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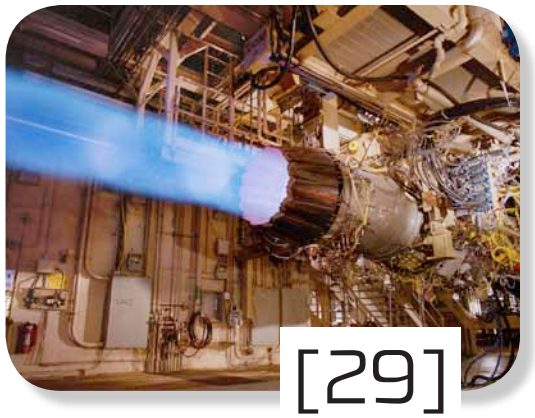

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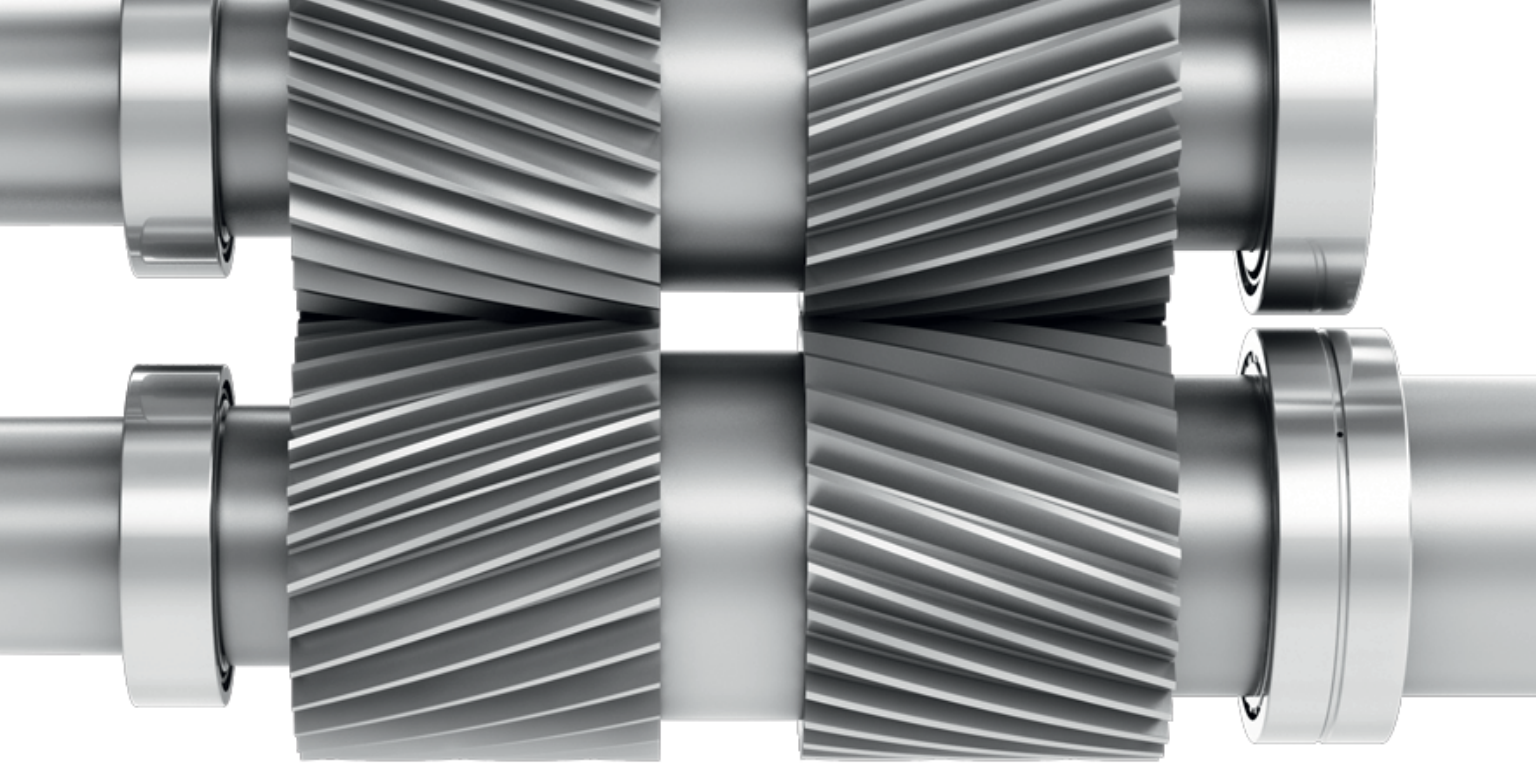
FEATURE ARTICLES

TECHNICAL ARTICLES

Power Transmission Engineering

VOL. 7, NO. 2

Photos courtesy of the U.S. Department of Defense and Arrow Gear



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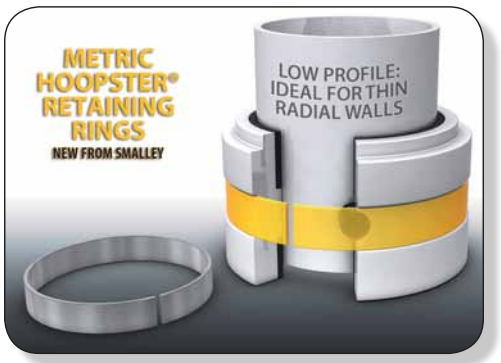
PTE Newsletter

Smalley Steel Ring Company, the developer of Spirolox Retaining Rings, Constant Section Rings and Smalley Wave Springs recently announced the launch of the new Metric Hoopster Retaining Rings. Take an in-depth look at this new product in the March PTE E-Newsletter.



www.powertransmission.com/newsletter/pt0313.htm

PTE Videos

Dual-Shaft Stepper Motors

AutomationDirect has added twelve new parts to its motion control line including ten SureStep dual-shaft stepper motors, one new single-shaft motor and one reducer bushing. Hear about these new products in a video on *www.powertransmission.com*.

New Additions and Updates

The following companies have recently added premium listings or updated their listings on powertransmission.com. For the up-to-date directory, visit *www.powertransmission.com/directory*.

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The Gear and Transmission division of LiuGong has more than 30 years of experience in manufacturing powertrain components including clutch discs, gears and toothed parts, splined shafts, housings for powertrain components and more.

Stay Connected with Social Media

PTE's LinkedIn page features a link to R+W's Niilo Nykanen's article on Using Mechanical Torque Limiters for Servo Drive Systems. (See the original article here: *http://blog.rw-america.com*).

We now have more than 830 followers on Twitter including recent additions like Florida Bearings (@FloridaBearings), Crouzet (@CrouzetCST) and Martin Sprocket (@MartinSprocket).

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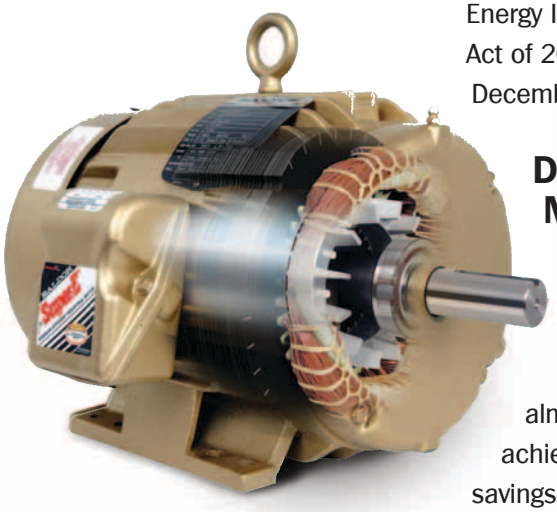

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Randy Stott, Managing Editor

Chasing the Dream

Over the past several weeks, I've had quite an interesting back-and-forth e-mail conversation with John Pellegrino, an engineer, inventor and dreamer whose letter appears on page 8.

For well over a decade, Pellegrino has been working on his design for a device that has eluded some of the brightest minds in engineering—a positively engaged, continuously variable transmission (CVT). It's a concept with great potential.

The CVT has intrigued automobile manufacturers since the beginning. In fact, Karl Benz's first patent for an automobile, in 1886, included a friction-based belt CVT. Over the years, a number of attempts have been made, and some have even made it into production. Notable examples include the British Clyno gearbox, built in the 1920s; and the DAF 600 with its Variomatic transmission, produced from 1959-1964.

Beginning in the 1980s, interest in automobile CVTs really took off, and today, with continuous pressure on automakers to increase fuel efficiency, there are literally hundreds of cars offered with different types of CVT transmissions, including belt-driven, chain-driven and toroidal roller based models.

Of course, CVTs have also been fraught with problems. There have been lawsuits, recalls, and a history of repairs and trouble. Not to mention the fact that auto enthusiasts absolutely loathe them. A car without actual gears in the transmission is just not as much fun to drive. GM and Ford have abandoned the concept (at least for now).

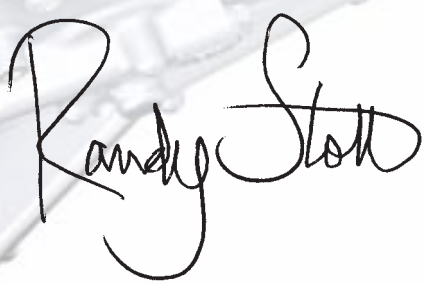
Nevertheless, *Automotive News* predicts that CVTs will grow from seven percent of the market in 2010 to 16 percent by 2015. And some automakers are clearly all-in. Nissan, for example, uses CVTs on all of its current front-wheel-drive models.

Photos Benz 1886 reproduction car (above), Modern Audi CVT (background)

What we really need is a better CVT, Pellegrino says. All of the current models and past attempts suffer from one or more deficiencies. In 1995, Pellegrino published an article that included his requirements for a viable automobile transmission:

- No reliance on rubber-like elements such as belts and/or rollers. These devices have severe power limitations and are subject to rapid wear.
- No reliance on power transfer through high-force, metal-to-metal traction (friction). These devices have severe wear and grooving problems and are difficult to shift.
- No reliance on one-way clutches or ratchets. These devices have power limitations and are prone to high wear rates.
- No reliance on oscillating mechanical elements, which can create vibration and low efficiency.
- No reliance on additional subsystems such as pneumatic, hydraulic or electrical components.
- The ability to execute rapid ratio shifts without having to overcome high friction or other forces.
- The ability to deliver a smooth, nonpulsating, rotational output.
- The ability to operate in a direct-drive manner in both the forward and reverse mode with no free-wheeling in either direction at any time.
- Reliance on well-established mechanical elements throughout.
- Manufacturability using current production techniques.
- Good adaptability to industrial and automotive applications.
- Smooth, quiet operation at a high level of mechanical efficiency.

So far, Pellegrino says, none of the previous CVTs have met all those requirements. But he still thinks it's possible to build a better mousetrap. Do you? **PTE**



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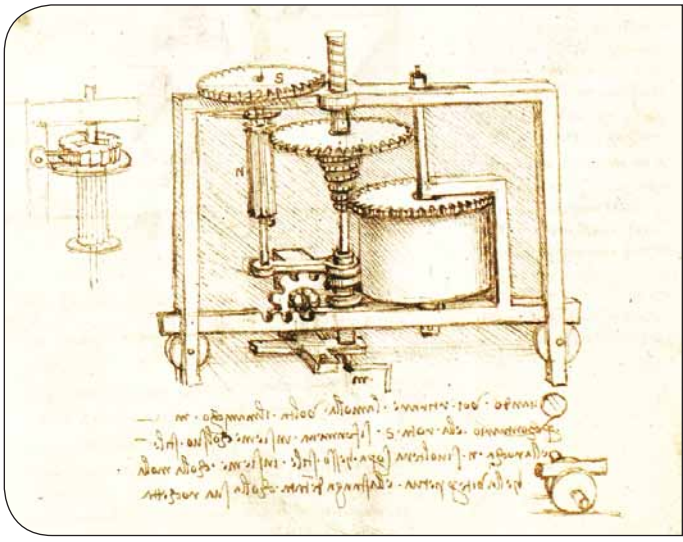
Am I Wasting My Time?

Attention Power Transmission Engineering magazine readers!

I need your opinion/expertise on an issue that has been puzzling me for some time. The subject of the issue is that of a mechanical, continuously variable transmission (CVT)—specifically for automotive use. It is an acknowledged fact that a vehicle equipped with a CVT achieves better fuel efficiency and reduced emissions (20 percent each) as well as improved driveability. That is the good news.

Unfortunately, current CVT technologies, which are all based on friction between smooth surfaces, are limited to smaller vehicles with modest amounts of power. In the case of mid- and larger-sized vehicles, the friction-based concept does not pass the durability and practicality test. That is the bad news.



What is needed is a positive displacement design that does all of the things that a viable CVT should do but without any of the power limitations inherent in current units.

So far, no one has stepped forward with such a design.

This leads me to pose the question: "Is it physically impossible to produce such a design, just as it is impossible to graphically trisect an angle?"

History tells us that in the year 1490, Leonardo da Vinci sketched a variable speed drive mechanism that operated in steps rather than being continuous. (Close, but no cigar.) Legend also has it that in the early stages of the Ford Motor Company, Henry Ford charged his engineers with the task of developing a viable CVT. After some time, they concluded that it could not be done.

I am of the opinion that a viable CVT design is possible, and as such, I am working on a design that is showing a lot of promise. However, considering the history of this subject leads me to pose the following question:

Am I wasting my time in this pursuit?

Readers are encouraged to contact me with their comments and/or questions.

Replies can be made to John Pellegrino, *patp07960@yahoo.com* or (973) 539-2932.

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As Risk Recedes, Market Rises

Doggedly improving economy — and Fed printing press — trump sequestration.

Brian Langenberg, CFA

The S&P 500 (Fig. 1) has rallied six percent since our last review; driven by near-term relief about debt ceiling concern and straightforward signals out of the Federal Reserve that money will be printed in sufficient quantities to support financial assets (i.e. stocks and a nascent housing recovery).

All sectors are up this quarter, led by healthcare (the growth area in government), financials (Fed printing press), consumer-related (discretionary and staples) and closely followed by industrials. Laggards – Info Tech (AAPL) and Materials (mining is weakening).

Two months ago the market risk was, in our view, surprise resilience by tax cutters (Tea Party) in the face of President Obama's reelection. Because about two-thirds of institutional investment funds are managed in Blue States (NY, MA, CA) by people who do NOT know many truck drivers or mechanical engineers, or Tea Party people with disposable incomes below six figures, there is sometimes a disconnect between what markets price in and how things play out.

That risk was quickly chopped away when the Koch brothers (George Soros and others fund the Left; the Koch brothers fund the Right) publicly signaled to the Tea Party that using debt ceiling to get spending down was a bad, bad, idea in pursuit of a good goal. Message received.

The "kicked can" is in play. What each side wants is obvious; their strategies and tactics are evolving, and the question will be for both those in an actual capital goods business and for investors is what government spending gets cut and which end markets does it affect.

Here is our matrix of likely outcomes (Fig. 2), scientifically derived by powerful secret algorithms in a secure underground location (okay, my own judgment):

At this juncture the factions in both parties have absorbed and are beginning to execute their political strategies according to their worldviews. Under the noise (administration, media, both sides) it appears as though the Republicans will play a ground game – Cantor, Ryan, et al. and work through a normal (or semi-normal) budget process and committees. President Obama has decided, apparently, that in year five of his Presidency that meeting with members of Congress who don't agree with him is worth doing (something about having divided government – it's called the legislative branch!). It will be a "process"—but at least now there appears to be one.

We have no reason to anticipate a grand bargain on corporate tax reform — which would drive U.S. job growth into the ozone layer — so figure on continued muddling and a dogged economic recovery.

Debt-ceiling-as-weapon. Unlikely — but there *will* be **economic impact**. The $85 billion in sequestration works out to less than 0.5 percent of the total U.S. economy and perhaps 1.5 percent of total (Fed, State, Local) government spending. But the multiplier effect (number of times a dollar of economic activity generates another dollar of activity) means these cuts, if they continue, can significantly dampen overall GDP growth. The question is where and who.

Defense has less risk than you think. The obvious chatter is around Defense, which involves more than economics. As with any nation, domestic policy inevitably impacts relationships with the outside world. Delaying deployment

S&P 500 SECTOR PERFORMANCE	MTD	QTD	YTD
Energy	1.0%	8.7%	8.7%
Materials	2.9%	4.9%	4.9%
Industrials	2.0%	9.9%	9.9%
Consumer Cyclical	3.8%	10.7%	10.7%
Consumer Staples	1.4%	10.4%	10.4%
Healthcare	2.6%	11.2%	11.2%
Financials	3.7%	10.9%	10.9%
Into Tech	2.2%	3.9%	3.9%
Telecom	2.3%	7.2%	7.2%
Utilities	1.4%	7.9%	7.9%

Source: Standard & Poors

Figure 1

Market Return	% Prob.	
↑	0.001%	Obama Caves On Spending
↑	0.01%	Grand Bargain (Intelligent policy, corporate tax reform)
↓	25%	Cage Match (Republicans win on spending)
→	**74%**	**Muddle Some More**
→	0.999%	Republicans Steamrolled

Figure 2

of an aircraft carrier to highlight budget issues while Iran's nuclear program continues unhindered, for example, will not reduce defense spending longer term. Currently I am reading *Diplomacy,* authored by some guy named Dr. Henry Kissinger. It seems appeasement doesn't work.

That kind of irresponsibility leads to a) potentially a lot more people dying in war, later — and not "one per centers" — because of inadequate deterrence, before, and b) spending more on defense, anyway. For example: when the F-22 Raptor was canceled in 2009, and we refused to sell it to Japan and Australia, it reportedly was because there was "no need." Now Japan is seeking to raise defense spending, and the Philippines has publicly stated it likes the idea. Defense will remain a solid area of demand — whether by the U.S. or somebody else.

Questions about Boeing and the 787. The problem is a *battery*, people — *not* the plane. This will pass.

So who gets the knuckle sandwich? Municipal spending-driven end markets — water and wastewater, building construction. While not a federal budget issue directly, austerity rolls downhill and no small part of stimulus spend was federal money funding state and local capital projects. When sugar daddy has no sugar, things get sour. And the improving real estate markets will take at least two years to translate into higher tax receipts at the local level. With respect to highway and infrastructure spending, we anticipate continued stability, but while construction equipment markets are well above-trough on replacement, demand is nowhere near peak.

Market View: Cautious. Our base case for the S&P 500 remains 1,575 at year-end (Fig. 3). Much of the 7 percent upside was realized in the past two months, not on fundamental economics (which are doggedly improving) but the aforementioned Fed and risk issues in the market.

Generally speaking, market multiples are driven by interest rates (lower rate equals higher multiples and unanticipated changes) and risk premium (more volatility / fear drives lower multiples).

We think we have the economics right (U.S. improving, Europe stagnant, China accelerating); interest rates cannot

S&P 500: 1548.2 *After market close 3/7/13*

	S&P 500 Earnings			Implied Price Return		
P/E	$95	$105	$112	$95	$105	$112
13x	1,235	1,365	1,456	(20%)	(12%)	(6%)
14x	1,330	1,470	1,568	(14%)	(5%)	1%
15x	1,425	1,575	1,680	(8%)	2%	9%
16x	1,520	1,680	1,792	(2%)	9%	16%
17x	1,615	1,785	1,904	4%	15%	23%

Figure 3

really go lower (but unlikely to move higher), so upside revaluation of the market would likely come from "chopping away" some risk. Consensus operating S&P 500 estimates are $112 for 2013 and $125 for 2014. We use $105 for 2013 because consensus is slowly drifting lower and, traditionally, forecasts start out too high. Also, something usually goes wrong.

Risk. We did not anticipate a rapid backing away from using the debt ceiling as a negotiating tool, but with that risk chopped away the market has been able to rally and the CBOE Volatility Index continues to signal a sanguine view of damaging action by either party. Stocks climb a wall of worry — and it has indeed climbed (Fig. 4).

