June 2009

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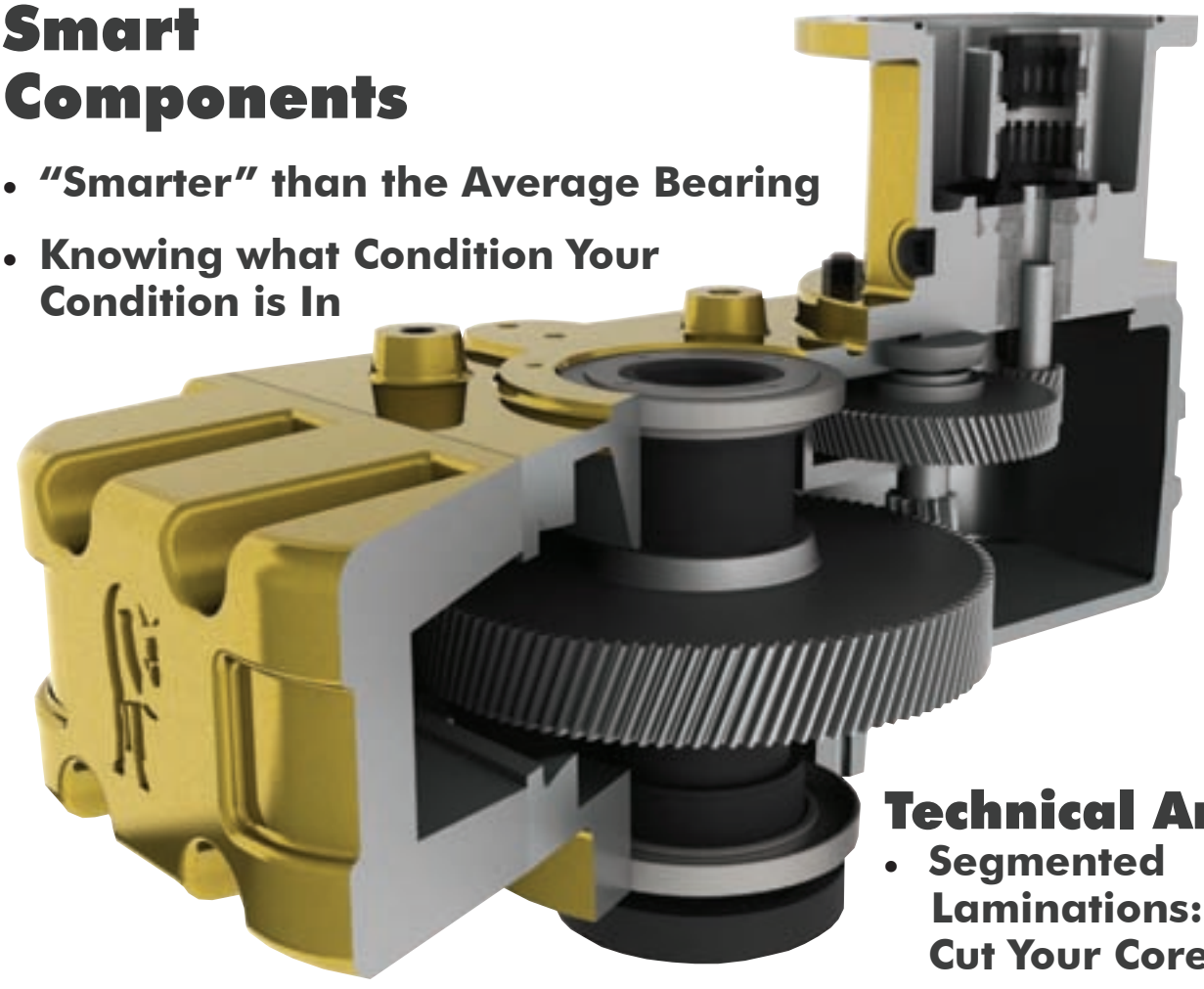
- Knowing what Condition Your Condition is In



Technical Articles

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- Hydraulic Applications Get a Jolt

Power Play

- It's Not Just Directors that Control the Camera

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5 hp 575V	$470.00 GS2-55P0		$1,030.00 22B-E6P6N104

All prices are U.S. list prices. AutomationDirect prices are from April 2009 Price List. Allen-Bradley prices taken from http://shop.rockwellautomation.com December 2008. Prices and specifications may vary by dealer and configuration. Prices subject to change without notice. * Includes sensorless vector control - least expensive series with 575V capability.

