don Vesco and the Turbinator III. Courtesy of Team Vesco.

Welcome to **Revolutions**, *the column that brings you the latest, most up-to-date and easy-to-read information about the people and technology of the gear industry.* **Revolutions** *welcomes your submissions. Please send them to* **Gear Technology, P.O. Box 1426, Elk Grove Village, IL 60009, fax (847) 437-6618 or e-mail people@geartechnology.com.** *If you'd like more information about any of the articles that appear, please circle the appropriate number on the Reader Service Card.*

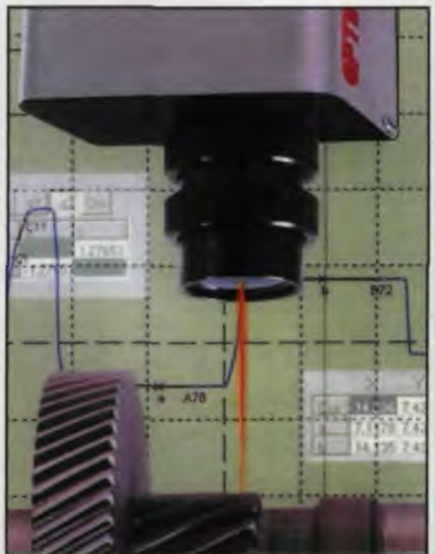
Holographic Measurements in 3D

Non-contact measuring systems have been electro-optical or laser-based in nature, the first taking a digital image of the part under inspection and comparing it to a digital nominal part, the second using lasers as a kind of touch probe. Both are precise methods, but the folks at Optimet believe that they have come up with something better. They have introduced holographic measurement to the art of gear metrology.

Optimet, a division of Ophir Optronics, Inc., has just developed a new way to precisely measure parts. Called the Conoprobe 1000, the unit is a general purpose, non-contact measurement probe that uses the concept of conoscopic holographic measurement to create three-dimensional digital images of the parts it measures quickly and from remarkable distances.

What is Conoscopic Holography? In regular holography, a three-dimensional image is formed when an interference pattern is created between two coherent light sources, such as lasers. The beams from these light sources, called the object beam and the reference beam, travel at the same speed but they follow differing courses. This creates what is called the Gabor Zone Lens (named after Denis Gabor, the Hungarian physicist who discovered holography in 1947) and the image.

Conoscopic holography is slightly different. It uses the ordinary and extraordinary components of a single coherent light beam passing through a uni-axial crystal to create the hologram. This conoscopic hologram has fringe periods that can be precisely measured.



The Conoprobe 1000. Courtesy of Optimet.

The Technology. This method uses concentric optics that function regardless of their position to key optical elements, making the system flexible and rugged while maintaining repeatable precision to 1/8000th of the working range. The scale of the measurement, from sub-microns to meters, is adjusted by changing the objective lens on the probe. And because the probe is collinear, changing over to bending optics will permit measurements to be taken around blind corners.

The new system is also surface independent, meaning that it can create holograms from a greater variety of surfaces than previous non-contact methods. This includes very shiny objects as well as those with wide variations in reflectivity. It is also capable of working very close to grazing incidence, a mere five-degrees from normal incidence in all directions.

The Conoprobe 1000. Designed to be integrated into existing measurement systems, The Conoprobe 1000 is capable of taking up to 700 data points per minute while the probe is in motion. This permits the unit to develop precise holographic images of virtually any part including machine parts and tools, plastic and rubber industrial molds and components, auto parts, electronic parts and more.

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The Coriolis Drive

It all started with an observation made over a century ago. If you lay two coins of the same size next to each other on a table and then roll one around the other, the coin in motion will rotate 720°. Why? The answer to this question, called the "Two Penny Paradox," is as valid for gears as it is for pennies and, according to Ken L. Baker, a design engineer for Fleetwood Systems, Inc., of Romeoville, Illinois, it is the basis for the Coriolis force, the principal upon which his Coriolis drive works.

According to Baker, the way that the Coriolis drive relates to the two penny paradox is like this: "A wheel turns around another wheel and it goes around two times, once because of the distance it has travelled and once because of the shape of the path." This is an example of a law in physics called conservation of angular momentum. The penny has to move an equal distance in two directions; therefore it has to rotate twice.

The same principal makes a rotating disk wobble as gravity pulls it down. "Roll a coin across a table and observe its motion after it begins to topple," said Baker. "It's propelled by linear momentum and rotational inertia while under the influence of gravity. it swerves into an ever-tightening spiral course and eventually starts wobbling around a single point. If you look at it closely, you'll see that it is rotating backwards."

