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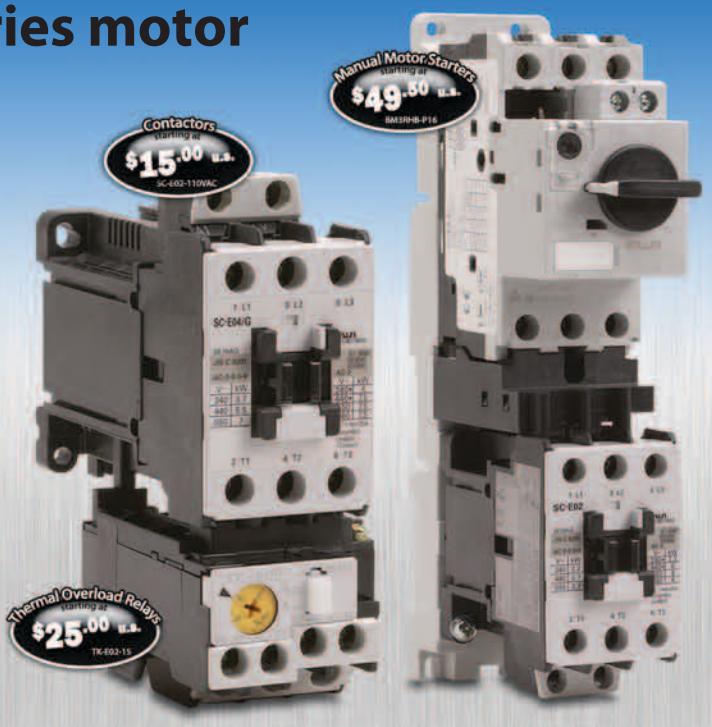

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Power Transmission Engineering

VOL. 7, NO. 1

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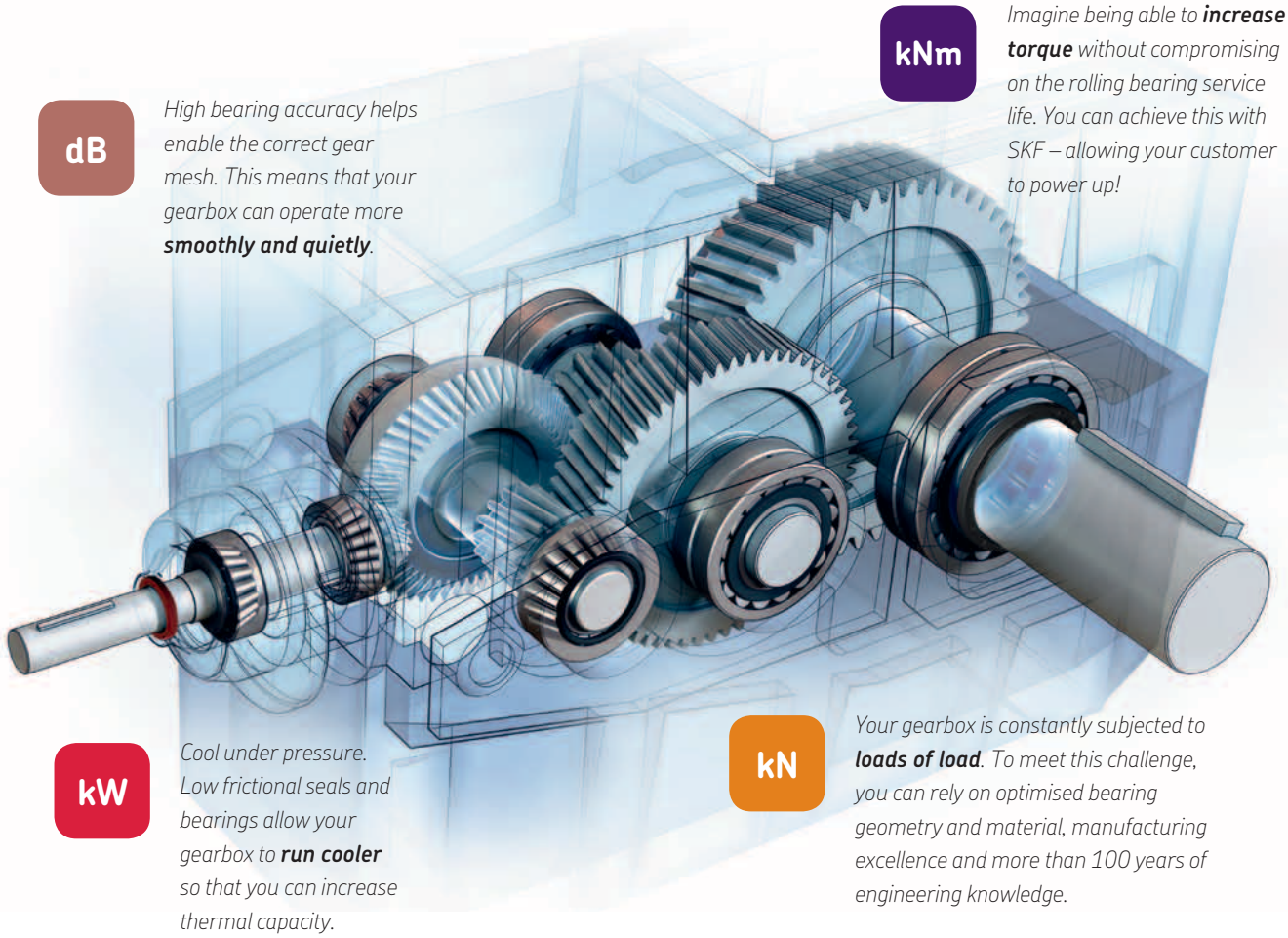

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PTE Newsletter

New technology from Schaeffler Group, Igus Inc. and Rotek demonstrate the latest in slewing ring applications, and Kaydon offers a white paper on "How to Extend the Life of Your Slewing Ring Bearings" in the January PTE Newsletter at *www.powertransmission.com/newsletter/*.

PTE Videos

Timken spherical roller bearings utilized in a European saw mill reduce operating costs and increase productivity. "Now our mills can operate much longer without interruption," said Bruno Simon, manager of pellet production at Belgian-based Industrie du Bois Vielsalm (IBV). To extract full value from its timber, IBV converts byproducts into wood-based pellets that it both sells and uses to power its own facilities. Visit *www.powertransmission.com* to see the latest power transmission and motion control videos.

New Additions and Updates

The following companies have recently added premium listings or updated their listings on *powertransmission.com*. For the most current and up-to-date directory of mechanical power transmission component suppliers, visit *www.powertransmission.com/directory*.

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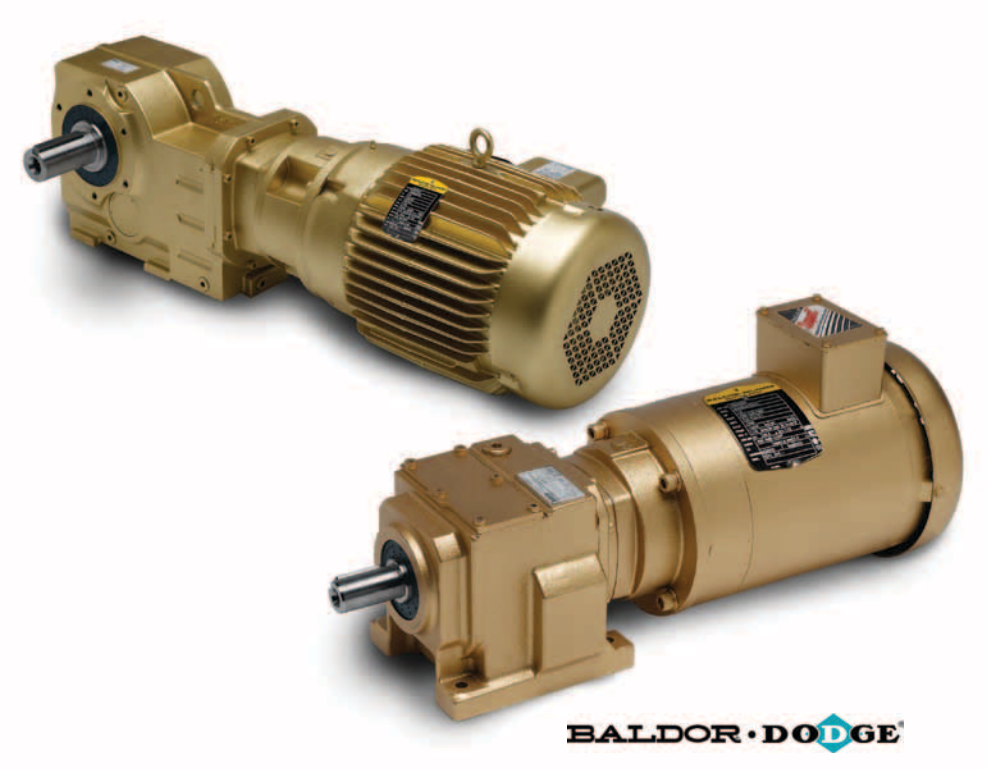

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Randy Stott, Managing Editor

The New and Improved *powertransmission.com*

You may have noticed that we've spiffed up the website a bit. A clean, modern look was just the beginning, however. Our goal was to get you more quickly to the information you need.

We know you're busy. We also know you constantly need information about the latest technology. You're involved with specifying gears, bearings, motors, gearboxes and other mechanical power transmission components. So when you need that information, you need it now.

Our website has always been designed around the Buyers Guide—and helping you find the right suppliers is just as important to us today as it has been since *powertransmission.com* was launched in 1997. In fact, all of the Buyers Guide main categories and premium listing suppliers are available directly via the home page.

But over the past six years, we've accumulated a lot of great content in our magazine, and we needed a better way to help you find it. So one of the most significant changes we made was a complete revamping of our site search engine. Now all those articles in our archive are tied to the search engine via keywords. So if you want to see everything we have on gears, just type "gears" into the search engine and see what comes up.

We also recognize that the website and magazine go hand in hand, and that their tools are best used together. So important updates to the website will always be featured on our **PTExtras** page (page 4). More importantly, when we run articles in the magazine, we'll do our best to point you toward related articles online. Just look for the search symbol throughout the magazine. It'll tell you just how to find what you're looking for.

This issue we've put together a great lineup of articles for you. Our focus on gears and gear drives includes a product focus (p. 20), a feature article by Associate Editor Matt Jaster on gear design software (p. 25), and a technical article by David Conrad of Master Power Transmission on the importance of the gearbox when calculating overall system efficiency. Our industry spotlight on off-highway equipment includes articles from Thomson Actuators (p. 12) and Bosch-Rexroth (p. 30).

Also, we're pleased to present part one of a two-part series on the history and metallurgy of bearing steels (p.40). The article is written by Erv Zaretsky, one of the world's foremost authorities on bearings. We also have a follow-up to last issue's "Ask the Expert" column on ball screw sizing (p. 35) and Brian Langenberg's latest "Market Update" with his usual actionable insight about the global industrial economy (p. 8).

Finally, we hope you'll take the time to read our preview of Hannover Messe (p. 50), which takes place April 8-12 in Hannover, Germany. If you've never been to the show, it's an amazing collection of technology from the world's leading manufacturers. This year's show includes a pavilion dedicated to motion, drives and automation, and there will be plenty to see for buyers of mechanical power transmission components. Both Matt Jaster and Dave Friedman from our staff will be attending the show this year, so if you're going to the show, maybe you'll run into them over there. But if not, you can look forward to their follow-up coverage in the coming issues. **PTE**

P.S. We'd love to hear from you about what you think of our changes – both in the magazine and online. Please drop us a line at *publisher@powertransmission.com* to give us your feedback.

Need High-Quality Gears For Off-Highway Applications? Child's Play...At Forest City Gear

Construction, mining and agricultural vehicles and equipment are pushing into some pretty out-of-the-way places these days. Vital components like gears are expected to operate smoothly, quietly and around the clock in the harshest environments – and reliability is paramount. Forest City Gear is pushing into new frontiers as well – like helping develop and manufacture large gears for some of the leaders in these industries.

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Kicking the Can… Into February!

Why we don't like the market here

Brian Langenberg, CFA

Washington political dysfunction is not as bad as we feared. It is worse.

And while personal tax rates for most U.S. citizens are now a settled matter, there was no discernible change in the House or Senate. The President has nominated a tough political operator, Jack Lew, to head Treasury, and other picks, though not directly involved in economics, do not signal "new ideas" or change in direction.

Vice President Joe Biden—this is why you love your crazy uncle. He fumbles; he stumbles, and can run a 400-meter relay with a foot in his mouth because practice makes perfect. But at the end of the day, he is the dance partner from the administration. It is probable some "good cop/bad cop" was going on, but when all was said and done it was the VP who actually negotiated to get the last tax deal passed—even if it only kicked the can into February.

Brinkmanship (Cliff 2.0) will continue in the battle over spending. No matter what was agreed to in private, the Democrats are going to pitch the recent tax hikes in public as a down payment, while the Republicans will attempt to point out that taxes ("revenue" for some) have been addressed. Much ink will be spilt in the coming months with regard to the budget, mostly skewed against the Republicans.

Both sides have levers. The President has the bully pulpit and a Senate majority; the Republicans have Mitch McConnell who is a) tough, b) up for re-election in '14 and c) got the last deal done through Vice President Biden. Republican odds for success depend upon unity—and signals from House Majority Leader John Boehner that he will eschew further "talks" with the President in favor of working through the committees, and that he moves two smart, eloquent budget cutters—Eric Cantor (R-VA) and Paul Ryan (R-WI)—to the fore. Get your popcorn.

Long-term, three things matter: 1) Entitlement growth; 2) corporate tax reform; and 3) regulation. The near-term discussion will only be about entitlements and taxes on people. The administration wants wealth redistribution (no cuts anywhere, raise taxes), the Tea Party wants cuts everywhere, no taxes).

But don't expect any long-term fixes. While corporate tax reform has support on both sides of the aisle, every recent post-election political move we see does not signal bipartisanship or the possibility of a "grand bargain" that will help U.S. manufacturing by getting domestic corporate tax rates competitive with the rest of the world.

U.S. equities are likely (hopefully) to trade sideways. When it's all over, the range of likely outcomes around budget get us to "some entitlement cuts but not enough" and incremental "revenues" (taxes) elsewhere, thus reflecting the realities of a divided House, Senate and Administration. We have become very selective on names to own since December, reflecting higher stock prices (less potential return) and the likelihood of a noisy, dysfunctional battle on entitlements (higher risk) that will likely see Republicans using the debt ceiling as a cudgel against an Administration arguing for no restraints on growing entitlement spend.

Market View: Cautious

The S&P 500 has risen six percent since our last article, discounting (temporary) resolution of fiscal cliff and an improving economy in China. Because of the changed relationship between risk (higher) and return (lower), we are very selective in our recommendations to institutional investors.

Generally speaking, market multiples are driven by interest rates (lower rate equals higher multiples) and risk premium (more volatility/fear drives lower multiples). The market trades at about 14× S&P 500 consensus 2013 estimates of $107, which has drifted

S&P 500
Monthly Returns Since 1994 (CourtesyBigCharts.com)

S&P 500:	1472.1			Pre-market 1/14/2013		
	S&P 500 Earnings			Implied Price Return		
P/E	$95	$105	$112	$95	$105	$110
13x	1,235	1,365	1,456	(16%)	(7%)	(1%)
14x	1,330	1,470	1,568	(10%)	(0%)	7%
15x	1,425	1,575	1,680	(3%)	7%	14%
16x	1,520	1,680	1,792	3%	14%	22%
17x	1,615	1,785	1,904	10%	21%	29%

down from $112 in November toward our $105 working assumption.

Using this relationship—broadly referred to in investing as the "Fed Earnings Model"—and dividing $107 by the S&P 500 Index ($107/1,471) translates into a seven percent "Earnings Yield," which compares to the 10-year Treasury at under two percent. However, we are living in "interesting times," with government, central bank and Treasury activity effectively supporting markets.

Assuming no expansion or contraction in the market multiple suggests a flat market at year-end. For what it is worth, most "large brokerage" strategists are calling for 1,400–1,600, with an average of 1,534.

Risk: More Downside than Upside

Our base case for the market is "about flat" at year-end with current levels. However, between there (December) and here (now), the only real potential upside driver would come from better than expected economic growth.

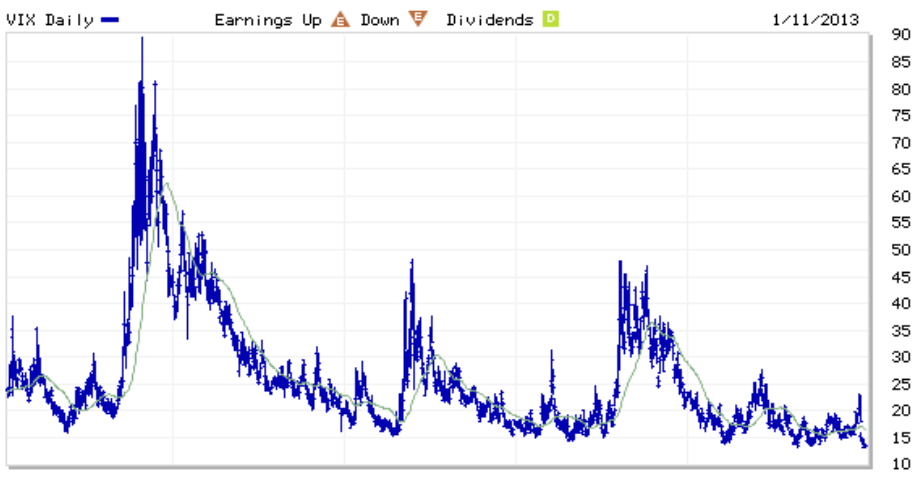
Pockets of strength will be found in the U.S. this year and China acceleration should drive better results for global operations and a number of European capital goods exporters. However, we believe those trends are largely built into industrial stock prices and the broader market.

The ***CBOE Volatility Index***, which we show here, is a measure of expectation of risk in the stock market. The higher the index, the more implied risk.

Right now, the VIX is telling us there are no significant worries; the U.S. economy is gradually improving though underperforming its potential; and China is getting ready to accelerate. We think that is how things play out.

Which skews risk and return. The path to attractive returns is uphill in that an upward market move won't come from declining interest rates, which are already artificially depressed, or declining market volatil-

CBOE Volatility Index — Courtesy of MarketWatch



ity (already low). If the market is right, which we call a 75 percent probability, you can expect a 0-5 percent return in the market this year.

And the market may be wrong. We see a 25 percent probability of a protracted, drag-out fight that could lead to debt ceiling challenges and partial government shutdown, and plausibly impact the broader market. In this scenario, a successfully formed Republican United Front—Establishment + Tea Party—slugs it out with the administration, using its power over the purse strings, which can only be offset by the printing press at Treasury for just so long. Whatever the end result—and we have no reason to believe it will be a tea-and-crumpets discussion in DC, the media, or elsewhere—there is a pathway in the next several months to market softness and incremental negative economic impact.

Moving over to the actual industrial economy….

China: Beginning to Accelerate

The ducks are getting lined up in a row. A new political leadership team is taking the reins and has to "prove itself" to everyone—the Party elders and broader population—and seek to boost its consumer economy while remaining competitive as an exporter. Which obviously means infrastructure development, social housing, healthcare investment and capital spending to substitute capital for labor.

Europe Will Benefit

We expect the European heavy capital equipment complex can start to benefit by the second half from both rising demand from China and easy comparisons, including motors, drives, bearings and industrial automation.

Market Return	% Prob.	
↑	0.001%	Obama Steamrolled
↑	0.01%	Grand Bargain
↓	25%	Cage Match (Republicans go to the mat)
→	**74%**	**Muddle Some More**
→	1%	Republicans Steamrolled

SKY IS FALLING	S&P 500	Impl. Ret.
5/6/09 Armaggedon	683.38	(54)%
8/19/11 US Downgrade	1123.53	(24)%

While austerity, banking system issues and unemployment will likely dominate European "news flow" for awhile, we expect the *industrial* economy will strengthen on the back of capital investment driven exports.

What's Hot

We see a few opportunities for double-digit growth in 2013:

Global themes: Commercial aviation

U.S.: Automotive, residential construction, appliances, energy 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).

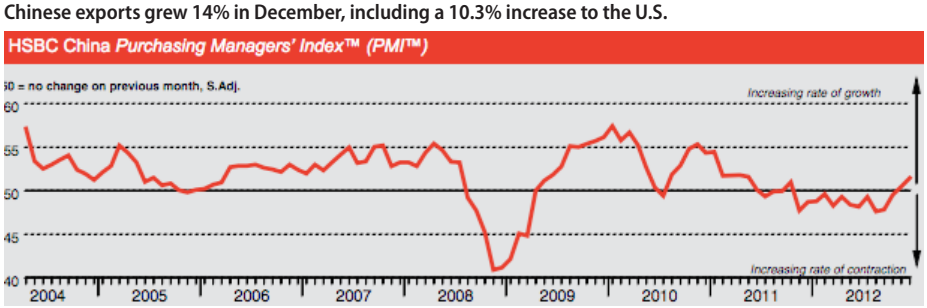
For those whose responsibilities include business planning and having a broader, deeper grasp of major trends, we encourage you to consider subscribing to our Global Industrial Outlook (see page 49).