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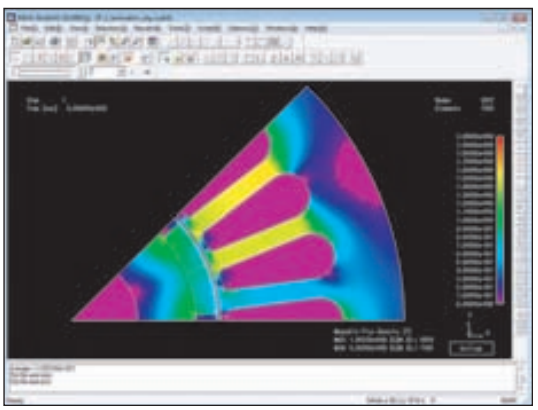
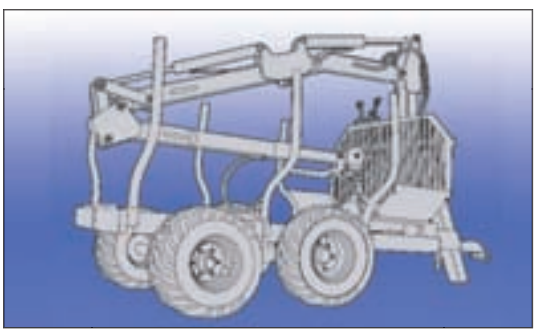


TECHNICAL ARTICLES



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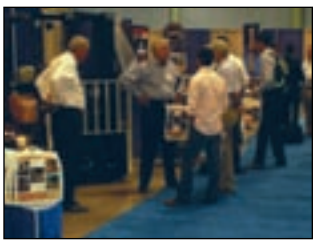

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New Boston Gear Stainless Steel 700 Series speed reducers are optimized for washdown applications.

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Boston® Gear

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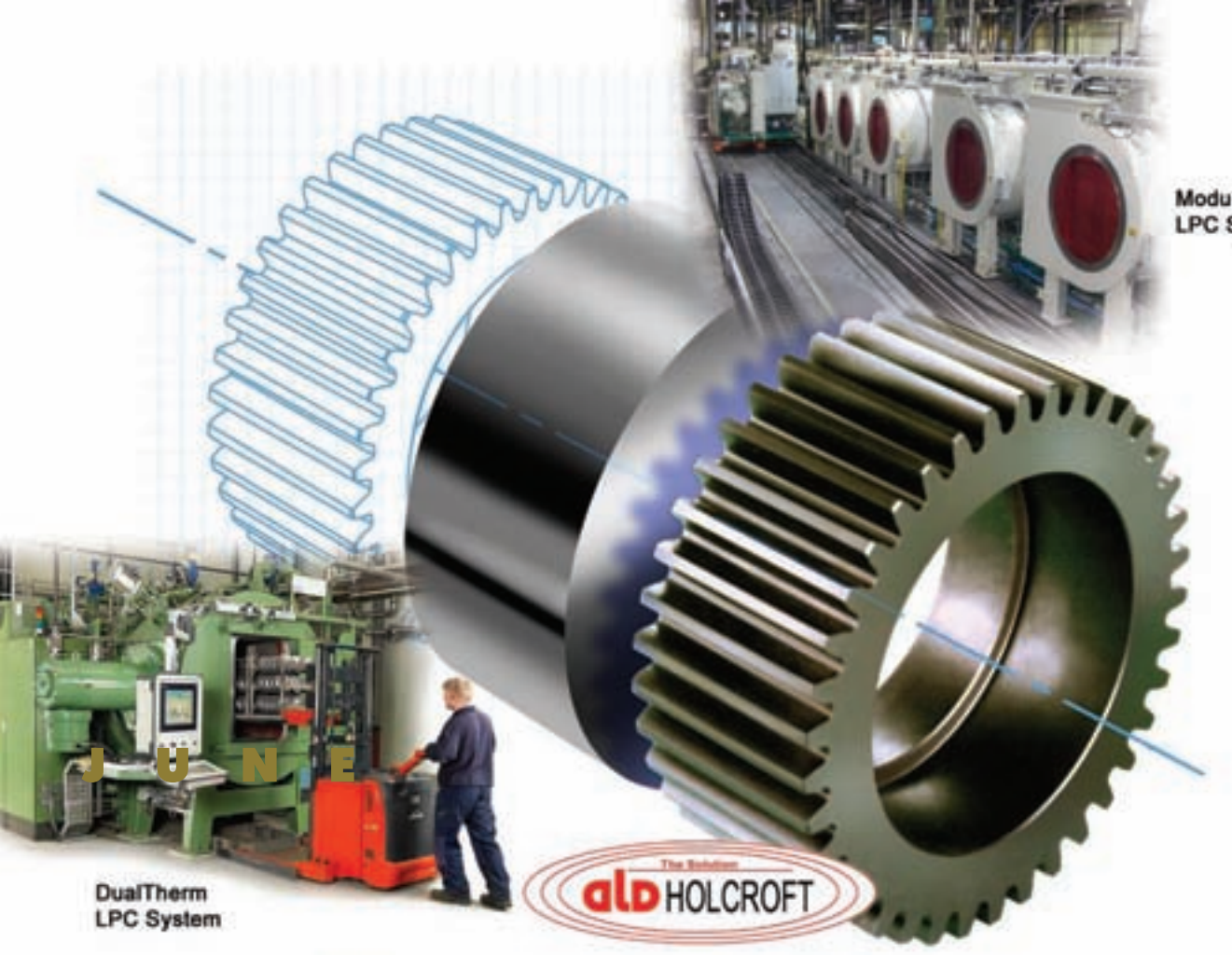
Cover photo courtesy of Big Ass Fans.