***China*:** Firm evidence of accelerating demand, particularly in HVAC-related end markets including company commentary from 4Q and (more recently) monthly order data from Emerson. Construction equipment is another matter; figure at least six months of excess inventory to work off (Fig. 5).

***Europe*:** Heavy industry (Germany, Nordics) should benefit from China and emerging market acceleration; rest of Europe likely remains stagnant but stable.

End Markets: No change here — just a few opportunities for double-digit growth in 2013, including:

Global themes: Commercial aviation.

U.S.: Automotive, residential construction, appliances, power transmission, power distribution.

China: Industrial automation, rail, social housing, auto. Overhang in construction equipment likely to persist for at least another 2-3 quarters.

Japan: Military spend.

Europe: Could see strong comparisons in late '13 (China).

What about power generation? Order push-outs at Flowserve signal to us that while inquiries and activity remain high, the combination of efficiency gains (HVAC, grid-versus-generation) and regulation make an upturn in gas turbines in the U.S. unlikely before 2014 at the earliest.

(For those whose responsibilities include business planning and having a broader, deeper grasp of major trends, we encourage you to consider subscribing to Global Industrial Outlook [see our ad, page 50]). **PTE**

CBOE Volatility Index
Courtesy of MarketWatch

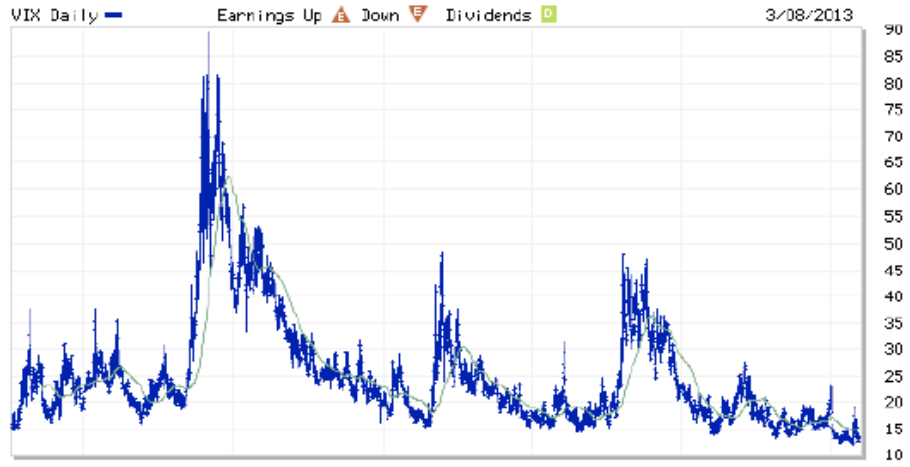

Figure 4

Revenue: Caterpillar, Asia Pacific
Change: year/year

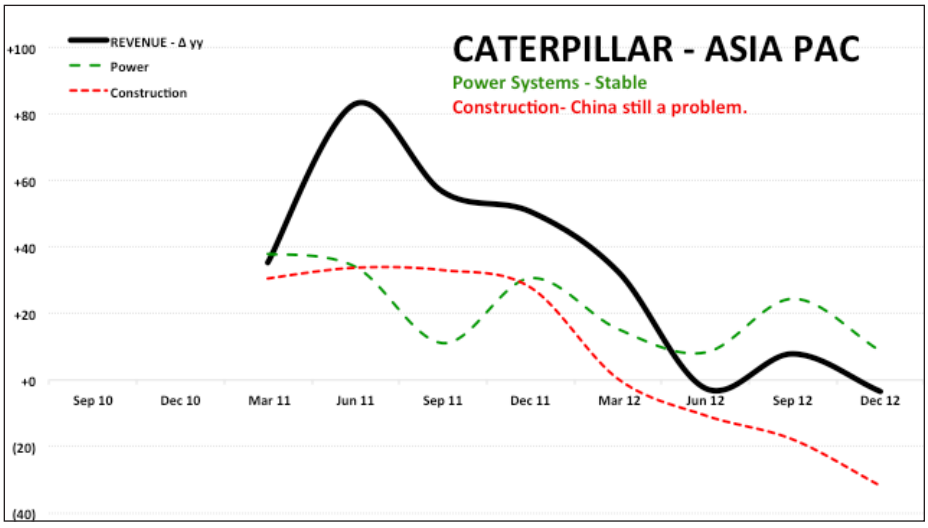

Figure 5

Brian's Quick Picks:

GE: You get the yield, and the long-term value is there. My $2.50 earnings power view is intact, but will need a U.S. power cycle that is starting to smell more muted and gradual than I would like. That is, energy-efficiency gains on both the demand side (energy retrofit) and the supply side (utilities investing in transmission to forego further generation capacity additions); but directionally, we have earnings power, limited expectations, late cycle and yield.

UTX: A simple, easy path to value. Guide of $5.85–6.15 (as of this writing) is conservative; I remain at $6.20. Most of what we need to happen, the company can control, i.e., executing the Goodrich integration, cleaning up CCS (Carrier HVAC + Fire & Security), and leverage to a China upturn (Otis).

Brian K. Langenberg, CFA, has been recognized as a member of the Institutional Investor All-America Research Team, a *Wall Street Journal* All-Star, and *Forbes/Starmine* (#1 earnings estimator for industrials). Langenberg speaks and meets regularly with CEOs and senior executives of companies with over $1 trillion in global revenue. His team publishes the *Quarterly Earnings Monitor/Survey*—gathering intelligence and global insight to support decision-making. You can reach him at *Brian@Langenberg-llc.com* or his website at *www.Langenberg-LLC.com*.

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ENERGY EFFICIENT BEARINGS ON A ROLL AT INDONESIAN TEXTILES PLANT

Along with the rest of Indonesian industry, the Leuwijaya Utama textile company, a Leuwitex company, was confronted with a government-mandated increase in electricity costs in July, 2010. For Leuwitex, it meant an increase of approximately 18 percent. For a company with 300 textile-weaving machines and 176 twisting machines consuming 2,120 megawatt-hours (MWh) per month, in their Bandung factory, this represented a major increase in operating costs; it required a speedy reaction in order to reduce the effect on the threat to bottom-line profitablility.

Immediately after the increases were announced, plant management set about searching for ways to reduce energy consumption throughout the entire factory. Along with shutting down all unnecessary power feeds (lighting, standby machinery, etc.), the team took a detailed look at production. The factory, one of three Leuwitex plants in Indonesia, produces some of the most sought-after fabrics in Indonesia and exports to the Middle East, Malaysia and Europe. Over the years, Leuwitex has developed a number of design and manufacturing techniques to create a wide range of fabrics—including a custom-made fabric that customers report has exceptional feel, design and wear properties—that have placed them among the top 10 producers in Indonesia.

A focus on twisting machines . To produce the daily volume of almost two tons of fabric, the Bandung factory has the usual range of textile machinery including electric motors, weaving machines, spinning machines, twisting machines, etc. Initial investigations showed that 30 percent of the factory's energy consumption was consumed by the twisting machines—an important piece of machinery that is critical to fabric quality. So along with taking measures to correct electric motor energy losses and optimizing frequency converters for the overall electricity supply, the energy consumption of the twisting machinery was addressed.

Mechanically, these machines are fairly straightforward: a series of lines of high- precision spindles are driven by two powerful motors. Frictional losses (energy losses) occur in the rotational motion, as these machines operate 24/7 by virtue of the quality of the bearings fitted at each end of each spindle. With 176 twisting machines, each having 256 spindles, this was clearly an opportunity for energy saving.

Evaluating the options. Zenzen, the Leuwitex plant manager, decided on a very practical and specific way to investigate a way to reduce energy consumption for the long term. He would select three of the most likely ways to optimize bearing cost and frictional losses and put them to the test in his spindles. The three potential solutions were:

- New bearings from the supplier of those in the original spindles (not SKF)
- Low-cost bearings of local Chinese manufacture
- SKF Energy Efficient bearings, claiming up to 30 percent friction savings

Zenzen fitted the bearings to three separate spindle lines and ran them for three months, monitoring specifically the energy consumption of the three lines. The result was an overwhelming victory for the SKF Energy Efficient bearing, with around 10 percent total energy savings. Extrapolating this result to the expected lifetime of the spindles would conclusively save the most energy and deliver the lowest total cost of operation.

"Having satisfied myself on the energy savings issue," said Zenzen, "I needed to also be sure that the overall SKF bearing performance was equally reliable in the spindles that are so critical to the final product quality. The twisting machines have two contra spinning spindles rotating in synchrony in opposite directions. To maintain product quality, it is of utmost importance that these two spindles are rotating exactly as expected through the entire and continuous spinning/twisting operation."

Extending tests to a production run. So Zenzen's next test was to fit SKF Energy Efficient bearings to 10 twisting machines and simulate a production run. "I was delighted to find that the product quality was exactly the same as before with constant, uniform delivery of the various designs, material thickness and feel. This was especially important because we were in the process of expanding and also replacing some machinery in readiness for a new fabric product, and needed to be sure we could rely on the machinery," he says.

This initial test was then extended by adding more lines of spindles while keeping the original 10 operating. Regular product quality checks among all the machines convinced Zenzen that he had indeed found his answer to the best bearings for his textile machin-

ery—from both an energy efficiency and a bearing performance point of view. "I was extremely happy at the outcome of this project," said Zenzen. "We took the right amount of time to be sure we had done all that was needed to be certain that we had chosen the best solution for our original short-term energy cost problem. And, at the same time, we came to agree that it was the correct solution for our long-term plans as well."

SKF Energy Efficient bearings

The SKF Energy Efficient (E2) deep-groove ball bearing is one of the SKF performance-class energy efficient bearings. SKF E2 deep-groove ball bearings reduce frictional losses in a bearing by 30 percent or more when compared to a comparably sized standard SKF bearing. The performance increase comes from an optimized internal geometry, low friction grease, and a special, low-friction polyamide cage. Designed for grease-lubricated, light- to-normal-load applications, SKF E2 deep-groove ball bearings also consume less lubricant than comparable SKF Explorer bearings and enable longer bearing service.

Shielded SKF Energy Efficient deep-groove ball bearings can last twice as long as comparably sized shielded, standard SKF bearings. This means that the number of bearings needed to run an application over its lifetime can be halved. In instances where an application is run-to-failure, these E2 bearings can conceivably outlast other components in the application.

Typical examples of applications for SKF E2 deep-groove ball bearings include electric motors, pumps, conveyors, fans, textile spindles, etc.

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Bishop-Wisecarver

OFFERS GUIDED MOTION SYSTEM

The Bishop-Wisecarver Corporation (BWC) recently announced the latest addition to their collection of rotary motion solutions: 1-Trak, a single piece track system that is completely seamless and free running with no possibility of misalignment during installation or in service, resulting in smoother, quieter motion.

While conventional track technology limits track paths to simple combinations of straights and curved track segments, 1-Trak allows any conceivable 2-D shape to be realized.

"This patent-pending guided motion system is an innovative addition to our HepcoMotion collection of rotary track options as it is now possible to specify any shape with no joints," said Ali Jabbari, vice president of engineering at BWC. "The design can also include an integral base to form the structural part of a machine."

The entire track element is manufactured from a single piece of steel, with or without a base plate, and features a three-bearing wheel plate. The design's natural strength and accuracy makes it suitable as a structural element of the machine. The product can be customized with holes, slots and other features, eliminating the time and cost involved in designing a separate mounting plate for the track system, and it can be supplied mounted to an aluminum machine frame.

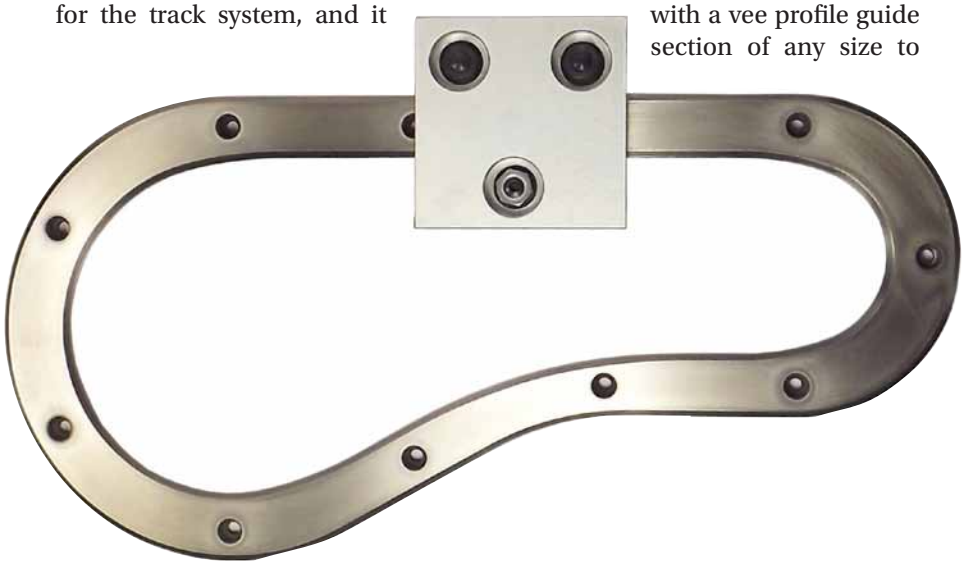
"This is a significant technical breakthrough for complex and jointless motion shapes," said Brian Burke, product manager at BWC. "Carriages maintain zero play on all areas of the track and can accommodate very tight curve radii due to variable track widths."

In addition to facilitating a high degree of flexibility in track configuration, the unique three-bearing geometry combined with the track shape ensures that the wheel plate exhibits zero play everywhere on the circuit. This is a key benefit compared to other tracks where there is "lift off" of the wheel plate from the track between straight and curved sections.

The 1-Trak circuits can also accommodate much tighter bends than is possible with other systems, saving space and costs while allowing the manufacturer to optimize production layout.

Where the application involves higher moment loads, the 1-Trak solution is also available in a wide track section. Wide slide sections with widely spaced bearings both across and along the wheel plate can also be supplied to create a very rigid platform and increased moment load capacity.

Track systems can be specified with a vee profile guide section of any size to



suit bearings from the extensive HepcoMotion PRT2 or Heavy Duty HDS2 ranges from 13 mm to 150 mm in diameter. Wheel plates can carry loads from 67 to 51,000 N, and tracks can be made up to 5.5 x 1 m or 1.9 m square. Corrosion resistant versions as standard are also available.

A rack and pinion driven wheel plate is another standard option when choosing 1-Trak. Its unique design permits a correct and constant mesh between pinion and rack around the entire circuit. It eliminates the need for the pinion to be sprung against the rack to compensate for varying engagement. This substantially simplifies the wheel plate design, reduces cost and dramatically increases system driving forces.

The gear teeth on the track are precision machined and surface hardened to provide outstanding strength and durability. Gears are available from MOD 1.5 to MOD 10 and beyond, depending on application requirements. The system designer can specify pinions alone, a wheel plate complete with pinion and drive flange or with pinions mounted onto a gearbox geared motor.

Also within the new product range is the availability of rectangular flat track profiles and track roller wheel plates. This option is recommended for use when two track systems are mounted in parallel. It allows the roller bearings on one side to "float" axially whilst the other side is fixed and captivated by the vee bearings. This type of configuration compensates for parallelism tolerances, and completely eliminates the excessive loading and binding that can occur.

For more information:
Bishop-Wisecarver
Phone: (800) 580-8272
sales@bwc.com
www.bwc.com

Weiss
INTRODUCES TORQUE ROTARY TABLE

Weiss North America, Inc. (Willoughby, OH) has recently introduced its largest torque rotary table to date–the TO1300. An extension of its established smaller direct-drive tables (TO150, 220 and 750), the TO1300 combines the advantages of direct drive with high torque – allowing larger scale application scenarios that require high speed and high accuracy to be fully realized.

Boasting a 1,300 mm footprint, the TO1300 suddenly makes larger scale applications possible that previously seemed out of reach – as current direct-drive tables are relatively small and limited to a diameter of 750 mm. Additionally the TO1300's high-tech drive operates predominantly without mechanics or gearboxes.

With over ten years of expertise in the field of direct-drive torque motors, Weiss often designs and develops out of the logical response to changing market requirements and customer demand. This was the case with the TO1300, as a client's concrete custom requirements stipulated a high mass inertia of 160 kgm^2 and a large index increment of 45° with fast cycles–namely an index time of 0.21 seconds with a dwell time of 0.29 seconds.

For challenging tasks of this nature, a mechanical heavy-duty table is typically the logical choice. Due to their gearing ratio, however, these tables don't fare well in service life calculations for use at such high speeds, as the needle bearings simply suffer from too much wear.

A suitable alternative is a direct drive, which inspired the development of the TO1300. With a direct drive, only one bearing is under load — virtually free of backlash. The table is low-wear and easily capable of delivering the desired dynamic performance requirements. Notably, it has the ability to cover a significantly more versatile range of tasks–including repeat use through reprogramming, which allows customers to cultivate value added potential. Unique to the TO1300 is that customers can customize it to their individual requirements. For example, they can make a modular selection between bearings, encoder and motor, and thereby alter the following table characteristics: Drive torque variable through different motor lengths; rated power variable through water cooling option; table speed variable through various combinations of motor/bearing/control technology (field weakening); precision variable through optical or magnetic measuring system; method of functioning variable through incremental or absolute encoder.

Configured in a uniquely robust design, the TO1300 offers new possibilities for high-speed automation applications such as lighting, automotive, cleanroom, small gear assembly, switches/sockets and electronic components.

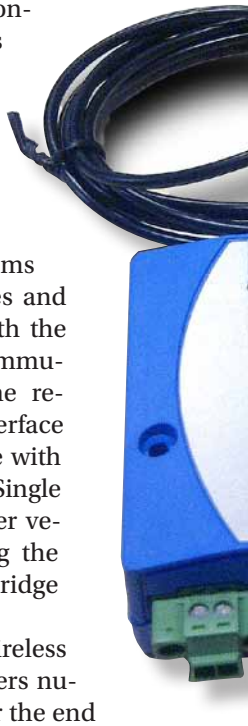
A specialist in automation, Weiss also offers many sizes for the TO series direct-drive rotary indexing tables, ranging from small to very large. Optimal solutions for specific application challenges can be achieved from the series' wide range of options. Each TO model is also available in a version with a cleanroom certificate.

For more information:
Weiss North America, Inc.
Phone: (888) 934-7762
www.weissna.com

Mico

INTRODUCES WIRELESS BRAKING SYSTEM

Mico, Incorporated introduces a new, wireless CAN interface for Mico Mobeus electrohydraulic braking systems. The Mico Electrohydraulic (EH) wireless CAN-bus interfaces with the Mobeus ABS/TC/ESC ECU (Electronic Control Unit) utilizing a CAN-Bluetooth connection to the Mobeus Service & Diagnostic Tool LINC. The Mico Mobeus EH Wireless CAN-bus interface is designed for use with Mico EH braking systems in off-highway vehicles and is fully compatible with the SAE J1939 CAN Communication standard. The result is a CAN-bus interface that can communicate with Mico Mobeus LINC (Single Mode), as well as other vehicle controls utilizing the vehicles CAN-bus (Bridge Mode).



Mico Mobeus EH Wireless CAN-bus interface offers numerous advantages for the end user, including:

- Wireless access to CAN systems using the standard Bluetooth interface provided within many notebooks (single mode)
- Up to 100 m transmission range (single mode) and up to 300 m in bridge mode
- CAN-bus data monitoring and data logging outside the vehicle during tuning and diagnostic
- Compliant to Bluetooth specification V2.1 EDR
- –40°C to +85°C Temperature range
- Powered through vehicle battery power (9-30 V DC) or independent 9 V battery

Mico Mobeus EH systems are designed to provide state-of-the-art vehicular braking control of off-highway vehicles. The EH Wireless CAN-bus interface provides an alternative to standard wired USB/CAN adaptors.