Top Picks

GE: You get the yield and the long-term value is there. Also, it has traded down nearly 10 percent from its high. My $2.50 earnings power view is intact—but there is a fly in my ointment about the power cycle. 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: Simple, easy path to value. Guide of $5.85–6.15 is conservative; I am at $6.20. Most of what we need to happen the company can control—executing the Goodrich integration, cleaning up CCS (Carrier HVAC + Fire & Security), and leverage to a China upturn (Otis). **PTE**

Chinese exports grew 14% in December, including a 10.3% increase to the U.S.



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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Smart Actuators Bring Big Benefits to Utility and Other Off-Highway Vehicles

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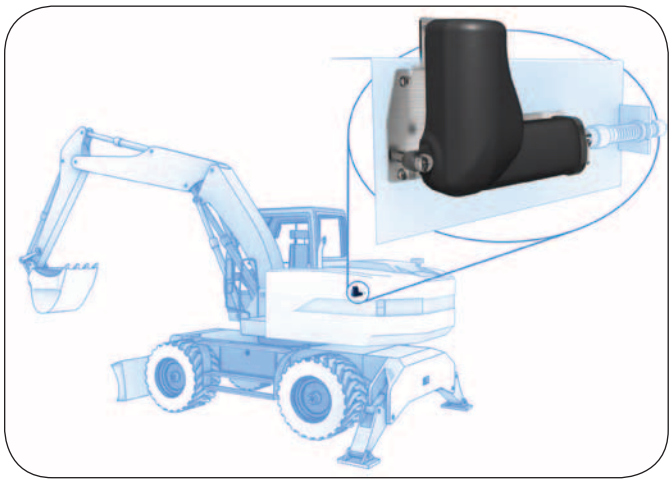

Figure 1 Throttle actuators allow automatic control of engine speed for reduced noise and emissions, and improved fuel economy.

Original equipment manufacturers (OEMs) of industrial utility and other off-highway vehicles are adding automated or improved manual control of many features and functions in order to improve performance, safety, ergonomics and cost. Frequently these improvements are based in computing technology that must be translated into physical motion in order to provide a benefit to the customer. Traditional hydraulic and pneumatic controls are often unsuitable for computer-driven operation, so there is a trend towards increasing use of electrical drive solutions. Smart electrical actuators with built-in position feedback, power systems and bus communications provide a cost-efficient solution that converts control logic into smart-motion articulation.

The traditional role of actuators in off-highway vehicles has involved the application of force under the guiding control of the operator to perform a task. As vehicles become more sophisticated, OEMs are adding cutting-edge features that typically involve the use of electronic controls to deliver optimized, more complex and safer motion tasks, etc. For example, a joystick provides inputs to a control that drives electrical actuators that steer the tracks of a skid steer (Fig. 1). Interposing the control system between driver and steering gear makes it possible to improve the safety of the vehicle by setting limits on the speed with which it can be safely driven through a turn. Or, an onboard computer controls a construction excavator to automatically increase the throttle as needed to operate hydraulic equipment and then decreases that throttle to return to the idle position when power is no longer required.

A major obstacle to further advances in this area has been the limitations of conventional actuator technology. Traditional hydraulic and pneumatic actuators typically run from one end of the range of motion to the other without any means for accurate mid-range positioning—required by nearly all of the more sophisticated applications. Pneumatic and hydraulic actuators are sometimes fitted with electronic closed-loop feedback, but this adds considerable cost and complexity since both electronic and hydraulic or pneumatic controls and cabling are needed. Pneumatic and hydraulic actuators also require bulky pumps and valves, as well as the need to send heavy cables anywhere that power is to be deployed or controlled (Fig. 2).

For these reasons there has been a significant trend towards the use of electric actuators. Electric actuators dramatically reduce the number of components needed by eliminating those required of a hydraulic system, such as: reservoir, pump, DC motor, motor relay, solenoid valve, check valve, hydraulic cylinder and pushbutton station. They replace cumbersome and sometimes dangerous hydraulic hoses with small, light wires and use actuators that are usually smaller and lighter than hydraulic cylinders while yet retaining the same force and stroke (Fig. 2). In addition, electric actuators are considerably quieter than a hydraulic system.

One available electrical actuator option consists of servo and stepper motor actuators typically designed to function in an industrial process with a very high level of accuracy and repeatability, and a 100 percent duty cycle. However these motors are quite expensive and, in most cases, their high cost is not justified for off-highway vehicle applications where objects are positioned a few times an hour, rather than continuously, and accuracy of 1/16 of an inch rather than 0.001 inch is sufficient.

DC actuators provide a much less expensive alternative that still meets the requirements of most off-highway vehicle applications. However, conventional DC actuators require a number of add-on components, such as an

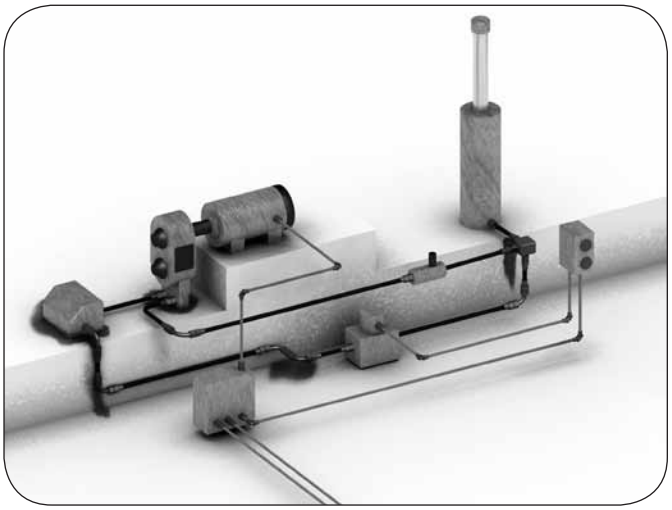

Figure 2 Replacing hydraulic and pneumatic cylinders with electrical linear actuators enables simpler and smaller installation, easier control, lower energy costs, higher accuracy, less maintenance, less noise and a clean, healthier environment.

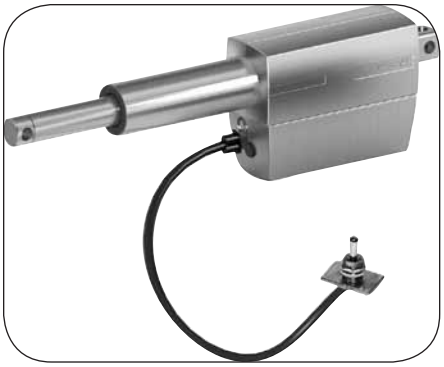

Figure 3 Detail view of a smart actuator developed by Thomson that includes H-bridge, power, control and position feedback systems integrated into one actuator.

H-bridge, which is needed for reversing the direction of the motor, as well as power, control and position sensing systems. These add-ons increase the cost and complexity of the actuator, requiring additional cabling and connectors and extra steps during the assembly process and maintenance.

More recently, smart actuators have been developed specifically to address the requirements of off-highway vehicle manufacturers by packaging the H-bridge, power, control and position feedback systems in a single actuator. Assembly and maintenance of the vehicle are simplified because with the now-integrated H-bridge, all users have to do is connect power cables and bus to the actuator (Fig. 3).

This new generation of smart actuators builds on the proliferation of bus communication that substantially reduces the cost and complexity of integrated vehicle operation. With bus communications, a single control unit can replace the need for multiple single-function controllers. This approach also substantially reduces the wiring required in the vehicle. Bus communication has already been proven in the automobile industry, and is also used in many other vehicle types. Now, manufacturers of off-highway vehicles can utilize the technological advancements and economies of scale that have been developed for the automotive industry in order to increase functionality while reducing the cost of their own vehicles.

With the traditional approach, an electronic control unit (ECU) is required for each actuator. By using a smart actuator with a bus, rather than running a separate cable from the controller to each actuator, as required with the traditional approach, only a single cable needs to run from the controller that passes each actuator. Each actuator control has a unique address, listens to every signal from the vehicle control system, and responds only to signals having its own address.

Actuators also offer the advantage of providing status information. The command goes out to an actuator to travel to a certain position; when the actuator reaches that position it sends a clear signal to the control unit. The actuator can also return position and

speed information. The implementation of the bus system also makes it simple to add additional sensors that can track other measurements such as temperature or load.

Smart actuators also provide the opportunity to synchronize vehicle functions. For example, suppose two actuators are required to lift the hood of a vehicle and these actuators must move in tandem with each other in order to ensure that the load is shared between the two actuators. This is difficult—if not impossible—to accomplish with a hydraulic or pneumatic actuator, but can be done easily with smart DC actuators. The control system simply sends out a command to move one step to each of the actuators; it then waits until clear signals are received from each actuator indicating it has reached the desired position before sending the next move command.

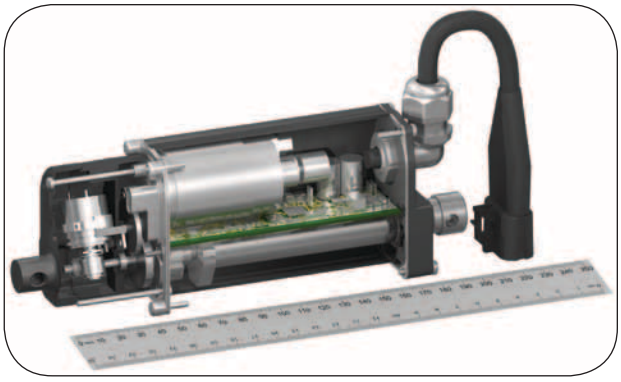

Figure 4 Thomson torque feedback device (TFD) provides variable torque output—in proportion to a DC input—for steering and other by-wire applications.

Replacing hydraulic steering with electronic steer-by-wire systems offers the potential to add significant functionality by customizing the connection between steering wheel and steering mechanism. Design engineers can easily change the steering ratio with a software command and can even design the vehicle so that the steering ratio can be changed in the field or programmed to change on the fly, depending on vehicle operating conditions. For example, an electronic steering system could be configured to have a high steering ratio at low speeds and a lower ratio at high speeds to help avoid sudden turns at high speed, or configured to allow for rapid maneuvering at low speed. Electronic steering can be programmed to indicate that the vehicle is nearing the end of the steering range by increasing torque resistance. Electronic steering also opens up the door to other more advanced options such as using torque resistance to prevent the operator from steering towards detected obstacles (Fig. 4).

Likewise, smart actuators can be used in agricultural vehicles to optimize the adjustment of harvesting systems in combines. The combine's grain processing chamber takes the threshed grain and cleans it from its chaff by blasting it with air and running it through a sieve. The air flow louver adjustment controls the volume of air flowing through the cleaning system and the louvers must frequently be adjusted to optimize the performance of the cleaning unit for various crop conditions. Too much air flow and you lose grain, too little air flow and the chaff is

not cleared. Normally, the operator must climb down from the cab to make these adjustments, which reduces productivity. With electric actuators this can now be controlled directly from inside the cab.

There are many potential applications on nearly every type of off-highway vehicle to combine onboard computers with smart actuators to deliver unique functionality that can set an OEM's product apart from its competitors. OEMs can capitalize on these advantages at the lowest cost by utilizing smart actuators that integrate all of the components needed to deliver motion control in a single package.

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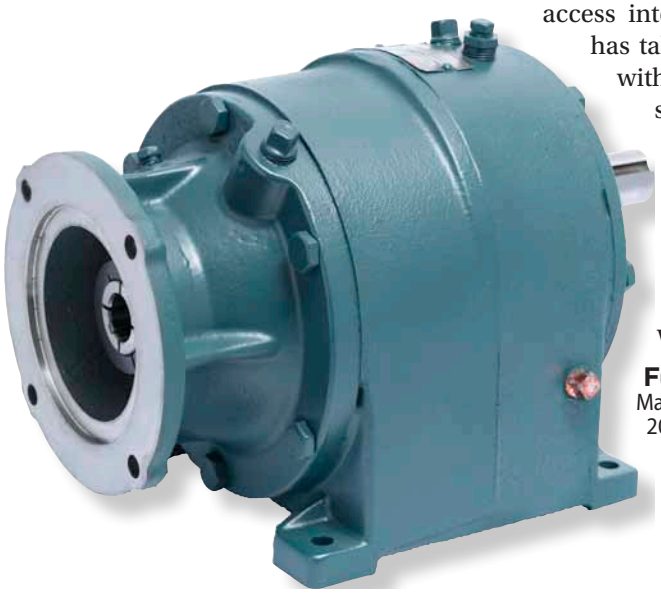
Master Power Transmission

PROVIDES PARALLEL AND RIGHT-ANGLE GEARBOXES

Master Power Transmission (MPT) provides enclosed parallel and right-angle gearboxes for use in many industrial applications including material handling, food processing and mixing. MPT's APG is a gearbox product designed and manufactured in the U.S. for applications requiring efficiency and power density without sacrificing quality and robust performance.



Using Finite Element Analysis (FEA), the housing is designed to be compact while maintaining housing rigidity to ensure shafts, gears and bearings are not exposed to excessive flexure and extraneous loads during operation. Bearing spans for the MPT APG are kept to a minimum to avoid shaft deflection and excessive loads, and all Master APG gearboxes are designed with bearings that will provide a B10 life of at least 5,000 hours.

The spring-loaded lip seals in all APG gearboxes are specially formulated for low drag, reduced heat generation and long life. Each APG unit is factory filled with a long-life synthetic lubricant having a wide temperature operating range well in excess of 200° F at full load, and is USDA H2-approved for most food processing and handling applications.

Gear tooth angles in the helical gearing of the APG are optimized to minimize bearing size, maximize gear load sharing and provide quiet operation. All MPT APG gears and pinions are case carburized and ground for an AGMA Class 9 precision finish. The result is a gear with a very hard outer shell (minimum Rockwell 58Rc) for suitable wear resistance and a ductile inner core that provides the gear or pinion with the toughness required to withstand shocks and vibration.

Many gearboxes use heavy press fits on all mating internal components, making component disassembly and replacement very difficult. Additionally, housings are often cast as one or two pieces, making it very difficult to access internal components. MPT has taken a different approach with APG, keeping disassembly in mind, including pry slots on housing covers. Features such as these make it easy to access the internal components to change seals, bearings and gears whenever necessary.

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www.master-pt.com

Voith Turbo

OFFERS HIGHLY FLEXIBLE COUPLINGS

Permanently high stress levels and sub-standard components can lead to reduced equipment performance and reliability as a result of wear and failure of components. No one knows this better than the engineers of drivelines for heavy-duty applications like steel mills, cement plants and mining operations. Heavy shock loads, arduous working conditions and non-stop loading are all factors that can affect the performance of a product in these types

of applications. These issues are not only issues for the driven equipment such as table roller drives, conveyors etc., but can also create problems in the driving equipment itself, such as the engine or motor. To protect the whole driveline from these factors, a coupling is typically used between the driving and driven equipment. The same goes for diesel/gas-driven equipment, where a coupling is often used to protect the driven equipment from the harmful effects of torsional vibrations that occur as a result of the reciprocating motion of the diesel/gas engine.

Gear, grid and disc pack type couplings are commonly used in these types of applications, but a great substitute can be compression-type highly flexible couplings. The main advantage is that compression-type highly flexible couplings need no lubrication at all in operation. In fact, once installed, there is nothing to worry about for several years in the vast majority of applications. The only replacement part, the rubber elements, can be switched in very

short periods of time in most cases (space allowing), and without moving either the driving or driven equipment. In addition the metal components almost never need replacing at all. The CT (compression-type) coupling is the latest addition to the large product range of the German-based Voith Company. It is especially designed for industrial applications; e.g., metal manufacturing, mining, cement and power generating set applications.

Selection of the right compression-type highly flexible coupling is the most difficult part. Every individual component of the drive chain has to be considered to find the right coupling for perfecting the drive system.

For more information:
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Maxon Motors

RELEASES FOUR-QUADRANT SERVO CONTROLLER

Maxon's new Escon 36/3 EC is a four-quadrant PWM servo controller designed for efficient control of brushless DC motors with Hall sensors up to approximately 100 watts. The Escon 36/3 EC has suitable control properties and a very fast digital current controller with a large bandwidth for optimal motor current/torque control. The drift-free yet dynamic speed behavior enables a speed range of 0 to 150,000 rpm. The Escon 36/3 EC provides a wide range of functions, with fully configurable digital and analog inputs and outputs. It allows dynamic drive solutions that meet the highest demands and can be run in various operating modes (speed controller (closed loop), speed controller (open loop), current controller).

The compact servo controller is controlled by means of an analog set value. This value can be specified by means of analog voltage, an external or internal potentiometer, a defined value or by means of a PWM signal with variable duty cycle. Other functions include the ability to enable or disable the power stage, depending on the direction of rotation, or to use speed ramps for acceleration and deceleration. The speed can be regulated by means of Hall sensors.

When the servo controller is connected to a PC via a USB port, it can easily and efficiently be configured with the "Escon Studio" graphical user interface. During startup and configuration of the inputs and outputs, monitoring, data recording and diagnostics, the user has access to a large variety of functions and is assisted by user friendly software wizards, as well as a well-designed automatic procedure for fine tuning the controller.

The Escon 36/3 EC has protective circuits against overcurrent, excess temperature, under- and over-voltage, voltage transients and short-circuits in the motor cable. It is equipped with protected digital inputs and outputs and an adjustable current limitation for protecting the motor and the load. The motor current and the actual speed of the motor shaft can be monitored by means of the analog output voltage. The large range for the input voltage and the operating temperature allows flexible use in a variety of drive applications.

For more information:
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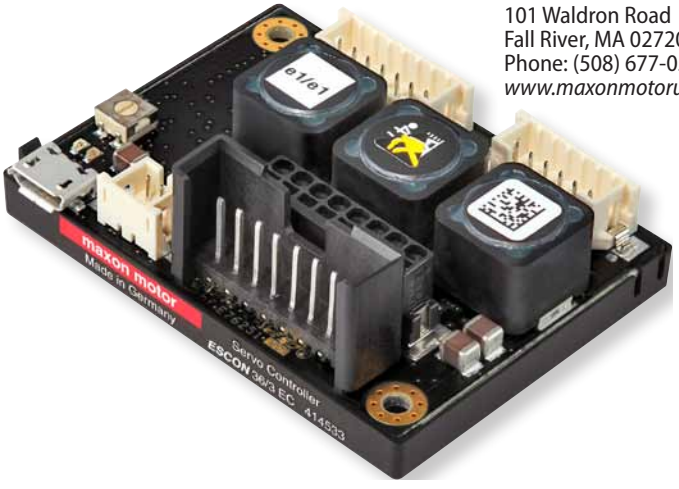


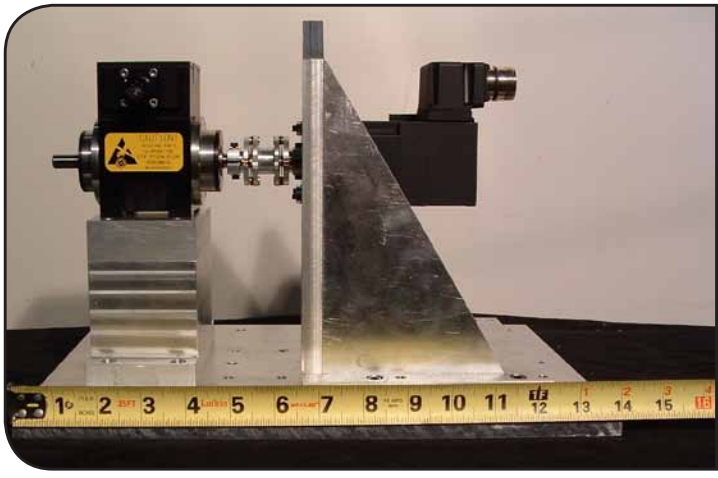
Sakor Technologies

ANNOUNCES FAMILY OF AC DYNAMOMETERS

Sakor Technologies, Inc. recently introduced its Accudyne family of AC Motoring Dynamometers. The Accudyne offers an extremely flexible dynamometer system that is readily compatible with a broad range of testing applications, including conventional engine and powertrain systems, hybrid vehicle drives, electric motors and rotary components, such as alternators, generators, pumps, compressors and much more. Available in sizes ranging from fractional to over 2,000 hp, and speeds in excess of 30,000 rpm, Accudyne dynamometers are appropriate for almost any rotational testing need.

Modern vector drive technology allows the Accudyne system to provide true 4-quadrant capability, with completely seamless crossover between motoring and loading modes. It also offers the most precise speed and torque control available, especially in low-speed applications where full torque can be applied all the way to stall (zero speed). For more sophisticated testing requirements, the Accudyne dynamometer family offers advanced features, such as inertia simulation, engine simulation and NVH Testing.

Additionally, Sakor recently introduced the MicroDyne series of small motoring dynamometers. Suitable for a wide range of automotive, military and aerospace testing applications, this newest innovation from Sakor is capable of testing all types of small rotary devices such as motors, pumps, generators, compressors and more. The MicroDyne is a fully functional, four-quadrant dynamometer engineered specifically for low-power applications. Versions are available in sizes from 100 watts to five kilowatts.



