Magnetic Gears

Sleeping Giant or Toothless Tiger?

By Jack McGuinn, Senior Editor

When is a gear not a gear? Pardon my Zen, but that is a bit like asking, "What is the sound of one hand clapping?" Or there's the old bromide, "If it walks like a duck, talks like a duck," etc.

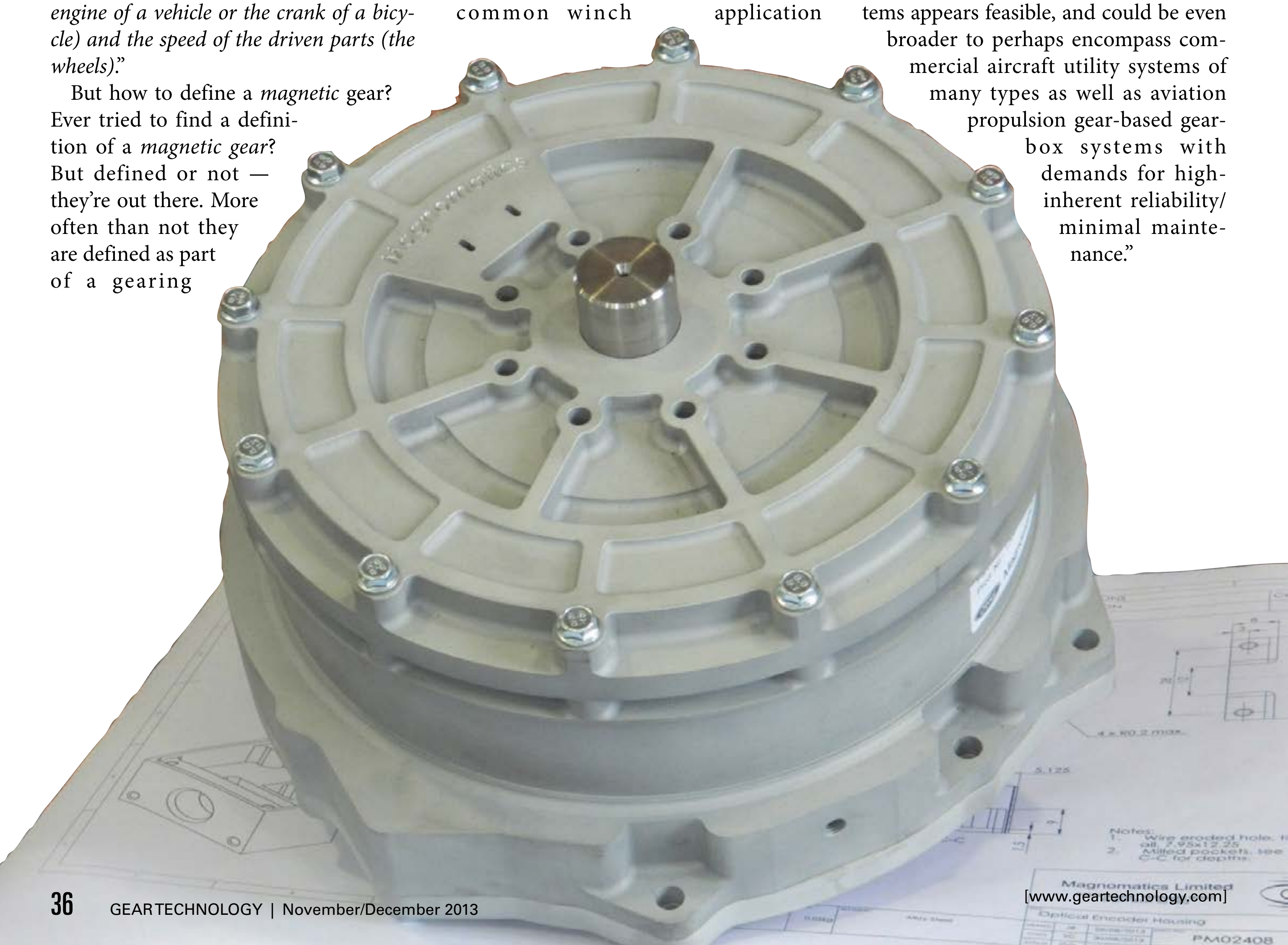
Just work with me here…

The *Gear Gospel According to Dudley* defines a gear as "*A geometric shape that has teeth uniformly spaced around the circumference. In general, a gear is made to mesh its teeth with another gear.*" A typical dictionary definition goes something like this, and for the purposes of this article, is in some ways better suited: "*One of a set of toothed wheels that work together to alter the relation between the speed of a driving mechanism (such as the engine of a vehicle or the crank of a bicycle) and the speed of the driven parts (the wheels).*"

But how to define a *magnetic* gear? Ever tried to find a definition of a *magnetic gear*? But defined or not — they're out there. More often than not they are defined as part of a gearing "system" — a gearbox, for example. But here's the thing: magnetic gears have no *teeth*. Oh, they mesh and all that, in their own unique way, and make things move; *but they have no teeth.*

The U.S. Navy certainly knows its magnetic gears, because they are found specified in Department of Defense RFPs, much like this one from 2010 (Magnetic Gears for Utility Actuation Gearbox Applications Navy SBIR 2010.2 — Topic N102-115): "Objective: Develop and demonstrate an airworthy magnetic gear-based gearbox suitable for utility actuation winch applications. Magnetic gear-based gearbox suitable for utility actuation winch applications" has become a common specification for a common winch application — one of many applications magnetic gear systems are now handling in lieu of traditional wrought-gear systems.

Indeed, the above-referenced RFP goes on to enumerate various other applications — existing or possible — that are commercially suitable for "magnetic gear-based winch gearbox systems," including: "winching/reeling systems on commercial aircraft such as search and rescue aircraft; police/security helicopters; logging operation aircraft; and off-shore oil rig aircraft operation. Other potential applications include industrial control and heavy equipment used in construction and mining operations. Indirect application of the technology to other non-winch gearbox systems appears feasible, and could be even broader to perhaps encompass commercial aircraft utility systems of many types as well as aviation propulsion gear-based gearbox systems with demands for high-inherent reliability/minimal maintenance."