Yes. ModulTherm

is a powerful gear design tool from ALD-Holcroft

ModulTherm® is a low pressure carburizing (LPC) system that allows engineers to design out problems like intergranular oxidation (IGO), post heat treat machining, and poor surface finish. It gives gear designers unparalleled control over alloy selection, heat treatment, quenching, and end product performance.

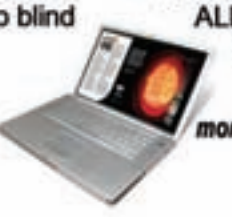
What's unique about the ALD-Holcroft system is multiple quench options. In addition to 20 bar high pressure gas quenching (HPGQ), ModulTherm systems provide oil, water, and press quench capabilities. With this versatility, gear designers can work with low and high alloy steels without sacrificing strength and fatigue resistance.

ModulTherm gear design benefits include alloy flexibility, no IGO, no decarburization, little or no part distortion, and excellent root and deep blind hole penetration.

ModulTherm gear manufacturing benefits include quench flexibility, the industry's largest vacuum chambers, 15 to 25% shorter cycle times than atmosphere furnaces, part-to-part consistency, less machining, less destructive testing, lower product costs, and a low Green House Gas emission profile.

ModulTherm installations are fully integrated, fully automated systems with up to 20 vacuum chambers. Lower volumes are handled by DualTherm®, a dedicated LPC/HPGQ system.

ALD-Holcroft Vacuum Technologies Co., Inc. has 80 years of vacuum-based gear processing experience. Our e-mail address is sales@ald-holcroft.com. Our phone number is 248.668.4130. If you design, manufacture, or heat treat gears, call. With an ALD-Holcroft ModulTherm or DualTherm LPC system, everyone wins.



Go to www.ald-holcroft.com to learn more about ModulTherm and DualTherm

Custom-Collaboration

SETS BIG ASS FAN IN MOTION

Anyone who has ever strained a neck muscle checking out the ceiling in a warehouse—or any large, indoor space—notices there are some pretty big fans required to circulate the air. Embracing this concept with its name, the Big Ass Fans Company, of Lexington, KY, produces six- to 24-foot-diameter ceiling fans that use their immense size, not speed, to move massive amounts of air over large spaces. The Powerfoil X, the company's latest brainchild, rolled off the production line in February and features a custom gearbox created in close collaboration with Stöber Drives.

"We wanted to develop the absolute best industrial fan ever built, and it all started with designing the NitroSeal Drive for an incredibly long fan life," says Katie Cecil, marketing communications specialist for Big Ass Fans.

The NitroSeal Drive is a maintenance-free, lubed-for-life, two-stage reduction gearbox featuring Stöber's HeliCamber gearing. The method of cutting this style of gear involves cambering the tooth profile and crowning the lead of the tooth to give the highest possible number of teeth in contact. The gear technology provides minimum wear, low backlash and low noise.

"All the gearing was designed specifically for that gearbox application," says Mike Mitchell, product manager for Stöber. "An air moving device is not just like a general conveyor application where you mount the reducer and it sits there, and it just sees the torque loads of the conveyor belt. You have to have many things come into play.

"There are three gear passes and they're all optimized for that air moving device," Mitchell explains. "The tooth profile, everything was done to optimize for the shocks and torsional effects associated with an air moving device."

The Powerfoil X fan features the NitroSeal gear drive built by Stöber Drives in collaboration with the Big Ass Fans Company (courtesy Big Ass Fans).

Long life, reliability and efficiency were the main concerns in the gear selection. Mitchell cites environmental concerns as part of these design considerations. "We live in a new market, a new evolution, where we want to be green," he says. "The helical gearing that was used for this is very, very efficient; therefore, the reducer runs cooler, it consumes less energy, so all that's good in our environment that's trying to go green."

Mitchell says Stöber always has environmental issues in mind. "We don't even market some of the high energy consuming gears anymore. We have migrated from that into helical gearing—for that reason."