Multiple operating modes and simplified wireless system communication make this interface a valuable tool for vehicle tuning, diagnostic, and start-up.

For more information:
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Phone: (507) 625-6426
micomail@mico.com
www.mico.com

Nord Drivesystems

OFFERS WORM GEAR SERIES

Nord Drivesystems now offers a new range of worm gear units in a robust, one-piece Unicase housing in five sizes with a maximum torque of 427 Nm. New, larger output bearings allow users to choose increased shaft diameters compared with the previously available series. In addition, the large bearings ensure a much extended service life. The aluminum permanent mold casting process was optimized for the SMI series, resulting in an especially smooth surface that prevents dirt build-up. Closed SMI worm gear versions are washdown-capable, and can therefore be easily cleaned along with other systems during plant cleaning processes. If required, these gear units are available with Nord's NSD tupH surface conversion treatment which transforms their durability with up to seven times the hardness of the base aluminum material, providing excellent protection against acids and alkaline solutions. A synthetic long-life lubricant makes the worm gears maintenance-free during their entire service life. Equipped with oil gauge screws, the gear units are now also suitable for use in hazardous areas. The worm gear units provide transmission ratios between 5:1 and 3000:1. Thanks to the modular design, they are easily configured according to application requirements. Users can optionally select the field-proven and extensive SI series modular worm gear unit program which is flange-compatible to the SMI series, allowing for very versatile configuration. On the drive side, several standard IEC interfaces (B5/B14) are available for every gear unit size. The worm gear units can be foot- or flange-mounted and equipped with solid or hollow shafts, and as closed or open frame versions.

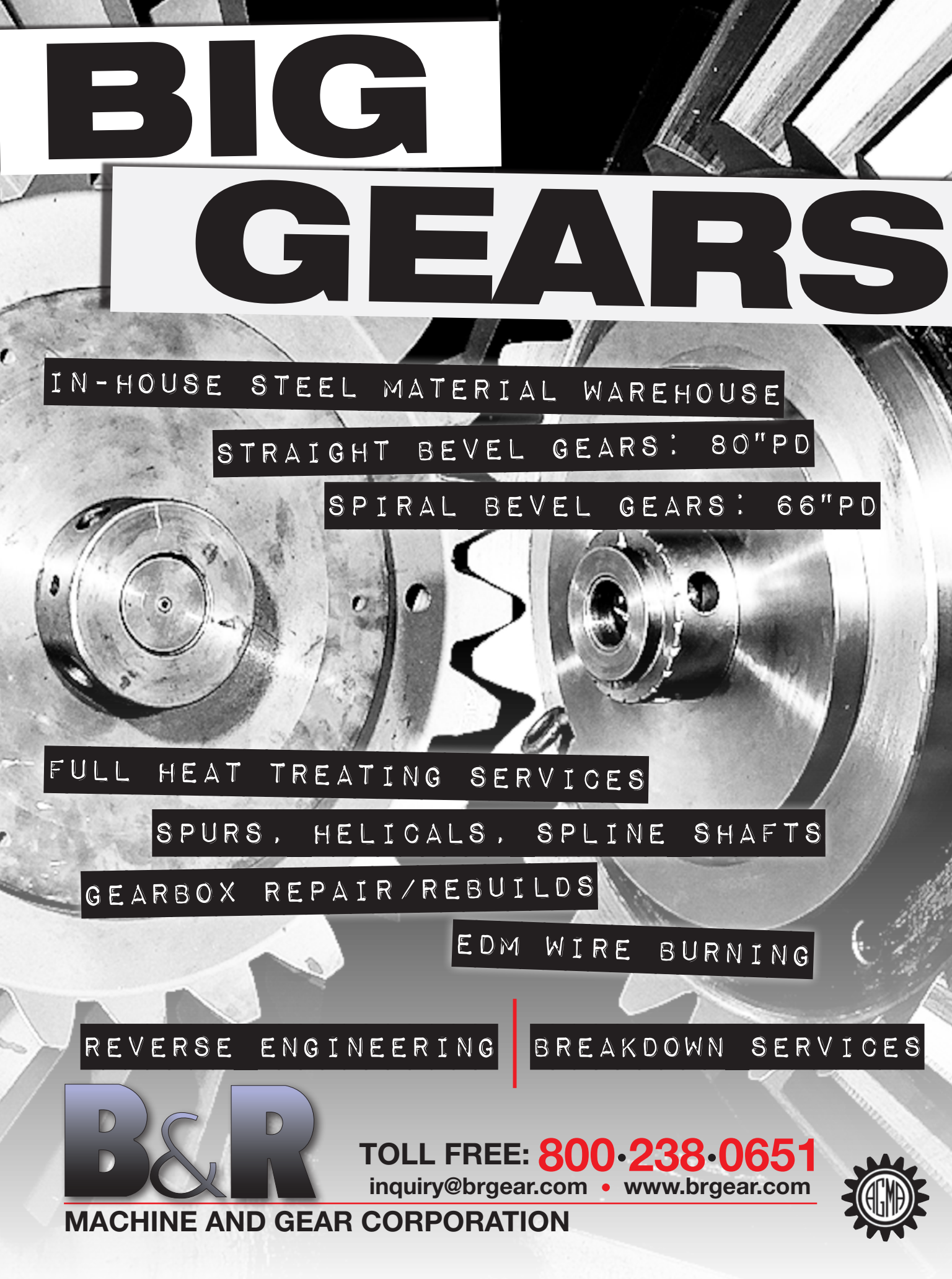
For more information:
Nord Drivesystems
Phone: (888) 314-6673
www.nord.com

SKF

EXPANDS RANGE OF COUPLINGS

SKF offers an extensive range of standard and customized couplings engineered for high performance and reliability in power transmission applications. A wide variety of coupling types combined with a wide range of sizes and bores equips users with suitable solutions to mechanically connect two rotating shafts and transmit power from one shaft to the other. They additionally can compensate for shaft misalignment that otherwise could adversely affect velocity and acceleration of the driven shaft. The standard SKF coupling product line includes jaw, grid, gear, flex, FRC, rigid, and universal joints for quick and easy mounting directly on the shaft or using various compatible bushings or weld-on hubs. For heavy-duty applications, large-size couplings can be supplied to provide optimum contact with shafts, accommodate high torque values, reduce power loss, and minimize the effects of misalignment. All SKF couplings benefit from proven designs and materials to withstand vibration and shock loads encountered in most motor, turbine, or engine-driven applications. Customized coupling products can be developed to satisfy the most demanding or specialized application requirements.

For more information:
SKF USA Inc.
Phone: (267) 436-6000
www.skf.com


BIG
GEARS
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MACHINE AND GEAR CORPORATION
AGMA

New Motor Technology

NovaTorque

INCREASES ECPM LINE

NovaTorque Inc.'s family of Gen2.0 PremiumPlus+ Electronically Commutated Permanent Magnet (ECPM) motors will soon be available in high speed 3 hp and 5 hp 2,400 rpm (maximum speed 3,600 rpm) models. Also available in 3 hp and 5 hp 1,800 rpm models (maximum speed 2700 rpm), NovaTorque motors utilize low-cost ferrite magnets in an innovative flux-focusing design to deliver the efficiency of rare-earth permanent magnet motors at a price that is competitive with induction motors.

"Anyone can build a high efficiency motor using expensive materials and costly manufacturing tolerances and processes. It is also easy to build a low-cost motor with low efficiency. The real challenge is to build a high efficiency motor with a low manufacturing cost, and our Gen2.0 PremiumPlus motors do that," says John Petro, NovaTorque founder and CTO. "Making a significant environmental impact requires that this new motor technology become nearly as ubiquitous as the AC induction motor is today. That can only be achieved by meeting efficiency goals at a cost and price point that encourages widespread adoption. So our goal has been to create the best efficiency per dollar motor available on the market today."

Driven by variable frequency drives, Gen2.0 PremiumPlus+ ECPM motors boast motor-only rated point efficiencies of 93 and 92 percent for 3 hp and 5 hp versions respectively, far exceeding the levels achieved with induction motors. Additionally, unlike induction motors, NovaTorque's PremiumPlus+ ECPM motors maintain their high efficiency and high torque over a very broad speed and load range.

"Electric motors are everywhere, and nearly half of the electricity produced in the word is used to drive electric motors. The International Energy Agency estimates that the potential exists to cost effectively improve the energy efficiency of electric motor systems by 20 to 30 percent," explains Emily Liggett, NovaTorque CEO. "Adoption of their recommendations, all easily economically justified, would result in a savings of $110 billion/year in energy costs and a reduction in 1.3 billion tons of CO_2 emissions each year. These are significant numbers with enormously positive potential consequences, both economic and environmental. Further, they are based on what was considered the current state of art – premium efficient induction motors driven by variable frequency drives. NovaTorque's innovative technology, with patented flux-focusing stator and rotor hub geometry, produces this performance with an all-ferrite (versus rare earth) magnet design."

NovaTorque PremiumPlus+ motors are packaged in standard NEMA frame sizes and mounting dimensions for easy substitution. Due to their high power density, NovaTorque motors are available both in the mounting frame size typical for induction motors, as well as one frame size smaller. NovaTorque PremiumPlus+ motors are compatible with readily available variable frequency drives (VFDs) from most leading manufacturers, including ABB, Yaskawa, Mitsubishi, Fuji, Hitachi, Toshiba, Danfoss, Siemens and others.

For more information:

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motors
at www.powertransmission.com

Portescap

OFFERS SIZE REDUCTION WITHOUT COMPROMISING EFFICIENCY

Portescap introduces 12GS motors to their Athlonix platform of high-power density brush DC motors. New 12GS high endurance motors deliver spectacular speed-to-torque performance in a compact lighter weight package (13.5 g / 0.47 oz) with output power up to 1.2 watts. This enables OEMs to build smaller, lighter and higher performing machines and devices. 12GS motors also feature an energy-efficient coreless design with an optimized self-supporting coil and magnetic circuit to maximize power density, while also providing sustained endurance over the life of the motor. The 12GS brush DC motors are available with three winding options to suit varied application needs. Customers appreciate the 12GS motor's optimized package size-to-performance ratio, offering 10 percent less volume for the same performance and 50 percent more torque in the same package.

"Our new size 12GS motors provide energy efficiency approaching 80 percent, allowing users to benefit from increased performance over the life of the motor, especially in portable applications," says Lionel Munsch, project manager at Portescap. "Design engineers will realize the benefit of 12GS motors because they will be able to miniaturize their equipment without compromising on power density, efficiency or battery life," he says.

Athlonix 12GS motors provide maximum continuous torque up to 1.5 mN-m to deliver higher endurance and performance while maintaining operational efficiency. This makes 12GS motors ideally suited for use in life science and medical applications including fluid handling machines, insulin pumps, and collimators.

Portescap's new Athlonix 12GS motors are compatible with incremental encoders and gearheads of various sizes and ratios. They are manufactured in an ISO certified facility and are RoHS compliant. Contact Portescap's application and sales support team to obtain additional specifications and rapid prototype samples.

For more information:
Portescap
Phone: (610) 235-5499
sales.america@portescap.com
www.portescap.com

Pittman

CUSTOMIZED MOTORS MEET SPECIFIC NEEDS

Pittman Motors, a unit of Ametek Precision Motion Control, offers customized motor designs for high-end motion control applications. With Pittman customized motors, design and automation engineers are not limited to an off-the-shelf motor that may not completely meet application requirements, especially in applications where the motor is expected to operate continuously in a harsh environment. Highly customized DC motors can be designed to meet strict customer specifications for use in harsh environments or demanding applications.

The customer first gained an understanding of the base-model motors that Pittman offers and then worked closely with Pittman design engineers to customize a motor to meet the customer's specific needs. The motor's outside is built using stainless steel for the housing, flanges, and shaft. The motor's inside is protected from debris and moisture using a combination of seals, including a dynamic labyrinth seal on the front mounting surface and o-rings between the flanges and housing.

The customized brushless motor design provides a high level of sealing against particulates and moisture as well as splashes from the corrosive environment. A dynamic labyrinth seal provides protection from dust contamination, while allowing the motor to operate at high shaft speeds. A stainless steel cable gland and silicon cable sleeve are used for enhanced ingress protection.

The 4-pole brushless motor also was optimized for 24 hour/day operation at speeds ranging from 500 rpm up to 15,000 rpm. It is constructed using high-grade, low-loss lamination steel to increase efficiency at high speeds and skewed rare-earth permanent magnets to minimize cogging at low speeds. The motor is electronically commutated using integrated hall-effect devices. The above example offers just a sampling of the customization capabilities available from Pittman. Thousands of application-specific solutions have been designed for a broad range of systems such as medical devices, laboratory instrumentation, semiconductor fabrication equipment, robotics, business machines and numerous others.

Pittman also offers a wide range of standard brush and brushless DC motors that are available in a variety of frame sizes, torque and power ratings. Frame sizes range from 0.375-in (9.5 mm) for miniature high-speed brushless DC motors up to 5.25-in (133 mm) for high-torque brushless DC motors with integrated controllers. Output torque ranges from 0.3 oz-in (0.00224-m) to 1,824 oz-in (12.8824-m) without a gearbox. Both planetary and spur gearboxes are available for most brushless DC motors, greatly increasing the available torque output. Gear ratios up to 4732.5:1 are possible. A wide variety of encoder types also are available.

For more information:
Pittman Motors
Phone: (267) 933-2105
www.pittman-motors.com

Kollmorgen

W SERIES PROMOTES RELIABLE OPERATION

Kollmorgen introduces Stainless Steel W Series motors. These IP69K-sealed hygienic servomotors feature an all stainless steel, round housing design that promotes long life and reliable operation in harsh food, beverage and pharmaceutical applications, even subject to frequent high-pressure washdown cleaning. With a robust design that eliminates the need for additional housing, an innovative venting system that eliminates the need for machine builders to supply compressed air to the motor and a 3 and 6 meter standard flying lead option that eliminates the need for intermediate cables, the W series simplifies machine design and component integration.

Precision balanced, low-cogging and high torque density W Series motors use high grade stainless steel for all external and internal metal components, food-grade bearing grease, a food-grade shaft seal and a laser-etched nameplate. They are available in 16 frame/stack combinations, delivering continuous torque to 80 Nm and peak torque to 39024-m at rated speeds to 7,500 rpm. These attributes and performance enable food, beverage and pharmaceutical OEMs to specify exactly the right motor for the application without having to overpay for an over-specified motor, or settle

for a standard motor with a modified housing.

Food, beverage and pharmaceutical equipment machine builders generally use as many stainless steel components as possible, and are increasingly doing so even in areas where non-hygienic motors have historically been used. Non-hygienic motors are difficult to clean and are prone to failure under the harsh operating conditions and rigorous cleaning schedules. Over time the exterior of painted motors can wear and chip, potentially causing paint to get into the end product. Stainless Steel W Series Hygienic motors overcome these concerns and deliver the performance that will keep equipment up and running to maximize productivity.

"Shutdowns by the U.S. Food and Drug Administration can be a public relations and productivity nightmare, and they can be prevented by utilizing hygienic components that are specifically designed for these environments," says Gene Matthews, product manager, Kollmorgen. "So whether an OEM is designing new equipment, or working a redesign to proactively prevent the possibility of a shutdown or to get an operation back up and running quickly after a shutdown, Kollmorgen's Stainless Steel W Series motors are a hygienic, high-performance solution that can help."

For more information:
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Crouzet

EXPANDS MOTOR SERIES

Crouzet, a brand of Custom Sensors & Technologies (CST), has introduced the DCmind Brushless direct current motor series, augmenting the recent market debut of the DCmind Brush Series. The latest in the DCmind offering includes the TNi21 and SMi21 brushless motors featuring integrated electronics, power capabilities from 60 to 150 Watts, and high accuracy.

A key benefit to the new series' design is the integrated electronics that save space and provide a smart, compact motor solution. Other important characteristics include an optimized control loop which allows simple and accurate motor management, carefully designed internal thermal protection for improved safety, and intuitive, easy-to-use software. Suitable EMC characteristics assure operational safety and reliability. Available options include mechanical brake and a variety of planetary and worm gearboxes. Either model can be used as a standalone motor or in combination with other motors, or controlled by a PLC.

The DCmind SMi21 Series is designed for motion control applications that require precise accuracy. These motors feature a range of 66, 90 and 150 watts nominal usable power at 24VDC and support 9-56 VDC. The SMi21 incorporates a quality 4096 step encoder that controls position, torque, speed, direction, braking and other functions and includes 6 inputs and 4 outputs. Suitable uses include a variety of access control applications such as automatic doors and screen doors used in metro systems, trams, trains, and bank airlocks; as well as turnstiles, barriers and motorized traffic controls.

The DCmind TNi21 Series Motors are rated at 60, 80 and 140 watts nominal usable power at 24VDC and support 10-36 VDC. This series was designed for simple applications dedicated to speed and torque control. Overall, the new brushless motors are excellent for applications found in medical, packaging, robotics, printing/mail sorting and many others.

"The new DCmind Brushless motors add a premium product to our line," says Jerry Brierton, national sales manager. "With the model SMi21's power capabilities to 150 Watts, Crouzet can effectively expand its application reach to the automation positioning market. Additionally, Crouzet's ability to provide adaptations and customization make the product even more attractive to customers looking for a motor that can be modified to meet their exact requirements."

DCmind Brushless motors are manufactured under ISO 9001, ISO 14001, approved in accordance with CE, and are RoHS compliant. Delivery is from stock to 12 weeks.

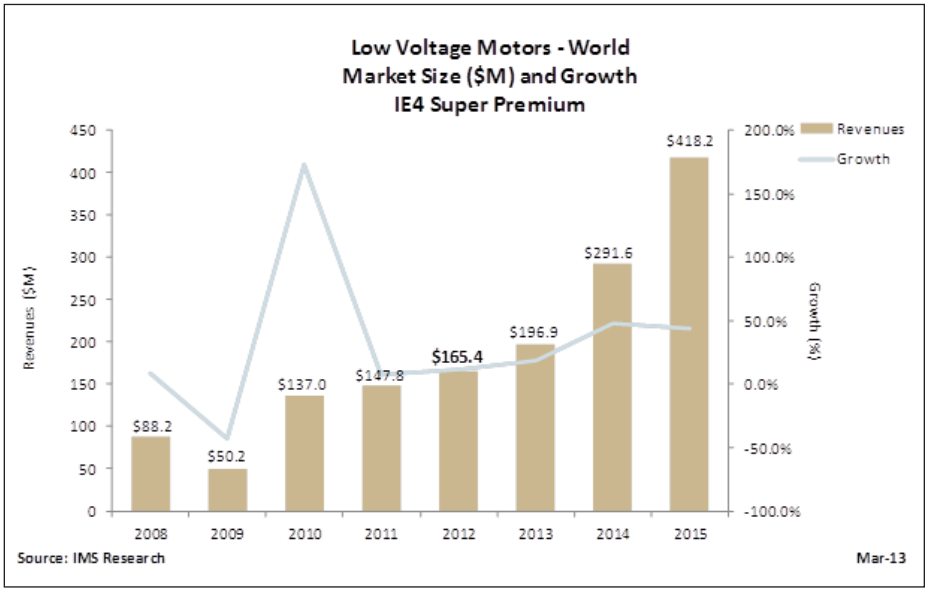
For more information:

Crouzet
Phone: (800) 677-5311
crz-na.motors@crouzet.com
www.crouzet.com

IHS

REPORTS ON RARE-EARTH MINERAL SUPPLY

China's move to corner the market for rare-earth minerals (REMs) has prompted manufacturers of low voltage industrial motors to adopt alternative technologies that reduce or eliminate the use of these materials, spurring new growth in the motors market. The global market for industrial IE4 Super Premium Efficiency low voltage motors will reach an estimated $418.2 million by the end of 2015, up 153% percent from $165.4 million in 2012, according to "The World Market for Low Voltage Motors – 2013 Edition," an upcoming report from IMS Research, recently acquired by IHS Inc. Emerging lower-cost



alternatives to traditional permanent magnet synchronous motors (PMSMs) that achieve IE4 levels of efficiency have added momentum to this niche market.