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To get closer to the can-do capabilities of magnetic gears we questioned David Latimer, business development manager of Yorkshire-based Magnomatics in the UK.

Accounts vary, but according to Latimer, "The first magnetic gears were proposed as far back as 1968. Magnomatics has developed these early ideas and can produce some very high-torque devices."

"Magnetic gears work by creating harmonics in magnetic fields," Latimer explains. "Predicting the effects of these harmonic fields has historically been very difficult," But he points out that, by employing "the most advanced finite element analysis tools, combined with in-house design methods," the company is able to "predict and understand these harmonics."

Those proprietary "in-house design methods" would appear to be the key to the puzzle.

At the company's technological heart — and where its growth depends — is in its three core offerings: 1) Magnetic Gears — A contactless, high-efficiency, high-torque transmission with inherent overload protection; 2) Magnetic CVT (mCVT) — A contactless, high-efficiency, continuously variable transmission system with inherent overload protection (MAGSPLIT, designed to duplicate the mCVT's capabilities and more, does so by providing the same functionality, but requiring much less real estate. MAGSPLIT also substantially improves the system efficiency and therefore fuel economy, compared to the mechanical gear and motor/generator combination found in many of today's hybrid cars; and 3) Pseudo Direct Drive (PDD) — An electrical machine, with fully integrated magnetic gearing offering unrivaled torque density.

By most accounts, the Holy Grail of magnetic gearing — both in the U.S. and around the world — is how to develop a magnetically geared — i.e. — electric — continuously variable transmission (CVT) — designed for use in *all* types of vehicles — large, small, personal and commercial. The benefits that accrue — better mileage, less pollution and smoother ride — are goals that automakers have pursued since the discovery of the combustion engine. And for Magnomatics, its techno trinity is sufficient justification for continued R&D in pursuit of that goal. What's more, recently announced — if not yet in practice — pollution mandates around the world — particularly in Europe, for now — render the need to succeed even more critical. Latimer points out that electric CVTs in fact already exist in compact hybrids from Toyota and Ford that "combine a planetary gear and an electric motor generator (see *http://eahart.com/prius/psd*)." And while the need continues to exist for larger, faster, more durable vehicles for both personal and commercial use, Latimer says that Magnomatics has "MAGSPLIT units being tested on rigs" — both in-house and at customer sites.