A 2.56" stationary output hollow drive shaft runs through the gearbox. The hollow shaft is 275 percent stronger than a standard solid output shaft,

according to Big Ass Fans, and it allows for stationary piping for integrating electrical functions, such as lighting, cameras, sensors or smoke detectors. This type of shaft is a feature of one other Big Ass Fan model, the Element. "We expect to see this feature in more models in the future, but retrofitting it to older ones is problematic because of the physical configuration of the gearboxes on the older fans," says Rick Oleson, engineering manager for Big Ass Fans.

SKF tapered roller bearings were used throughout the gearbox to support the axial load and at the bottom end of the hollow shaft. The bearings hold 100 percent of the axial load and are approximately 15 percent stronger than traditional ball bearings in this application due to the increased surface area the tapered bearings allow for.

A hub wheel assembly is responsible for attaching the NitroSeal Drive's output shaft to the hub mounting flange. The mounting flange is bolted to the gearbox shaft on one side, and the hub is mounted to the other side of the flange. The hub wheel assembly was included in lieu of a friction coupling, which relies on one piece to expand and hold all the suspended weight.

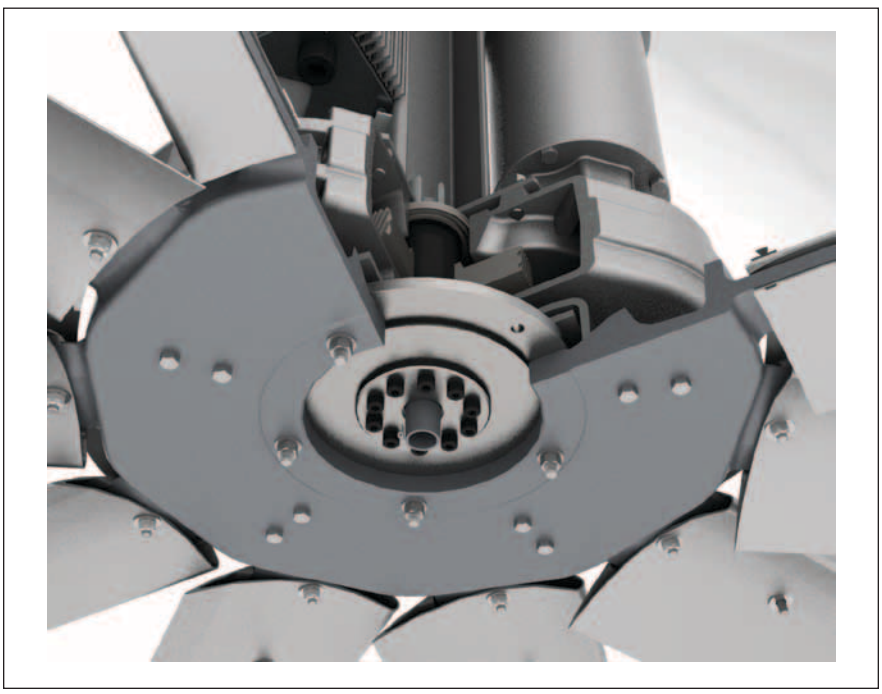
"The friction couplings have proven to offer excellent performance in many thousands of installations, and we continue to use them in a number of models," Oleson says. "In the models with a hollow output shaft, however, the much larger diameter of the shaft lends itself better to the bolted flange interface that we have chosen for the Element and Powerfoil X fans."

The last few steps in production of the NitroSeal Drive include Mobil SHC 630 synthetic gear oil to protect the gears from corrosion and filling the gearbox with nitrogen, prior to hermetically sealing it using Simrit seals. "The final detail was to fill the gearbox with nitrogen before it was sealed, ensuring a perfectly pure internal environment in which corrosion cannot occur," Oleson says.

The hollow output shaft creates a stationary platform for integrating electrical functions, like lights, cameras, motion sensors and smoke detectors.

As this was a custom design, don't expect to find the NitroSeal Drive anywhere but inside a Big Ass Fan. However, Stöber Drives will likely continue to co-develop products for Big Ass Fans judging by the degree of amicable cooperation achieved in this project. "It was multifunctional teams," Mitchell says. "You had your application engineering, product management, your quality people were involved, your design engineering—of course your materials people—and that was from