Rare-earth minerals get rarer

IE4 low-voltage motors based on the traditional AC induction squirrel-cage design—most commonly referred to as PMSMs—have been heavily dependent on REMs like neodymium and dysprosium, which are needed for the high-powered magnets that generate motor efficiencies above IE3 and NEMA Premium. PMSM motor manufacturers experienced a significant setback in prior years due to REM export caps imposed by China, the world's leading producer and processor of these minerals, which caused neomagnet prices to skyrocket in 2011. Some degree of stabilization has occurred as of mid-2012, but prices still remain high and represent a cost concern that motor manufacturers must pass on to their customers.

Magnetic repulsion

"Similar to the samarium cobalt (SmCo) magnet sourcing scarcity of the 1980s, which hastened the development and introduction of neodymium magnets to the marketplace, China's tightening of its grip on REM exports has caused manufacturers to seek alternative IE4 technologies," said Mark Meza, analyst with IHS. "Manufacturers have been very creative in dealing with magnet sourcing issues by producing drive technologies that reduce the number of neodymium magnets needed in a PMSM motor, or by producing IE4 class motors that use no magnets."

Proprietary solutions

"When discussing the industrial IE4 motor market in the past, the landscape was mostly limited to neo-based PM motors, or motors with copper rotors," Meza added. "Now, several proprietary designs that use traditional ferrite magnet technology must be included in the discussion as well."

US-based NovaTorque produces an electrically commutated PM (ECPM) IE4 motor using traditional ferrite magnets (*Ed's note: See NovaTorque news item on page 22*), while Hitachi Metals Ltd. has been at the forefront of developing an axial flux motor technology using amorphous metal ribbons made of iron, silicon and boron (FeSiB), coupled with traditional ferrite magnet technology to achieve an IE4 level of efficiency.

For more information:

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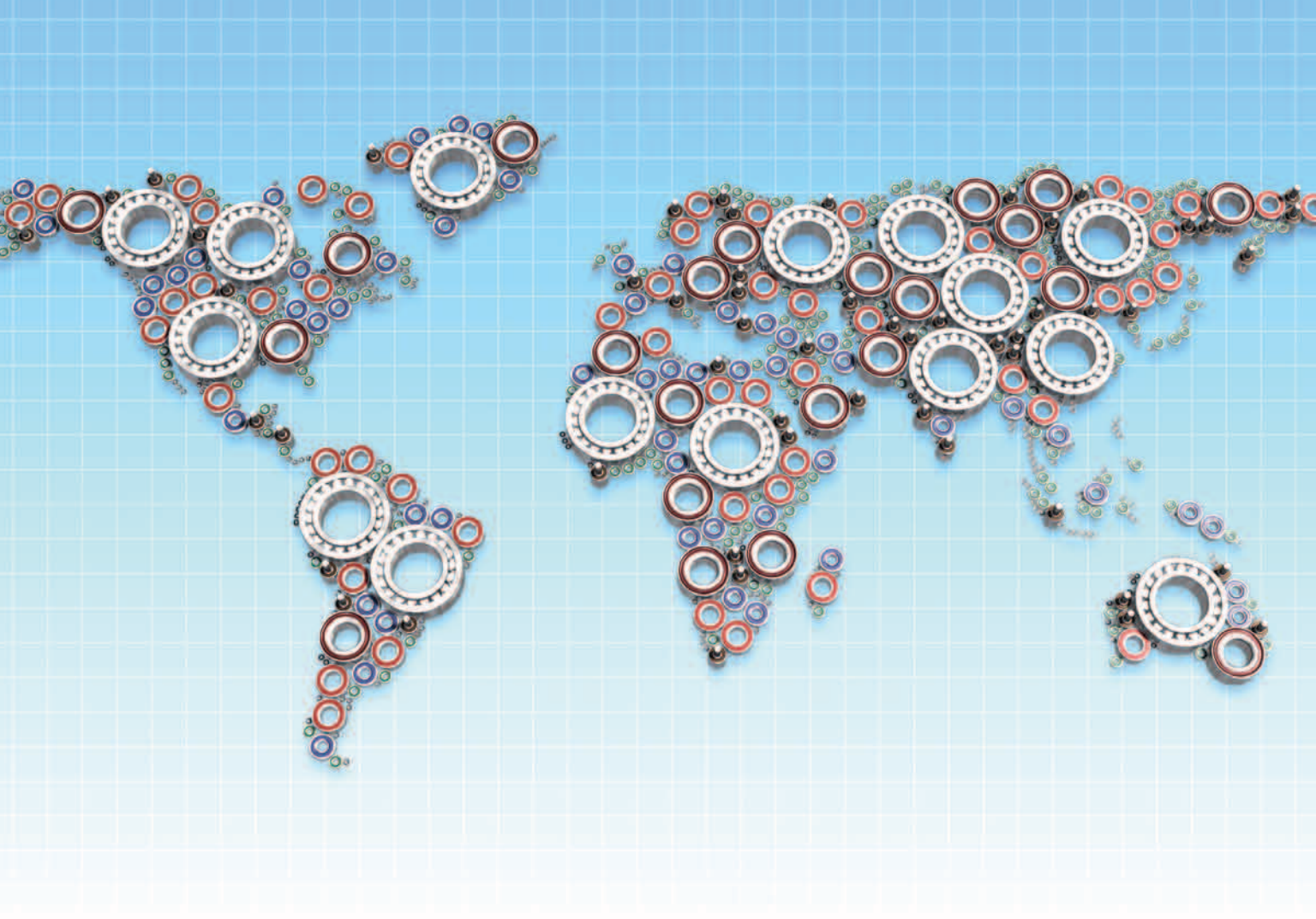

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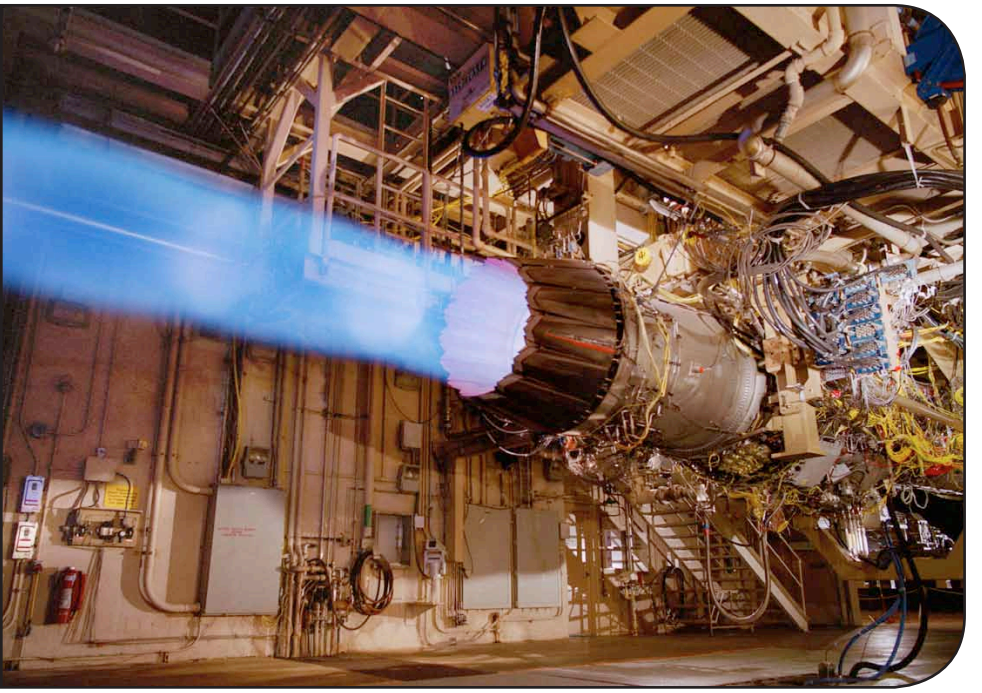
Up in the Air

Volatile Aerospace Market Keeps Gear Manufacturers Guessing

Matthew Jaster, Senior Editor

The highly competitive aerospace/defense market is chock-full of holes in 2013. The budget— particularly in defense spending—has been a hot topic. Programs are being cut, research and development is being pulled back and blue/red states are debating national security issues. Some analysts want to see reductions in aerospace/defense spending across the board. Others—such as the 45 states involved in the F-35 Joint Strike Fighter Program—refuse to get caught up in a political chess match when high-paying jobs are at stake.

According to *www.deloitte.com*, despite the notion that it costs too much to develop and produce a new commercial airline in today's market, the commercial aircraft segment is expected to reach record revenues in 2013 after posting its best production year in 2012. Global defense contracts, however, are expected to decline for the third straight year. Trimming the 'budget fat' is becoming the norm for many involved in these high risk, high reward aerospace/defense projects. In a recent *New York Times* article by David E. Sanger and Thom Shanker, the authors suggested that military officials should abandon the phrase "do more with less" and start to assess what it would mean to "just do less."



Commercial aerospace forecasts look up but global defense contracts will most likely decline in 2013 (photo courtesy of U.S. Department of Defense).

Arrow Gear, Delta Research and Precipart Corporation continue to find success in the aerospace/defense sector despite these various question marks. This is accomplished for a number of reasons including an emphasis on machine tool technology, customer service and quality control. They've managed to maintain a significant market presence in aerospace while branching out to the other industries. It also helps to have the Boy Scout mantra "Be Prepared" in your back pocket, as aerospace/defense plans frequently change.

Tried and True Technology

If there's a formula to aerospace/defense work it would surely start with new technology. A company eager to gain work in this highly critical field needs both the machines and the skilled manpower to succeed. This means consistently upgrading machine tool equipment to handle multiple operations and getting equipment shipped ahead of schedule. For the time being, the United States is very good at this.

"The United States remains the leader in many advanced technologies, and low volume, high quality products are still a U.S. specialty," says Joseph L. Arvin, president and COO at Arrow Gear, located in Downers Grove, Illinois. "We have largely lost high volume, low quality products. I have concerns about the United States retaining its role as the top producer of high quality products as China's industrial sector becomes more advanced. There has been a lot of talk about reshoring and jobs coming back, but until we see a reversal of our trade deficit of manufactured products ($436 billion in 2012), the United States runs the risk of further decline and deindustrialization, not to mention the negative impact on our overall economy."

For Arrow Gear to remain at the leading edge of the gear industry, Arvin believes they must continue to improve on both technology and new machine tools.

"In 2010, we expanded our manufacturing capabilities to accommodate larger gears. This investment of over $4 million led to the addition of 65 new employees and allowed us to secure new work on two different military helicopter projects. Currently, we are in the process of purchasing additional new machine tools and inspection equipment to en-

hance our productivity. This is critical to remain competitive because our foreign counterparts, particularly in China, are equipped with the latest technology."

The Delta family of companies (Delta Gear, Delta Research and Delta Inspection), located in Livonia, Michigan, continue to invest in leading technology and capital equipment for aerospace applications. The organization has invested in Reishauer 260s for production gear grinding and a Niles 800 that grinds internal and external gears (a machine will be used for prototype internal ring gear grinding for new jet engine projects). The six different grinding arms on Delta's two Kapp VUS machines also work on the Niles 800. Additionally, Delta has Gleason GP 300 shapers for internal and external gears and splines. "They have electronic lead guides and a tilting column which allows us to produce back-tapered splines and exotic type gear and spline profiles. We will also be able to 'shuttle shape' extremely long splines," says Tony Werschky, sales/partner at Delta. "We also have a new Koepfer 300 CNC hobber. This machine has built-in automation for ease of use for low-volume automation, which is great for aerospace. It also has special software for producing special lead-in on gear/spline profiles, which is used in circumstances when assemblies continuously engage and disengage in operation."

New machine technology doesn't add up to much more than shiny new toys if you don't have the business to take advantage of the highly specialized work found in aerospace/defense applications. "The key to developing long-lasting relationships with large OEMs and primary contractors is by solving their problems, consistently meeting their needs and through all this, providing consistent communication that always gives them a level of security where they know they are being taken care of," Werschky says. "We have a high degree of expertise in the demanding requirements of aerospace gearing," adds Arvin. "Foremost among our core strengths is our gear design and development capabilities. Using state-of-the-art technology, we use computer models to predict the contact pattern location of the gear teeth under load before actual fabrication. This approach, which replaces the conventional trial and error method, saves our customers a great deal of time and expense. I noticed 20 years ago that most major aerospace corporations were divesting themselves of the actual gear tooth design. For the past several years, Arrow has acquired this complete capability and currently we do not rely on any outside services for support. Within the last three years we have completed 24 new developments, which include jet engine PTOs, transfer boxes, and accessory drives. For helicopters: main drive bevels, intermediate, nose, and tail gears."

Aerospace gearing has helped companies like Delta improve work in other areas such as the automotive prototype industry.

Delta recently moved into a new building in Michigan to streamline the production process and increase throughput.

John P. Walter, president and CEO at Precipart Corporation says the company provides custom-designed actuators, motion control components and precision mechanical assemblies for several aerospace companies. "We have increased our workforce throughout the organization in both our manufacturing and office areas by approximately 33 percent. We have also added machinery in critical areas to stay ahead of projected demand increases. This new machinery is allowing us to hold tighter tolerances while increasing throughput."

Machine tool technology, according to Arvin, is progressing and evolving at a brisk rate. It's no coincidence that aerospace gear manufacturers are beginning to reap the benefits from machine tools that handle multiple manufacturing functions.

"As these technologies change, the result is faster, more accurate and efficient machining operations. We are currently investing in multi-

purpose machining centers that will perform multiple operations," Arvin says.

"We recently purchased a Mori Seiki NL2000 T2Y2, which is a 4-axis lathe with twin chucks, live tooling and bar-feeding capabilities," Werschky says. "This machine can handle multiple operations in one setup, which allows for better throughput on low-volume production."

The Benefits Beyond Aerospace/Defense

It's hardly a trade secret that a state-of-the-art facility and a strong engineering team must be in place in order to keep up with the high demands of aerospace/defense work. While it takes a major investment and plenty of man hours to get there, the benefits can actually be greater *outside* the market segment.

"Since our facility is optimized for aerospace work, this is beneficial in our work with non-aerospace customers in that we are able to provide extremely high precision products," Arvin says. "Arrow supplies gears for a very wide variety of customer applications that are quite demanding from a quality perspective, such as oil rigs, mining, off-road equipment, machine tools, auto racing (on and off road) and ships, etc. We do work with more than 500 customers over any two year period."

Delta's aerospace work has spilled over to other applications, particularly in the automotive prototype industry. "Our high-precision gears are no longer only needed in the aerospace industry; automotive gear engineers are pushing the envelope with new gear profile modifications, which can only be met with the latest gear grinding machines," Werschky says. "We have met these engineers' needs by working collaboratively with them to show them what these machines can do in production, which helps them to develop long-term solutions for their company's production automotive gearbox designs."

Delta has positioned itself for growth by investing not only in high-precision production equipment but also by investing in equipment to measure these tight-tolerance gears, shafts and assemblies. "You're only as good as what you can measure, and there's not much we can't measure," Werschky adds.

The Challenges of High Quality Components

The most significant challenges facing aerospace gear manufacturers today involve global competition, business incentives, raw materials, lower prices and shorter delivery times.

"Many foreign companies have lower overhead than we do here in the United States, coupled with the latest machine technology. All other foreign governments know how important manufacturing is to a nation's economy and in providing jobs for its people. High quality aerospace products are next on their agenda!" Arvin says. "Every major aerospace corporation has already flocked to China to make a quick few billion dollars to help China build their C919. I see this as very unfortunately short-sighted. In 10 to 15 years they will be laying off employees in their U.S. plants (our children and grandchildren) for today's big bonuses and golden para-

chutes – all of this while saying, 'I am doing this for the sake of stockholders.'"

"We believe we are going to see more of the high-precision parts that were sourced to low-cost countries come back to U.S. suppliers as OEMs and primary contractors get a better understanding of what the overall cost impact can be. Having a U.S. supplier allows the OEM more control to quickly rectify a quality or delivery problem."

Werschky continues, "We now live in a world economy where your parts can be made anywhere around the globe. And all companies, both small and large, can do business wherever they want. To drill down on this question a little more, the Detroit Metropolitan area has the largest population of engineers in the world per capita. Detroit is still a hot-bed for the design of gears, gearboxes and transmission components and assemblies. The state of Michigan has recognized this and knows that it must continue to develop this competitive advantage if they want to stay the leader in the world economy. Fortunately, the Michigan State Legislature has taken multiple steps to move Michigan from being the 46th worst state to do business in to now being in the top 10 percent. Future enhancements are coming as well. This will help to give companies the incentive to come to Detroit to start their new business."

"Although we have an internal training program, finding the right mix of people who are ready, willing and capable of performing at such high levels of performance can be difficult," Werschky says. "That is why we are partnering with our local community college (Schoolcraft College – Livonia, Michigan) to develop a gear curriculum for students and prospects which will enhance their understanding of gears and give them a solid foundation of understanding of gears from which they can build upon."

At Precipart, Walter believes that the general economy is still having a negative effect on some of the company's commercial aircraft business. "The cost, quality and lead-time issues related to supply chain led us to bring some secondary operation capability in-house. This helps us control processes and keeps us highly competitive," Walter says.

"One of our challenges is the lead time required to get raw material for our aerospace gears," Arvin adds. "I have been told that South African mills that supply much of the aerospace grade steel are once again having a difficult time meeting the demand from China. As a result, we may need to wait for months to get forgings. Another challenge is the ongoing pressure for lower prices and shorter deliveries."

"I think the industry will become more regionalized – aircraft will be built in the countries where they will be purchased and used. China and India will be busy making aircraft for their own consumers and the U.S. will be in a similar position," Werschky says.

A Critical Calling

Not lost on any of the people involved in aerospace/defense projects is the high level of manufacturability needed to complete these complex components. The staffs at Arrow, Delta and Precipart take great pride in each unique job in this field.

"At Precipart, we are very aware that we play a crucial role in things bigger than ourselves. Our people take pride knowing that the components we make contribute to the safety and integrity of platforms carrying airline passengers, as well as military personnel," Walter says. "We are driven to work to the highest quality standards because we know the critical nature of these aerospace and defense applications."

"Producing the product we do is challenging, but I believe all of us here take great pride in the fact that our gears are used in some of the most advanced aircraft produced by our civilization. I can see the pride in their faces when I take customers and other visitors through our plant," Arvin says.

"We love a challenge," Werschky says. "When we finish a difficult program and send the parts or assemblies on their way, everyone knows they did their best and when the customer's contact is only to make more — that meant everything was right the first time around."

Steady As She Goes

Gear manufacturers will tell you that the last economic downturn left many unanswered questions. While things have picked up in 2013, most manufacturers are approaching 2013-2014 with cautious optimism. They're keeping an eye on Washington while defense spending and budget constraints get sorted out. Still, meeting customer demands in this field can be very rewarding. "From engineering the elaborate processes for manufacture to actually running the multi-million dollar machines that produce aerospace gears, we've built a world class reputation by consistently meeting our customers' needs and being honest and open," Werschky says. "This is what we feel keeps them coming back for more." **PTE**

A PECo ND300 inspects gear attributes at Precipart Corporation.

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Electrical and Mechanical Torque Limiting

THE QUESTION

My company manufactures high-speed metal forming machinery. We have one application on a feed axis where we are encountering problems with the coupling. Every time the drive axis encounters a blockage due to operator error, the coupling is destroyed. This does not make much sense to me because I have the servo current limited to never exceed the coupling's torque rating. The coupling manufacturer has recommended trying a larger size, but we simply do not have the space for it. Since it is a high-performance application on a servo gearbox, I need zero backlash and my options are somewhat limited. What alternatives might be out there?