In the meantime, says Latimer, Magnomatics designs gear systems for "down bore-hole pumps, marine propulsion, wheel motors, hybrid powertrains and aerospace actuation." Clients include Messier-Bugatti, Goodrich, Turbo Technologies, Ultra Electronics and Macon.

Maybe by now, rather than wondering *why* magnetic gears, you are wondering *why not*. After all, according to Magnomatics they are: contactless (a magnetic gear uses those permanent magnets to transmit torque between an input and output shaft without mechanical contact; since there is no mechanical contact between the moving parts, there is no wear and lubrication is not required); highly efficient (torque densities "comparable" to mechanical gears can be achieved with an efficiency > 99 percent at full-load and with "much higher" part load efficiencies than a mechanical gear); high in torque transmission (for higher power ratings a magnetic gear will be smaller, lighter and lower cost than a mechanical gear); fail-safe-overload-protected (magnetic gears inherently protect against overloads by harmlessly slipping if an overload torque is applied, and automatically and safely re-engaging when the fault torque is removed). Other pluses include: significant reduction in harmful drivetrain pulsations; allows for misalignment/vibration of shafts; very low acoustic noise and vibration; gear ratios of 50:1 down to 1.01:1, with almost zero torque ripple are readily achievable.

But we don't have to take a commercial entity's word for all this. Let's return to that Navy RFP for the straight scuttlebutt on some of these same points.

According to the U.S. Navy:

Application: "Modern rotary wing aircraft have a number of utility winching/reeling systems for cargo, rescue, and sensor deployment applications."

Wrought gears. "Degradation or failure of these systems through wear of gear teeth can cause serious mission, reliability, maintenance, and logistical impacts."

Magnetic gears. "Magnetic gears afford the opportunity to provide speed and torque multiplication similar to a traditional geared gearbox or transmission, but by using magnetic attraction between rotating members rather than actual physical contact, as between gear teeth. It may be possible to greatly reduce, or potentially eliminate, lubrication requirements, compared to existing traditional gearboxes. A magnetic gear-based gearbox for winch applications could increase reliability and mission availability by reducing — or perhaps eliminating — wear-related gearbox failures attributable to traditional tooth-to-tooth contact."

But beyond what-if, blue-sky thinking, what is the application sweet-spot for magnetic gearing in the here-and-now?

"Our first production application is to drive a down bore-hole pump for artificial lift to improve yield in an oil and gas application," says Latimer. "The gear comes into its own because it can be made to work in a small diameter and is very reliable (the pump's installation, downtime and removal costs are high)."

In general, according to Latimer, and beyond the examples already cited, magnetic gearing's capabilities are dictated by "the speeds, torques and space available."

And here's a good news (for bearing manufacturers), bad news (for design engineers) fact of magnetic gearing life: bearings are required, just as with steel gears. And just as with steel gears, says Latimer, "The most likely weak point of a magnetic gearing system will be the bearings."

As for AGMA or ISO standards, "We have not seen any particular impact as yet and tend to use (IEEE) standards intended for electrical machines as a reference."

So here we are on the doorstep of 2014, some of us still waiting for magnetic gears' big roll-out. What's the hang-up?

Could it be because China controls approximately 90 percent of the rare earth materials needed for the magnets that constitute magnetic gears? That would seem to keep prices artificially high and induce supply chain management nightmares in any design team contemplating magnetic gearing technology in any significant way.

Latimer doesn't see it that way.

"We think it just takes time for a new technology to be adopted. Our gears use the same magnet materials commonly found in permanent magnet electric machines, and those sell in abundance. We have seen magnet prices reduce and stabilize recently. The Chinese now realize that if they force up the price it becomes economical to open mines elsewhere."

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