continued

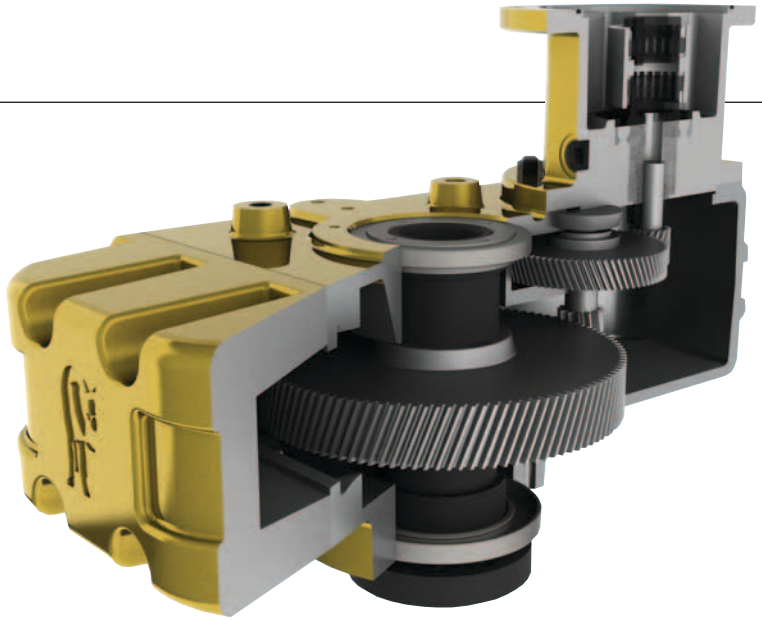


The hub wheel assembly relies on one piece to expand and hold all the assembly weight instead of using friction couplings.

both companies. So we had interactions at all those levels to make sure we packaged a reliable product."

Mitchell and Oleson both commented positively on the collaboration. "It was great," Mitchell says. "We got to hear their requirements; we got to be involved in analyzing, and that way we could properly affect the internal components of the gearbox to meet the aggressive guidelines they were putting out to solve all of their concerns from their customers in the past."

Oleson says, "This is the first time that we have worked with Stöber to develop an entirely new, custom gearbox for our application. We look at this as part of a continuing, ongoing relationship, which will result in more innovations in the future."



The NitroSeal drive features Helicamber gearing, which provides low friction between gear teeth. The drive is filled with nitrogen and hermetically sealed for life, making it maintenance free.

For more information:

Stöber Drives, Inc.
1781 Downing Drive
Maysville, KY 41056
Phone: (606) 759-5090 or
(800) 711-3588
Fax: (888) 478-6237
sales@stober.com
www.stober.com

Big Ass Fans
2425 Merchant Street
Lexington, KY 40511
Phone: (877) BIG-FANS(244-3267)
www.bigassfans.com

Linear/Rotary Platform

COMBINES MATERIAL HANDLING
WITH DIRECT DRIVE, ROTARY MOTION

The LaserTurn 1 is a linear/rotary motion subsystem that integrates automated material handling with direct-drive linear and rotary motors to produce a cylindrical laser processing system that features a high throughput and accuracy. The design targets manufacturing cardiovascular and neural stents.

The system uses a pneumatically actuated type D collet closer with an aperture for product feed-through. The closer holds tubing with diameters from 0.1 mm to 7.9 mm in dry cutting applications and up to 3 mm for wet cutting applications. The closer is "designed to minimize axial tube motion during clamping operations by keeping the collet stationary and moving the tapered mating surface during collet open/close operation," says Byron Fruit, application engineer for Aerotech, Inc. "This minimization of tube motion eliminates the need for some operator intervention during processing, so as to provide a more automated and streamlined process."

The LaserTurn 1 has front and rear tooling platforms with M4 mounting features. They are bolted to the linear stage base to allow a stiff, common inertial frame of reference. This permits fixtures to be attached easily. The LaserTurn 1 is protected from fluids in

wet cutting processing by a sloped, hard cover design.

Both the linear and rotary axes use a direct drive motor and encoder technology. Linear and rotary encoders are coupled directly to the load for high accuracy and repeatability.

The motion subsystem uses Aerotech's A3200 control system, which is completely digital and features FireWire networked drives. The digital construction optimizes current, velocity and position servo loops for performance. "The A3200 controller comes with a powerful software suite, which includes advanced diagnostic and tuning capabilities that allow the user to easily optimize the servo loop gains and view system response through a simple GUI," Fruit says.

The control system is capable of advanced trajectory generation capabilities like multi-block look-ahead, which reduces geometry errors that can occur in tight profiles by regulating cutting speed. The position-synchronized laser firing output feature adjusts laser pulse frequency to match the cutting speed, so optimal laser power coupling is maintained.

With the LaserTurn 1, "Aerotech's goal was to provide a motion subsystem tailored specifically to cardiovascular and neural stent manufacturing in order to provide the highest throughput and performance possible in a compact form factor," Fruit says. "This combination yields the lowest cost of ownership in the industry."