Response provided by Niilo Nykanen, application engineer and quality coordinator, R + W.

Electronic current limiting is not always a 100-percent-effective way to prevent torque overloads in a mechanical system. On a servo motor it is relatively easy to set torque limits in the parameter programming of the machine. When doing so, one must remember that the electronic torque limit is at the motor only. This means that the motor's electronics do not account for the masses of gears, couplings, shafts, etc., further along down the driveline. Oftentimes a manufacturing process is many mechanical power transmission components away from the motor. Additionally, the servo drive and/or PLC monitoring the torque of the motor may not pick up an over-torque condition quickly enough to prevent damage from occurring. In the case of rotating equipment, there are often gearboxes and shafts which have a lot of rotating inertia not accounted for by electronic means. Additionally, linear applications impart their inertia into the rotating components, driving them when they stop or crash.

When we examine what happens in a machine crash, it is often useful to look at an impact force equation:

$$F = (.5m*v\text{^}2)/s$$

where:

F = force in Newtons
M = mass in kilograms
v = velocity in meters-per-second
s = stopping distance in meters

Examining this equation tells us that the force imparted by an impact is directly proportional to the mass and/or velocity, while being inversely proportional to the stopping distance. That being said, the more massive any component is—and the faster it's moving—the more impact force exhorted during a crash. For many mechanical designers this is pretty obvious, although many electronic programmers do not account for this principle while limiting currents and/or torque values. Because the stopping distance is in inverse proportion to the impact force, the smaller it gets, the more force is imparted by the crash. This can be very difficult to predict and plan for by system designers. It can be fairly straightforward to find the mass of mechanical power transmission components and know how fast they will be moving. What is difficult to gauge is how the machine will likely crash and what will cause this to happen.

Further examining the force equation above from a mechanical design side, one can see that the effects of a machine crash can be mitigated by keeping the mass of the moving parts to a minimum. One way to do this would be to use lighter materials, such as aluminum vs. steel, if possible. There are companies that produce hollow carbon fiber and aluminum line shafts for this reason. Slowing down the speed of moving parts also cuts down on the forces associated with a machine system crash. While decreasing speeds are not often a good option in the world of manufacturing machine building, designers can be creative. For example, in

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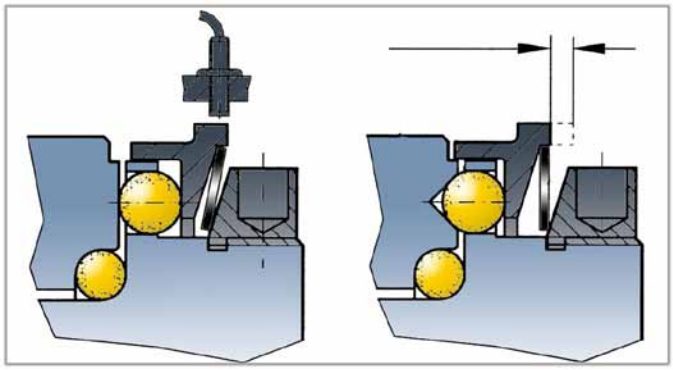
certain metal forming operations, making multiple parts in a slower fashion can be preferable to making single parts very quickly.

Because mass and velocity are directly proportional to inertia, decreasing either obviously cuts down on impact forces in a machine crash. Preventing a crash and/or cutting down the distance at which it occurs is difficult. One obvious method of protecting operators and preventing externally initiated jams would be to ensure proper guarding is always in place. This is an OSHA requirement around many processes and prevents operators from dropping tools, clothing—even themselves—into moving parts. Limit switches at the ends of actuation paths in conjunction with soft bumper stops can also be very helpful. A linear motion application, such as moving a machine center's cutting table with ball screws can benefit from this. One example would be a table moving past its limit switch with enough inertia from the workpiece that it shuts down the process by moving past the limit switch, but still hits the soft bumper at the mechanical stop. This is a case where the stopping distance would be significantly increased, which would decrease the impact force of the crash.

Because many people from different backgrounds are often involved in machine design, aspects of how the machine will operate holistically can be ignored by folks concentrating on their area alone. Mechanical drive guys may concentrate on the process and drive components without thinking about the full capabilities of the motor and electronics. Conversely, electrical programmers and designers do not always consider how the total mechanical inertia of drive systems can impact their overload settings.

Electrical designers are generally trained to implement multiple levels of overload protection into circuits. Most industrial control boxes normally have main breakers and or fuses and protection on each branch circuit. Many individual devices also have their own overload protection. This concept has not taken as deep of a root in the mechanical design side of machine building. Oftentimes drive components such as belts, chains, and couplings are designed to be mechanical fuses. Many systems are built with a series of shear pins to protect the drive line. A newer technology on the market is mechanical torque limiters. These can be used to limit torque as well as linear chain or belt pull. A torque limiter is essentially a mechanical circuit breaker. Rather than having a component that breaks and needs to be replaced, a torque limiter can trip and be reset many times during its life.



An advantage of using mechanical torque limiters over shear pins and/or relying on a belt or coupling to break apart in an over-torque condition is that they are available in maintenance-free designs. The best advantage of using them in conjunction with electronic torque limiting is that they can usually be installed very close to the device where a crash could occur, as well as at multiple points in the system. Mechanical torque limiters are designed to instantaneously detect an over-torque condition and disengage very quickly. On occasion mechanical torque limiters are capable of disengaging an over-torque drive line before an electronic device, such as servo motor, even begins to pick up the condition.

In the newly developing study and career field of mechatronics, a mechanical torque limiter allows for an integration of mechanical and electrical design. An electronic proximity switch can be positioned near an actuation mechanism which moves in the event of an overload. This system works well because the overload is detected and disengaged, followed by an electronic signal to a PLC or process controller to shut down the part of the system with the over-torque condition. Because torque limiters can be placed in multiple parts of a machine, the source of the jam can be detected very quickly using proximity sensors.

To summarize the answer to the question, the peak process torque value must be known. This value must be calculated through the driveline back to the servomotor and be programmed into the servo drive parameters. Bear in mind that this will only truly protect the motor from the over-torque condition. The best backlash-free option to limit torque at the process is to install a mechanical torque limiter as close to the area that jams as is practical (both for maintenance of the process and possibly resetting the limiter). Essentially, machine builders should be aware of not putting all of their eggs in one basket when mitigating machine crashes. Circuit breakers, fuses and electronic limiting should be used at multiple levels on the electrical design. Torque limiters, guarding and bumpers should be employed on the mechanical design. As always, consult the manufacturers of each component if there are any questions or concerns. **PTE**

Rolling Bearing Steels—A Technical and Historical Perspective, Part II

Erwin V. Zaretsky

This paper summarizes the chemical, metallurgical and physical aspects of bearing steels and their effect on rolling bearing life and reliability.

Heat Treatment

Steel hardness. Hardness is an influential heat treatment-induced variable. For most rolling bearing applications it is required that the Rockwell *C* hardness at operating temperature be 58 or higher. In general, the higher the hardness of the bearing steel at operating temperature, the longer the life. A relationship that approximates the effect of bearing material hardness on fatigue life has been developed (Refs. 20 and 31).

$$LF = \exp\{m[(\mathrm{RC})_T - 60]\} \quad (5)$$

where:

m is an exponent relating material hardness and life (typically $m = 0.1$) and $(RC)_T$ is the Rockwell *C* hardness at operating temperature. It was assumed for the purpose of this relationship, which was obtained for AISI 52100, that all components in the rolling element bearing (i.e., the rolling elements and the races) are of the same hardness. It was further assumed that this equation can be extended to other bearing steels. A 3 point increase in hardness can result in a 35 percent increase in bearing life. With the exception of AISI 52100 and other low-tempering-temperature bearing steels, most bearing steels can be expected to maintain their room-temperature hardness after soaking at elevated temperatures.

As was discussed for through-hardened steels, the bearing industry also assumed that materials with higher alloy content would have better hardness retention at elevated temperatures. A study to verify this assumption was undertaken at NASA Lewis Research Center (Refs. 32 to 34). Short-term, hot-hardness measurements were made for groups of through-hardened specimens of AISI 52100, M–1, M–50, 440C, Halmo, WB–49, WD65, and Matrix II. Measurements were also made of specimens of Super Nitralloy (5Ni-2A1) and case-carburized AISI 8620, CBS 600, CBS 1000, and Vasco X–2. The results for the AISI 52100 and the other through-hardened steels were normalized and are shown in Figure 5. These normalized data show that regardless of the initial hardness, the hot hardness of individual materials shows the same functional dependence. These results completely changed previously held assumptions (Ref. 20). These data can be represented by a straight line having the form:

$$(RC)_T = (RC)_{RT} - \alpha\,\Delta T^{\beta} \quad (6)$$

where:

$(RC)_T$ is the Rockwell *C* hardness at operating temperature; $(RC)_{RT}$ is the Rockwell *C* hardness at room temperature; ΔT is the difference between operating temperature and room temperature, α is a material constant, and β is a material exponent. Values of α and β for various bearing steels are given in Table 4.

To determine hardness effects at the bearing operating temperature (Eqs. 2 and 3) can be combined to obtain a life factor as follows:

$$LF = \exp\left(0.1\left\{[(\mathrm{RC})_{RT} - 60] - \alpha(T_T - T_{RT})^{\beta}\right\}\right) \quad (7)$$

where:

T_{RT} is 22°C (70°F). Equation 7 is benchmarked to a Rockwell *C* hardness equal 60

where:

$L_F = 1$.

Compressive Residual Stresses

From the late 1920s through to the 1960s, Almen (Ref. 35) and his colleagues (Refs. 36 to 38) at the General Motors Research Laboratories pioneered the study of residual stresses in rotating steel components that included rolling element bearings. These residual stresses can either be tensile or compressive. They can be induced by producing microscopic and macroscopic deformations and by transformations in the microstructure of the steel. Residual stresses can also be induced by heat treating, rolling, shot peening, diamond burnishing, and severe grinding. Each of these methods (except heat treating) is a separate mechanical process that is performed after heat treating (Ref. 15).

They found that compressive residual stresses induced beneath the surface of ball bearing race grooves increase rolling element fatigue life. According to Gentile and Martin (Ref. 37) ball bearing lives were doubled when metallurgically induced ("pre-nitrided") compressive residual stresses were present in the inner races. Scott et al. (Ref. 38) found that compressive residual stresses induced by unidentified "mechanical processing" extend the fatigue life of ball bearings (Ref. 15).

Figure 6 shows representative residual stresses as a function of depth below the surface for three heat treated bearing steels. In general, most—if not all—carburized bearing steels have induced compressive residual stresses represented by those shown for AISI 9310 steel (Fig. 6). These stresses are induced by the carburization process.

In 1965 E.V. Zaretsky (Refs. 15 and 39) and his colleagues at the NASA Lewis (now Glenn) Research Center published an equation relating rolling element fatigue life to these compressive residual stresses. The maximum shearing stress τmax for a given contact stress is decreased by the presence of a compressive residual stress σ_r. This results in the following life factor due to residual stresses alone:

$$LF = \left[\frac{\tau_{max}}{\tau_{max} - \tfrac{1}{2}\sigma_r}\right] \quad (8)$$

where:

exponent c is typically 9.

For light-to-moderately loaded bearings, a typical value of τ_{max} is 414 MPa (60 ksi). For heavily loaded bearings a typical value of τ_{max} is 724 MPa (105 ksi).

From Figure 6, assume AISI 9310 as the bearing steel; the compressive residual stress σ_r is 200 MPa (29 ksi); from

Equation 8, for a lightly loaded bearing, $LF \approx 12$; for a heavily loaded bearing, $LF \approx 3.8$. These life factors can be applied in Equation 1 together with the other life factors discussed. However, when bearing life results are analyzed independent of these residual stresses, the load-life exponent p appears to increase from their accepted values (Ref. 40).

Investigators have misinterpreted these results caused by the presence of residual stresses as a "fatigue limit" (Ref. 41). They have incorporated them into bearing life predictions and in some cases bearing manufacturer catalogues (Ref. 42). The concept of a fatigue limit has also been incorporated into an ISO standard (Ref. 43) for bearing life prediction for AISI 52100 steel where there are no residual stresses in the as-heat treated steel (Ref. 42). This can result in bearing life over prediction and/or undersizing a bearing for a particular application (Refs. 41 and 42).

There are two problems associated with the use of a fatigue limit for bearing steels: 1) the form of the equation as expressed in the ISO standard (Ref. 43) may not reflect a fatigue limit, but the presence of a compressive residual stress; and 2) there are no data in the open literature that would justify the use of a fatigue limit for through-hardened bearing steels such as AISI 52100 and AISI M-50 (Refs. 41 and 42).

In 2007 Sakai (Refs. 44 and 45) presented stress/life rotating bending fatigue data from six different laboratories in Japan for AISI 52100 steel. He also presented stress/life fatigue data for axial loading. The resultant lives were in excess of one billion (>109) stress cycles at a maximum shearing stress τ_{max} as low as 350 MPa (51 ksi) without an apparent fatigue limit.

In 2008, Tosha et al. (Ref. 46) of Meiji University in Japan reported rotating bending stress life fatigue tests for through-hardened bearing steels having Rockwell C hardness above 58. The results of these tests at maximum shearing stresses τ_{max} as low as 480 MPa (70 ksi) produced fatigue lives in excess of 100 million (>108) stress cycles without the manifestation of a fatigue limit.

In 2009, in order to verify the Sakai results (Refs. 44 and 45) and Tosha, et al. (Ref. 46), Shimizu, et al. (Ref. 47), also of Meiji University, published the results from six groups of AISI 52100 bearing steel specimens using four alternating torsion fatigue tests rigs to determine whether a fatigue limit exists or not, and to compare the resultant shear stress life relation with that used for rolling element bearing life prediction (Ref. 42). The results of these tests at maximum shearing stresses τ_{max} as low as 500 MPa (76 ksi) produced fatigue lives in excess of 10 million (>107) stress cycles without a fatigue limit. Shimizu, et al. (Ref. 47) reported that the resultant fatigue life was inversely related to the shearing stress to the 10.34 power (Ref. 42).

Retained Austenite

In the early 1960s a major U.S. aircraft engine company had to discard unused rolling element bearings made from AISI M-50 because their bore diameter had increased from that specified for the engine shaft diameter (in a personal communication with E.N. Bamberger, General Electric Company, February 1963). This expansion in bore size was attributed to the presence of large amounts of retained austenite in the microstructure of the steel. The retained austenite transformed to martensite and bainite on the shelf at room temperature. As a result, for most critical aerospace applications, the retained austenite is limited to 2 to 5 percent. However, for noncritical applications, higher amounts of retained austenite are allowed or may, in some instances, be uncontrolled. Experience has suggested that lower values of retained austenite are preferable for reliable bearing operation (Ref. 15).

L.R. Waldmiller, of Frost, Inc. (in a personal communication, December 1994) described un-run, carburized, 12.7-mm (0.5-in.) diameter AISI 1022 balls having 40 to 50 percent retained austenite. The balls lost a portion of the case material while at room temperature due to transformation of the retained austenite. The lost material had the appearance of a "skullcap" and the phenomenon was referred to as "capping." He reported that the phenomenon also occurs during bearing operation. The same material with a lower amount of retained austenite did not experience capping (Ref. 15).

In general, for a given through-hardened material, the amount of retained austenite increases with increasing material hardness. Experience has also

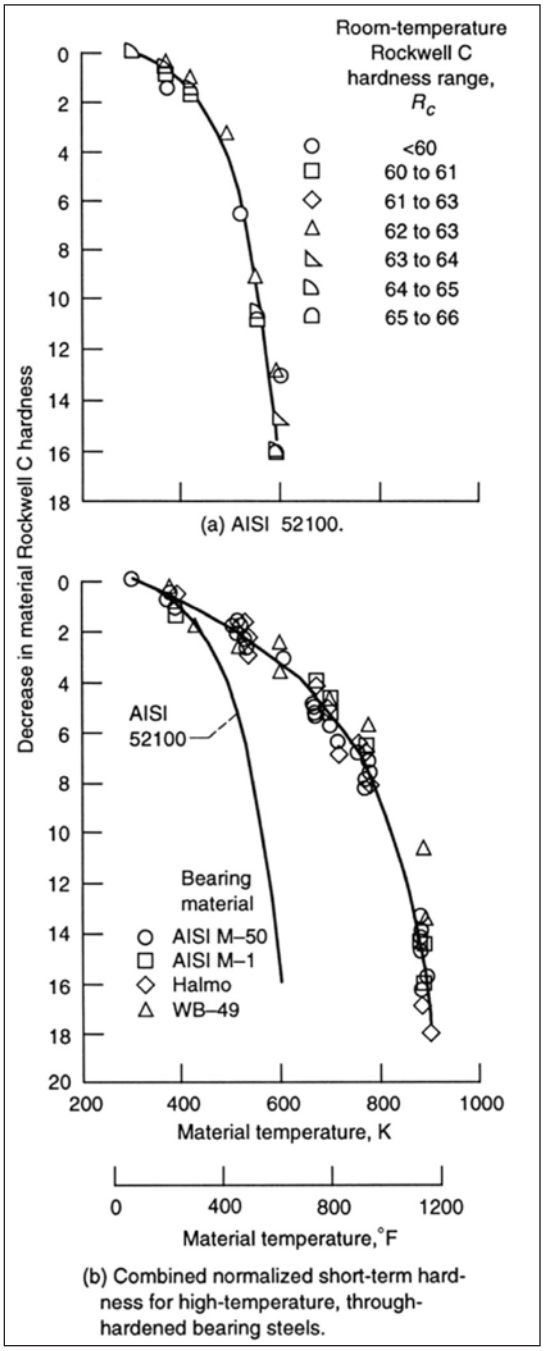


Figure 5 Summary of short-term, hot-hardness, through-hardened bearing steel data (Ref. 20).

shown that test rollers made from AISI 52100 of Rockwell C hardness greater than 63 will have sufficient austenite-to-martensite transformation during rolling contact to alter the surface waviness and cause early surface spalling (Ref. 15).

Johnston et al. (Ref. 48) studied the effect of the decomposition of retained austenite and the inducement of compressive residual stress as a result of bearing operation. What is unique for their data is that the magnitudes of the compressive residual stresses are directly proportional to the decomposition of retained austenite (Ref. 15).

Changes in microstructure (phase transformations) have been reported to occur in the same areas as the maximum induced residual stress (Refs. 36 and 49). Under some conditions of extremely high contact stresses, nonmicrostructural alteration was apparent after significant residual stresses had been induced in a few cycles (Ref. 49). Muro and Tsushima (Ref. 50) proposed that the induced residual stresses and the microstructural alterations are independent phenomena (Ref. 15).

Research performed by Zhu et al. (Ref. 51) in 1985 on carburized rollers suggested that the structural change in the zone of maximum resolved shearing stresses observed by Jones (Ref. 52) in 1947 and later by Carter (Ref. 53) in 1960, as well as others is a manifestation of retained austenite transforming to martensite under cyclic Hertzian stress conditions. A combination of thermal and strain energy and time is believed to cause this change (Ref. 15).

Grain Size

It is generally accepted in the bearing industry that prior austenite grain size should be ASTM No. 8—or finer—and that individual grains should not exceed ASTM No. 5 (Ref. 54). The higher the ASTM number, the finer the grain size. The 1960 work of R.A. Baughman (Ref. 55) suggested that rolling element fatigue life increases with finer grain sizes (Ref. 20). A recent analysis of grain size and orientation on rolling element fatigue life was performed by N. Weinzapfel, et al. (Ref. 56).

Carbides

Residual carbides are those carbides that do not go completely into solution during austenitizing and are a function of the alloying elements and raw material processing. In contrast, hardening carbides precipitate upon aging at the tempering temperature. The carbides referred to in the following paragraphs are the residual carbides.