For more information:

Sakor Technologies, Inc.
2855 W. Jolly Road
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Gears and Gear Drives

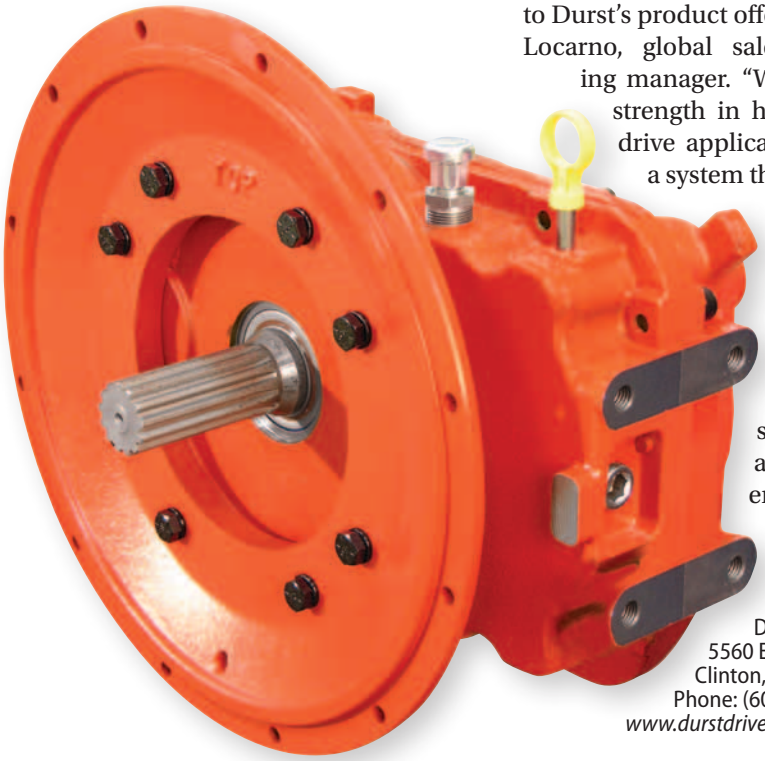
Durst

COMPACT TWO-PUMP DRIVE TARGETS OIL, AGRICULTURE AND RAIL APPLICATIONS

The model 2PD05 further expands the broad portfolio of Durst modular hydraulic pump drives to include a two-pad design with 10-inch pump centers and 5-inch gear centers. Durst engineered the 2PD05 specifically for mobile off-highway applications requiring a compact footprint, lighter weight and versatile mounting configuration. The new pump drive affords a cost-effective drive solution including, but not limited to, construction, mining, forestry, agriculture, rail maintenance and oil field equipment. Weighing approximately 200 pounds, the 2PD05 measures 8 inches deep x 11 inches high x 21 inches wide. The 2PD05 meets SAE and AGMA standards and is compatible with SAE pump shafts up to a 13 tooth – 8/16 spline (SAE D). It can be used as a drop-in replacement for Funk's 28000 series pump drives. The simple, one-piece modular format allows for easier assembly and installation. The 2PD05 has a maximum torque rating of 700 lb-ft. The pump drive is rated for a maximum input power of 370 horsepower. It offers a choice of gear ratios from 1:1 to 2:1.

One of the most important benefits of the 2PD05 is its flexible mounting options. The pump drive can be mounted horizontally or vertically to overcome space constraints and restrictive limitations in equipment design. Long life and reliable performance are hallmarks of Durst's modular pump drive line. The 2PD05 runs cooler and is simpler to service. The class 10 spur gears run on heavy-duty ball bearings. Bearings and gears are self-contained within the housings. Durst's patented casting design keeps oil constantly flowing through the bearings and provides for wet spline operation, even at startup, thereby preventing fretting corrosion. Pump pads and input adapters can be easily changed without disturbing bearings. Because of the single seal, bearing, gear and adapter group design, there are fewer parts to inventory.

"The 2PD05 adds depth and breadth to Durst's product offerings," said John Locarno, global sales and marketing manager. "We leveraged our strength in heavy-duty pump drive applications to develop a system that is ideal for applications up to 370 horsepower. Introducing this new drive moves us closer to our goal of becoming the single source for all our customers' pump drive needs."



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Bauer Gear Motor

DEVELOPS NEW PMSM TECHNOLOGIES

Bauer Gear Motor has welcomed the results from a direct product comparison test to see how it's latest IE4, super premium efficiency permanent magnetic synchronous motor (PMSM) performed against a standard asynchronous motor. The test was carried out on a Hüber disc thickener at a waste water treatment plant in Germany in partnership with inverter drive specialist Danfoss. Once installed the motor from Bauer was found to operate with 87.7 percent efficiency and delivered energy savings of almost 40 percent.

Bauer Gear Motor, part of the global Altra Industrial Motion Group, has stated a commitment to developing new technologies with a desire to improve energy efficiency and reduce costs for its customers. It is this commitment to efficiency that has led to the introduction of a new range of PMSMs which meet the requirements of the IE4 (Super Premium Efficiency) classification.

Jens Gabel, vice president global sales and R&D for Bauer Gear Motor, comments: "In today's market energy efficiency has to be one of the key determining factors when specifying geared motor solutions. Energy prices are only going to go one way, so it is important that a drive's lifelong running costs are considered; rather than simply the cost of procurement. We have developed the new motor in anticipation of the new IE4 classification and to offer our customers the very best in terms of efficiency."

Bauer's PMSM series is an environmentally friendly range of motors, employing a highly efficient design of rotor that integrates embedded permanent magnets made from rare-earth metals, in place of a squirrel-cage rotor found in most LV induction motors. This design offers a number of key benefits. It reduces heat losses from the rotor by 100 percent, total losses by approximately 25 percent and increases total efficiency by 10 percent or more. For the PMSM user, this improved perfor-

mance translates into a lower total cost of ownership, a reduction in CO_2 emissions, and on-going savings that buffer against future increases in energy costs.

During the product's development, it was clear that the new PMSM would offer consumers impressive energy savings over conventional, inverter driven asynchronous motors (ASM). There has been a large amount of publicity recently about PM motors, but there is still reluctance in the market to buy them, as the purchase cost is higher than that of standard motors. In some light duty applications where the motor is rarely on, it is still more economical to specify a standard motor, but, if the duty cycle is high, then a PM motor can quickly meet its ROI figure and then go on to deliver savings for a long time to come.

Keen to prove the real life savings potential of using a PMSM, Bauer was a willing volunteer to take part in the direct product comparison test which was carried out at a live and operational waste water treatment plant in Landsberg am Lech, South West Germany. The disc thickener is in continuous operation for seven hours per day, seven days a week, so provided an excellent test opportunity.

Prior to the test, the existing ASM motor was running on a standard inverter. An inverter drive regulates power consumption based on load and frequency, as required by the application, which inherently makes a motor run more efficiently so, prior to the PMSM being installed, a Danfoss inverter drive was retro-fitted to the original system in order to ensure an accurate comparison.

The frequency inverter was programmed to monitor the loads on each motor to ensure that they ran at optimum efficiency. To ensure that any differences in efficiency could be attributed to the motors, each drive used the same Bauer gearbox, which had a reduction ratio of 381:5 at 94 percent efficiency. It was found that with the frequency inverter installed, the ASM created 2.62 N-m torque at 1,350 rpm and operated with 61.5 percent efficiency using 0.26 kW/H.

Having completed the measurements on the ASM, the PMSM was installed. The new product from Bauer created 3.5 N-m at 1,500 rpm and operated with 87.7 percent efficiency using only 0.16 kW/H. The energy savings from installing the PMSM yielded a 40 percent saving in energy use over the ASM with the same inverter drive installed. Over a four-year period, it was estimated that, with an inverter used in both cases, an ASM would use 2,657 kW whereas Bauer's PMSM would use 1,635 kW; a total saving of 1,022 kW.

Gabel continues: "A lot of work has gone into developing our latest series of motors, and we had hoped to be able to offer the customer very real savings in terms of energy costs. We are very happy with the results of the test, as they show that super premium efficiency motors do deliver a real-life measurable benefit and in many higher demand applications should certainly be considered both by design engineers and maintenance engineers alike."

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Sumitomo

DEVELOPS MODEL GENERATOR AND CONFIGURATOR

Sumitomo is pleased to announce the release of its new *Cyclo HBB CAD Model Generator*, which is designed to provide 3-D models and 2-D dimensional drawings online for the Cyclo Helical Buddybox product line. Available 24 hours a day, 7 days a week, this tool provides users with easy access to Cyclo HBB CAD models from Sumitomo's pre-existing CAD model library. 2-D Dimensional Drawings are available in DWG and DXF formats with scaling in either mm or inches, and 3-D models are available in SAT, STP and IGES formats. Users can log in at their convenience and retrieve their selected CAD model within minutes.

In addition, Sumitomo continues to enhance their customer service with the launch of their online *Cyclo HBB Product Configurator* application. The user-friendly application streamlines the selection process of Sumitomo's Cyclo Helical Buddybox, an innovative shaft mounted drive that combines the quiet, efficient and reliable performance of the Cyclo input with the rugged helical gear output. The modular design provides a compact, efficient product and the most flexible range of output speed and torque combinations available. Users quickly receive results that include downloadable 2-D and 3-D CAD files, product literature, and a Technical Specification Sheet, which includes weights and dimension data, dynamically generated from the actual configured unit.

For more information:
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www.sumitomodrive.com/configurator

Maxon Motors

RELEASES DCX MOTOR LINE

The DCX motors have precious metal or graphite brushes and may be equipped with standard preloaded ball bearings or sintered bearings and cover a large voltage range with six different ironless windings. With the new housing, almost all mechanical configurations are possible. The mounting flange can be fully configured. This includes the thread diameter, position and number of mounting holes as well as the dimensions of the centering collar. For use in small spaces, the DCX motor is also available in a short configuration without a flange. The length and diameter of the output shaft can be selected, with or without flat. The DCX motors can also be ordered with cables or with terminals. Cables are available in various lengths and with connectors.

New gearheads and encoders have also been developed for the DCX motors. The GPX22 gearhead consists of individually configurable gear stages and is now even quieter and even more robust than equivalent sized gearheads. With a laser weld, the gearhead interface is joined seamlessly to the DCX motor. The GPX gearheads also come with a configurable flange. The output shaft is available in different lengths, with or without a flat, and even with cross holes or a key.

Matching Maxon ENX encoders feature a strong industrialized design and high signal quality. The ENX Quad encoder is a single-pulse, 2-channel encoder. With a built in ESD protection network, reverse polarity protection, cable strain relief and the robust design, it is an economic choice for simple closed-loop tasks. The ENX Easy is a 3-channel encoder with line driver. A resolution of up to 1,024 pulses per revolution can be selected. The cables of the ENX encoder are configurable in seven lengths, from 50 mm to 1,000 mm.

When combined together, the Maxon DCX, GPX and ENX form a high-precision, robust drive system suitable for many applications, including aerospace, medical and robotics. With just a few clicks of the mouse, it is possible to configure a powerful DCX drive with reliable and fast delivery. In addition, detailed product data may be viewed immediately online and 3-D CAD data for the configuration is available for downloading.

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Brevini

DISPLAYS RANGE OF PRODUCTS AT U.K. EXHIBITION

Brevini Power Transmission displayed a range of power transmission products and hydraulic motors from sister company, Brevini Fluid Power at the 2013 Subsea U.K. exhibition. Products included planetary gear units, helical and bevel helical gear units, hydraulic lifting winches and special lifting winches. With many years of experience working within the marine and offshore industries, a large part of the Brevini product range has DNV type approval and can be certified as required by other approval bodies, such as Lloyds and ABS. Brevini has an extensive history of supplying reliable and innovative solutions for deck machinery, including winches, cranes, tensioners, carousels and drilling equipment. Brevini Power Transmission also has experience refurbishing and repairing all models and makes of gearboxes through its service and repair center. As a gearbox manufacturer, it is able to draw on its many resources, from technical expertise to commercial purchasing power

to ensure that it delivers service at competitive rates. The partnership between Brevini and Brevini Fluid Power allows the company to form a hydraulic motor gearbox package that provides the reassurance of two well established brands.

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Siemens

LAUNCHES GEARED MOTOR SERIES

The new SIMOGEAR geared motor series encompasses an intricately stepped line of geared motors. Optimally designed for conveyor applications, the series features helical, parallel shaft and bevel gear unit types plus high efficient and NEMA Premium motors. As one example of engineered efficiencies, the two-stage helical bevel unit averages two percent higher efficiency than competitive three-stage units. SIMOGEAR geared motors smoothly integrate with other Siemens drivetrain components. These drive systems are specifically designed for the U.S. market. Siemens responded to what its customer base wants with compact and highly efficient motors, short delivery times and long-term, single-source service.

The new SIMOGEAR gear motor delivers performance from 0.09 kW up to 15 kW. It can achieve a gear unit torque up to 1,850 Nm with helical, parallel shaft and helical bevel gear units, additional types and sizes will follow. "With its SIMOGEAR range of geared motors, Siemens has further advanced the standard for geared motors used in industrial drive systems," says Dirk Bauer, Head of the Standard Gear Units and Couplings Segment at Siemens Drive Technologies. He further stated that "these geared motors are ideal for use in conveyor systems. They combine the benefits of exceptional energy efficiency, high power density and excellent quality." Conventional gear unit types which are classified according to fixed torque stages are available as well. The new SIMOGEAR family also offers supplementary gear unit sizes which are graded in a harmonized manner so as to reduce the differences in output between different sizes. As a result, it is possible to choose the right drive in terms of gear unit type, gear torque and gear ratio for any application.

The efficiency of two-stage bevel helical gear units which have been specially developed for use in conveyor systems is particularly high. The new helical and parallel shaft gear units also feature this outstanding efficiency. Due to their high gear ratios resulting from application of the plug-in pinion principle, two-stage gear units with an efficiency of at least 96 percent can often be used instead of three-stage gear units with an efficiency of around 94 percent.

For more information:

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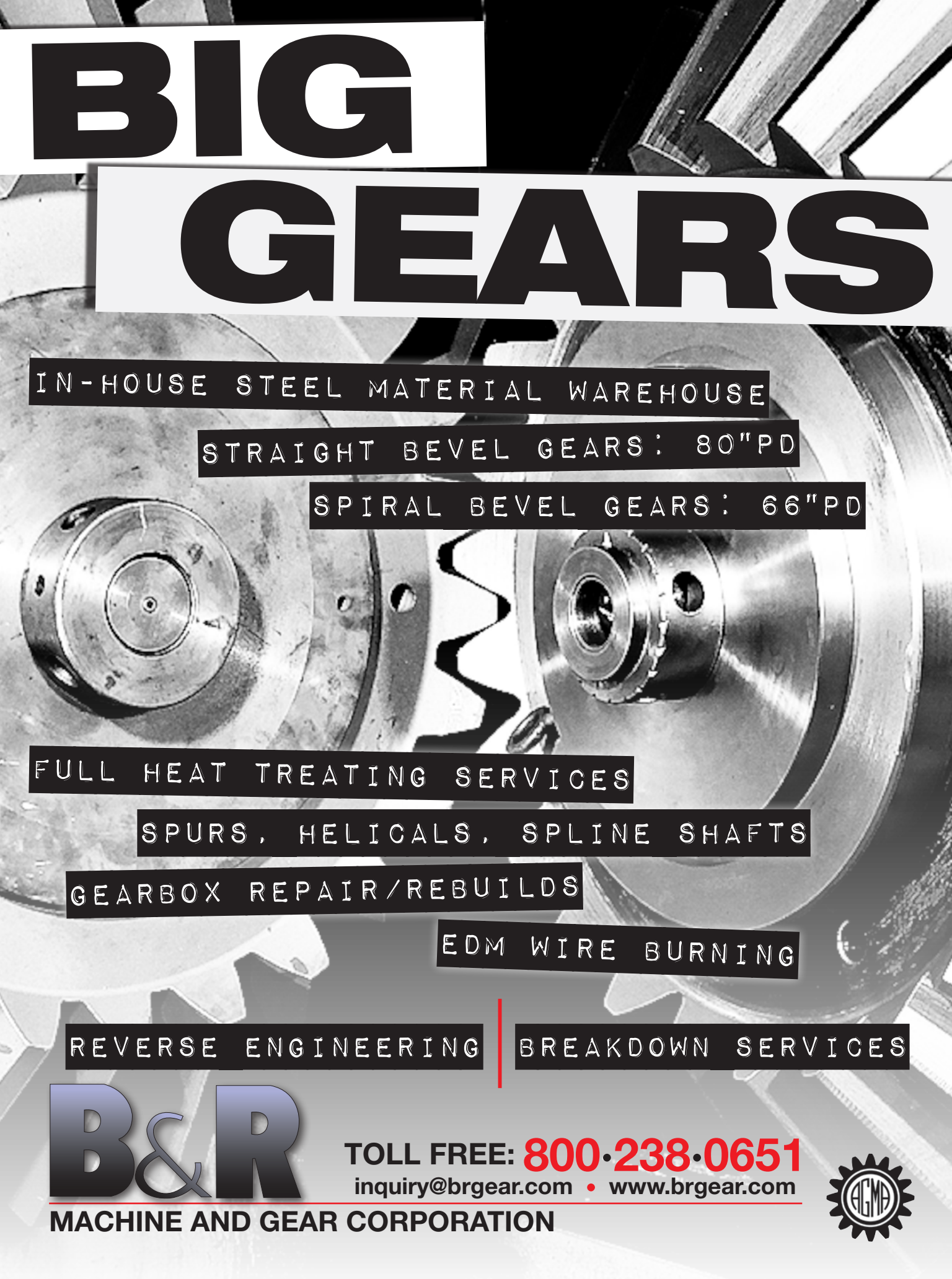
BIG GEARS



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Gear Design Software

An Ongoing Exercise in Learning

Matthew Jaster, Associate Editor

For five days, sun up to sun down, Romax Technology hosts a comprehensive software training seminar at their location in Troy, Michigan. Attendees are politely asked to shut down their cell phones (unless the world is ending) and focus on the information that is being presented. These work sessions typically go through lunch and sometimes even carry on during dinner. "Even the sharpest minds leave the training session with more questions than answers," says Miland Dange, general manager at Romax. "There is so much information presented that the mind is racing. This is why it's *so important* to have a comprehensive training program as well as a high tech support system." Engineers that have worked with gear software can tell you with confidence that the complexity of it can be daunting, particularly when trying to understand not only what can be done with the software, but the steps needed to achieve it.

The truth is there is no shortage of gear design software packages. Some have enhanced features, global market appeal, user-friendly interfaces or specific areas of expertise. Others simply cost less than the competition. Every company, large and small, believes that the support and training element is just as important as the original purchase of the software itself. In reality, it's probably more important.

Software Support & Training

Twenty years ago, it may have taken a gear engineer weeks to complete a computer model. Many of the software programs today can complete the same task in a few days. "It used to be that you could wow a potential customer with the software capabilities alone," says Dange at Romax. "In today's market, people really pay attention to comparing tools and figuring out how much money and time they can save. Since the software is so dynamic, it's important to visit your customers regularly and make sure they're getting the most out of the various features and capabilities."

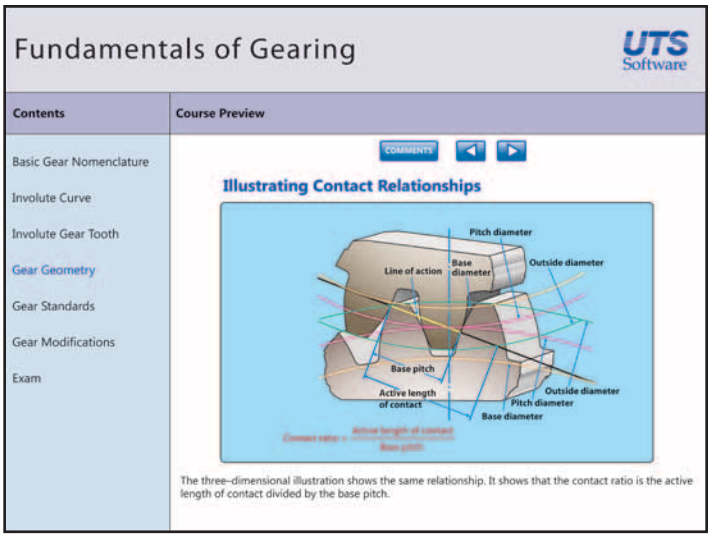
"An important part of successfully using any software program is ensuring that the user fully understands how the program works," says Gunther Weser, manager at GWJ Technology GmbH.

"By attending our workshops, the user can benefit from the knowledge of our qualified engineers. Customers can gain a deeper understanding of basic skills, design strategies or optimizations of machine elements."

"Customers are interested in specific and focused training. For example: if they are making power tools then they want training regarding how best to design and or manufacture gears used in power tools. Or how to manufacture plastic gears, etc. They want very targeted rather than generic training," says S.M. "Jack" Marathe, president and CEO of UTS. "The issue is not as much about learning how to use to software. Instead it is about trying out many different scenarios and thus developing a good insight about which factors affect a design and by how much. In such cases a well-designed software package helps in speeding up the process. That is the approach UTS has always taken, and we have found that the customers like such an approach."

"Detailed product training and theory is essential to the correct use of our product, so in our training courses we would introduce specific examples possibly provided by the customer which demonstrate why the software is required," says Mike Fish, co-director of Dontyne Systems Limited. "We offer courses based on our own product capability. We identify why the software is necessary rather than simply which buttons to press. We have different modules to look at different aspects of production but we try to demonstrate how effective it is to link several modules together directly. This more accurately models real world situations as the stages are effectively linked."

Stefan Beermann, CEO at KISSsoft AG, says that the scope of the training is usually not just the software but must also cover the machine design aspects related to it. "This means the implemented methods, strategies for optimization, typical errors and known problems in the application are also covered," Beerman says.