For more information:

Aerotech, Inc.
101 Zeta Drive
Pittsburgh, PA 15238-2897
Phone: (412) 963-7470
Fax: (412) 963-7459

Automation Series Conveyors

FEATURE DRIVES THAT ROTATE TO MOST POSITIONS

The Automation Series AS40 and AS65 low-profile belt conveyors from QC Industries provide high speeds with a single-piece extruded aluminum frame and feature tool-less belt changes, rotate-to-replace drive bearings and the Pivot rotatable drives, which can quickly be rotated to almost any position as application requirements change. The Pivot drives can also be positioned to avoid products on the conveyor belt or obstructions integrated machines cause.

"The drive adds flexibility to the conveyor application," says Chris Round, marketing manager for QC Industries. "In the past, from conveyor manufacturers, we used to have to ask customers, 'do you want it on the left or right? And do you want it top or bottom?' So it would have to be top left, bottom left, top right, bottom right. And you had to ask them, 'OK, are the parts coming towards you?' and you had to really figure all this out. Now you can just say left and right. They can put it at the top, they can put it at the bottom, they can put it straight out.

"One of the additional advantages is they can actually tuck it back up underneath the conveyor. Where in the past, there would be a bunch of drive components hanging outward past the conveyor that would have to be considered as you draw different automation components around this. Those drive parts a lot of times get in the way."

The drive rotates to a new position by loosening two set screws, rotating the drive and retightening the screws. The drive locks into place with a knurled collar. Torque is transferred from the motor to the conveyor's drive pulley by a timing belt inside the guard. The Pivot drives are available on any AS40 end drive conveyor and are compatible with any standard QC Industries AC or DC gearmotor, side rails and guides with both flat and v-guided belts. They are capable of belt speeds up to 400 feet per minute.

The AS65 center drive conveyors fit well with integrated machinery using the below-belt drive that can be positioned at any point along the length of the conveyor.

Belt tension is released by a button release mechanism, so belt changes are made without tools, and under-belt cleaning is simple. Sealed, deep-groove ball bearings are used, which can be replaced easily by rotating and pulling them out.

The single-piece aluminum frame has tee slots for mounting a stand or accessories quickly. The conveyors are 18" wide and up and have a multi-piece aluminum and steel frame. Drive packages have DC and AC motors in both standard- and heavy-duty models with various mounting options. The conveyors are efficient and do not require much torque beyond the initial load at startup, according to the company's news release.

Appropriate belt tracking is ensured by a crowned pulley. V-guide belts are available without changing any of the components. Over 50 belt styles are offered, from multi-purpose and accumulation belts to anti-static and color contrasting specialty belts.

The Automation Series conveyors handle speeds up to 400 feet per minute and loads up to 120 pounds. They come in widths from 2 to 24", lengths from 18" to 13 feet for single-piece frames and 14 to 25 feet for multi-piece frames. The conveyor can extend or shorten as requirements change due to a modular design, and they feature a five-year warranty.

For more information:

QC Industries Conveyors
4057 Clough Woods Drive
Cincinnati, OH 45103
Phone: (513) 753-6000
sales@qcindustries.com
www.qcindustries.com

PMDC Speed Control

MOUNTS TO MOTOR

The TightDrive speed control from Bison Gear was designed for convenience by mounting directly to permanent magnet DC motors up to 1/6 hp (124 W), as opposed to being wired to the motor through an independent cable system. The TightDrive provides a 20:1 speed range and maximum output of 90 V.

The aluminum extrusion housing protects to NEMA 1 (IP 30) and has high heat dissipation. The on/off switch is combined with a speed potentiometer for speed control. Three adjustable potentiometers supply settings for minimum rpm, maximum rpm and current limiting. SCR control architecture allows for tighter speed regulation than alternative controls, according to a Bison press release.

Designed for 115 V 50/60 Hz operation, the TightDrive motor-mounted speed control includes a three-foot power cord and NEMA 5–15P plug. The control can mount to the motor in 90-degree increments for best positioning of the cord exit and motor leads.

"Simple solutions are often the best," says Matt Hanson, Bison Gear vice president of portfolio management. "The new TightDrive enables machine builders to put the control, the power and the gearmotor more conveniently at the point of use, while saving installation time and reducing costs. As a bonus, users can maximize energy savings by easily changing speeds as requirements change."

For more information;

Bison Gear and Engineering Corp.
3850 Ohio Ave.
St. Charles, IL 60174
Phone: (630) 377-GEAR (4327)
info@bisongear.com
www.bisongear.com

Economical Slide

FITS INTO TIGHT SPACES

Techno Inc.'s ZF1 belt drive slide is a lightweight model driven by a 9 mm-wide HTD belt available in travel ranges from 153 mm through 2,853 mm. The low cost belt slide is 30 mm wide with an accompanying carriage 72 mm wide, so it can be placed in tight spaces.