Carbide composition has been found to vary among steel producers. Heat treating steel ingots creates large, extremely hard metal carbides (MC), considered to be essentially a vanadium carbide that can act as asperities in the bearing surface (Ref. 57). J.E. Bridge, et al. (Ref. 58) identified the primary carbides in AISI M–50 as MC and M2C. Pearson and Dickinson (Ref. 57) found that the M2C carbides contain a high percentage of molybdenum, and that in a bearing ball under thin film elastohydrodynamic (EHD) lubrication conditions, they can cause distress or peeling of the bearing race surfaces. The carbide "stick out" has been attributed in whole or in part to an excessive rate of grinding in the manufacture of bearing balls made from AISI M-50 steel.

Parker et al. (Refs. 17, 59 and 60) have shown an interrelation among steel alloy content; median residual carbide size; number of residual carbide particles-per-unit area; percentage of residual carbide area in through-hardened bearing steels; and rolling element fatigue life. As the percentage of alloying elements increases in a steel, the number and size of the carbides increase (Refs. 61 and 62). Subsequent research by Parker and Bamberger (Ref. 63) for AMS 5749 steel further substantiated the negative effect of large-carbide-size and banded-carbide distribution on rolling element fatigue life.

Pearson and Dickinson (Ref. 57) verified the observations of Butterfield and T.R. McNelley (Ref. 64), who reported voids of the order of 1 μm (40 μin.) adjacent to carbides of AISI M–50 steel. This work (Ref. 64) suggested that these voids form during bearing operation at the site of the carbide tip and can act as a nucleus for crack initiation in the subsurface zone of maximum shear stresses. The large carbides act as stress raisers to initiate an incipient crack that results in a rolling element fatigue spall. The effect of carbides on rolling element fatigue life is reflected in the life factors displayed in Table 1 (Ref. 15).

In general, case-carburized bearing steels, with the exception of M50 NiL, have a courser and larger carbide structure when compared to through-hardened bearing steels such as AISI 52100 or AISI M-50. However, this disadvantage is more than offset by the compressive

Table 4 Temperature proportionality factors α and e × ponents β for bearings steels $(RC)_T = (RC)_{RT} - \alpha \Delta T_\beta$; (Ref. 20).

Material	Temperature range, °C (°F)	α		β	
		°C	°F	°C	°F
AISI 8620	21 to 316 (70 to 600)	73×10^{-5}	26×10^{-5}	1.7	1.7
CBS 600	21 to 316 (70 to 600)	$.75 \times 10^{-5}$	$.18 \times 10^{-5}$	2.4	2.4
Vasco ×-2	21 to 538 (70 to 1000)	1.4×10^{-5}	$.38 \times 10^{-5}$	2.2	2.2
CBS 1000	21 to 538 (70 to 1000)	93×10^{-5}	38×10^{-5}	1.5	1.5
CBS 1000M	21 to 538 (70 to 1000)	340×10^{-5}	160×10^{-5}	1.3	1.3
Super Nitralloy	21 to 327 (70 to 620)	1.3×10^{-5}	$.33 \times 10^{-5}$	2.3	2.3
AISI 52100	21 to 260 (70 to 500)	92×10^{-5}	34×10^{-5}	1.6	1.6
AISI M-50	21 to 538 (70 to 1000)	133×10^{-5}	54×10^{-5}	1.4	1.4
AISI M-1	↓	↓	↓	↓	↓
AISI M-2					
AISI M-10					
AISI M-42					
AISI T-1 (18-4-1)					
Halmo					
WB-49					
WD-65					
Matri× II					
AISI 440C					
AMS 5749 (BG42)					
AMS 6278 (M50 NiL)					

residual stresses induced into the case by the carburization process.

Summary

In order to assure long rolling element bearing life and reliability for commercial, industrial and aerospace applications, materials, lubricants and design variables must be carefully considered and specified. The catalyst to quantum advances in high-performance rolling element bearing steels was the advent of the aircraft gas turbine engine. The reliability of these bearings became a major consideration because of system and mission complexities and because of the high costs involved. With improved bearing manufacturing and steel processing together with advanced lubrication technology, the potential improvements in bearing life can be as much as 80 times that attainable in the late 1950s or as much as 400 times that attainable in 1940. The following summarizes the chemical, metallurgical and physical aspects of bearing steels and their effect on rolling bearing life and reliability:

For temperatures less than 149° C (300° F) the bearing steels of choice are: through-hardened, AISI 52100; case-carburized, AISI 8620 and AISI 9310; and corrosion-resistant, AISI 440C. For temperatures greater than 149° C (300° F) the bearing steels of choice are: through-hardened, AISI M-50; case-carburized, M50 Nil; and corrosion-resistant, BG-42.

Vacuum processing of bearing steel reduces or eliminates the amount of nonmetallic inclusions, entrapped gases and trace elements in structural alloys, resulting in substantially cleaner material and significantly longer bearing life.

For a post-1960 vacuum-processed bearing steels such as AISI 52100 and AISI M-50, the values for the load life-exponent p, where life is inversely proportional to load to the exponent p, increased from three and four for ball and roller bearings, respectively, to four and five.

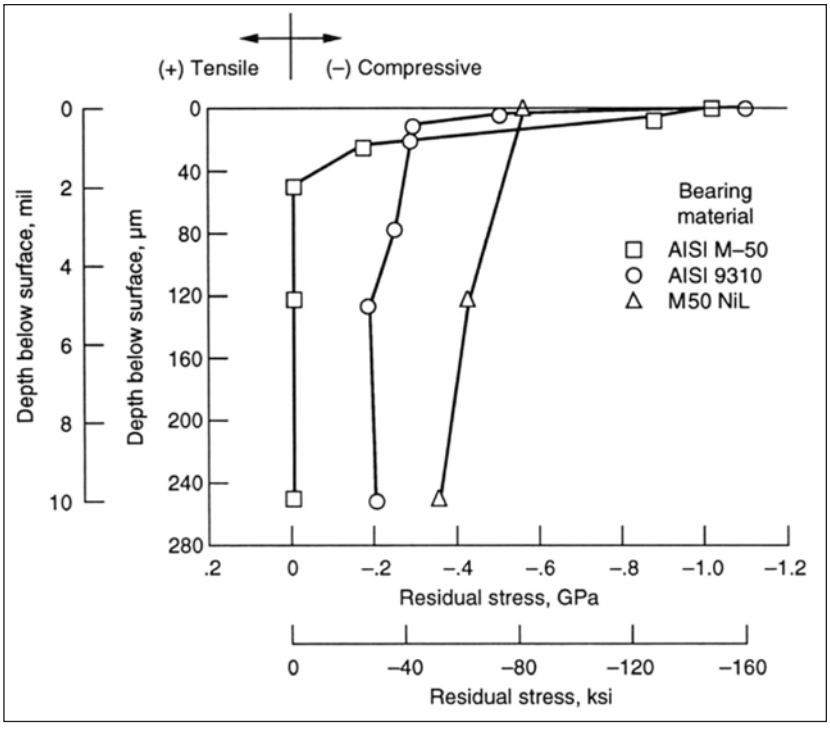


Figure 6 Representative principal residual stress as a function of depth below surface for heat-treated AISI M–50, AISI 9310 and M50 NiL (AMS 6278) (Ref. 3).

Minimum hardness for bearing steel at operating temperature should not be less than Rockwell C 58. Bearing life increases with increasing steel hardness at operating temperature. A three-point increase in hardness can result in a 35 percent increase in bearing life. For M-Series bearing steels, the change in hardness with temperature is independent of alloy content.

Bearing steels with high chromium content, greater than 12 percent, such as AISI 440° C are considered corrosion-resistant. Although the chromium forms a passive, chromium oxide layer at the surface that provides substantial protection, it is not inert and these alloys will corrode in hostile environments.

Compressive residual stresses induced or present from heat treatment beneath the surface of bearing steel components increase rolling element fatigue life and can alter the Hertzian stress-life relation. A compressive residual stress of 200 MPa (29 ksi) can increase bearing life for a lightly loaded bearing by a life factor, $LF \approx 12$; for a heavily loaded bearing, $LF \approx 3.8$.

For most critical aerospace applications, retained austenite is limited to two-to-five percent. However, for non-critical applications, higher amounts of retained austenite are allowed or may, in some instances, be uncontrolled. Experience has suggested that lower values of retained austenite are preferable for reliable bearing operation.

Rolling element fatigue life increases with finer grain sizes. Prior austenite grain size should be ASTM No. 8 or finer, and that individual grains should not exceed ASTM No. 5. The higher the ASTM number, the smaller the grain size.

There is an interrelation among steel alloy content, median residual carbide size, number of residual carbide particles per-unit-area, percentage of residual carbide area, and rolling element fatigue life. The large carbides act as stress raisers to initiate an incipient crack that results in a rolling element fatigue spall. As the percentage of alloying elements increases in through-hardened bearing steel, the number and size of the carbides increase.

Case-carburized bearing steels, with the exception of M50 NiL, have a courser and larger carbide structure when compared to through-hardened bearing steels such as AISI 52100 or AISI M-50. However, this disadvantage is more than offset by the compressive residual stresses induced into the case by the carburization process. **PTE**

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While **Erwin V. Zaretsky, PE,** is retired from his post as chief engineer/materials and structures, at the NASA Glenn Research Center, he remains a noted speaker, educator (Case Western Reserve University, University of Wisconsin/ Milwaukee and Cleveland State University), writer (at least 180 technical papers and two books) and consultant to both government and industry. A 1957 graduate of the Illinois Institute of Technology in Chicago—and with a 1963 doctorate from Cleveland State University—Zaretsky is also a former head of the NASA Bearing, Gearing and Transmission Section, where he was responsible for most of the NASA mechanical component research for air-breathing engines and helicopter transmissions. With approximately a half-century of experience in mechanical engineering related to rotating machinery and tribology, Zaretsky has performed pioneering research in rolling-element fatigue, lubrication and probabilistic life prediction; his work resulted in the first successful 3 million DN bearing. Zaretsky is an adjunct professor at Case-Western Reserve University and is a member of the executive advisory board of the Northern Illinois University College of Engineering. In 1992 he edited and co-authored the STLE (Society of Tribologists and Lubrication Engineers) book, Life Factors for Rolling Bearings, as he had done previously, in 1997—Tribology for Aerospace Applications. Zaretsky is the recipient of numerous NASA awards for his contributions to the Space Program, among which are the NASA Medal for Exceptional Engineering Achievement, the NESC Director's Award and the astronauts' Silver Snoopy Award. In 1999 the STLE honored him with the Wilber E. Deutsch Memorial Award; he has also received four IR-100 awards. Zaretsky is a Life Fellow of the ASME and a Fellow of STLE.

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Trends in Industrial Gear Oils

Jean Van Rensselar

With today's smaller, hotter—and overloaded—machinery, specifying the correct lubricant is vital.

An alarming 30 percent of recently surveyed U.S. industrial companies said they experienced a lubricant-related gearbox failure within the last year **(Ref. 1).** These failures were most likely due to extreme operating temperatures that created break-point stress on critical gearbox parts such as seals, bearings and gear teeth.

These higher operating temperatures are fueled by the demand for 1) more power; 2) a smaller footprint; and 3) decreased oil volume. Today's equipment also must handle increased loads while contending with a host of contaminants, including water. Dealing with these demanding conditions requires gear oil that is formulated to reduce stress in a number of ways.

The basic requirements for today's industrial gear oils are:

- Appropriate viscosity
- Oxidative and thermal stability
- Solid load-carrying capacity
- Demulsibility (ability to shed water)
- Resistance to foaming
- Protection against rust and corrosion

The difference between automotive and industrial gear oils is that the latter must perform in conditions and applications that can vary significantly. Just two examples are the highly contaminated conditions that exist in mines, and the highly aqueous conditions found in steel mills. So it's not surprising that gear base oil and additive manufacturers need a thorough grasp of the performance (application) requirements of today's advanced machinery and the end-user's needs.

Additives protect seals and improve thermal, oxidative and viscosity stability; they also provide micropitting resistance, bearing corrosion protection, foam resistance and enhanced demulsibility and load-carrying capacity.

For guidance, there are many gear oil standards, such as North America's AGMA 9005–E02 EP, Europe's DIN 51517–3 and Germany's SEBI 181 226. The newest is the Siemens (Flender) MD specification. In addition, OEMs often use standard performance tests together with their own requirements. There are also specifications for certain industries such as food processing. The increasing strictures of these specifications and the unique challenges posed by technologically advanced gearboxes require advanced gear oils to fully protect components**.**

And while choosing the wrong lubricant and incorporating certain additives that promote micropitting can cause lubricant-attributed gearbox failure, the *two most common culprits* are excessive heat and water contamination.

Micropitting

While it's fairly easy to spot micropitted gear teeth with a basic flashlight (they appear dull, etched and/or stained with gray speckles and sparkles), micropitting can be difficult to see under, for example, fluorescent lighting.

Bob Shorter, industrial specialist for Chevron Global Marketing, explains, "Micropitting on gear teeth is the result of metal-to-metal contact at the asperity scale where plastic or elastic deformation creates material loss that manifests as micropits. Micropitting is a function of many things, including gear manufacture and quality, EHL viscosity calculation/selection, the EP additive package, base oil selection, debris/contamination and operating parameters—including temperature and load."

Micropitting starts with fatigue cracks on the surface—or just below the surface—of the gear teeth. These pits are caused by metal-to-metal contact of rough surfaces. But because cracks can form below the surface of the gear teeth, high-speed gears with smooth surfaces and good film thickness also can become pitted.

Ravi Shah, staff engineer at Chevron, explains, "Typically, lubrication in this equipment is under a hydrodynamic or elastohydrodynamic (EHD) regime. In the EHD regime, when the surface roughness of bearings or gears matches the lubricant film thickness, parts of the two surfaces engage with each other, causing micropitting."

"Surfaces subjected to heavy loads, high temperatures and a lubricant that doesn't have a high enough viscosity will experience micropitting," Shah adds. "The presence of water will also aggravate micropitting. Too, certain properties of lubricant base stocks and additives (i.e., anti-scuff agents) affect micropitting, as does viscosity. On the other hand, some lubricants can stop the process."

As Tim Cooper, Lubrizol's industrial products manager for Europe, Africa and the Middle East, explains it, "There are various theories regarding the causes of micropitting. It is often talked about in relation to the wind turbine industry, but we see it in many other applications, too. In some cases micropitting may lessen over time, while in others it can ultimately lead to vibration, noise or even more destructive phenomena such as macropitting."

Heat

When it comes to heat-related issues, gear oil serves two functions: 1) to remove heat in the machinery generated by friction, and 2) to protect itself from heat-induced viscosity breakdown. The viscosity of a lubricant decreases as the temperature increases, so the viscosity of the oil must be high enough to provide an adequate lubricating film—but not so high that it creates friction within the film itself.

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With the constant pressure to increase operating loads, gearboxes today are burdened with increasingly hotter operating temperatures; as a result, improved thermal stability in gear lubricants is an imperative. Today's gear oils need to withstand the entire temperature range that the gear could be exposed to, both within the system and in the ambient operating environment. This will not only help to maximize the life of the gear oil, but also of the gears themselves.

Water Contamination

"Contamination is a key interest for some industrial customers," says Nelson Tam, Lubrizol's industrial products manager/ROA (Rest of Asia). "Their most common problem is foaming and lowering of demulsibility performance. Contamination is most common in gearboxes in cement plants and plants that handle coal, such as coal mines and coal-fired power plants."

Chevron's Shah adds that contamination also can occur in the proximity of sea and some other water sources, and where temperatures vary significantly between day and night.

Abrasive dust particles can penetrate the oil film and cause surface distortion and wear. Water contamination can corrode gear surfaces and, in the extreme, destroy a gear completely. Consider that industrial gear oil with just *one-percent* water content can reduce bearing life by up to 90 percent (**Ref. 2),** and the damage and contamination can quickly escalate.

The effectiveness of a gear oil is compromised when the oil and water do not separate and the oil becomes diluted. Experts agree that using a gear oil that quickly separates from water is the most effective way of reducing the risk and consequences of water contamination. Gear oil with improved water separation properties not only allows faster and easier water draining, it also reduces the frequency of oil changes.

Another way to manage water contamination is to identify potential contamination points early on and institute measures to reduce the ingress and counteract the effects. Of course the best strategy is to prevent water from entering the system in the first place; a "Plan B" strategy is to limit water's ability to damage components. A good way to do that is to opt for a lubricant designed to maintain its properties when even small amounts of water enter the system.

"All industries are susceptible to contamination," Shorter says. "Some of the worst environments are generally those industries that are dealing with climate elements."

Trends

"The general trend is toward gears operating under heavier loads and higher temperatures, smaller sumps (lubricant volume) and higher power density," Shah says. "The demand on lubricant performance has significantly increased, requiring better EP performance, micropitting resistance, oxidative properties, lower sludge-forming tendency and better foam performance."

Also consider that today's increasingly smaller gearboxes are made from lighter-weight materials, and yet they must produce more power while being more durable and more reliable. Bearing loads and speeds of the gear teeth are also trending higher; this means that a smaller gearbox with less lubricating oil needs to support gears with much higher workloads. Not surprisingly, this results in higher temperatures; it also results in accelerated oxidation. Oxidation is a particular problem for industrial gear oils because it contributes to sludge formation.

"Just like many other types of equipment, industrial gearboxes are experiencing a drive toward higher power densities that place greater demands on the lubricant," Cooper explains. "In some cases, they are also using steel qualities that have propagated the amount of micropitting fatigue in a range of applications and industries. Other trends include energy-efficient oils and longer-life oils to extend drain (and maintenance) intervals."

Cooper adds that "Oils today are formulated with a greater level of durability in mind; i.e., resistance to micropitting fatigue, greater thermal stability, and—very important—the realization that performance must be retained through the life of the oil. As an example, it's no

FOUR TYPES OF GEAR OILS

R&O INHIBITING GEAR OILS. Rust and oxidation (R&O) inhibiting gear lubricants perform well over a range of gear sizes, speeds and outside temperatures. They lubricate well if both the gears and bearings are lubricated from the same reservoir. Because they do not adhere to the gear tooth surface, it's best if the gear teeth are constantly relubricated. R&O inhibiting gear oils can be conditioned with heat exchangers and filters for consistent temperature and cleanliness.

EP GEAR OILS. Extreme-pressure (EP) gear oils are recommended for gear drives subjected to conditions of high load, medium-to-high slide and high-power transmit. EP gear oils can contain additives that are corrosive to brass and bronze components. But EP gear oils that utilize chemistries noncorrosive to these components are available. These oils also perform well over a range of gear sizes and speeds and outside temperatures. Gear teeth must be continually relubricated.

COMPOUNDED GEAR OILS. Compounded gear oils lubricate gear drives where the high sliding of gear teeth requires a friction-reducing agent to minimize heat and improve efficiency (enclosed worm gear drives). Unlike R&O and EP oils, they do not perform well over a wide temperature range and have a high operating temperature of 180 F (82 C). Like R&O and EP oils, constant relubrication of the gear teeth is encouraged.

SYNTHETICS. Synthetic gear oils are primarily used in applications where mineral-based industrial gear oils are unable to perform. Synthetic gear lubricants can contain R&O inhibitive additives and/or EP additives. Synthetic gear lubricants offer advantages such as improved thermal and oxidation stability, lower volatility and evaporation rates, improved energy consumption and reduced flammability.

longer acceptable to market oil that has good foam control or water-shedding properties when new, but after a few months of service the properties fall away, leaving the gearbox operator with an underperforming system."

Even with regular lubricant maintenance, punishing operating conditions of higher heat, higher loads, higher pressures and contaminants can compromise a gear system. The lubricants must withstand increasingly harsh environments that also quickly deplete essential gear oil additives.