Marathe at UTS believes a well-designed intuitive software package is preferred over just adding bells and whistles to an existing program.

This 24/7 training and support system can be accomplished in many different ways. While some software suppliers prefer sending representatives onsite to assist with troubleshooting, others prefer webinars, video conferencing or e-mail.

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"Most of the training is face-to-face. Webinars are done in an increasing number, but they will never replace the face-to-face trainings completely. This is comparable in using the telephone instead of visiting someone. Most often conversation is done via phone or e-mail, but still we meet in person frequently," Beermann says. "Recently we are conducting scientific conferences and user meetings as well. This way we can address a larger number of users in one place, making the communication more efficient."

"I would say that it is becoming easier to arrange Internet training. It is more flexible for both parties as it could be re-arranged at short notice and much lower cost. We would use local support to follow up during the year. We would prefer to avoid an on-site training session as it takes much greater time and money, but it is always possible," Fish adds.

"Having said that, it is also important to make sure the customer is comfortable with the support organization and availability of support to them. This includes things like time differences and language differences. For these reasons we have expanded our online training and demo capability, as well as our direct support organization. We have recently opened a U.S. support office and now provide support personnel around the world—Europe, Japan, Australia and the United States," says Rich Easley, North American business development manager for Dontyne.

"E-mails and voicemails are not practical solutions in our line of work," Marathe adds. "Prompt and insightful response to the questions raised by the customers is very important to keep the customer happy, and that is the strategy UTS has used since 1984."

"Gear engineers should first attempt to resolve problems themselves. If a resolution is not possible, the engineer can contact us," Weser says. "We use online solutions in order to support the user and to hold interactive meetings if the user has any questions or needs help to resolve specific design problems."

For Dange at Romax, it comes back to the importance of training sessions. "We conduct performance audits onsite with our customers to verify that they are getting the most they can from our codes, but we can't stress enough the importance of attending a five-day course with us where the focus is on the software itself. As dedicated as our customers are, sometimes they will not let go of their problems on the manufacturing floor. This means that they're frequently called away from training or support sessions or end up leaving the training altogether. It's important that each and every customer is engaged and ready to solve each problem."

Which Came First—the Software or the Gear Engineer?

A shortage in basic gear design skills contributes significantly to problems if the gear engineer uses the software as a crutch. Beermann at KISSsoft believes there will always be engineers that use gear software without the appropriate knowledge, hoping that the software magically compensates for their lack of experience.

"This is no different from computer natives using the automatic spell checker on their text processor instead of learning spelling and grammar," Beermann says. "On a higher level, gear software can be the right means to achieve gear specific knowledge. Even gear experts do not follow every change in the standards anymore, delegating

the knowledge about the formulae to the software. Also consistency checks can be done by the software, relieving the engineer from thinking about every little detail."

"Gearing is not taught much in engineering colleges. The extent of training may involve two weeks out of a 14 week semester course in machine design in the third year engineering curriculum and may be the same amount in the final year. That is about it! Hence when engineers enter the workplace, if their job involves designing or manufacturing gears, then it pretty much involves using the software that they have access to and hope for the best," says Marathe at UTS.

"It is possible to become *too* reliant on the software. Despite testing and various checks coded into software it is possible to generate errors by incorrect input for example," adds Fish at Dontyne. "It is essential for engineers to recognize a mistake in the data entry or results. During training it would be beneficial to introduce examples with wrong answers to see how many participants flag it and how many let it go."

"In principle, the basic knowledge should come from the universities. Unfortunately, machine elements are no longer a hot topic, so most universities reduce the amount of gear know-how provided. To compensate the gear engineer can attend one of the AGMA courses which are all conducted by real experts. (Especially, the courses of Robert Errichello and Ray Drago which will be a good basis as far as gear design is concerned). We also offer training that covers relevant topics. Still, most important is doing it yourself, learning on the fly. This includes discussions with experts and gaining knowledge by experience. Gear design is not complicated in detail; it is only the huge amount of details that take time to learn," Beermann says.

"At the end of the day, it comes down to hands-on experience," adds Dange at Romax. "Unless you have an opportunity to mess around with the hardware and really spend some time on Gear Engineering 101, you won't be there quite yet. The Gear Lab at Ohio State is one example of a university that offers fantastic basic gear design courses. We pride ourselves at Romax with hiring gear engineers with real world experience, it's important that they can relate to the problems our customers face."

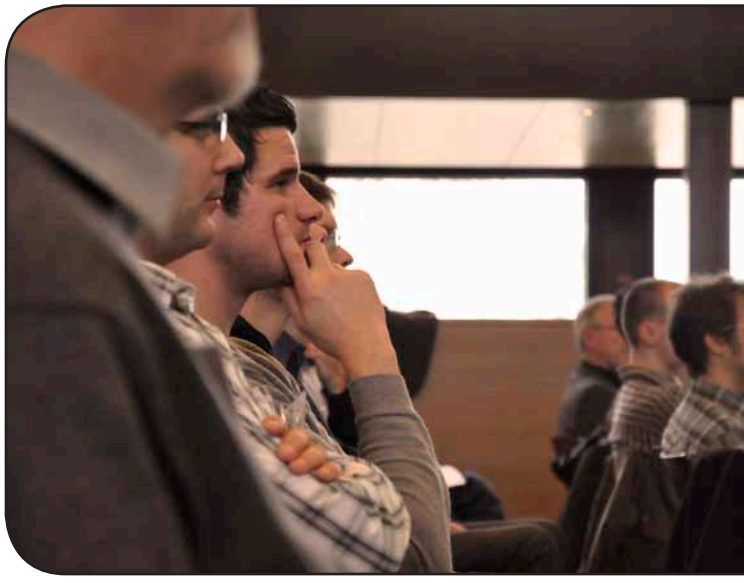
"Gear engineers have the necessary technical background but the demands mean not only good basic knowledge but also ongoing continuous training to keep pace with all the new developments in gear design," says Weser at GWJ Technology. "The engineers have the knowledge to use our *eAssistant* or *GearEngineer* software, but if specific design problems occur, a deeper knowledge is needed to resolve the problems. The software does most of the work but the users should not rely solely on software."

Maintenance & Upkeep

Another key aspect of support is software updates and maintenance. Every company interviewed for this article strongly believes that keeping up with customer requests and feedback is essential to long-term success.

"Permanent maintenance is a decisive factor for software products. To keep our customers and to fulfill their needs, it is important to update our software tools regularly. Many helpful suggestions by the users support the development process. We recently released a new software product, the *eAssistant SystemManager* which enables the user to create complex shaft systems. First feedback received from our users and clients was positive with regards to operational ease and flexibility," Weser says.

"We currently have a frequency of one new release per year. After nearly 35 years of development most of the changes with a new release are very specific and detailed. Still, each release contains one or two larger new highlights, as for instance the contact analysis for a planetary system in the current new release. Patches are provided whenever appropriate, as soon as an issue is found and fixed. These patches are available for free via download from our website," Beermann says.



Attendees of KISSsoft's Swiss Machineelements Colloquium 2012 learn about the latest software updates and products.

"We produce major releases every 1-2 years but our *Gear Production Suite* is evolving so quickly we tend to put 2-3 minor releases out each year. This allows us to insert customer requested functions and other changes from feedback from our customers on a regular basis. Because our distribution is downloaded, in many cases we can update a customer immediately if a specific function has been requested," Fish says.

"We keep a product requirement list and when we have significant market input, we act on it. The road map is very dynamic. It's constantly monitored. While these have been sporadic in the past, we now have a cadence of releases, something exciting coming out on a regular basis," Dange says.

UTS keeps up with customer requests for updates but is mindful that too many changes can sometimes cause confusion. "There needs to be a balance in how often software

updates are released. Customers actually do not like too many updates unless such updates are really necessary to keep pace with the changes in platforms like the operating system," Marathe says.

Getting Your Money's Worth

Gear design software is evolving like the rest of the software industry and the main objective for KISSsoft, Romax, GWJ, UTS and Dontyne is to keep up with the ever-changing requirements of the customers.

"With a software as comprehensive as *KISSsoft*, even the experts will have questions frequently, only on a higher level. So the support is treated as part of the product," Beermann says. "The management should allow time for learning. Often the expectation is that after the purchase of gear software, the engineers can solve every problem immediately. This will not work. The engineers will need some extra time for getting used to the software."

"The pace of technological development is incredibly quick and with the growing popularity of smartphones and tablets, mobile technology is becoming an increasingly interesting part. There are also demands for parallelization of processes (processes that are allowed to run simultaneously), providing much more efficient calculation and in order to work faster and execute more complex tasks," Weser says. "It is also observed that the processes of calculation, design and manufacturing are tightly linked together. Our national and international collaborations are growing significantly. Several colleagues worldwide are now actively involved in certain projects."

"Making the software more intuitive and doing as much handholding as possible to guide the customer to creating prudent designs is what the customers are looking for. Adding more bells and whistles is far from what the real serious customers want. The other trend is more industry specific software modules. More vertical, the better," adds Marathe.

"I think regular communication is still the key. This should be used to establish the current usage. If a customer has purchased a product but does not fully understand how to make it perform after the initial training it is essential for them to say so or for the supplier to determine it," Fish says. "The software may become less and less used and revert to old methods. While probably still effective, they may well not be as quick or as safe as using the software, which is a key aspect of modern design."

Training seminars like GWJ's Fundamentals of Bevel Gear Design lets participants focus on bevel gears, tooth design parameters and manufacturing processes.

"The young engineer will never even think about not using a computer for his work. So the discussion, 'Why should someone use a computer program to calculate a gear?' came to an end," says Beermann. "On the other hand, the number of engineers that need a computer to calculate the reference diameter for a spur gear is increasing. So in the future, we will have to discuss why it is necessary to be able to do these calculations with mental arithmetic. Computer natives are more willing to accept flaws in software; however, there is a danger that many of them do not have a healthy suspicion about results from a computer and the gut feeling if something is lost." **PTE**

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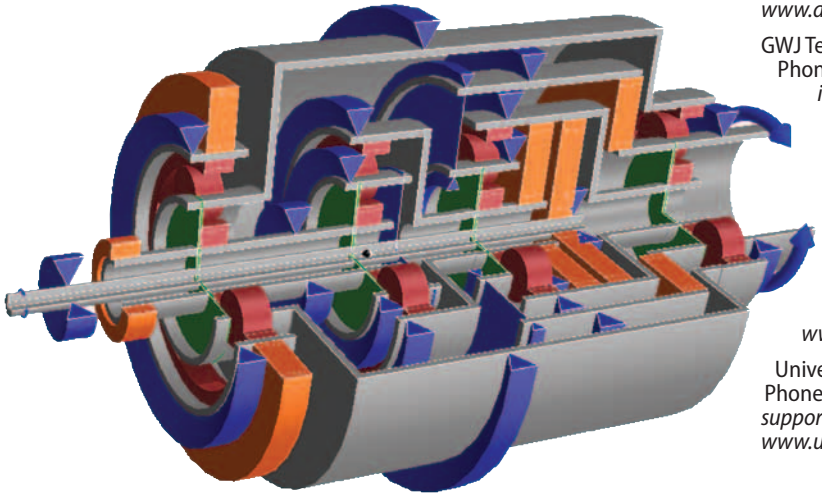

Romax's *Concept* provides a user-friendly representation of an 8-speed gearbox model.

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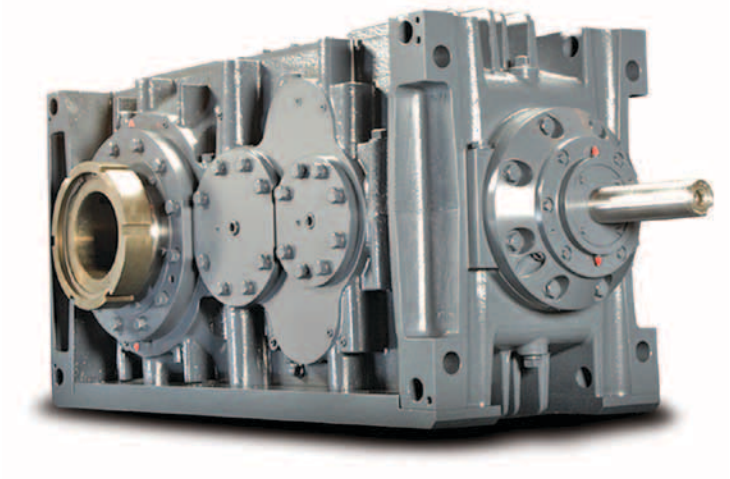

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Traversing Steep Slopes

Hydrostatic Drive Concept Gives LinsiTrak Flexibility and Versatility

Bosch Rexroth

The LinsiTrak's operator sits vertically in the seat even on a 45 degree slope (all photos courtesy of Bosch Rexroth).

"In landscape gardening you will find special-purpose vehicles for almost every task – from the riding lawn mower to the equipment trailer. And anyone confronted with steep slopes faces a real challenge, since these vehicles are normally designed for relatively flat and level fields," says Werner Müller, owner and operator of LinsiTrak. "When we launched development for the LinsiTrak, the target was clear: A versatile tractor for landscape gardening that maintains its maneuverability even on steep grades. Only a hydraulic drive concept could master this challenge. But initial trials came to nothing. The project actually didn't pick up speed until 2006, when we were able to recruit Rexroth as a partner. There was no concept available that we could have simply taken 'off the shelf.'"

The major challenge, according to Müller, was to apply the appropriate amount of driving power to each of the four wheels at all times. That is simply impossible using conventional differentials, since on a slope the wheels that are not in contact with the ground will always spin. And the locking differential offers no real help, either. "The wheels would rotate at identical speeds in every curve, thus causing unnecessary slip and that would ultimately plow up the ground. Travelling in circles or evading obstacles would be very critical," says Müller.

All three A10VG adjustable pumps used in the LinsiTrak are at a common location.

Rexroth offered a hydrostatic drive concept with its High-Efficiency Traction Control (HET). But even that design did not exactly match the requirements for the LinsiTrak. In the normal case a HET drive, with one adjustable-displacement pump each in two circuits, will drive two hydraulic motors connected in series. Power distribution in this concept is entirely dependent on the torque, which means that pressure splitting depends on the traction at each wheel. The consequence is that the uphill wheels would always spin.

Ready for the Slopes

To modify the HET concept for operation at an angle, Müller pursued a new path for the LinsiTrak. There are now two separate HET circuits in the vehicle, comprising one each A10VG adjustable-displacement pump, two MCR wheel motors and an HET con-

trol block. One circuit drives the left side, one the right side of the vehicle. What might at first glance seem like a step backwards is in fact the decisive feature. In this way the differential can balance power distribution on the two sides of the vehicle. The BODAS RC 36-20 control unit made by Rexroth automatically regulates the outputs of both pumps, in dependency on the steering radius, to deliver the exact volume of fluid required by the hydraulic motors. When traveling around a curve, the pump for the motors at the outside of the curve will always provide proportionately more fluid than to the inside wheels and thus forms a perfect basis for the motion. The electronics control not only these features, but all the vehicle's other functions, too. The LinsiTrak has no mechanical levers, no clutch and no chain.

Thrifty Both on Slopes and on the Road

A vehicle like the LinsiTrak will be used above all by municipal road maintenance departments. And efficiency plays a major role, for simple cost reasons, particularly in towns and cities. The LinsiTrak runs for ten hours with a single tank of fuel, which means that large areas can be worked without interruption. Although its power output exceeds that of comparable vehicles, it is more efficient in operation. On the road, with the series connection active, fuel consumption would jump when speed tops the 40 km/h mark. This is because each wheel traces a slightly different curve during travel, which would result in continuous application of pressure without a load actually being applied. In order to avoid this needless consumption, the user can select from several operating modes for the hydrostatic drive system. In on-road operations the series connection is disabled. Only one wheel motor in each circuit is involved in locomotion. Just like a rear-wheel-drive passenger car, in this mode the drive power for forward travel is applied entirely at the rear wheels, making for optimal traction during acceleration.

"By contrast, the hydrostatic braking acts almost exclusively on the front wheels. This is all the more important when travelling downhill, since the weight shift to the front axle enhances the braking effect at the front wheels," Müller adds. "When travelling forward on flat surfaces, those wheels simply 'idle' in the hydraulic circuit. Driving wheels individually in this way saves fuel."

Adjustments are easily made using the D13 color display.

A special HET valve made by Rexroth thus disables the series connections and applies only the required pressure level to the front wheels. The "series connection active or inactive" option makes sure that the drive is easy on the environment at all times and under all circumstances. A third mode, the so-called "offset mode" is interesting especially when traveling over soils sensitive to compaction. In this mode the tracks of the front and rear wheels at the LinsiTrak are offset and thus help to protect the substrate.

Many Functions, No Tools

But even the very best drive concept will be of no use to the landscape gardener without the right implements. That is why – adjacent to the two adjustable-displacement pumps for the drive motors at the rear of the vehicle – there is an additional axial piston pump to power implements such as the lawn mower, mulcher or sweeper. Several attachment points on the vehicle, between the axles at the front and rear, match a variety of implements, which can be attached without tools. Just like the HET drives, the power take-off guarantees maximum energy efficiency thanks to its stepless speed control and since the diesel engine is regulated to the most efficient speed. And in spite of its many functions and elaborate technology, the LinsiTrak is a compact and easy-to-steer unit. Even on 45-degree slopes, the driver's seat is always horizontal, thanks to the automatic tilt feature. The slope sensors used here work something like an electronic spirit level. They continuously transmit the tilt angle to the electronics, which then regulate the seat hydraulically. The complex functions for the various work tools are implemented in the electronic controls. At market launch any fine adjustments can be made conveniently, using a color display and from the driver's seat. By the time these functions are programmed, the LinsiTrak will also have adopted its final form – the roll bar has to be slightly higher, the vehicle is to be a total of about twenty centimeters shorter and an optional cab will be available. The bulk of the work has been completed, however: developing an innovative drive concept that will also provide valuable impetus for future solutions.

PTE

The major challenge was to apply the appropriate amount of driving power to each of the four wheels at all times.

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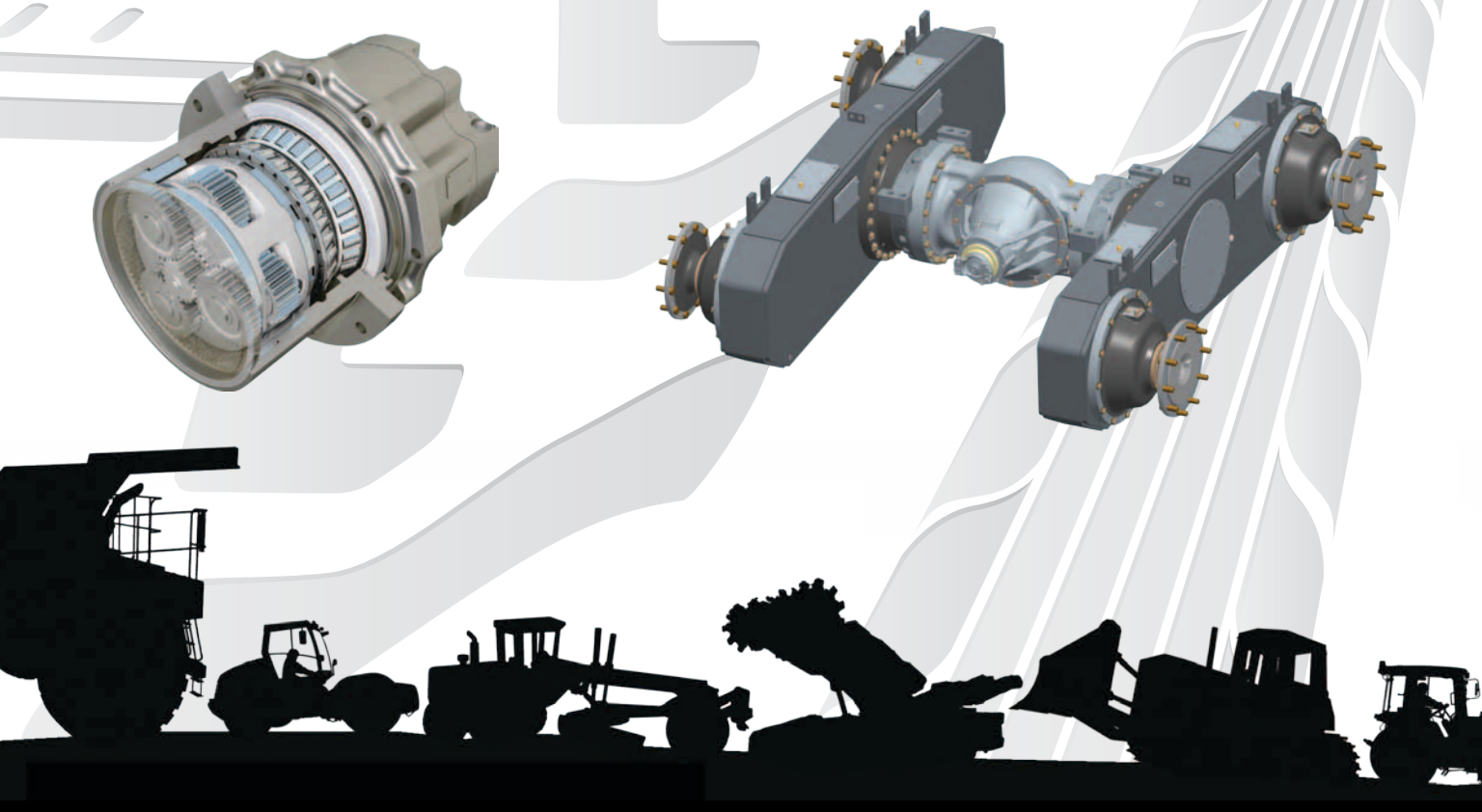

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THE QUESTION

My question is related to the technical article about selecting and sizing ball screw drives in the October 2012 issue of *PTE (page 36)*. When calculating the load on the ball screw, I followed the frictional force and thrust force calculations, but on the last line, *F* (*eq.*) is arrived at without definition (presumably because it is something intuitive). Perhaps, because I'm still fairly new to this stuff, I failed to intuit the calculation correctly. Short form of the question: How'd you get *F* (*eq*)?