The ZF1 belt drive slides have a maximum speed of 1.5 m/sec, and can be ordered with 200 W (2:1 ratio) or 100 W (2:1 ratio) servomotors; 50 N·cm, 160 N·cm stepper motors; or a 2:1 ratio assembly without a motor. The belt's drive pulley is 19.1 mm in diameter and has a specific mass of 0.0225 kg/m.

"The ZF1 belt drive slide is our most economical option. Customers will receive a slide that is compact, but powerful," says Joe Griffin, linear motion sales manager. "The carriage rides on two precision ground steel shafts that are supported the entire length of travel to minimize deflection, while the HTD belt profile helps to eliminate backlash."

For more information:

Techno, Inc.
2101 Jericho Turnpike
New Hyde Park, NY 11042-5416
Phone: (516) 328-3970
Fax: (516) 358-2576
support@techno-isel.com
www.technoautomation.com

Arched Tooth Profile

IMPROVES DRIVE BELT SYSTEM

The Excel-A-Belt miniature drive belt system from NBK features an arched tooth profile with zero backlash, so the system runs longer, cleaner and quieter. The upgraded tooth profile allows for high accuracy positioning and precise rotation transmission by providing a rolling action between the belt and the drive sprocket. The belt tooth enters and leaves the sprocket in a rocking motion, so contamination from belt or sprocket tooth abrasion and wear is reduced.

The drive sprockets have bore sizes from 3–25 mm and PD's of 17–54 mm, and they come standard for shaft clamping. Four belt widths are available in 3, 4, 6 and 9 mm. The drive system is suited for operation with motors of 10–1,000 W.

For more information:

The Precision Alliance
4215 Pleasant Rd.
Fort Mill, SC 29708
Phone: (803) 396–5544
Fax: (803) 396-7810
dbarnes@tpa-us.com
www.tpa-us.com

Polymer Ball Bearings

WITHSTAND HARSHEST ENVIRONMENTS

The lubrication-free polymer Xiros ball bearings from igus were developed to perform where conventional metal ball bearings are limited by factors like temperature, chemical or moisture exposure. They are technically optimized, available from stock and feature a predictable service life. The ball bearings were developed in response to customer demand.

"We were hearing that while metal ball bearings are suitable for most applications, they sometimes fail in severe environments," says Tom Miller, igus bearings unit manager. "In applications with high temperatures, chemicals or washdowns, metal bearings can corrode and cause contamination leading to costly maintenance and downtime. In washdown applications, the grease and oil used to keep these bearings lubricated can drip onto the machine or anything it is handling. Corrosion is also a problem for metal anytime water or chemicals are present."

The dry running polymer ball bearings don't compare with permanently-lubricated metal roller bearings when considering service life, speed or permissible loads; however, in many applications—such as medical engineering, chemical, food, pharmaceutical, biotechnology and plant engineering—low friction values and minimal driving forces are the basic requirements.

"By combining our extensive knowledge of bearings and tribologically optimized polymers, we are able to offer a ball bearing for the harshest applications," Miller says. "The races and cage

of Xiros ball bearings are available in two material blends, including igus' high-temperature iglide A500, which has good chemical resistance and can operate in temperatures reaching 302 degrees Fahrenheit, and a more economical material for less severe applications. The corrosion-free balls are made from stainless steel, and glass balls are also available for maximum corrosion resistance."

For more information:

igus Inc.
P.O. Box 14349
East Providence, RI 02914
Phone: (800) 521-2747
Fax: (401) 438-7270
www.igus.com

Adjustable Speed Applications

BENEFIT FROM MOTOR, CONTROL'S BRUSHLESS TECHNOLOGY

Baldor Electric Company introduces the BSM25C and BSM33C brushless motors that provide designers with brushless motor benefits like higher torque, more power in smaller packages, reduced maintenance and quieter operation. The motors are available from stock with standard NEMA face/foot mount and ranging from 1/4 to 3 HP (0.18–2.2 Kw).