New Gear Oils

With the increased demand on the lubricant, some lubricant companies are developing higher-quality lubricants with improved EP and micropitting resistance; oxidative properties; lower sludge-forming tendency; and better foam performance. Some lubricants are moving to synthetics, using Group III, IV and V components (**Ref. 3).**

The two major considerations in the formulation of new industrial gear oils are:

1. Increased emphasis on cost reduction (longer lubricant life)
2. Design changes to improve gearbox efficiency (smaller gearboxes with less oil capacity)

The good news is that the newer oils are formulated with high levels of extreme-pressure properties across a spectrum of viscosities. This affords those smaller gearboxes tasked with carrying high loads extra protection. But additives to improve extreme-pressure properties can decrease thermal stability, resulting in the formation of sludge. Industrial gear oil additives do exist, however, that provide the balance of thermal stability and extreme-pressure protection. The value-added combination of these two factors prolongs the life of gearboxes and maximizes efficiency (**Refs. 4–5**).

Regarding the Asian market, Tam explains, "The general trends in Asia are the same as in other zones; but more customers in Asia are looking at cost-effective products, which means special and long-drain products. They would like a product developed using their own base oil. Asian customers are always interested in long-drain intervals, energy efficiency, low cost, OEM approval and high loading."

The trend toward lowering gearbox manufacturing costs while at the same time allowing for increased, in-use productivity, imposes even greater demands on gear oils. This means that high load-carrying capabilities that maintain gearbox cleanliness will be the new norm for gear oils.

Synthetic Fluids

Synthetic industrial gear oil goes where mineral gear oil can't—as in temperature extremes, exceptionally high loads, challenging operating environments, and "special" requirements.

Shah explains, "Replacing fluid in a gearbox located 100-meters-high is not an easy task. As a result, synthetic products are finding more and more use in manufacturing wind turbine gearbox lubricants. The same is true of other difficult and demanding applications involving factors such as high loads, extremes of temperature or vibrations."

TRAITS OF A GOOD GEAR OIL*

LOW VISCOSITY. As the lubricant travels through the filter system contaminants, (which may originate outside the system or result from inside wear) should be removed. Slow-moving, highly viscous lubricants can be difficult to filter. They can cause pressure at the filter to increase. If sufficiently high, it will trigger a system bypass and allow contaminant-laden lubricant to circumvent the filters. Less viscous lubricants flow more easily through the filtration system where contaminants are effectively removed. This reduces the likelihood of machinery damage and increases equipment life.

Another benefit of using a lower viscosity gear oil is that it may not need to be changed as often, resulting in less costly downtime. Industrial gears operating under heavy loads require extreme-pressure protection for gear components, but mainstream industria gear oils do not always provide high extreme-pressure performance at low viscosity grades. This means that not just any low viscosity fluid will perform well.

DURABILITY. Industrial gear oils formulated for extended durability keep gears operating correctly and protect equipment by prolonging life, minimizing downtime, maximizing productivity and reducing maintenance costs.

DEMULSIBILITY. Water can get into the system (especially the reservoir) in many ways, leading to corrosion and compromised performance. Because of this, gear oil must be formulated to quickly separate water through the range of temperatures found in industrial gearboxes. This will extend the life of the oil and the machinery.

DEDICATED FOR INDUSTRIAL USE. There are two types of industrial gear lubricants. The first, so-called universal gear oils, are formulated so they can also be used in automotive gear applications. Universal fluids (formulated for automotive and industrial use) may contain components that are unnecessary for and/or harmful to industrial gears. On the other hand, they may omit components that are critical to industrial use (demulsibility additives). Gear oils for industrial applications are formulated with additives necessary for protection and optimal functioning.

SMART ADDITIVES. Conventional additives that improve extreme-pressure properties in gear oil are often susceptible to thermal instability, which encourages sludge. But additives are available that improve thermal stability, discourage sludge formation and provide extreme-pressure protection. This allows high extreme-pressure performance and cleanliness throughout the full range of viscosities.

*** Based on five factors cited by Lubrizol product manager Tim Cooper.**

The most commonly used synthetic industrial gear oils are ester oils, synthetic hydrocarbon oils and polyglycols. It's important to note that while synthetics have many advantages, in some instances they do not perform as well as mineral-based oils.

The specific advantages of synthetics (which vary according to the base stock) can include the following:

- Better viscosity protection in high temperatures
- Better low-temperature properties
- Better thermal and oxidative resistance
- Reduced volatility and evaporation
- Better lubricity
- Reduced flammability (depending on the basestock)
- Resistance to residues and deposits at high temperatures
- Extended drain intervals
- Reduced energy consumption
- Disadvantages may include the following:
- Reactions (such as corrosion and hydrolysis) in the presence of water
- Compatibility issues with materials such as some metals, paints and elastomers
- Poor miscibility with mineral oils
- Higher price (usually, but not always)

Synthetic industrial gear oils may contain rust and oxidation-inhibiting additives and/or antiwear/EP additives. "Synthetics offer an alternative for the end-user, but Group II+, Group III and Group IV base oils are all viable choices," Shorter says. "These base oils often lead to longer lubricant life, better performance and, ultimately, value for the end-user."

Siemens MD Specification

Cooper explains that the latest Siemens MD specification not only looks into the conventional aspects of gear and bearing lubrication (wear protection, corrosion resistance, etc.), but also takes into consideration compatibility between the lubricant and every component within the gearbox that it will contact.

"Thus there is a very strong emphasis on elastomeric seal and paint compatibility with the oil. This can place limitations on the types and amount of additive chemistry that can be deployed to deliver the necessary lubrication properties."

Before Siemens MD approves oils for use in Flender helical, bevel and planetary gear units, the manufacturer must warrant that the oils are of CLP-quality according to DIN 51517–3.6 There are also many other application-specific properties that must be met. The qualification testing and submission of the approval documentation must be conducted by the oil manufacturer or marketer, meaning that gearbox users cannot request approvals.

All tests must be conducted no more than *one* grade *above* the lowest viscosity of the oil. The exception to this rule is the *Flender foam test*, which must be tested in the highest viscosity grade. All test data must be carried out on oil samples of the same composition and according to the formulation table—and which must be enclosed. In addition to the testing and performance requirements, the material safety data sheet (MSDS) and technical data sheets (TDS)—including the temperature-viscosity curves for each visincosity grade—must be submitted for approval. The lubricants must be identified by submission of an IR (infrared) reference spectrum and ICP (inductively coupled plasma) reference values for the viscosity grades requested for approval (**Ref. 7**).

All test data must be generated within a Siemens-approved laboratory for application-specific testing; Siemens will not accept test data generated in an unapproved laboratory (Ref. 8). For approval of a viscosity range, oil manufacturers must guarantee that the performance level obtained in a specific test—and with a specific oil—is consistent with that product—independent of production location or viscosity grade across the viscosity range. In addition, the oil manufacturer has to guarantee that the required properties do not only apply to fresh oil, but that they also

SELECTING THE CORRECT GEAR OIL*

There are two primary considerations for selecting the correct gear oil for an application:

GEAR SPEED

The now superseded Industrial Gear Lubrication Standards, AGMA 250.04, used center distance as the primary criterion for gear lubricant selection. The new version of this standard, designated AGMA 9005-D94 Industrial Gear Lubrication, has adopted pitchline velocity as the primary selection criterion. The pitchline velocity determines the contact time between gear teeth. High velocities are generally associated with light loads and very short contact times. For these applications, low-viscosity oils are usually adequate. In contrast, low speeds are associated with high loads and long contact times. These conditions require higher viscosity oils. EP additives may be required if the loads are very high.

TEMPERATURE

Ambient and operating temperatures also determine the selection of gear lubricants. Normal gear oil operating temperature ranges from 90 F to 100 F (50 C to 55 C) above ambient. Oils operating at high temperatures require good viscosity and high resistance to oxidation and foaming. Caution should be exercised with abnormally high temperatures. High operating temperatures indicate oils that are too viscous for the application, excess oil in the housing or an overloaded condition. Each of these conditions should be investigated to determine the cause and correct the problem. Oil for gears operating at low ambient temperatures must be able to flow easily and provide adequate viscosity. Therefore, these gear oils must possess high viscosity indices and low pour points.

*From: *www.agroengineers.com/gears/gears-lubrication.shtml*.

do not deteriorate within permissible tolerances through the entire period of use. The period of use for mineral oils must be at least 10,000 operating hours—or two years maximum; and for synthetic oils, at least 20,000 operating hours—or four years maximum, assuming an average oil operating temperature of 176°F (80°C).

"Some of the challenges of the specification include extensive and expensive testing of lubricants against a battery of tests outlined in the specifications," Shah says. "Additionally, sometimes there are differences in results when run at different labs. It would be helpful if these tests become standardized DIN and/or ASTM tests."

The formulations tested and approved by Siemens MD must be identical to the oils produced commercially under the approved fluid name. Any changes to the approved formulations beyond permissible tolerances within production must be noted in writing and sent to Siemens MD. Unacceptable changes will result in voided approval and removal of the oil brand from the approved lubricant list.

Tam points out that "Asian customers ask for Siemens MD-approved products, and commercially we have a problem if we cannot deliver such products. It is particularly challenging for some customers who need approval in their own base oil."

"The pending Revision 14 to the Siemens/Flender specification addresses some of the technical challenges, but the certification/approval process timeframe continues to be slow," Shorter says (**Ref. 9);** lubricant approval is limited to five years (**Refs. 10–11).**

The Siemens MD specification and its revisions are a giant step forward in ensuring the quality and performance of critical industrial gear oils. OEMs, formulators and end-users welcome the enhanced regulation of basestock, additives and end products.

With tougher operating conditions, the demands on industrial gearboxes have reached levels that no one could have anticipated even five years ago. As OEMs and operators struggle to ensure the reliability and longevity of equipment, new industrial gear oils that offer protection against high heat and contamination will continue to be a key weapon in their arsenal. **PTE**

References

1. Study conducted by Shell and cited at: *http://www.gearsolutions.com/article/detail/5490/motion-impossible--without-the-right-lube.*
2. From: *http://www.gearsolutions.com/article/detail/5490/motion-impossible--without-the-right-lube.*
3. Group I is solvent de-waxed oil; Group II is hydro-processing and refining oil; Group III is further-refined hydro-processing and refining oil; Group IV is chemically engineered synthetic, including PAO (polyalphaolefin) oil; Group V is a blend of oils.
4. DIN 51517, Part 3, U.S. Steel 224, ISO 12925–1 CKC/CKD, Cincinnati Machine, AGMA 9005–E02, and GM LS–2 and David Brown S1.53.101.
5. From: *http://www.machinerylubrication.com/Read/1292/industrial-gear-oils.*
6. Except tests acc. ISO 6247 and DIN ISO 1817. 32.
7. IR and ICP test machinery are used to identify the fingerprint of a lubricant.
8. The list of approved laboratories and contact details can be found using the following link: *http://support.automation.siemens.com/ww/view/en/44240585.*
9. Revision 14 is designed to streamline the approval process.
10. From: *http://cache.automation.siemens.com/dnl/zc/zc3ndQ1aaaa_44241193_faQ/en_Specification_for_oil_approval_SKP__rev_13.pdf.*
11. Revision 13 includes the following changes: a second approval criterion for the foaming test; temperature-viscosity curves for each viscosity grade must be submitted; some wording was changed.

ADDITIONAL OEM GEAR OIL SPECIFICATIONS*

In addition to standard specifications for industrial gear oil, many gear manufacturers' specifications contain additional demands, such as the following:

- Intensified scuffing tests
- Micropitting tests at 140°F (60°C) and at 194°F (90°C)
- A roller bearing wear test
- A low-speed wear test
- A pitting test
- A test to determine load-carrying capacity
- A filtration test
- A foaming test
- Low-temperature tests (for behavior and flow)

These additional bench tests attempt to replicate the extreme conditions to which gearboxes and gear oils are subject and quantify the performance of the various formulations.

*From: *www.fuchs-europe.com/uploads/media/RENOLIN_Industrial_gear_and_lubricanting_oils_07-2009_01.pdf.*

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Timken

ACQUIRES INTERLUBE SYSTEMS

Plymouth, U.K.-based Interlube Systems Ltd. has been acquired by Timken for an undisclosed sum. Interlube employs 90 people and turned over around £8.7 million (more than 13 million U.S.) in 2012. The company, which makes and markets automated lubrication delivery systems and related components for use in commercial vehicles, construction, mining and heavy and general industries, operates in Dayton, Ohio and a joint venture in Zhuhai, China.

The purchase also includes MSP Distributors Ltd. based in Cheltenham, U.K. and acquired by Interlube in 2007. Interlube Managing Director Mike Cusack says, "Interlube are delighted to be joining The Timken group. Their global reach will allow Interlube to continue expanding its markets, and should provide enhanced investment in the Plymouth facility."

Pictured left to right: **Andreas Roellgen** (Timken), **Richard Cobb** (Michelmores), **Michael Boyd** (Interlube), **Michael J. Connors** (Timken), **Mike Cusack** (Interlube), **Ian Curtis** (Timken).

The Timken Company engineers, manufactures and markets mechanical components and high-performance steel. It had sales of $5 billion last year and around 20,000 people operating from 30 countries.

Making the announcement, Michael J. Connors, vice president of distribution for Timken, says, "We're pleased to have Interlube join the Timken team. The management team brings a wealth of experience and established customer relationships, and their automated lubrication delivery systems certainly complement the Timken portfolio of power transmission products."

As part of its growth strategy, Timken has been steadily adding to its product portfolio and sees Interlube as highly compatible to its core product lines and recent acquisitions. "Their expertise and quality product line, coupled with our global reach and market access, will allow us to grow market share for Interlube products," Connors added, "as well as expose new market space for existing Timken applications."

Interlube was advised by Gary Partridge, of PwC, and Richard Cobb, of Michelmores in Exeter. Gary Partridge said: "We're delighted with the outcome, Timken is the perfect strategic buyer for Interlube." Michelmores partner Richard Cobb said: "It is always rewarding to help an MBO team achieve the exit they have worked towards for many years."

Klüber Lubrication

ANNOUNCES PERSONNEL CHANGES

Klüber Lubrication, a worldwide manufacturer of specialty lubricants, announces the appointment of **Ralf Kraemer** as chief executive officer. Kraemer assumes the role of CEO from Dieter A. Becker, who returns to Klüber's global headquarters in Munich, Germany, after leading the North American operations for nearly three years. Born in Germany, Kraemer brings more than 15 years of sales, marketing and management experience in the metal cutting, woodworking, industrial equipment and power transmission industries to his new role at Klüber.

"We're excited for the opportunity to have Ralf lead Klüber Lubrication North America," said Becker. "Klüber places particular importance on its industry-leading customer service and in-depth technical and application support. We are committed to providing excellent support to our thousands of customers throughout North America, and Ralf's skills, experience and dedication to a customer service-oriented focus make him the perfect fit to execute this promise." Prior to joining Klüber, Kraemer managed operations at a Swiss technology company in the Chicago area and established and developed the North American manufacturing facility and business operations for a German machine tool accessories company near Raleigh, N.C. For the past nine years, he was responsible for the North American operations of a German machine tool company in Pittsburgh, PA. Kraemer holds a degree in industrial engineering and management from the Karlsruhe Institute of Technology and an MBA from the Isenberg School of Management from the University of Massachusetts Amherst.

Additionally, **Ron Person** has joined Klüber's North American operations as director of business development for oil and gas. In his new role, Person will be responsible for further developing application-specific support and customer service initiatives designed to better position Klüber Lubrication as a leading specialty lubricant producer in the oil and gas market. Person will work closely with key equipment manufacturers in the industry to match existing Klüber products to applications, as well as identify areas for new product development. Person has more

than 20 years of experience in the oil and gas industry. Prior to joining Klüber, he was a global subsea manager for BP Lubricants. Prior to that, Person held business and technical roles at Deutsch Offshore, Teledyne Technologies, M-I SWACO and Cameron. Person holds a bachelor of science in industrial distribution from Texas A&M University, where he was a member of the Corps of Cadets, accepting a commission into the U.S. Army.

Sumitomo Machinery Corporation

TRANSITIONS TO FULL U.S. PRODUCTION RUNS

Sumitomo Machinery Corporation of America, U.S. headquarters for Sumitomo Drive Technologies, is pleased to announce that Phase I of the Cyclo Bevel Buddybox (Cyclo BBB) bevel gear Domestic Manufacturing Initiative has been completed, and the company has transitioned to full production runs. As part of a 2015 Manufacturing Vision launched in 2011, this represents a major milestone in the plan to increase the company's domestic manufacturing capabilities. SMA's new bevel gear manufacturing process utilizes some of the most state-of-the-art technology the market offers today. Gears are cut on a newly installed Gleason bevel gear generator, which boasts 35 percent productivity increases over any bevel equipment offered in the past decade. These productivity increases are due to advances in dry cutting technology and an integrated chamfering and deburring station. In addition to the gear generator, a new gear lapper and tester are helping to increase assembly through-put and accuracy. The last major component of our Cyclo BBB Phase I Domestic Manufacturing Initiative, a new hollow shaft machine from Bardons & Oliver, has also been installed and is now producing completed Hyponic blanks. Completed hollow bore shafts are currently being developed, and the company expects this machine to produce all Hyponic shafts in house by end of March 2013. Once that stage is finished, they will begin developing Cyclo BBB Keyed Hollow Bore and Taper Grip Hub shafts (estimated to be complete by end of April 2013).

NFPA

RELEASES NEW TECHNICAL STANDARDS

A new technical document has recently been published and is now available from the National Fluid Power Association (NFPA).

ISO 7790:2013 (supersedes ISO 7790:1997) Hydraulic fluid power – Four-port modular stack valves and four-port directional control valves, sizes 02, 03, 05, 07, 08 and 10 – Clamping dimensions

Scope: This International Standard specifies clamping dimensions of four-port modular stack valves and four-port directional control valves, sizes 02, 03, 05, 07, 08 and 10, on mounting surfaces. The dimensions and sizes conform to ISO 4401 so as to ensure interchangeability of these valves and to reduce the number of fixing devices to be used.

It applies to clamping dimensions of four-port modular stack valves and four-port directional control valves which represent current practice. They are generally applicable to industrial equipment.

Benefits: ISO 7790 is a dimensional interchangeability standard that benefits users by allowing them to purchase hydraulic four-port modular stack valves from multiple suppliers, and manufacturers of these valves to benefit from economies of scale afforded by the standard.

NFPA list price: $54.00

NFPA member price: $43.00

ISO 6195:2013 (supersedes ISO 6195:2002) Fluid power systems and components — Cylinder-rod wiper-ring housings in reciprocating applications — Dimensions and tolerances

Scope: This International Standard specifies dimensions and tolerances of housings for wiper rings used in reciprocating rod applications for fluid power cylinders. The range of rod diameters is from 4 mm to 360 mm. This International Standard is applicable to five housing designs, types A through E. These housing designs are intended for use with the wiper rings according to Figure 1. This International Standard does not otherwise specify the style, configurations, materials or performance ratings for the wiper ring.

Benefits: ISO 6195 benefits cylinder manufacturers by establishing a standard series of rod wiper-ring seal housings that can be incorporated in their components. It benefits sealing device manufacturers by providing a standard series of housings for which they can create standard sealing devices for a global market.

NFPA list price: $108.00

NFPA member price: $86.00

NFPA provides a forum for the fluid power industry's channel partners—manufacturers, suppliers, distributors, customers and educators. Its U.S. and multinational members work cooperatively in advancing hydraulic and pneumatic technology through the association's many programs and initiatives. NFPA coordinates standards development for fluid power at the industry and international levels. These standards are intended as guides to aid the manufacturer, the consumer, and the user. For more information, visit *www.nfpa.com*.