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Response provided by Jeff G. Johnson, product engineer, Thomson Industries

The formula for determining the equivalent operating load (F_{eq}) should have been included. Many engineers will just use the nominal operating load (F) when calculating the life of a ball screw, but in extreme cases this may neglect some significant loads and forces such as those due to impact, shock, extreme acceleration/deceleration, externally applied loads, etc.

In the example used in the (Oct. 2012) article, I assumed a simple trapezoidal motion profile (Fig. 1), whereas the system was accelerating or decelerating approximately 9% of the time and was at constant velocity for 91% of the time.

Figure 2 is an excerpt from the engineering section of the Thomson catalog and can be found in most ball screw texts. The equivalent force equation is given as:

where

F_{eq} = Equivalent Load
n_{eq} = Equivalent Speed
q = percentage of time

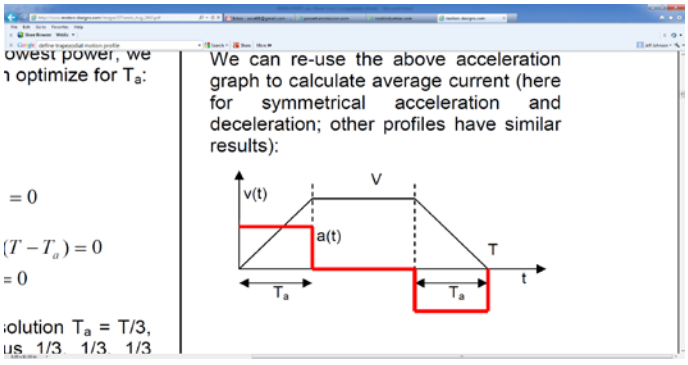

Figure 1 Trapezoidal motion profile.

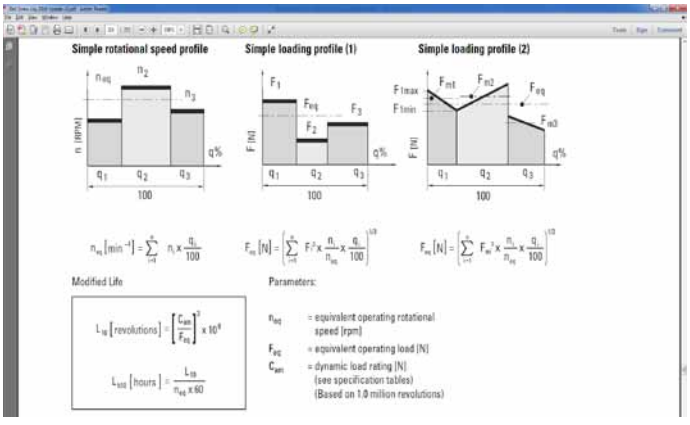

Figure 2 Equivalent force equations.

Since this is a constant velocity application, we will ignore the equivalent speed term and simplify the equivalent load equation as follows:

Solving this equation gives us the final answer of approximately 304 N.

Jeff Johnson, product engineer for industrial screws, has been with Thomson for nearly six years. He is responsible for new product development and application support for the NA market, and specializes in ball screws and lead screws.

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Considering Energy-Efficient Motors? Don't Forget the Gearbox

David. W. Conrad

The mechanical components of your drive system play a major role in overall system efficiency. Don't cut corners.

Most manufacturing facilities are trying to reduce their energy usage today. Average cost-per-kWh has more than tripled in the past two decades due to increased demand and less development of energy resources. Those manufacturing processes utilizing numerous power transmission applications (motors/gearboxes) are particularly concerned with energy consumption. These operations include—among others—warehouse distribution centers, food processing and bottling plants—i.e., anywhere automated conveyance is needed and often requires a right-angle change of power transmission.

In recent years much emphasis has been placed on high-efficiency NEMA premium motors—and with good reason. Higher-efficiency motors can play an important role in your energy conservation efforts. Yet today, it is estimated that half of all U.S. manufacturers still use outdated right-angle gearing technology that may have low initial cost, but is inefficient, wears quickly, wastes energy and fails prematurely—limiting the effectiveness of your new premium motor.

Generally, there are two common indicators in gearing that most of us intuitively understand indicate inefficiency: high noise and vibration, and high heat generation.

Rotating machines that generate high noise and high vibration can have any number of quality issues: e.g., rotating components may not be balanced properly; mating components may be not be machined precisely enough regarding perpendicularity, concentricity and true position; or components may not be rigid enough, flexing under load, which can result in misalignment.

High heat generation (Fig. 1) is always the result of low efficiency in rotating machines, which can also have many causes, including inefficient design, misalignment and poor product selection.

In general, gearboxes that generate excessive noise and vibration—or regularly run at temperatures >75°F above ambient—are poorly designed, poorly manufactured or poorly selected.

Design. Although traditional worm-only, right-angle gearboxes are widespread and relatively inexpensive, they are also quite inefficient. Worm gears operate mainly by sliding contact, resulting in high friction and inefficient operation (25-80 percent). The worm set is not only performing the function of changing the torque transmission direction, but is also bearing the burden of all of the speed reduction and torque increase, thus requiring more turns in the worm gear. The efficiency of the worm set depends on the number of turns on the worm—the more turns, the larger the ratio and the lower the efficiency. Helical gear sets, although not used to change torque transmission direction, are very efficient (> 98 percent-per-stage). Decreased tooth loading is a chief advantage of helical gears, allowing operation with high speed and torque changes with minimal rolling friction and minimized heat generation. Helical gearing is much more ef-

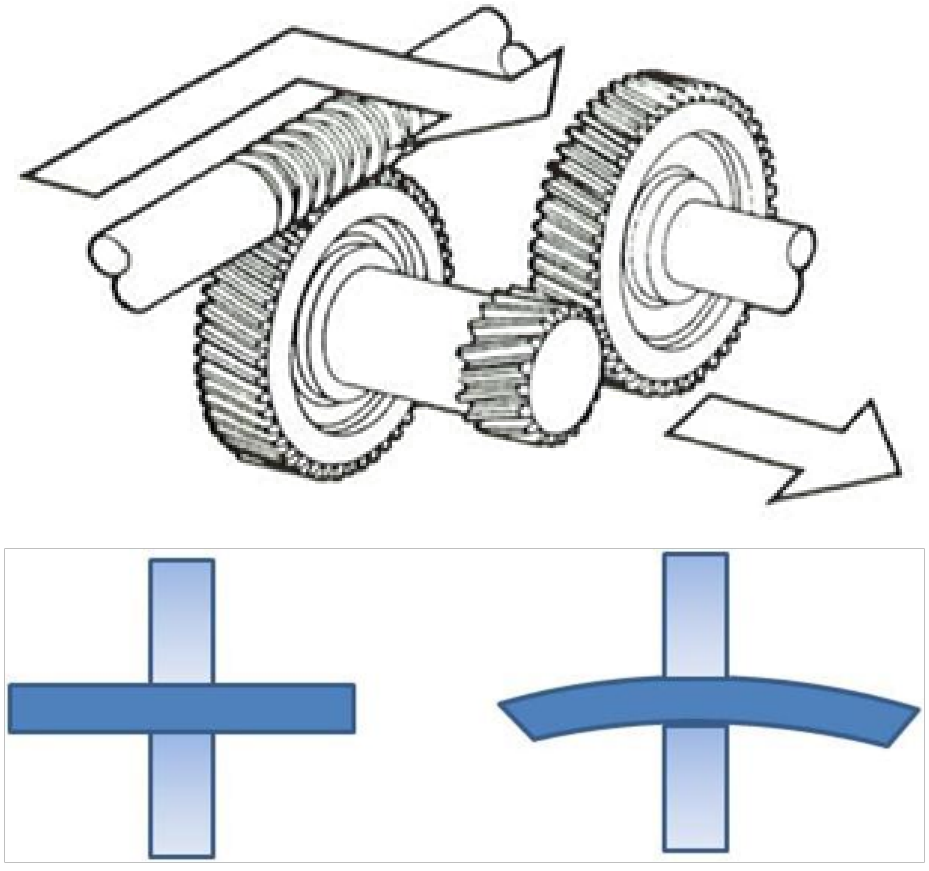


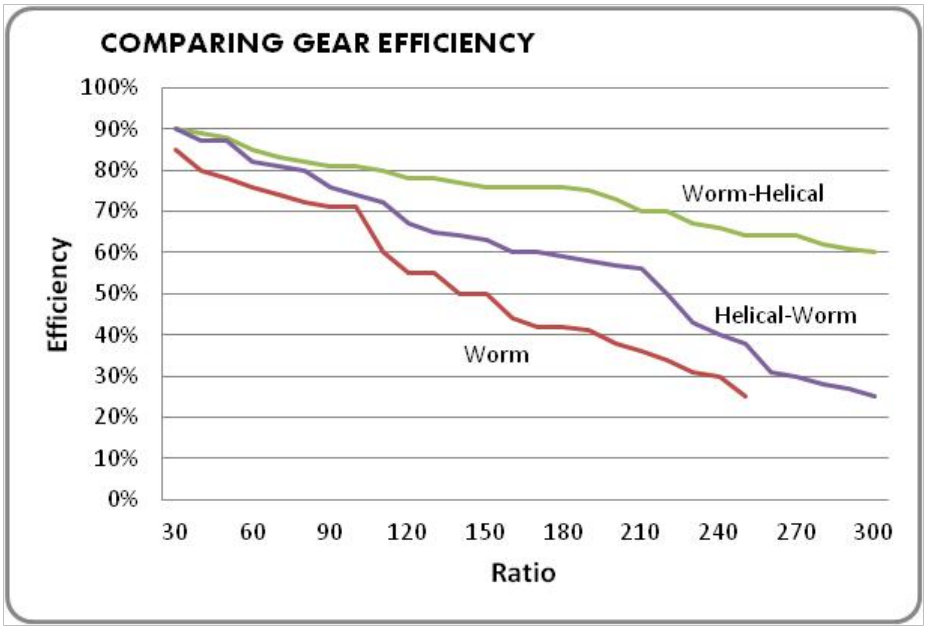
Figure 1 Inefficient gearing generates high heat losses that in turn elevate pressure inside the gear reducers that require venting to the outside environment.

ficient than worm gearing, so even for a single, one-HP motor running in a 24/7 operation, that can mean hundreds of dollars per year in energy savings. A well-designed, precisely manufactured and effectively applied helical gearbox can last many years under normal operating conditions.

Understanding that worm gearing alone is relatively inefficient and helical gearing is very efficient, some gear manufacturers offer right-angle gearboxes that include worm *and* helical gearing (Fig. 2). The worm portion of the gearbox serves to achieve the right-angle direction change of power transmission and the helical portion provides very efficient speed reduction. These types of gearboxes can be obtained with a helical input and worm output (helical/worm) or with a worm input and helical output (worm/helical). In most cases the latter (worm/helical) is the more efficient option. When the worm gear is used as the input (first stage), its primary function is the right-angle change in direction of power transmission. Very little speed reduction is required, so fewer turns are required on the worm gear, sliding friction is reduced, efficiency loss minimized. The helical portion of the gearbox (second stage) bears the primary load of torque increase and speed reduction. This results in a right-angle gearbox offering considerably higher efficiencies—especially at high-reduction ratios.

When the helical gear set is the first stage or input, the size of the shaft—and, therefore, the gear set—are limited, because input shaft size and torque are low, and input speed is high. The result is less of the speed reduction and torque increase can be counted on from the first-stage helical set and the second-stage worm set must make up the difference. This makes the total gear train less efficient and generates more heat. The result is a right-angle gearbox offering efficiencies of 65–70 percent.

When right-angle gear reduction is required, worm/helical gearboxes are generally the best-suited for applications that require an efficient right-angle solution with low output speed and high output torque. Typical applications include conveyor systems, food processing equipment, medical equipment and factory automation.



EFFICIENCY COMPARISON

40:1 RATIO		200:1 RATIO	
REDUCTION	EFFICIENCY	REDUCTION	EFFICIENCY
Worm/Helical	87%	Worm/Helical	68%
Helical/Worm	80%	Helical/Worm	59%
Single Worm	77%	Single Worm	55%

Figure 2 Efficiency comparison based on worm set ratio; as ratios increase, savings decrease.

Manufacture. Well-manufactured helical gearing is machined with angled teeth that are hardened and then ground—a complex but necessary process to achieve the high-efficiency gear mesh. The teeth are cut across each gear at an angle, such that the gears gradually mesh. Because of the angled teeth, two or three teeth of each gear are always in contact with other gears. This alleviates the load on each tooth and creates a smooth transition of forces from one tooth to the next. The result: less vibration, wear, noise and longer life.

Many gear reducers are designed and manufactured to limit size and weight in an effort to claim higher "power density." The result is a smaller, lighter gearbox that is less rigid. Robustly designed

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Table 1 Energy savings are there for the taking—if you have the right gearbox

SYSTEM	ENERGY SAVINGS POTENTIAL
Mechanical Power Transmission	60%
Variable Speed and Energy Controls	30%
High Efficiency NEMA Premium Motors	10%

and manufactured gearboxes are compactly designed to fit easily into new and existing applications, but maintain the mass of the housing to provide a more structurally stable and rigid product. The resulting housing stiffness and rigidity keeps shafts and gears precisely aligned—even at high loads. Adherence to tight tolerances on the machining of the housings is critical as well, to ensure the optimal radial meshing of the gears and optimal perpendicularity of gears to each other.

Inefficient gearing generates high heat losses that in turn elevate pressures inside the gear reducers that require venting to the outside environment. Venting lets air out, but it also lets air in. Incoming air contains contaminants and adds moisture, which breaks down the oil inside the gear reducers. Well-designed and precisely manufactured worm/helical gearboxes are very efficient and do not generate much heat. This, along with high-quality synthetic oil, allows these gear reducers to be completely sealed, thus preventing moisture and contaminants from entering the oil chamber and breaking down the oil. Oil, under normal operation, should not break down and should not need to be changed for the life of a gearbox designed and manufactured in this manner, even in the harshest environments.

Seal surfaces run at high speed against metal surfaces, thus making them the wear items that often determine the life of a gear reducer. The highest quality designs, materials, handling and assembly practices are required to ensure that oil seals perform to the level required for long-life gear reducers. This is another area where a worm/helical input/output gearbox usually functions better than a simple worm or helical/worm combination gearbox. Because the worm input is used primarily for changing the direction of torque (leaving most of the heavy lifting to the helical gears), the input shaft diameter can be smaller, resulting in less linear speed between the seal lip and the shaft. This results in less seal lip friction, which is especially important on the input side of the gear train, which is closer to the heat generated by the motor and the worm gear mesh. Small shaft diameters are less important on the output as speeds are lower and the seals are further away from heat sources (motor and worm mesh).

Finally, bearings—whether ball, spherical or tapered—are the other wear items within gear reducers with high-speed, metal-to-metal rolling contact under various load conditions. Proper selection and sizing, correct handling and assembly are all critical to ensure long life in gear reducers. Minimized bearing spans, rigid housing construction and well-controlled housing tolerances are very critical to the life of bearings in an enclosed gearbox.

Proper selection. Even industry-leading designs and manufacturing practices cannot prevent failure if a gearbox is improperly sized or applied. It is imperative that the application power requirements and demands are clearly understood. Utilization of the appropriate service factor for the speed of the reducer must be taken into consideration and applied. If the gearbox is unnecessarily oversized and the power capacity of the gearbox greatly exceeds the power of the applied motor, much of the motor horsepower will be used to overcome the constant losses within the gearbox, thereby leaving little additional, usable power and torque for the application itself. As such, this would be a situation where the speed reducer is yielding a very low efficiency. Conversely, a gearbox undersized for an application runs the risk of low life expectancy due to overload conditions, despite a seemingly high efficiency.

Conclusion

The initial cost of a well-designed, precisely manufactured and properly selected right-angle gearbox will be higher than the lowest initial cost solution, but that investment is returned many times over during the life of the application. The temptation to cut corners to lower initial cost is always present. Price competition in the market is fierce; many companies attempt to lower costs in areas that result in a compromise of design and quality. Robust and efficient right-angle gear solutions are manufactured by companies that focus cost control efforts on areas like design and manufacturing efficiency, waste reduction and continuous improvement. The quality and durability of the gear reducers should never be compromised. **PTE**

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David Conrad's career began with several management-level positions at Dodge (Rockwell Automation), including, engineering manager, director of lean enterprise and plant manager. He moved on in 2007 to Richmond Gear/Velvet Drive (Regal Beloit Corp.), assuming the role of VP/general manager. He now serves as VP of engineering at Master Power Transmission in Greenville, SC–a manufacturer of quality industrial mechanical power transmission products. Conrad is a licensed professional engineer, with a Master of Science in mechanical engineering from the University of South Carolina. He holds a number of U.S. patents related to industrial mechanical power transmission and is the author of several articles on related topics.

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Rolling Bearing Steels—A Technical and Historical Perspective - Part I

Erwin V. Zaretsky

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

Introduction

Jacob Rowe applied for a British patent in 1734 for a rolling element bearing. In his patent he defined the advantages of such a bearing:

(With the adoption of such bearings to) "…wheel carriages, one horse now will do the labor of two. And I will suppose that there will be occasion to employ only 20,000 horses … instead of the 40,000 existing in the United Kingdom at an annual savings of 1,095,000 pounds per year."

B.W. Kelly (Ref. 1), in writing about Rowe, said that he "was not able to find historical records that reported such sudden prosperity had occurred. As a result, he concluded that that the cost for keeping a horse that was not working was as much as it was for one that was in fact working."

Things really have not changed in over 275 years.

The rolling bearing materials used in Rowe's era would have been wood, bronze and iron. Modern steel and metallurgy do not begin until about 1856 with the Bessemer process. In this process air is blown through molten pig iron to produce a relatively high grade of steel. This was followed 10 years later by the invention of open-hearth melting, which further improved quality and made steel far more accessible to industry. However, because heat treatment of steel was still an art known only to a few, most rolling-element bearings were probably made of unhardened steel. In 1879, British patent 869 was issued to J. Harrington and H. Brent for a hardened steel bushing—or inner shaft—fitted with a groove for balls. About the same time, Englishman W. Hillman constructed a machine for cutting balls from steel wire (Refs. 2 and 3).

In 1900, according to Stribeck (Ref. 4), the use of carbon and chromium steels for bearings gradually increased during the last quarter of the 19th century, as the need for bearings capable of reliably supporting heavy loads increased. He reported that water-hardened steel gave higher elastic limits and greater capacity than oil-hardened steel. In a discussion of the Stribeck paper, Hess (Ref. 4) presented chemical analyses of four bearing steels then in use. Hess stated that these bearing steels "harden throughout and (are) uniformly hard and tough where durability and long life are wanted." The chemistry of one of the French steels, No. 88, listed in the table, closely matches that of AISI 52100. This steel was first specified about 1920 and remains the most used bearing steel today (Refs. 2 and 3).

Starting about 1920 it becomes easier to track the growth of bearing materials technology. Until 1955, with few exceptions, comparatively little progress was made in this area. AISI 52100 and some carburizing grades (AISI 4320, AISI 9310) were adequate for most applications. Materials such as AISI 440 were available in those cases where improved corrosion resistance was required (Ref. 3). In one of the classic textbooks on bearing analysis, by Shaw and Macks (Ref. 5) in 1949, the only rolling element bearing steel discussed was AISI 52100. Even as recently as 1957, in another authoritative text written by Wilcock and Booser (Ref. 6), the authors made only incidental note of the fact that AISI 52100 is not useful over 177°C (350°F). And, according to Wilcock and Booser (Ref. 6), "For temperatures above 177°C (350°F), bearing manufacturers have made small lots of bearings of AISI M–l and AISI M–10 tool steels. These steels retain their hardness to temperatures approaching 538°C (1,000°F). Evidence available to date indicates that they operate satisfactorily, provided lubrication can be maintained."

As discussed by Bamberger (Ref. 2) of General Electric Company Engine Division, Cincinnati, Ohio, the catalyst to quantum advances in all high-performance materials, including those steels used for bearings, was the advent of the aircraft gas turbine engine. The impact of the gas turbine engine on the growth of the aircraft industry after the Second World War created unprecedented needs for better materials and designs for rolling element bearings. These needs included bearings for higher temperatures, higher speeds and greater loads. The continuously increasing thrust-to-weight ratio for the aircraft jet engines required the use of smaller and lighter bearings. The reliability of these bearings became a major consideration because of system and mission complexities, and because of the high costs involved (Refs. 2 and 3).