Geometry can explain part of the phenomenon. Due to the angle of incline that the coin makes with the table, the radius of the path (and therefore its circumference) is shorter than that of the coin. "For each trip around the path," Baker explains, "the coin is required to make less than one complete rotation. At 1:1, no rotation at all would be required, but at greater differentials the rotation reverses for exactly the same reasons that cause the Two Penny Paradox." From that coin wobbling on the table it is just a short leap of the imagination to Baker's machine.

Baker's Coriolis Drive takes advantage of the difference in rotation between the wobbling action and the revolving action to act as a gearless speed reducer. With Baker's device, when you start it spinning, all it does is spin. But when you start it wobbling, some of that spinning motion is converted into that wobbling action. "For example, if you have it revolving at a speed of 100 rpm and it begins to wobble, and that wobble causes a 1 rpm precession motion, the original rotational speed will drop to 99 rpm." Taken together, the two rotational speeds still equal 100 rpm. This satisfies the law of conservation of angular momentum. What determines the amount of precession is the amount of wobbling. "The greater the force that wants it to fall (wobble)," explained Baker, "the greater the force that wants it to precess."

Rather than create the wobble with gravity, Baker chose to do it mechanically, to force the wheel to tilt. "The tilt will, itself, pull enough energy out of the wheel's rotation to cause the wheel to precess," said Baker. "I'll use that energy. That's my gear reduction. I'm leveraging one spinning motion against another spinning motion the way that gears leverage the short radius of one gear against the long radius of another gear. Gears use geometry, and what I'm using is physics. But both of them come from the same mathematics. They come from the same science."

Baker has developed a working demonstration model of his Coriolis drive that he is currently in the process of refining. Apart from bearings and a frame, the machine has only four moving parts—a drive shaft and disc mounted off center at an incline, a rotor on a fixed axle, a flexible universal-type coupling and an output shaft.

According to Baker, "The offset of the disc is what maintains a fixed angle of precession, as the central perpendicular axis of the disc is coaxial with that of the rotor. A projected extension of this inclined axis would intersect the major input/output axis at the exact center of the universal joint. Thus, by rotating the input shaft, the rotor and its axis are forced to precess about the major axis of the universal joint. This precessional motion induces rotation into the rotor, which causes the output shaft to rotate in the same direction and with the same force."

While Baker freely admits that there are a number of applications where a Coriolis drive would not be a viable alternative to gears, he also holds that there are quite a few areas where his invention would, as he puts it, "outshine a gear motor and perform the same task more efficiently."

These applications include variable speed, low-friction motors and transmissions for applications ranging from small power tools, lawnmowers and pumps to motorcycle and helicopter engines and diesel locomotives.

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Where You Want To Be

AGMA has just released a new 14-minute video designed to introduce students to the gear industry. The video, called "Where You Want To Be: An Introduction to the Gear Industry," was a cooperative venture between AGMA's Education Council and the AGMA Foundation. The project was undertaken to increase awareness of the gear manufacturing industry as a career option for high school and trade school students and their families. Twenty-eight gear manufacturers contributed to the AGMA Foundation in support of this effort.

The video presents gear manufacturing as an industry featuring modern, clean, high-tech facilities where employees will be trained to use the latest in computerized and electronic machinery. It also describes the gear industry as being competitive in pay and benefits, geographically distributed across the country in both rural and urban areas, and offering positions ranging from machining to design to management. Finally, gear manufacturers are shown as companies where a positive attitude will buy the opportunity to work in a dynamic and challenging atmosphere producing the high precision products that keep America competitive and on the move.

Copies of the video will be provided free of charge to AGMA member companies, and additional copies can be purchased from AGMA. Brochures, which support the message of the video, are also available. Gear manufacturers are encouraged to contact their local secondary and trade schools and provide copies of the video and brochures to the guidance staff. To obtain copies of the video and brochures, contact AGMA at (703) 684-0211.

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Correction

We apologize for, and wish to correct, the following errors that appeared in the *Revolutions* article featuring Falk Corporation in the September/October 1999 issue of *Gear Technology*.

The name "Fimeston" should be spelled "Fimiston." The OEM for the mill located at Fimiston Mines is FFE Minerals of Australia. The flanges of Falk's large gears are locked together with tapered steel dowels, not locking pins. The pinions mating with these large gears are finished to AGMA 12 levels, not the ring gears themselves. Ring gear segments are finish cut to AGMA 10 tolerances with average tooth finishes falling around 63 to 100 RMS (not RMF). Average tooth finish is required because there are areas that could get as high as 125 RMS, and typical consultant specifications require a maximum of 125 RMS.

Again, *Gear Technology* apologizes for any confusion, inconvenience or consternation these errors might have caused.

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