Passive Magnetic Bearnings

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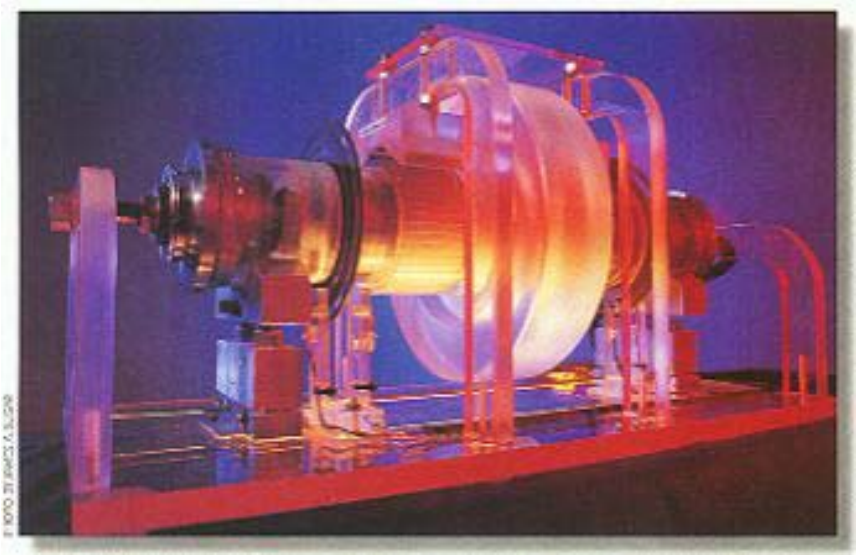
This Jim Wilson article about passive magnetic bearings is another wonderful and important invention from the mind of Dr. Richard F. Post, a renowned scientist at the Lawrence Livermore National Laboratories. Dr. Post also invented Inductrack - the passive MagLev system we will be using on SkyTran, which also utilizes permanent magnets cleverly arranged in a "Halbach Array" to concentrate and strengthen available magnetic forces. You get about 1/3rd of the levitation power of superconducting magnets without the cost, complexity and maintenance problems. PM thinks Dr. Post's newest invention will be someday be regarded as THE most significant mechanical device of the 20th Century.



Passive permanent magnet bearings could make oil and ball bearings obsolete. Bearings aren't as sexy as fusion reactors or hypersonic aircraft, but they have a more immediate connection with life in a modern industrialized society. Without bearings, wheels don't roll, planes don't fly, generators don't spin. Bearings are so important that when the Allies began their strategic bombing campaign against Nazi Germany, ball-bearing factories were at the top of their targeting list. Although the technology is mature, taking the next step and virtually eliminating demon friction could have far-reaching economic impacts. " Oil-lubricated bearings for a 50-hp electric motor typically dissipate approximately 1 percent of the input electric power," Post told POPULAR MECHANICS during a recent visit to his lab in Livermore, Calif.

As a kid you probably played with magnets. The first time you felt the repulsive force of like poles pushing your tiny hands apart, you might have thought about doing something practical with your discovery, like making one of your toys levitate. The problem, you promptly discovered, is that magnets aren't very cooperative. If you lay one atop the other, the top magnet flips over and twists, causing the opposite poles to lock together. Since elementary schools don't normally teach Earnshaw's theorem, you had no way of knowing that passive magnetic levitation is impossible. So, being a clever kid, you soldiered on, using Legos -- or in my case Tinker Toys -- to build some sort of compensating mechanism. Unless your name is Richard Post or J. Ray Smith you eventually got bored and went outside to play.

Tribology

Too bad you didn't stick with it. While Earnshaw's theorem is as valid a law of nature today as it was when it was first proposed by the Rev. Samuel Earnshaw in a scientific paper published in 1839, Post and Smith have found a clever way to work around it. In so doing, the two Lawrence Livermore National Laboratory (LLNL) researchers have invented what may someday be regarded as the most significant mechanical device of the 20th century -- the first passive permanent magnet bearing.

"For a continuously operating motor the annual electrical cost of this level of bearing friction loss would amount to nearly $200. Over the [typical 10-year] lifetime of the motor this added energy cost would amount to nearly as much as the initial cost of the motor. "If you don't routinely buy large electric motors, this comparison might strike closer to home: Imagine that by simply replacing one part on your car you would save enough gasoline to buy a new car every 10 years.

Active Versus Passive

To demonstrate that a passive magnetic bearing can work, Post's team has built several proof- of-concept models. They use a mechanical bearing to reduce friction until the rotor has reached a transition point-between a few hundred and a few thousand rpm at which time the repulsion of the magnets causes the rotor to levitate and center itself It's so simple you have to wonder why no one ever thought of it before. Post offers his theory: "Researchers have accepted the widely held belief that Earnshaw's theorem cannot be evaded without the use of active controls or of superconducters. "You need a good bit of math background to understand Earnshaw's theorem. In the case of magnetic levitation it basically means that you need to introduce some outside force to maintain a stable magnetic field. The active controls to which Post refers were offered as one possible way to solve the problem. Jesse Beams of the University of Virginia (UV) first proposed the idea 60 years ago and today more than a dozen companies make active bearings that use sensors and feedback circuits to achieve stable levitation of a spinning object. Active magnetic bearing technology works well enough, says Paul Allaire of UV's Center for Magnetic Bearings in Charlottesville. The tradeoff is that it's expensive.

Allaire recalls one project in which he helped design an active bearing for a $16,000 industrial pump: The bearing cost half. The first proof that it was possible to do an end run around Earnshaw using passive, permanent magnets came in a toy, a levitating top called a Levitron (see "Elevating Educational Toy," Aug. 1996, page 16). "The stable rotational state exhibited by this simple toy is an existence proof of a stable, passively levitated rotating system that is not limited by Earnshaw's theorem," says Post. There was only one problem, and it was a whopper: "Unfortunately, the Levitron concept does not appear to represent a practical approach to a passive bearing for most industrial applications."

And here it all might have ended, had Lawrence Berkeley Laboratory physicist Klaus Halbach not needed a better way to focus particle beams. He experimented with placing magnets in arrangements that came to be known as Halbach arrays. Post discovered that they were ideally suited for correcting the type of instabilities that would otherwise make a practical levitating bearing impossible.

Conversion Aversion

Now, it is up to the market to determine if the energy and cost savings will come to pass. Allaire is impressed but skeptical. "In a big motor everyone uses oil film bearings. The reason is that they

have a lot of [vibration] damping. I don't think the passive magnetic bearings will provide enough damping. Small electric motors use ball bearings that cost about 5 or 10 bucks. I don't think you can buy a Halbach array for that price," he said. "It will be an uphill struggle. In the economic realm better technology doesn't always win."

Comments on Allaire's comments:

Hundreds of millions of dollars have been spent over many decades to continually advance bearing materials and the automation manufacturing systems currently used to get the costs down to "5 or 10 bucks". Big bearings for large motors and generators are still quite expensive. We see passive magnetic bearings being initially used in that field and being cost effective in less than a decade.

Passive magnetic bearings are already being used in 400 horsepower Trinity Flywheels units. These flywheels have been so perfectly dynamically balanced, however, that one cannot feel any vibrations - even when the advanced composite rotor, which is magnetically suspended in a sealed vacuum, is spinning at 70,000 RPM!