In order to assure long rolling bearing life and reliability for commercial, industrial and aerospace applications, the materials, lubricants and design variables must be carefully con-

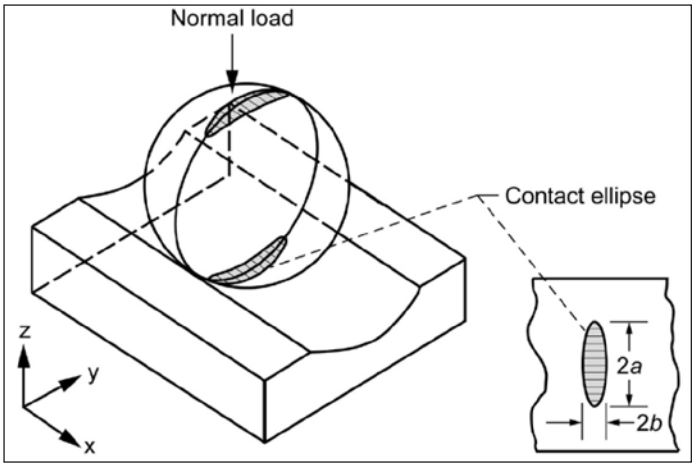


Figure 1 Schematic of contact profile of ball on raceway; a and b = semi-widths of major and minor axes of Hertzian contact area, respectively.

sidered and specified. The treatment of an alloy—from ore to finished bearing—can have a very significant effect on bearing performance, life and reliability. Experience has shown that different heats of the same material and process can produce life differences in the range of 2 to 1. It is therefore the objective of this paper to bring together and discuss—from both a technical and historical perspective—the chemical, metallurgical and physical aspects of bearing steels and their effect on rolling bearing life and reliability.

Bearing Life

Figure 1 is a schematic of the contact profile of a ball on a bearing race. Figure 2a shows the surface (Hertzian) stress distribution under the ball and the principal stresses at *z*—a critical location below the surface. Figure 2b shows the stress distribution below the surface. From these principal stresses the shearing stresses can be calculated.

Three shearing stresses can be applied to bearing life analysis: 1) orthogonal shearing stress—τ_o; 2) octahedral shearing stress— τ_{oct}; and 3) the maximum shearing stress—τ_{max}. The von Mises stress—which is not a shearing stress—has been inappropriately used by some investigators as a substitute for octahedral shearing stress τ_{oct}. All of these shearing stresses are a function of the maximum Hertz stress where:

$$\tau = k_1 S_{\max} \quad (1)$$

The proportionality constant k_1 is a variable related to the specific shearing stress, and the maximum Hertzian stress is the maximum value of the Hertzian stress distribution shown in Figure 2a. For ball bearings (point contact), $k_1 = 0.25$, 0.28 and 0.32 for orthogonal shearing stress τ_o; octahedral shearing stress τ_{oct}; and maximum shearing stress τ_{max}, respectively. For roller bearings (line contact), $k_1 = 0.25$, 0.29 and 0.30 for orthogonal shearing stress τ_o; octahedral shearing stress τ_{oct}; and maximum shearing stress τ_{max}, respectively.

For the analysis reported herein, only the maximum shearing stress is considered. The maximum shearing stress is one-half the maximum difference between the principal stresses:

$$\tau_{max} = \frac{\sigma_z - \sigma_x}{2} \quad (2)$$

Moyer and Zaretsky (Ref. 7) discuss in detail "failure modes related to bearing life." The ultimate failure mode limiting bearing life is classical rolling element fatigue of either a bearing race or rolling element. The failure manifests itself as a spall limited to the width of the running track and the depth of the maximum shearing stresses—a distance *z* below the contact surface where:

$$z = k_1 b \quad (3)$$

The proportionality constant k_2 is a variable related to the specific shearing stress, and *b* is the semi minor axis of the contact ellipse (Fig. 2). For ball bearings (point contact), $k_2 = 0.50$, 0.76 and 0.76 for orthogonal shearing stress τ_o; octahedral shearing stress τ_{oct}; and maximum shearing stress τ_{max}, respectively. For roller bearings (line contact), $k_2 = 0.50$, 0.79 and 079 for the orthogonal shearing stress τ_o; octahedral shearing stress τ_{oct}; and maximum shearing stress τ_{max}, respectively. The region or zone of maximum shearing stresses can be defined as the stressed volume beneath the Hertzian contact, ranging from a 0.50b to 0.79b depth below the stressed surface.

Generally, the spall begins in the region of maximum shearing stresses and propagates into a crack network. Most bearings, however, fail for other reasons. Failures other than those caused by classical rolling element fatigue are consid-

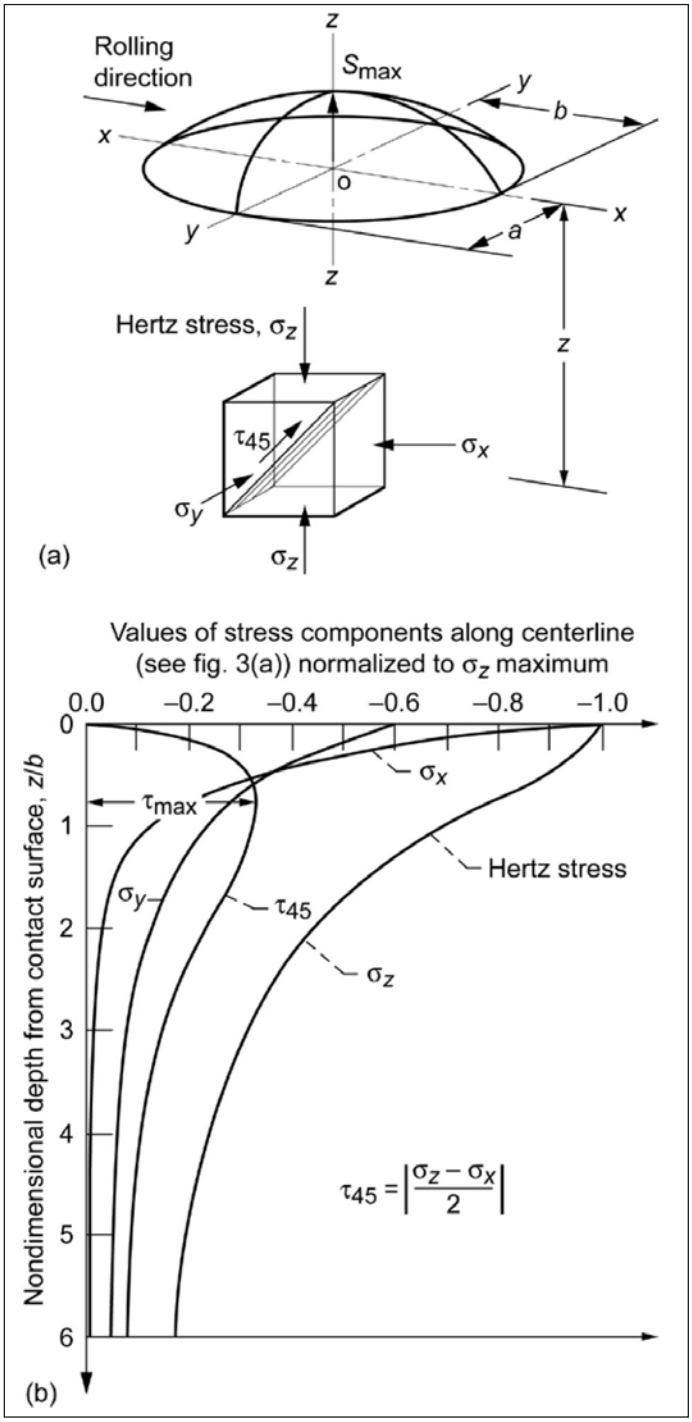


Figure 2 Sub-surface stress field under point contact. (a) Hertz stress distribution for ball on raceway showing principal stresses (σ = stress; τ = shear stress; and S_{max}, = maximum Hertz stress) at depth z below surface. (b) Distribution of principal and shearing stress as function of depth z/b below surface.

Table 1 Life factors for bearing steels (Ref. 3)

Material	Life factor, LF
Through-hardened steels	
AISI 52100	3
AISI M-10	2
AISI M-50	2
AISI T-1 (18-4-1)	2
Halmo	2
AISI M-1	.6
AISI M-2	.6
Corrosion-resistant steels	
AMS 5749 (BG-42)	2
AMS 5900 (CRB7)	2
AISI 440C	.6
Case-carburized steels	
AMS 6278 (VIM–VAR M50 NiL)	4
AISI 4620	3
AISI 8620	2
AISI 9310	2
CBS 600	2
Vasco X-2	2
CBS 1000	2
AISI 8720	1.5

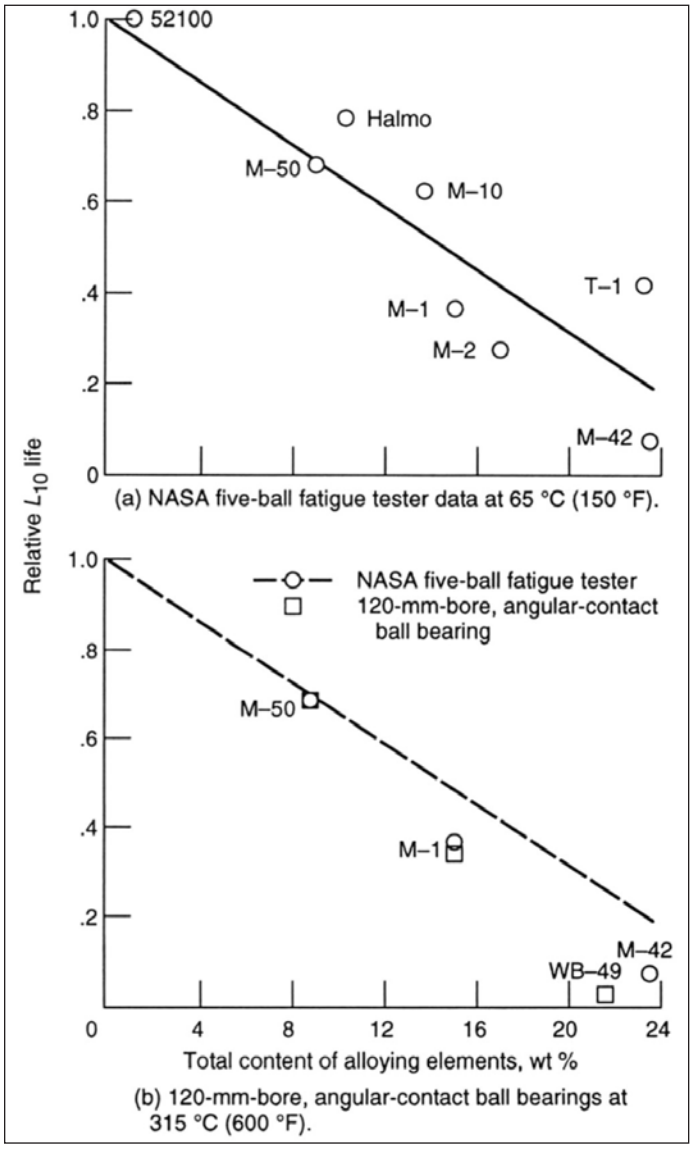


Figure 3 Rolling-element fatigue life as a function of total content of alloying elements tungsten, chromium, vanadium, molybdenum and cobalt (Ref. 17).

ered avoidable if the bearing is properly designed, handled, installed and lubricated and is not overloaded (Ref. 7).

Rolling element fatigue is extremely variable but is statistically predictable, depending on the steel type, steel processing, heat treatment, bearing manufacturing and type, and operating conditions. Sadeghi, et al. (Ref. 8) provide an excellent review of this failure mode.

Alley and Neu (Ref. 9) provide a recent attempt at modeling rolling element fatigue. With improved bearing manufacturing and steel processing, together with 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 (Ref. 3).

Based on the 1947 work by Lundberg and Palmgren (Refs. 10 and 11), who use the orthogonal shearing stress τ_o for their analysis, the life of a ball or roller bearing based on rolling element fatigue can be expressed in its most simplistic form as follows:

$$L_{10} = LF\left(\frac{C}{P}\right)^p \quad (4)$$

Equation 4 is benchmarked to pre-1940 air melt AISI 52100 steel where $LF = 1$.

The L_{10} life, in millions of inner race revolutions, is the theoretical life that 90 percent of a bearing population should equal or exceed without failure at their operating load P. C is defined as the theoretical load that a bearing can carry for a life of one million inner-race revolutions with a 90 percent probability of survival. The load-life exponent is p. And, L_F is a life factor dependent on the bearing steel and its processing (Ref. 11).

Lundberg and Palmgren (Ref. 10) derive the load-life exponent p to be three for ball bearings and four for roller bearings. However, in their 1952 paper (Ref. 12), Lundberg and Palmgren modified their value of the load-life exponent p for roller bearings from four to 10/3. Their rationale for doing so was that various roller bearing types had one contact that is line contact and another that is point contact. They state that "as a rule the contacts between the roller and the raceways transform from a point to a line for some certain load, so that the life exponent varies from three-to-four for differing loading intervals within the same bearing." The ANSI/ABMA (Ref. 13) and ISO (Ref. 14) standards incorporate $p = 10/3$ for roller bearings. Computer codes for rolling element bearings incorporate $p = 4$ for roller bearings and $p = 3$ for ball bearings (Ref. 11).

Bearing lives determined by using Equation 4 with the values of C given in bearing manufacturers' catalogues are based on the "first evidence of fatigue." This can be a tiny spall that may not significantly impair the function of the bearing; thus, the actual useful life can be much longer. Society of Tribologists and Lubrication Engineers (STLE) life factors L_F for various bearing steels are given in Table 1 (Ref. 3). It can be reasonably assumed that these life factors are benchmarked to air melt AISI 52100 steel at a maximum Hertzian (contact) stress of 1.723 GPa (250 ksi). Table 2 provides the designation and chemistry of these and other representative bearing steels (Ref. 15).

Steel Chemistry

Through-hardened steels. In the 1950s and through the 1960s the bearing industry assumed that materials with higher alloy content would have better hardness retention at elevated temperatures. It was reasoned that this would also result in higher ambient-temperature hardness as well as longer bearing life. Based on this assumption steel companies and research laboratories within the United States began to develop bearing steels with higher alloy content.

It is necessary to compare these steel and processing variables in rolling-element fatigue tests and/or actual bearing tests. Standard mechanical tests, such as tension and compression tests or rotating-beam tests, could not be correlated with rolling-element fatigue results (Ref. 16). Accordingly, a series of studies to verify the effect of increased alloying elements on rolling-element fatigue life was undertaken by the author and his colleagues at the NASA Lewis Research Center (now NASA Glenn Research Center), Cleveland, Ohio (Refs. 17 and 18).

Figure 3a summarizes the results of rolling-element fatigue tests conducted in the NASA five-ball fatigue tester (Ref. 17). Previous studies by others did not maintain the close control of operating and processing variables, such as material hardness, melting technique, and lubricant type and batch—required for a completely unbiased material comparison (Ref. 18). These tests comprised three groups each of eight through-hardened bearing steels. There were a total of 720 tests. All of the specimens for the specified steel came from the same heat of material and were manufactured and heat treated to the same hardness at the same time; all other variables were also carefully controlled. Contrary to expectation, rolling-element fatigue life decreases with increasing total content of alloying element in the steel. When present in high percentages these alloying elements appear to significantly decrease rolling element fatigue life.

Additional work (Fig. 3b) was performed with 120-mm-bore, angular-contact ball bearings made from VAR AISI M–I, AISI M–42, AISI M–50, and WB–49 steels to verify the results in the NASA five-ball fatigue tester (Refs. 17 and 19). Bearings were tested at an outer-race temperature of 316°C (600°F). These four test series comprised a total of 120 bearings—or 30 for each steel. The magnitudes of the differences seen in these bearing tests at 316°C (600°F) correlate well with the results of five-ball fatigue tests that are also shown in Figure 3a. Using the AISI M–50 L_{10} life as a comparison, the AISI M–1 data from the five-ball fatigue tests and from the bearing tests agree remarkably well. WB–49 in the bearing tests and AISI M–42 in the five-ball fatigue tests, both of which alloys contain relatively high percentages of cobalt and have similar microstructures, show reasonably good agreement (Ref. 20).

These results completely changed previously held assumptions regarding the effect of bearing steel alloying elements on rolling-element fatigue life. As a result, by the mid-1980s AISI M-50 steel became the steel of choice for most high-temperature bearing applications over 149°C (300°F). For bearing temperatures less than 149°C (300°F), AISI 52100 steel with the lowest alloying content has a longer fatigue life and is probably the most widely used bearing steel throughout the world. These steels are usually heat treated to Rockwell C hardness at room temperature of not less than 60. At operating temperature, it is a general requirement that the operating hot hardness be greater than Rockwell C 58.

Carburizing-grade steels. Bearings are required to tolerate substantial damage progression without catastrophic fracture during the interval between the onset of a problem and when routine maintenance identifies the need for repair (Refs. 21 and 22). Material toughness provides this capability. Fracture toughness is the material property that defines the stress required to initiate rapid fracture in the presence of a local defect (e.g., a fatigue spall). Initial defect size substantially affects fracture characteristics, but is beyond the control of the designer. Tensile stresses, either application-induced or residual, are necessary for rapid fracture to occur. These are somewhat controllable by the designer, but advanced applications will require tolerance to increased stress (Ref. 3).

Table 2 Representative bearing and gear steels (Ref. 15)

Material			Alloying element, percent by weight (balance Fe)												
Common designation	Description	Reference specifications	C	P (max)	S (max)	Mn	Si	Cr	V	W	Mo	Co	Nb	Ni	Other
50100	Cr alloy steel	UNS G 50986; AISI E 50100; AMS 6442	1.00	0.025	0.025	0.35	0.25	0.50							
51100	Cr alloy steel	UNS G 51986; AISI E 51100; AMS 6440, 6444, 6447	1.00	.025	.025	.35	.25	1.00							
52100	Cr alloy steel	UNS G 52986; AISI E 52100; AMS 6440, 6444, 6447	1.00	.025	.025	.35	.39		1.45						
MHT	Al-modified bearing steel		1.03	.025	.025	.35	.35	1.50							1.36 A1
Halmo	Bearing steel		.56	.003	.008	.36	1.12	4.84	0.53		5.18				
M-1	High-speed tool steel	UNS T 11301; AISI M-1	.80	.030	.030	.30	.30	4.00	1.00	1.50	8.00				
M-2	High-speed tool steel	TINT 11302; AISI M-2	.83	.030	.030	.30	.30	3.85	1.90	6.15	5.00				
M-10	High-speed tool steel	UNS T 11310; AISI M-10	.85	.030	.030	.25	.30	4.00	2.00		8.00				
M-42	High-speed tool steel	UN S42T 11342; AISI M-	1.10	.012	.007	.15	.17	3.77	1.15	1.66	9.51	7.99			
M-50	High-speed tool steel	UNS T 11350; AISI M-50; AMS 6490, 6491	.80	.030	.030	.30	.25	4.00	1.00		4.25				
M50 NiL[a]	Carburized steel	AMS 6278	.13	.030	.030	.30	.25	4.00	1.20	4.25				3.50	
T-1(18-4-1)	High-speed tool steel	UNS T 12001; AISI T-1; AMS 5626	.70	.030	.030	.30	.25	4.00	1.00	18.0					
T-15	High-speed tool steel	UNS T 12015; AISI T-15	1.52	.030	.030	.26	.25	4.70	4.90	12.5	'1.0	5.10			
440C	Hardenable Cr stainless steel	UNS S 44004; AISI 440C; AMS 5618, 5630, 5880, 7445	1.03	.018	.014	[b]1.0	.41	17.3	.14			.75			
AMS 5749	Martensitic stainless steel	UNS S 42700; AMS5749	1.15	.015	.010	.50	.30	14.5	1.20		4.00				[b].35 Cu
Vasco matrix II	Gear steel		.53	.014	.013	.12	.21	4.13	1.08	1.40	4.80	7.81		.10	
CRB-7	Bearing steel		1.10	.016	.003	.43	.31	14.0	1.03		2.02		.32		
AMS 5900	Martensitic stainless steel	UNS S 42800; AMS5900	1.10	.015	.010	.40	.30	14.0	1.00	2.00				[b].35	.25 Nb
9310[a]	Ni-Cr-Mo alloy steel	UNS G 93106; AISI 9310; AMS 6260, 6265, 6267	.10	.025	.025	.54	.28	1.18			.11			3.15	
CBS 600[a]	Alloy steel	UNS K 21940; AMS6255	.19	.010	.010	.61	1.05	1.50			.94			.18	.07 Al
CBS 1000[a]	Alloy steel		.14	.018	.019	.48	.43	1.12			4.77			2.94	
Vasco X-2[a]	Gear steel		.14	.011	.011	.24	.94	4.76	.45	1.40	1.40	.03		.10	
8620[a]	Ni-Cr-Mo alloy steel	UHS G 86200; AISI 8620; AMS 6274, 6276, 6277	.21	.035	.040	.80	.25	.50			.20			.55	
EX-53[a]	Gear steel		.10	.009	.006	.37	.98	1.05	.12	2.13	3.30				2.07 Cu
3310[a]	Alloy steel	UNS G 33106; AISI 3310	.11	.025	.040	.52	.22	1.58						3.50	
4320[a]	Ni-Cr-Mo alloy steel	UNS G 43200; AISI 4320	.20	.035	.040	.55	.25	.50			.25			1.82	
4620[a]	Ni-Mo alloy steel	UNS G 46200; AISI 4620; AMS 6294	.20	.035	.040	.55	.25				.25			1.82	
4720[a]	Ni-Cr-Ni alloy steel	AISI . UNS G 47200; 4720	.20	.035	.040	.55	.25	.45			.20			1.05	
Pyrowear 675	Carburized stainless steel		.07	.005	.003	.65	.40	13.0	.60		1.80	5.40		2.60	

[a] Carburized grades., [b] Maximum.