TPR International

CELEBRATES 10 YEARS AT HANNOVER MESSE

German PR agency TPR International is celebrating its tenth anniversary at this year's Hannover Fair in April 2013. Established in 2003, the agency has been specializing in the power transmission industry since its foundation. Covering the European and North American markets, its clients include manufacturers in Germany, Austria, the United Kingdom and the United States. Founder and owner of TPR International Christiane Tupac-Yupanqui, a qualified translator, first came in contact with the power transmission industry when she was working at the European Power Transmission Distributors Association (EPTDA). In the light of TPR's international activities, her background in languages has

proven to be a great asset: In addition to the German-speaking countries of Germany, Austria and Switzerland, TPR International's portfolio includes PR services for the United Kingdom, the USA and Canada as well as France, Italy, the Netherlands, Spain and Turkey and also the Czech Republic and Poland. "All press releases and articles are translated by our qualified specialist translators and reviewed in-country by our customers' sales partners. This ensures the correct use of technical terms and conventions: nothing is taken for granted in technical translation," explains Tupac-Yupanqui. "We are the ideal single-source PR service provider for our clients. With our international expertise we can save them the trouble of having to deal with a different agency in each country. And being specialized in just one sector we are intimately familiar with the trade press in each of the markets we cover and can take advantage of trade shows to build personal relations with editorial teams." Besides conventional PR work TPR International also places advertisements on request and provides a translation service for brochures, technical documents and websites.

TPR's long-standing customers are medium-sized manufacturers of high-quality components for power transmission, motion control, automation, electronic and fluid power applications. They include, in Germany, chain specialist Iwis, screw drive manufacturer Kammerer, fluid power specialist R+L Hydraulics, metal shim manufacturer Georg Martin, electronic components manufacturer SMP Sintermetalle

Christiane Tupac-Yupanqui, founder and owner of TPR International.

Prometheus as well as rolling bearing manufacturer NKE Austria, DC drives manufacturer Sprint Electric (U.K.), split roller bearings manufacturer Cooper (U.K.), couplings manufacturer Ruland (United States) and thin-section bearings manufacturer Kaydon (United States). For more information, visit *www.tradepressrelations.com*.

Motion Drive and Automation at Hannover 2013

Power transmission and control companies will be on-hand during Hannover Messe 2013 to display the latest technology offerings in key product categories including roller bearings, gear wheels, pumps, motors, transmissions, drive system components, clutches and braking systems. The Motion, Drive and Automation Fair, along with neighboring MobiliTec and Wind fairs, is designed to generate crossover visitor traffic which benefits both attendees and exhibitors.

"The positive feedback we've received from exhibitors and visitors alike and the excellent registration levels augur very well indeed for a strong Hannover Messe 2013," said Dr. Jochen Köckler, a member of Deutsche Messe's Managing Board. "Hannover Messe has shown time and again that it has the power and influence to kick off new trends and shape future developments."

The MDA Forum, organized by the German Engineering Federation (VDMA), offers Motion, Drive and Automation presentations dedicated to the latest developments and worldwide trends. It also serves as a platform for exchanging ideas and networking. In 2013, the MDA Forum topics will include: energy efficiency in industrial processes, solutions for high-speed applications, automation technology, condition monitoring systems, total cost of ownership, life cycle cost and return on investment.

On the MDA Exhibition floor, the focus will be on product roll-outs and topical themes – for example, new developments in components and systems for automation technology, areas of application in wind energy (e.g. offshore farms), new trends in electric mobility, and much more. The lead theme of Hannover Messe (Integrated Industry) will be manifested in several areas of the MDA fair as industrial automation and power transmission products steadily converge on the digital manufacturing floor. This trend is reflected in the fact that more and more suppliers of power transmission, linear motion and industrial gear systems are offering turnkey automation solutions.

Here's a second round of key exhibitors that will be displaying products and technologies at the MDA Fair at Hannover Messe (April 8-12, 2013):

FCMD GmbH

Hall 025, Stand A12

FCMD GmbH, a Groupe CIF company, will be presenting a full range of custom power transmission solutions for low speed, high torque process applications, including open gearing, speed reducers, couplings, and large reducer repair/refurbishment services. The company houses the largest open gear processing equipment possessed by Groupe CIF at its Hattingen (Germany) facility, including a 14 m diameter capacity gear cutter and a recently commissioned 16 m diameter capacity vertical boring and gear cutting machining center (capable of handling parts of 350-450 t). This facility also maintains a dedicated bay for the servicing of large gearboxes.

Groupe CIF is one of the largest, privately-held industrial groups in Europe, comprised of five operating companies with manufacturing activities in seven separate facilities located in France and Germany. Led by FCMD GmbH's sister companies, Ferry-Capitain and CMD, Groupe CIF serves customers in many industrial markets including mining, cement, steel, energy, offshore, environmental and aerospace. Principal activities are foundry (iron and steel), machining, fabrication, and the design and manufacturing of mechanical power transmission systems (*www.fcmd-gmbh.de*).

Gambini Meccanica/Gambini Deutschland

Hall 24, Stand D29

Founded in 1978, the company specializes in the production of transmission gears. Gambini Meccanica offers helical racks, straight racks, helical gears, straight gears/pinions, splined shafts, pulleys, round racks and worm gears. Application sectors include construction and furniture, industrial automation and oil mills, food processing and farm machinery. The company

opened a German branch in February 2012: Gambini Deutschland GmbH located in Munich. The goal of this location was to come as close to customers as possible in order to improve the collaboration and the innovation of Gambini products and services. The company recently moved to a new factory in Pesaro, which presents a surface of 7,000 square meters with an advanced logistics system.

Maxon Motors
Hall 15, Stand D05

Maxon Motor supplies high-precision drives and systems of up to 500 watts power output. The company develops and manufactures brushless and brushed DC motors with the unique ironless maxon winding, in addition to iron-cored brushless flat motors. Its modular product range is further complemented by planetary, spur and special gearheads, feedback devices and control electronics. The design and production of high-tech CIM and MIM components are achieved at a special competence center. Products at Hannover include direct current motors with ironless rotor and high performance permanent magnets, brushless DC motors with maximum service life and control electronics for DC and EC motors, positioning control units and speed control units (*www.maxonmotor.com*).

Moventas
Hall 25, Stand D23

Moventas is an international manufacturer of mechanical power transmission solutions and develops, manufacturers and distributes drives for industrial applications and wind turbines. Services turned to the entire life cycle complement the range of offerings. Moventas combines comprehensive competency, experiences of several decades and leading-edge technologies in the area of power transmission solutions derived from the corporate history. The former companies Santasalo, Valmet, Parkano Gears and Sauerwald make Moventas a preferred partner for demanding power transmission solutions. Products and services featured at Hannover 2013 include wind gears, factory service, field service, replacement gears and industrial gears (*www.moventas.com*).

NBC Bearings
Hall 24, Stand A28

National Engineering Industries Ltd. was founded in the year 1946, under the name of "National Bearing Company Limited," NEI has since then grown in strength to emerge as one of the pioneer manufacturers and exporters of ball bearings, hub bearings, clutch release bearings, DRAC bearings, tapered roller bearings, cylindrical roller bearings and axle boxes for railway rolling stock including spherical roller bearings, cartridge tapered roller bearings and large special bearings. The company manufactures 60 million bearings per year in more than 500 different sizes ranging from 6 mm bore to 1,300 mm outer diameter with a capacity up to 2,000 mm outer diameter (*www.nbcbearings.in*).

Wittenstein AG
Hall 15, Stand F08

Innovations are driven by market and user needs. Noise reduction, energy efficiency and downsizing are the three main trends in drive technology. Wittenstein alpha has responded to this demand by displaying the third generation of the LP+ planetary gearhead series, which will be launched to coincide with the Hannover Fair. Additionally, the company will be showing a low-backlash planetary gearhead in hygienic design. The Wittenstein Group comprises seven business units including servo gearheads, servo drive systems, medical technology, miniature servo units, gearing technology, rotary and linear actuator systems as well as electronic and software components for drive technologies (*www.wittenstein.de*).

Danfoss
Hall 14, Stand H30

Danfoss launched its first frequency converters in 1968 and since then has set milestone after milestone, culminating with its frequency converter platform, the VLT AutomationDrive FC 300. In addition to its VLT frequency converters for centralized and decentralized solutions, the current product range includes both soft starters and active and passive filters. The product portfolio is complemented by a comprehensive range of services — from individual drive components to the planning and supply of complete drive systems. When it comes to its consultancy work, Danfoss boasts more than 40 years of experience in the food and beverage, building automation, water/wastewater systems, conveyor technology, chemical and automotive industries. At Hannover, products on display will include the VLT Softstarter, VLT Aqua Drive, VLT HVAC Drive, VLT Low Harmonic Drive and VLT Automation Drive *(www.danfoss.com*).

April 25–27—2013 AGMA/ABMA Annual Meeting. Park Hyatt Aviara, Carlsbad, CA. More than 150 years ago thousands of people migrated to California, where they joined forces and tested their luck in the gold fields. Now fast forward to 2013. Whether you are a veteran or a "first timer" annual meeting attendee, expand your horizons and your colleagues in the Golden State. Increase knowledge from the industry's presentations and experience the majesty of Southern California in and around Carlsbad, Oceanside, La Jolla and Miramar. In 2013 attendees will bring home ideas, meet new business associates, and create a lifetime of memories. Featured presenters include Jay Timmons (National Association of Manufacturers), Jim Meil (Eaton Corporation) and Dan Campion (Solar Turbines). Former MLB pitcher Jim Abbott will also give a presentation on overcoming adversity. There's also a scheduled visit to the United States Marine Corps Air Station in Miramar and a night of entertainment celebrating the iconic music of the 1960s. For registration information, visit *www.agma.org*.

May 4–7—BSA Annual Convention. Westin Hilton Head Resort and Spa, Hilton Head, South Carolina. The BSA Annual Convention brings together the top leadership of authorized bearing distributors and manufacturers. As such, it offers networking opportunities along with a business program tailored for the industry leadership who attend. The 2013 business program will address winning strategies that meet customer needs. Speakers include Dr. Bruce Yandle, professor of economics emeritus, Clemson University; Lt. Col. Rob "Waldo" Waldman, founder and president of The Patriot Group; Eric Chester, author, speaker and founder of the Center for Work Ethic Development; and Terry Bowden, former college football National Coach of the Year. Also on the schedule, industry updates and BSA's Conference Table Session which encourages distributors and manufacturers to build problem-solving relationships. For more information, visit *www.bsaconventions.org*.

May 5–8—WindPower 2013. McCormick Place, Chicago. The AWEA brings together wind professionals to network, learn from industry leaders and experts and discover the latest industry products and services. The 2013 exhibition and conference includes 18 tracks, 38 sessions, knowledge hubs, power sessions and poster receptions from all the major players in the wind industry. Exhibitors include Bosch Rexroth, Bonfiglioli, Romax Technology, SKF and ZF Wind Power. Special events include the Suzlon and AWEA Golf Open, specialized technical training courses on topics like tower fabrication, new clean energy markets and electrical safety for managers, a special component manufacturing tour at S&C Electric and a conference dinner at The Field Museum. For more information, visit *www.windpowerexpo.org*.

May 14–16—Eastec 2013. Eastern States Exposition, West Springfield, Massachusetts. East Coast manufacturers come to Eastec looking for top suppliers and new partners and to evaluate new equipment and applications from industries like defense, aerospace, consumer products, medical, automotive, computers and more. Eastec traces its history to 1979 and attracts 45,000 manufacturers to learn about the latest management ideas. The educational program includes a leadership seminar, keynote speakers and a lean and a green resource center. Eastec technologies include bearings, gears and splines, material handling, packaging, sensors, controls, machine tools, machine centers, automation, plant efficiency and workholding. Exhibitors include Carl Zeiss, Emuge, Fanuc, Ingersoll, Lovejoy, Marposs, Pepperl and Fuchs, SKF and many more. The event is sponsored by the Society of Manufacturing Engineers (SME). For more information, visit *www.sme.org*.

May 21–23—Lubrication and Wear: Advanced Concepts. Notre Dame Conference Center, South Bend, Indiana. This course will bridge the gap between component design and failure as a result of relative motion between surfaces in contact and apply the latest lubrication technology to bearings. Courses will enhance attendees' understanding of regimes of lubrication, 2-D and 3-D surface topographical characterization, 2-D and 3-D contact mechanics, surface and subsurface analysis, asperity contact models, mixed lubrication, grease lubrication, applications in rolling element bearing design and more. Practical examples of bearing lubrication will be presented as well as tools to improve product life and performance. For more information, visit *www.americanbearings.org*.

June 10–14—NAMRC 41. Monona Terrace Community and Convention Center, Madison, Wisconsin. The North American Manufacturing Research Conference is sponsored by the North American Manufacturing Institution of the Society of Manufacturing Engineers (NAMRI/SME). It is co-located with the 8th Annual ASME International Manufacturing Science and Engineering Conference. The conference schedule will include keynote presentations, technical presentations, expert panels, student poster presentations, an early career forum, university lab tours and more. The purpose is to disseminate the most recent manufacturing research and development through both technical presentations and panel sessions. For more information, visit *www.conferencing.uwex.edu/conferences/namrcmsec2013/index.cfm*.

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☐ WE DESIGN products with power transmission components in them. (16)
☐ Other (please describe) (15)_____

5 → What is your primary job function responsibility? (Check one)

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❑ Plant Engineering (2)
❑ Design Engineering (3)
❑ Marketing & Sales (4)
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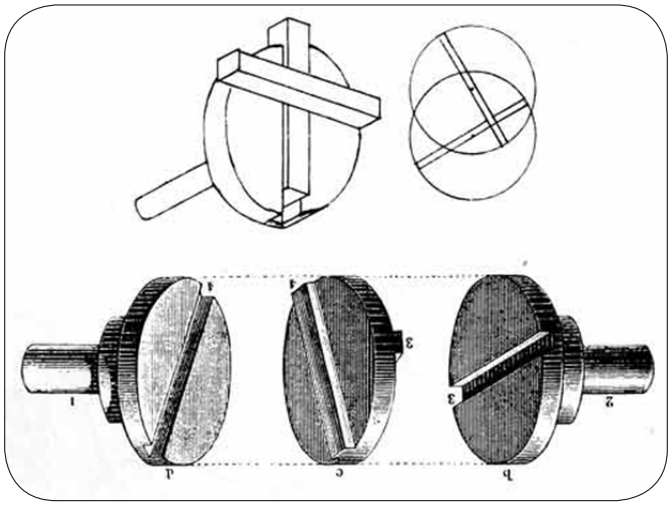
John Oldham: The Coupling Personified



Original Oldham coupling built before 1840, using a cross (instead of a center disk), as sketched by Robert Willis in personal copy of his Principles of Mechanism, Figure 39 (London, 1841, p. 167). Bottom: Oldham coupling as illustrated in Alexander B. W. Kennedy's, Kinematics of Machinery, a translation of Franz Reuleaux' Theoretische Kinematik (London, 1876, pp. 315–316).

Ireland is known for many things—the Book of Kells; peat bogs; gifted writers; drunken writers; gifted-and-drunken writers; Guinness Stout; bewitching music; and ever so much more. What you may not know about the Emerald Isle is that a widely used—and most effective power transmission component— was invented by an Irishman way back in the mid-19th century.

Meet John Oldham (no middle name — odd for an Irish Catholic; but on the other hand, was reported to have sired 17 children—but with whom, typical of the times, is not mentioned): engineer, engraver, philosopher, Royal Dublin Society member, miniatures painter *and*— inventor of the eponymous *Oldham coupling*.

Dublin-born in 1779, Oldham began as an engraver's apprentice before soon going on to invent a serialization (sequencing) machine intended to prevent the forgery of bank notes. Then, off on another creative path, in 1807 he created what he called an "eidograph," which, it was said, "upon being applied to one's face**,** would delineate the most expressive and animated miniature with unequalled accuracy and expedition." (Or as Webster puts it: *An instrument for copying drawings on the same or a different scale; a form of the pantograph.*)

As for his "artist's life," he exhibited five miniatures at the Parliament House in 1801, and was referred to, in a review of the exhibition in the *Freeman's Journal*, as "a young artist, now for the first time before the public, advancing with rapid strides."

His sequencing machine was acquired in 1812 by the Bank of Ireland, where he was also appointed engineer and chief engraver. But while still in the banking industry, Oldham was doing a lot more than counting banknotes, eidographs notwithstanding. Having a keen interest in marine propulsion, in 1817 he obtained a patent (No. 4169) for a device he had designed for propelling ships by means of paddles powered by a steam-engine — the object being to imitate the motion of a paddle when used in the ordinary way. In 1820 he then patented an improved model—or coupling, the word not yet invented — (Patent No. 4249), which called for the paddles to be placed on a shaft across the ship, which were then steam-powered to revolve, being feathered by an adaptation of the gearing used in his earlier design.

Though described in a report at that time as a "very imperfect contrivance" — by a Brit perhaps? — Oldham's coupling was in fact used in the power transmission design of the *Aaron Manby*. The steam-powered vessel, according to *oxfordindex.com*, represented "the first time that iron plates, and not wood, had been used to construct a seagoing ship — a landmark in the science of shipbuilding."

Built in 1822 at England's Horsely Iron Works, Oldham's invention was later described in an 1885 edition of the British *Proceedings: Institution of Mechanical Engineers* as "feathering-float paddle wheels." And with the help of Oldham's coupling, according to *gracesguide.co.uk*,

"Defying the prevailing wisdom of the day, the iron-hulled vessel not only floated but made nine knots and drew one foot less water than any other steamboat then operating."

Today, nearly 200 years after Oldham introduced his coupling, the man is still getting his props, as evidenced by a 21st century description of the component on *cncmentor.com*: "An Oldham coupler is a mechanical device which transmits rotary motion between shafts that are parallel but not always in perfect alignment. The **O**ldham coupler is built around three discs, one coupled to the input, one coupled to the output, and a middle disc that is joined to the first two by tongue and groove. The tongue and groove on one side is perpendicular to the tongue, and groove on the other. Often springs are used to reduce backlash of the mechanism. The coupler is much more compact than, for example, two universal joints. Its name originates from the Irish inventor, John Oldham."

Oldham went on to become a life member of the Royal Dublin Society beginning in 1827, also serving for a time on its natural philosophy committee (1829–32) during which he designed a "mechanical water supply system" for the society's botanic garden.

He moved on to London in 1837, where he worked for the Bank of England. He died there at his home on Valentine's Day, 1840, leaving behind an impressive legacy and — equally impressive — those 17 offspring. **PTE**

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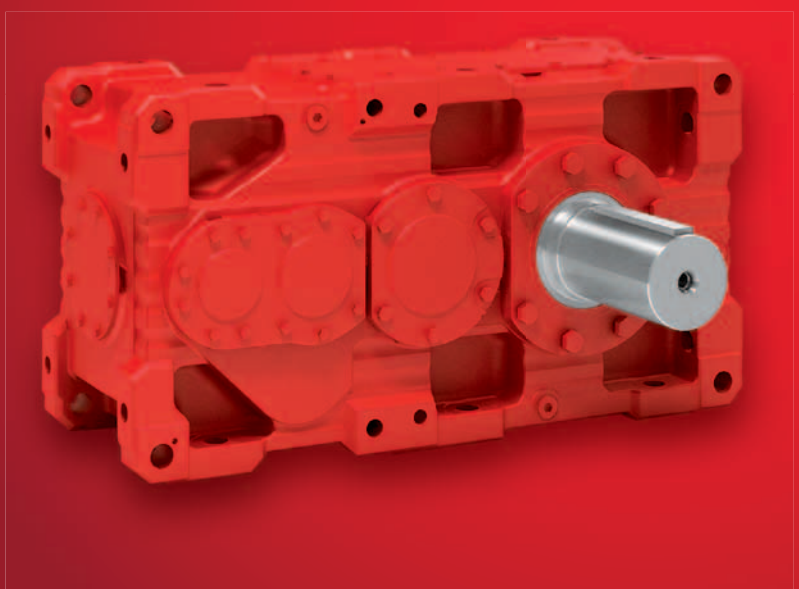

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