Through-hardened materials, heat treated to Rockwell C 60 hardness, as is typical with bearing components, have limited fracture toughness. The KIC is usually less than 24 MPa $m^{½}$ (22 ksi $in.^{½}$), depending upon heat treatment (Ref. 23). Materials with fracture toughness this low have limited bulk tensile stress capability if rapid fracture is to be avoided. A conservatively safe limit is 172.4 MPa (25 ksi). Applications requiring higher toughness will have to be made from a carburizing-grade steel (Ref. 3).

Carburizing-grade steels have reduced carbon content so that heat treatment normally results in moderate hardness and high toughness. High surface hardness, required for rolling-element bearing performance, is achieved by diffusing carbon into the surface, a process called carburizing, prior to heat treatment. Locally the steel is then a high-carbon alloy and is heat treatable to full hardness. The resulting structure has a surface layer with mechanical properties that are equivalent to those of traditional through-hardened bearing steels and a core that remains at low hardness, with corresponding high ductility and high fracture toughness. Surface-initiated defects (e.g., a spall) propagate cracks into the tough core before they reach critical size. The tough core prevents rapid and catastrophic fracture (Ref. 3).

Fracture toughness of a material is inversely proportional to its carbon content and hardness. The carbon content also determines hardness. Fracture toughness can be improved without affecting hardness by adding nickel. When present in high-chromium, low-carbon steels, nickel causes the steel to become fully austenitic above 875°C (1,605°F) where the steel is heat treated or carburized. Adding nickel also influences carbide size and distribution within the steel, which affects fatigue life. Recognizing this, Bamberger (Ref. 24) modified the chemistry of AISI M–50 steel by decreasing the amount of carbon and increasing the amount of nickel. He called this modified AISI M-50 steel M50 NiL (the "Ni" referring to increased nickel and the "L" to low carbon). The steel is also designated as Aerospace Material Specification (AMS) 6268.

M50 NiL, which is case carburized, has a core with a high fracture toughness KIC (over 60 MPa -$m^{½}$; 50 ksi-$in.^{½}$) than through-hardened AISI M-50 (29 MPa -$m^{½}$; 20 ksi-$in.^{½}$). The M50 NiL core hardness is Rockwell C 43 to 45. M50 NiL has finer carbides (compounds of carbon and various alloying elements) dispersed more evenly within its microstructure than standard AISI M–50. Compressive residual stresses in excess of 210 MPa (30 ksi) are induced in the zone of maximum resolved shear stresses during carburization of M50 NiL. These residual stresses combined with the fine carbide structure will increase its rolling-element fatigue life over that of conventional AISI M–50 (Ref. 25).

Many carburized gear steels are also used as bearing steels. These carburized steels are primarily used for tapered roller bearings or other bearings such as cylindrical roller bearings where tight interference fits are required between the bearing bore and shaft. A tight interference fit will induce large tensile (hoop) stresses in the bearing inner ring that can cause catastrophic fracture failure of the ring and the bearing. As with AISI 52100 steel, for temperatures less than 149°C (300°F), AISI 9310 and AISI 8620 are usually the materials of choice. However, for bearing operating temperatures greater than 149°C (300°F), M50 NiL is the steel of choice.

Corrosion-resistant steels. Although not normally a functional requirement, corrosion resistance is highly desirable because of its potentially large effect on life-cycle cost. Alloy steels with high chromium content, greater than 12 percent, are considered corrosion resistant. However, 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 (Ref. 3).

Available corrosion-resistant bearing alloys include AISI 440C and the high-temperature variations such as AISI 440C Mod, Aerospace Material Specification (AMS) 5749 (VIM–VAR BG-42), AMS 5900 (VIM–VAR CRB7) and Pyrowear 675. AISI 440C is widely used in instrument bearings and in bearings for food-processing equipment. In addition, AISI 440C is the traditional alloy chosen for use in cryogenic rocket engine turbo pumps such as those in the NASA Space Shuttle. AMS 5749 (VIM–VAR BG-42), AMS 5900 (VIM–VAR CRB7) and Pyrowear 675 are more recent developments (Ref. 3). For temperatures less than 149°C (300°F), AISI 440C is the corrosion-resistant steel of choice; for temperatures greater than 149°C (300°F), AMS 5749(BG-42) is the steel of choice.

Steel processing. In the early years of the bearing industry, acid- and base-refractory, air-melting methods were used to process steel. Major advances in steel producing have occurred, beginning with the 1950s by the introduction of vacuum-melting procedures. Vacuum processing reduces or eliminates the amount of nonmetallic inclusions, entrapped gases, and trace elements in structural alloys, resulting in substantially cleaner material. The two primary methods of vacuum processing are vacuum induction melting (VIM) and consumable-electrode vacuum melting (CEVM)—also called

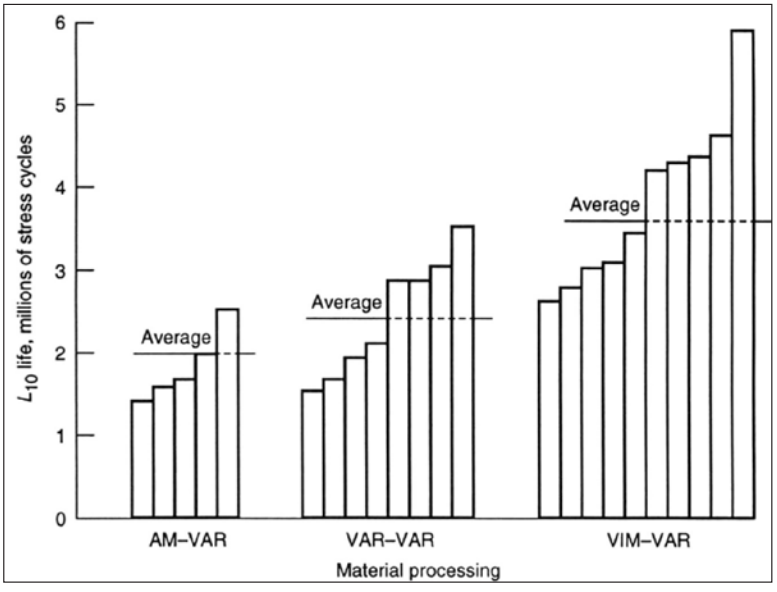


Figure 4 Rolling-element fatigue life of AISI M–50 steel in rolling-contact fatigue tester as a function of steel processing. Specimen diameter, 9.525 mm (3/8 in.); maximum Hertz stress, 4.8 GPa (700 ksi); speed, 12,500 rpm (Ref. 26).

Table 3 Life factors for melting practice (Ref. 3)	
Processing	**Life factor, LF**
Air melting (AM)	1
Vacuum processing (VP) or carbon vacuum degrassing (CVD)	1.5
Vacuum are remelting (VAR)[a]	3
Electroflux remelting (EFR)[b]	3
Vacuum are remelting-vacuum are remelting (VAR–VAR)	4.5
Vacuum induction melting-vacuum are remelting (VIM–VAR)	6

[a] Also called consumable-electrode vacuum melting (CEVM).
[b] Also called electroslag remelting (ESR).

vacuum arc re-melting (VAR). In the early 1970s these two methods were combined, whereby the vacuum induction primary melt is vacuum arc re-melted. This method, called VIM–VAR, produces much cleaner steel than either VIM or CEVM individually (Ref. 26; Fig. 4).

Although CEVM and VIM–VAR are the primary methods used today to produce materials such as AISI M–50, other vacuum processing methods have been developed, primarily aimed at improving AISI 52100. The effect of melting practice on rolling-element fatigue life is shown by STLE life factors (*LF*) in Table 3 (Ref. 3). The product of the life factors for bearing steel from Table 1 and melting practice from Table 3 is used as a single life factor *LF* in Equation 1 to determine the bearing L_{10} life.

Vacuum processing of bearing steel increases bearing life by eliminating hard oxide inclusions that act as stress raisers to initiate incipient failure. This results in an unforeseen secondary benefit. The fatigue life of the bearing steel becomes more sensitive to a reduction in stress. That is, as contact load or (Hertzian) stress is decreased, bearing fatigue life is increased at a faster rate than with the air melted bearing steels.

As previously discussed, the load-life exponent *p* in Equation 1 is three for ball bearings and four for roller bearings, based on pre-1940 air melt AISI 52100 steel. However, a reevaluation of the load-life relation (Refs. 27 to 29) based on a summary of published data by R.J. Parker and E.V. Zaretsky (Ref. 30), suggests that for post-1960 vacuum processed bearing steels, the load life exponent *p* equals four and five for ball and roller bearings, respectively. This accounts for another significant improvement in rolling bearing life and reliability. **PTE**

(Part II of "Rolling Bearing Steels—A Technical and Historical Perspective," will appear in the April issue of *Power Transmission Engineering*.)

References (Part I: 1–30)

1. Kelly, B.W. "Lubrication of Concentrated Contacts – The Practical Problem," *Interdisciplinary Approach to the Lubrication of Concentrated Contacts,* P. M. Ku, Ed., National Aeronautics and Space Administration, Washington, D.C., NASA SP–237, 1970, pp. 1–26.
2. Bamberger, E.N. "Materials for Rolling Element Bearings," *Bearing Design—Historical Aspects, Present Technology and Future Problems*, W.J. Anderson, Ed., ASME, New York, 1980, pp. 1–46.
3. Anderson, W.J., E.N. Bamberger, W.E. Poole, R.L. Thom and E.V. Zaretsky. "Materials and Processing," *STLE Life Factors for Rolling Bearings,* E.V. Zaretsky, Ed., Society of Tribologists and Lubrication Engineers, Park Ridge, IL, 1992, pp. 71–128.
4. Stribeck, R. "Reports from the Central Laboratory for Scientific Investigation," Translation by H. Hess, 1907, *ASME Trans.*, Vol. 29, 1900, pp. 420–466.
5. Shaw, M.C. and E.F. Macks. *Analysis and Lubrication of Bearings*, McGraw-Hill, 1949, New York.
6. Wilcock, D.F. and E.R. Booser. *Bearing Design and Application*, McGraw-Hill, 1957, New York.
7. Moyer, C.A., and E.V. Zaretsky. "Failure Modes Related to Bearing Life," *STLE Life Factors for Rolling Bearings,* E.V. Zaretsky, Ed., Society of Tribologists and Lubrication Engineers, Park Ridge, IL, 1992, pp. 47–69.
8. Sadeghi, F., B. Jalalahmadi, T.S. Slack, N. Raje and N.K. Arakere. "A Review of Rolling Contact Fatigue," *Journal of Tribology, ASME Trans.*, Vol. 131, No. 4, Art. No. 041403, Oct 2009.
9. Alley, E.S. and R.W. Neu. "Microstructure-Sensitive Modeling of Rolling Contact Fatigue," *International Jour. of Fatigue*, Vol. 32, No. 5, 2010, pp. 841–850.
10. Lundberg, G. and A. Palmgren. "Dynamic Capacity of Rolling Bearings," *Acta Polytechnica, Mechanical Engineering Series*, Vol. 1, No. 3, 1947, pp. 1–50.
11. Zaretsky, E.V. "Rolling Bearing Life Prediction, Theory, and Application," *Recent Developments in Wear Prevention, Friction and Lubrication*, G.K. Nikas, Ed., Research Signpost, Kerala, India, 2010, pp. 45–136.
12. Lundberg, G. and A. Palmgren. "Dynamic Capacity of Roller Bearings," *Acta Polytechnica, Mechanical Engineering Series*, Vol. 2, No. 4, 1952, pp. 243–247.
13. ANSI/AFBMA 11–1990. "Load Rating and Fatigue Life for Roller Bearings," The Anti-Friction Bearing Manufacturers Association, Washington, DC.
14. ISO 281: 1990(E). Rolling Bearing: Dynamic Load Ratios and Rating Life," International Organization for Standards, Geneva, Switzerland.
15. Zaretsky, E. V. (1997), "Rolling Bearing and Gear Materials," *Tribology for Aerospace Applications*, E. V. Zaretsky, Ed., STLE SP–37, Society of Tribologists and Lubrication Engineers, Park Ridge, IL, 1997, pp. 325–451.
16. Carter, T.L., E.V. Zaretsky and W.J. Anderson. "Effect of Hardness and Other Mechanical Properties on Rolling Contact Fatigue Life of Four High-Temperature Bearing Steels," NASA TN D–270, National Aeronautics and Space Administration, 1960, Washington, D.C.
17. Parker, R.J. and E.V. Zaretsky. "Rolling Element Fatigue Lives of Through- Hardened Bearing Materials," *Journal of Lubrication Technology*, Vol. 94, No. 2, 1972, pp. 165–173.
18. Zaretsky, E.V., R.J. Parker and W.J. Anderson. (1982), "NASA Five-Ball Fatigue Tester: Over 20 Years of Research," *Rolling Contact Fatigue Testing of Bearing Steels*, J.J.C. Hoo, Ed., ASTM STP–771, ASTM, Philadelphia, PA, 1982, pp. 5–45.
19. Bamberger, E.N. and E.V. Zaretsky. "Fatigue Lives at 600° F of 120-Millimeter-Bore Ball Bearings of AISI M–1 and WB–49 Steels," NASA TN D–6156, National Aeronautics and Space Administration, 1971, Washington, D.C.
20. Zaretsky, E.V. "Selection of Rolling Element Bearing Steels for Long-Life Application." J.J.C. Hoo, Ed., *Effect of Steel Manufacturing Processes on the Quality of Bearing Steels*, ASTM STP–987, ASTM, Philadelphia, 1988, pp. 51–43.
21. Clark, J.C. "Fracture Failure Modes in Lightweight Bearings," *Journal of Aircraft*, Vol. 12, No. 4, 1975, pp. 383–387.
22. Clark, J.C. "Fracture-Tough Bearings for High-Stress Applications," AIAA Paper, 1985, pp. 85–1138.
23. Bamberger, E.N., B.L. Averbach and P.K. Pearson. "Improved Fracture-Toughness Bearings," AFWAL TR–84–2103, 1985, Avail. NTIS, AD–B094304L.
24. Bamberger, E.N. "Status of Understanding for Bearing Materials," *Tribology in the '80's*, Vol. 2, NASA CP–2300–VOL–2, W.F. Loomis, Ed., National Aeronautics and Space Administration, Washington, D.C., 1983, pp. 773–794.
25. Philip, T.V. "New Bearing Steel Beats Speed and Heat," *Power Transmission Design*, Vol. 28, No. 6, 1986, pp. 43–46.
26. Bamberger, E.N. and J.C. Clark. "Development and Application of the Rolling Contact Fatigue Test Rig," *Rolling Contact Fatigue Testing of Bearing Steels*, ASTM STP–771, J.J.C. Hoo, Ed., American Society for Testing and Materials, Philadelphia, PA, 1982, pp. 85–106.
27. Poplawski, J. V., S.M. Peters and E.V. Zaretsky. "Effect of Roller Profile on Cylindrical Roller Bearing Life Prediction: Part I—Comparison of Bearing Life Theories," *STLE Tribology Trans.*, Vol. 44, No. 3, 2001, pp. 339–350.
28. Poplawski, J. V., S.M. Peters and E.V. Zaretsky. "Effect of Roller Profile on Cylindrical Roller Bearing Life Prediction: Part II—Comparison of Roller Profiles," *STLE Tribology Trans.*, Vol. 44, No. 3, 2001, pp. 417–427.
29. Zaretsky, E.V., D.G. Lewicki, M. Savage and B.L. Vlcek. "Determination of Turboprop Reduction Gearbox System Fatigue Life and Reliability," *Tribology Trans.*, Vol. 50, No. 4, 2007, pp. 225–262.
30. Parker, R.J. and E.V. Zaretsky. "Reevaluation of the Stress-Life Relation in Rolling Element Bearings," NASA TN D–6745, 1972, National Aeronautics and Space Administration, Washington, D.C.

ABB

WINS LONG-TERM SERVICE CONTRACT

ABB has won a long-term service contract from Star Cruises for preventive maintenance of all ABB equipment onboard SuperStar Virgo for the next five years. The approximately $1 million contract (U.S.) was signed in the fourth quarter of 2012 and commenced January 1, 2013. Star Cruises, the world's third largest cruise company, has led cruise development in the Asia-Pacific region, where it operates seven vessels between the ports of Singapore, Port Klang (Malaysia) and Hong Kong. Star caters to Asian passengers as well as to North Americans, Europeans and Australians interested in Asian destinations. Its energy saving program has given Star Cruises a best-in-class status in the cruise industry.

"A lot of effort and time has been put into coordinating several small service providers to do the maintenance of Star vessels," says Mikael Mattsson AVP marine operation,

Star Cruises. "Through this service agreement, ABB becomes our sole service provider for equipment such as rotating machines, switchgears, transformers, drives, automation, etc., considerably optimizing the maintenance process."

"The market is looking for ways to increase safety and uptime of vessel operation while extending the lifecycle of their assets and making costs more predictable," said Heikki Soljama, head of ABB's marine and crane business. "ABB has responded very successfully to this demand with a wide range of service agreements that provide security to our customers' operations and business. In ABB, this has been the basis for building long-lasting and trusting relationships with ship managers and ship owners."

The service contract covers periodic maintenance visits, scheduled when they least disturb SuperStar Virgo operations. A long-term approach to maintenance and reduction in the variable costs caused by maintenance-related actions make budgeting more predictable. Additionally, the contract ensures effective communication and transparency between Star ship-management and ABB engineers.

Amann

BECOMES BOSCH REXROTH BOARD MEMBER

Dr. Rolf-Dieter Amann, 54, was named Bosch Rexroth AG board member, effective April 1, 2013, succeeding Dr. Georg Hanen. After ten years on the Rexroth executive board, Hanen will move to the Bosch Management Support GmbH management board at the end of March. Amann will assume responsibility for purchasing, logistics, commercial tasks and personnel. Amann has served as commercial plant manager at Bosch Rexroth since 2006 – first in the hydraulics division and then for industrial applications. After studying economics and earning a doctorate in political science in Mannheim, he started as a trainee at Bosch in 1989. He then went on to serve the Bosch Group as commercial plant manager in Göttingen, as head of controlling at the plant in Cardiff (U.K.), and as CFO at Lenksysteme GmbH. Hanen, 59, has been a member of the Bosch Rexroth AG executive board since 2002. After holding several positions within the Bosch Group, Hanen worked abroad in the late 1980s as the commercial manager for three Bosch plants in Spain. Before moving to the Bosch Rexroth AG executive board, Hanen, who holds a doctorate in business administration, led the planning and controlling corporate department at Robert Bosch GmbH for four years.

QTC

DONATES AUTOMATION COMPONENTS TO CALIFORNIA STATE

Quality Transmission Components announced the donation of various industrial automation components to the California State University at Pomona Solar Boat student team, enabling the students to better learn about alternative designs for use in the concept building of an alternative fuel vehicle.

"We welcome the opportunity to support up-and-coming engineers in these types of engineering endeavors. The students not only put to use the engineering skills that they will need when they enter the workforce, but they also learn about teamwork and invaluable communication skills which are sometimes overlooked in a technical education," said Brian Dengel, assistant vice president and general manager at Quality Transmission Components. The students

at Cal Poly Pomona will benefit from the team building that a project like the Solar Boat requires. With Quality Transmission Components donating these components, the students can avoid spending their time on fundraising, resulting in more time being spent refining their designs and preparing their written reports.

Maxcess

RECEIVES CLEANER PRODUCTION ENTERPRISE AWARD

Maxcess received the Cleaner Production Enterprise award for its Chinese manufacturing facility. Maxcess China is the only company in the Zhuhai Free Trade Zone, and one of only four companies in all of Zhuhai, to earn such status. "We have worked to be environmentally friendly since the very beginning of Maxcess China," said Robert Liu, general manager of Maxcess China. The Cleaner Production Enterprise award program is managed by The Economic and Information Commission of Guangdong Province and Guangdong Provincial Science and Technology Department to recognize continuous improvement by companies to reduce pollution

in the manufacturing process and reduce or eliminate potential harm to people or the environment. Companies are scored by a professional audit group in the areas of continuous improvement; use of clean energy and raw materials: use of advanced technology and equipment,; reduction of pollution, : and efficient use of resources and the reduction or elimination of manufactured products or services that generate pollutants . "This positive acknowledgement from our government further strengthens our commitment to continue clean manufacturing processes, making a positive contribution to our customers, our region, and our Earth. Being a good corporate and global citizen is a basic principle for all of Maxcess," adds Liu.

C&U Americas

JOINS BSA AND PTDA

C&U Americas, the North American subsidiary of The C&U Group, China's largest bearing producer, and the 11th largest bearing maker in the world, has taken another major step in building an even stronger C&U Bearings brand and presence in the U.S. by becoming a member of the Bearing Specialists Association (BSA) and the Power Transmission Distributers Association (PTDA). The announcement was made by William A. Childers, president of C&U Americas, who noted that with the continued growth of economic globalization, the company's key goals are to become one of the top 10 bearing suppliers worldwide and to make a greater contribution to the bearing industry.

Timken

ACQUIRES WAZEE COMPANIES LLC

The Timken Company recently announced its acquisition of the assets of Wazee Companies, LLC, a regional leader providing motor, generator, wind and industrial crane services to diverse end markets including oil and gas, wind, agriculture, material handling and construction. The addition of Wazee to The Timken Company's process industries segment further expands the footprint of the Timken industrial services business. Based in Denver, Colorado, Wazee had trailing 12-month sales through December 2012 of approximately $30 million. The acquisition brings Timken additional diversified services including motor rewind, generator rebuild, electric controls, industrial bridge cranes and uptower wind maintenance and repair, operating from four western U.S. locations. "We continue to focus our strategy on further diversifying the Timken services portfolio," said Carl Rapp, vice president of industrial services for Timken. "Wazee complements our industrial repair capabilities at existing customers and takes us into critical motor and generator services."

Igus

LAUNCHES MANUS COMPETITION

Plastic plain bearing specialist Igus has launched its Manus competition for the sixth time. The international competition has taken place every two years since its inception in 2003. The last contest, which ran in 2011, received over 300 entries from all over the world. The Manus competition seeks innovative and challenging applications that use self-lubricating, maintenance-free polymer bearings to improve

technology and reduce costs. Winners will receive cash prizes totaling over $11,000.

Machine safety is one area that can be improved by installing dry-running plastic bearings. According to a study from MIT, machine stoppages resulting from insufficient lubrication total up to 240 million dollars in the United States alone. Today, metal bearings that require oil are frequently replaced by lubrication- and maintenance-free plastic bearings. It's easy to enter this year's Manus contest: The judging panel — comprising technology professors and editors-in-chief — require a short description of the polymer bearing application, an explanation of the problem the bearings solved, and accompanying photos or drawings. Applications using all-plastic or plastic-compound bearings are permitted, but not applications that use bearings coated in plastic. Those interested can enter at *www.igus.com/manus*. Entries must be received by February 28, 2013.

QA1

HIRES SALES MANAGER OF MOTORSPORTS

QA1 recently hired Dan Voight as the sales manager of motorsports. Within this role, Voight will work closely with QA1 dealers on product awareness, sales training and inventory management. He will also play an important part in developing new business partners along with maintaining existing relationships in the motorsports industry. "I enjoy every aspect of this business, but my number one goal has always been to meet or exceed the customer's satisfaction," said Voight. "With QA1, I am looking forward to working with many familiar faces as well as building new business relationships that make up our broad and ever expanding customer base." Voight brings nearly 30 years of motorsport industry experience ranging in all aspects of business operations including distribution account management, sales, tech support, marketing, product development and manufacturing. He has extensive experience working closely with and meeting the demands of weekend racers as well as top NASCAR teams.

"We are very excited to bring Dan on board," said QA1 Executive Vice President Melissa Scoles. "He has a great deal of industry knowledge and experience, and we know he will be a great addition to the QA1 team." In addition to family time, Voight enjoys working on his 1955 Chevy 210 Delray post coupe and riding his vintage metric sport bikes.

Motion, Drive and Automation at Hannover Messe 2013

Motion, Drive and Automation returns to Hannover Messe in 2013 (all photos courtesy of Deutsche Messe)

Power transmission and motion control companies will be on-hand during Hannover Messe 2013 to display the latest technology offerings in key product categories including roller bearings, gears, pumps, motors, transmissions, drive system components, clutches and braking systems. The Motion, Drive and Automation Fair, along with neighboring MobiliTec and Wind fairs, will 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 quick look at some of the key exhibitors that will be displaying products and technologies at the MDA Fair at Hannover Messe (April 8–12, 2013):

Baldor Electric Germany

Hall 15, Stand F01/Hall 24, Stand D23

Baldor (a member of the ABB Group) offers industrial electric motors, mechanical power transmission products, drives and generator sets. The company sells to distributors and OEMs in more than 70 countries with products produced in the United States, Canada, England, Mexico and China. ABB has a full range of NEMA motors by Baldor. The ABB NEMA cast iron motor is a cost-efficient, high voltage induction motor that can be delivered within days of ordering. The motor is suitable for the serial OEM who requires a standard product, the electrical and mechanical properties of which do not need to be altered (*www.baldor.com*).

Rexnord Industries

Hall 14, Stand H56

Rexnord (headquartered in Milwaukee, Wisconsin) is a worldwide industrial company comprised of two strategic platforms: Process & Motion Control and Water Management. The company designs, manufactures, markets and services highly engineered mechanical components used within complex systems where reliability requirements and the cost of failure or downtime are extremely high. Business units include power transmission, chains, couplings, bearings and gears (*www.rexnord.com*).

SEW-Eurodrive

Hall 15, Stand F10/Open-air site (FG), Stand M11

Product solutions and drive systems exist at SEW-Eurodrive with its universal concept of gearmotors, control systems, software, service and accessories. SEW gearmotors are developed and produced in-house with custom-

ized electronic solutions for optimum flow. This setup gives developers, designers and planners of systems and projects the drive solution from a single source (*www.seweurodrive.com*).

R+W Antriebselemente

Hall 25, Stand C30

R+W offers flexible shaft couplings, motor couplings and line shafts for any precision application: backlash-free torque limiters, torsionally rigid metal bellows couplings, vibration damping elastomer jaw-type couplings, compact miniature couplings, flexible servo couplings, axial zero backlash linear couplings and high quality line shafts. These couplings are wear- and maintenance-free and serve a variety of industries including machine construction, servo drives, medical, aerospace, marine, renewables, mining, pumps and compressors, transportation systems and steel (*www.rw-kupplungen.de*).

Sumitomo Cyclo Drive

Hall 25, Stand B03

Sumitomo Cyclo drives are unique to traditional gear mechanisms, since they operate only with rolling force and are not exposed to shear forces. By comparison to gears with contact loads, Cyclo drives are more resistant and can absorb extreme shock loads by means of uniform load distribution over the power transmitting components. Cyclo drives and Cyclo drive geared motors are characterized by their reliability, long service life and efficiency, even under difficult conditions (*www.sumitomodriveeurope.com*).

Bosch Rexroth

Hall 23, Stand C19

Bosch Rexroth AG offers premium drive and transport solutions that compete on an international scale for a wide variety of machines and systems. Virtually noise-free inverted tooth chains, also known as "silent chains," as well as the low-friction 2-pin, form the technological basis for this range. Rexroth offers high-performance, reliable chain drives. In the area of drive technology, these drives guarantee high-precision functioning in diverse applications at speeds of up to 50 m/s (*www.boschrexroth.com*).

WEG Electric Motors

Hall 15, Stand F11

Designed for controlling squirrel cage three-phase induction motors, the new CFW700 is a general-purpose drive that gives customers the flexibility needed for the control of applications ranging from simple speed control to more demanding ones such as torque control. Since it is included on its control, the CFW700 features sensorless and closed-loop control as a standard feature (factory built). By using the internal micro PLC (SoftPLC factory built), more sophisticated applications like overhead cranes, PCPs (Progressive Cavity Pumps), pump jacks and many more can be implemented (*www.weg.net*).

Dunkermotoren

Hall 15, Stand H39

The Dunkermotoren BG range of brushless, direct current motors (EC motors) are notable for long life, high efficiency and a wide speed range. These electronically-commutated DC motors can be combined with control electronics, gearboxes, and encoders in a modular system to provide a flexible, adaptable, market-oriented solution. Additionally, Dunkermotoren presents DC servomotors with Profibus DP Interface. The manufacturer of drive solutions is expanding its product range with the well-established Interface Profibus DP V1 (*www.dunkermotoren.com*).

SKF Group

Hall 22, Stand B12

Developed for stop/start and other electrically driven systems, SKF Rotor Positioning Bearings feature a high-performance magnetic impulse ring clamped to a high-speed, high-temperature bearing. The bearings generate strong magnetic impulses related to rotor angular position. Thanks to their high magnetic field strength, the units offer robust performance under severe running conditions. Additional products at Hannover include engine seals, solar linear actuators, electric cylinders, deep groove ball bearings, roll line units and energy monitoring equipment (*www.skf.com*).

For more information on the MDA fair or information on the 10 other leading trade fairs at Hannover Messe in 2013 including Industrial Automation, Energy, Wind, Mobilitec, Digital Factory, ComVac, Industrial Supply, Surface Technology, Industrial GreenTec and Research and Technology, visit *www.hannovermesse.de*

March 5–6— 2nd International VDI Conference: Maintenance of Wind Turbines. Hamburg, Germany. Wind turbines have an expected service life of some 20 years. However, manufacturers' liability mostly covers only the initial two to five years of operation. But systems will age, so operators must ensure technical support for maintenance needed in their wind turbines. A pro-active service and maintenance concept is one of the major success factors governing system availability of a high level in any machinery or plant. The conference will focus on issues like which promising maintenance concepts are available and what are their associated costs and risks. Experts will highlight major mechanisms causing structural damage or difficulties in the operation of wind power plants. Expert presenters will come from various renowned companies to report on the maintenance of electrical components and systems in wind turbines, present a comparative study on concepts for offshore maintenance, and demonstrate asset integrity management. For more information, go to *www.vdi.de/maintenance*.

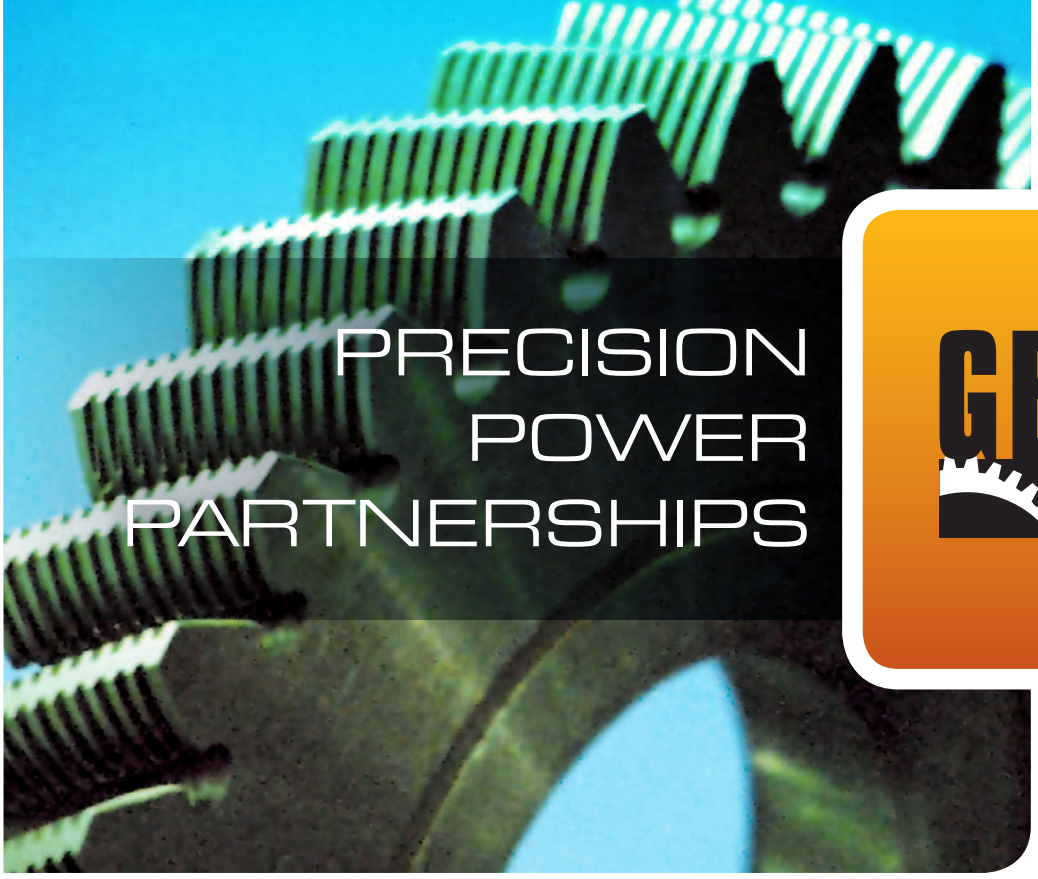
March 12–14—Gearbox CSI: Forensic Analysis of Gear and Braking Failures. Hyatt Regency Baltimore, on the Inner Harbor, Baltimore, Maryland. Determining the cause of failure in a gearbox is like a "whodunnit" mystery. What caused the failure: The bearings, a gear, the lubrication or a shaft problem? Where do you start, and how can you tell? Instructors Raymond Drago and Joseph Lenski, Jr., from Drive Systems Technology, Inc., will help gear designers gain a better understanding of various types of gears and bearings. Learn about the limitations and capabilities of rolling element bearings and the gears that they support so you can properly apply the best gear-bearing combination to any gearbox, whether simple or complex. A certificate will be awarded upon completion of the seminar. For more information, visit *www.agma.org*.

March 20–21—Gear Forum International 2013. Parma Exhibition Center, Parma, Italy. Opinion leaders, international buyers of gears and gear suppliers will meet to talk about issues regarding the future of gears, including expectations and solutions. The event is coordinated by an international steering committee chaired by Prof. Carlo Gorla, of the Mechanical Department of Politecnico di Milano and technical director of *Organi di Trasmissione*, and represented by leading experts of the gear sector that will discuss research trends, standards, present and future trends in the United States, worm gear performance, software and simulation for gears and automotive power transmission efficiency. Speakers include Prof. Dr. Ing. Karsten Stahl, director of Technische Universität Munchen; Charlie Fischer, vice president-technical division of the American Gear Manufacturers Association (AGMA); Michael Goldstein, publisher and editor-in-chief of *Gear Technology* magazine; Michel Octrue, president of Centre Technique des Industries Mécaniques; Dr. Ulrich Kissling, technical director and purchase manager of KISSsoft; and Andrea Piazza, transmission and hybrid design and testing department manager for Fiat Power Train. The event will be held within MECSPE, the international fair on technologies in the mechanical and subcontracting sectors. For more information, visit *www.senaf.it/MECSPE/home/117*.

March 21–23—PTDA Spring Leaders Conference. PTDA Spring Leaders Conference. Hotel Contessa, San Antonio, Texas. The three components of the Spring Leaders Conference include governance meetings for PTDA committees, the Leadership Development Conference and a General Educational Session. Kevin Boyle, president of Industrial Distribution Consulting, LLC, will present a three-hour interactive workshop focused on the power transmission distribution channel. Randy Disharoon, strategic account manager of Rexnord Industries, LLC will present a workshop on developing leaders in the PT/MC distribution sales channel. For more information, visit *www.ptda.org*.

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. 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 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. For more information, visit *www.sme.org*.



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Before There Were Bar Cars

"There is more poetry in the rush of a single railroad train across the continent than in all the gory story of burning Troy."

— Joaquin Miller,

pen name of American poet Cincinnatus Heine Miller, "Poet of the Sierras"

The history of railroading—here in the U.S. and around the world—is a saga of epic proportions: North meets South; Ocean meets Ocean. Track and trains and the locomotives that power them have long held Americans' fascination and fancy.

Here is a brief take on some of the earliest locomotive "prototypes." Most of these early "Iron Horses"—and the engineers who designed them—were derided in their day. But as the old saying goes—It's not where you start; it's where you finish that counts.

The information here is provided by Angus Sinclair (1841—1919), Scotsman émigré, writer, engineer and life-long railroader who attained greatest prominence as publisher, editor and scribe of the Bible-as-journal *Railway and Locomotive Engineering—A Practical Journal of Railway Motive Power and Rolling Stock* (find it on *Amazon* starting at $19), who states it much more eloquently.

"The man who ventures to stray from the familiar beaten path may stumble into a quagmire, but he may have the good fortune to discover a vein of rich ore which the beaten path would never reveal. When an inventor scorning the common forms proceeds to work out new and original shapes for himself, he may produce something which is ridiculous and impracticable. But even when he does that, the enterprising person deserves praise, for it has been by departing from other people's lead that new and original inventions have been given to the world."

Sinclair sailed to America in 1883 to accept a writing position offered him by the prestigious *American Machinist,* then the engineering tome of record. In 1887, *American Machinist* began publishing *Locomotive Engineering* under Sinclair's stewardship as its assistant editor. Just a year later, Sinclair was appointed secretary of the American Railway Master Mechanics Association, a position he held until 1896. In 1892 Sinclair partnered with his boss (managing editor) at *Locomotive Engineering* to buy the journal from *American Machinist*, Sinclair eventually assuming sole proprietorship five years later.

Our space is limited, so let's cannonball ahead to brief summaries of a number of Sinclair's published comments on the various locomotive "designs" of railroading's "getting the bugs out" days, and their manufacture—most of which were abject failures on any number of levels.

Angus Sinclair writes:

"**William Brunton's *Mechanical Traveller*** locomotive attempted to emulate mechanically the action of the horse, and was duly built to put that idea in practice. One day that it was on trial, rushing along at a speed of three miles an hour, accompanied by a host of admirers, the boiler exploded, throwing hot water, pieces of iron and disaster among the crowd, ending the career of the *Mechanical Traveller*."

"The **(Liverpool and Manchester) *Caledonian*** displayed a weakness for jumping the track; serving railway development only in emphasizing the mistake of using vertical cylinders.

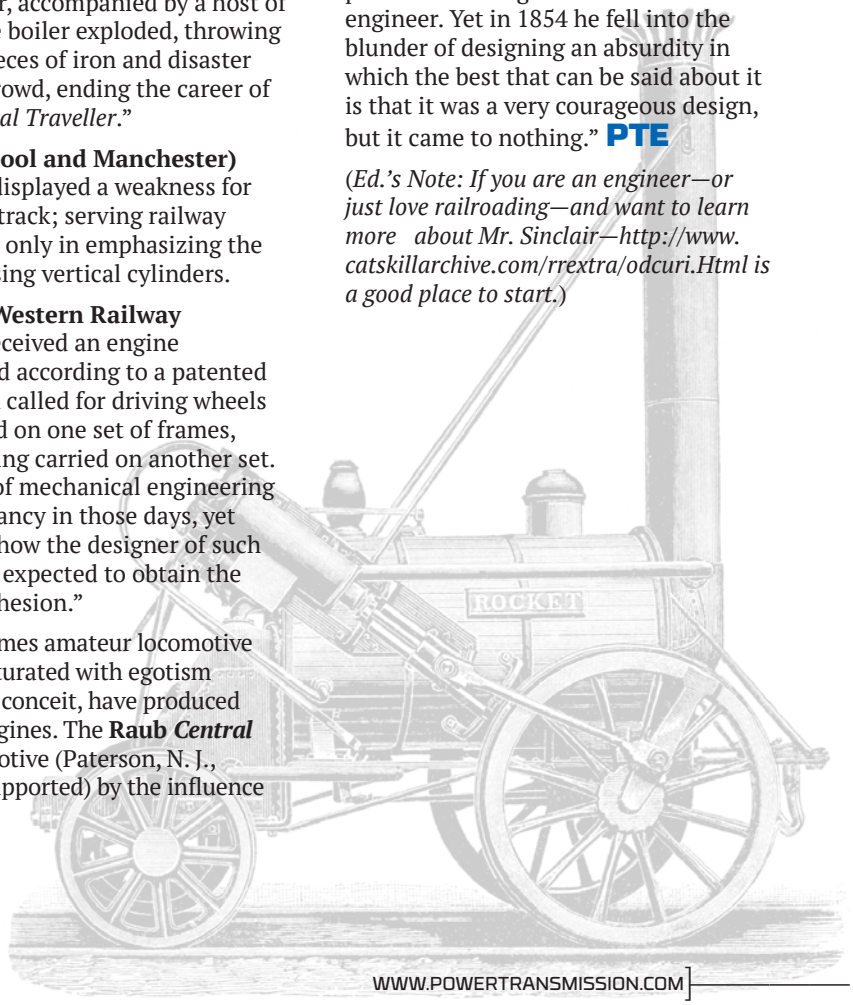
"The **Great Western Railway (England)** received an engine manufactured according to a patented design which called for driving wheels being secured on one set of frames, the boiler being carried on another set. The science of mechanical engineering was in its infancy in those days, yet one marvels how the designer of such a locomotive expected to obtain the necessary adhesion."

"At various times amateur locomotive designers, saturated with egotism and personal conceit, have produced ridiculous engines. The **Raub *Central Power*** locomotive (Paterson, N. J., 1892) was (supported) by the influence of sensational articles in the daily newspapers, their claims for speed and efficiency being senseless exaggerations. This engine was not only an oddity—it was a fake of the worst kind, a product of combined ignorance, egotism and perversity."

"The **Holman Locomotive Company** had a locomotive built that was immediately assailed by practical railroad men and others. My opinion: It is a humbug. It is sound engineering to hold that every piece added to a machine—after it has reached the practical stage—is a source of weakness. (The specified) locomotive design would be proposed only by one who is densely ignorant of mechanics."

"Some of the locomotives designed with a special view to securing low center of gravity are curious. **Zerah Colburn** was a sensible railway man with a good practical training as a mechanical engineer. Yet in 1854 he fell into the blunder of designing an absurdity in which the best that can be said about it is that it was a very courageous design, but it came to nothing." **PTE**

(Ed.'s Note: If you are an engineer—or just love railroading—and want to learn more about Mr. Sinclair—http://www.catskillarchive.com/rrextra/odcuri.Html is a good place to start.)



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