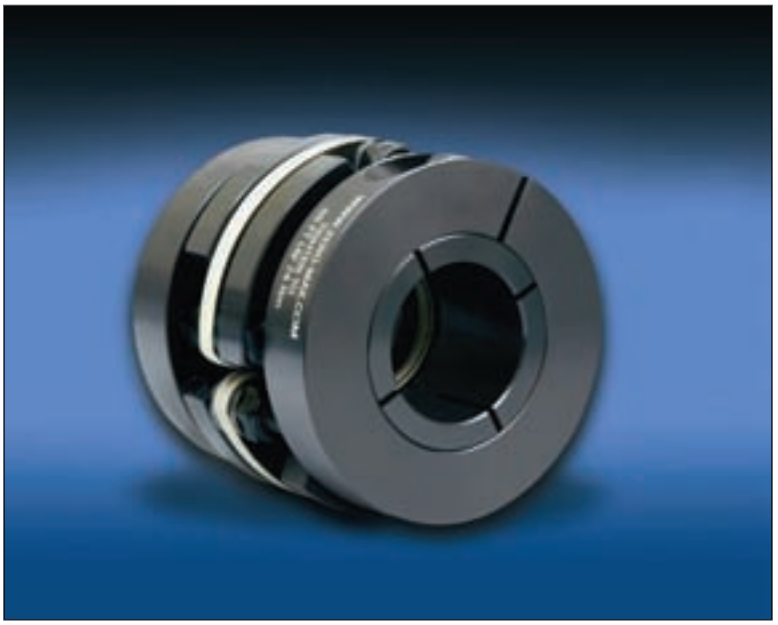
When combined, the BSM motor and BMC control can be adjusted to cover a speed range up to 7,000 rpm, adjustable acceleration time from 0.1–30 seconds, and it comes in a fully protected package that includes motor overload, short circuit and electronic inrush protection. Adjustable speed applications include mixers, blowers, indexers, feeders and conveyors.

For more information:

Baldor Electric Company
5711 R.S. Boreham, Jr. Street
P.O. Box 2400
Fort Smith, AR 72901
Phone: (479) 646-4711
Fax: (479) 648-5792
www.baldor.com

CD Shaft Couplings

HANDLE HIGH STRESS APPLICATIONS



Zero-Max's CD couplings combine high dynamic load capacity and high torsional stiffness for reliable system operations. They are suitable for fixed displacement hydraulic pumps driven by servomotors.

The working part is made of a composite material. The couplings feature a composite disc design that withstands the stress of a servomotor. They are available in single and double flex aluminum hub models with or without keyways. Single flex models have a torque capacity range from 40 Nm to 1,436 Nm and more with speed ratings from 4,400 rpm to 17,000 rpm.

"This new pump drive technology has become increasingly popular because of dramatic improvements in their energy efficiency and noise reduction," says Robert Mainz, Zero-Max sales manager. "These pump systems utilize the power and precision that only a servomotor can provide. The system pressure is controlled by modulating the output volume of a fixed displacement pump. This is made possible utilizing a high performance control system and the high performance qualities of a CD shaft coupling."

For more information:
Zero-Max
13200 Sixth Avenue North
Plymouth, MN 55441-5509
Phone: (800) 533-1731
Fax: (763) 546-8260
www.zero-max.com

Sterilizable Drives

SUIT HIGH-SPEED MEDICAL APPLICATIONS

Maxon Motor launched two sterilizable drives, EC size 5 and EC 13, for use with or without planetary gearheads in medical applications up to 90,000 rpm. The drives exhibit high nominal speed, low noise and low vibration operation, marginal thermal emission and small size.

The two drives are identical and have equal performance data and characteristics. The motor and gearhead of the size 5 version has an outside diameter of 0.5" and a shaft of 0.125". The motor features a servo mount type of motor fixation. The EC13/GP13 version is conveyed in metrics, with an outside diameter of 13 mm, a 3 mm shaft and a flange with three face side threads.

The drives have "personalized outer wrapping," according to the company's press release, but they are depicted by their similarities. They are both ideal for medical design applications, they have a compact design with high nominal speed, quiet running, minimal thermal emission and sterilizability of typically 500 autoclave cycles. They are equipped with either Hall sensors or sensorless and with three different windings. The gearheads come in versions with one, two or three stages and with or without output end shaft sealing.

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"Smart" Bearings are in Control—

BUT FULL POTENTIAL REMAINS UNTAPPED

Jack McGuinn, Senior Editor

To be clear, "smart" bearings—i.e., bearings and sensors integrated into a component to monitor bearing performance—are not new. They've been around for decades, dating back to military applications circa World War II. Since then, they have played a vital role, according to the Bearing Specialists Association (BSA), in the automotive, motion control, robotic control, paper and printing, web processing, wood processing, chemical, textile, agricultural and food processing industries. (*Ed.'s Note: Please see accompanying BSA sidebar on smart bearings.*)

Victoria Wikström, manager of SKF's industry applications segment group, provides some additional historical perspective.

A smart bearing from Dodge (courtesy Dodge Roller Bearings).

"(Smart bearings were developed) for applications where personal damage and safety are key, and the consequences of a bearing failure can lead to serious injury and even fatality, as opposed to 'merely' financial issues. Therefore, bearings in jet engines were first to be monitored by sensors (in flight), and by inspections and oil analyses on the ground. The automotive industry's adaptation of anti-lock brake systems (ABS) is probably the first large-volume sensorized bearings (position sensoring). Railway locomotives and cars have been using temperature warning sensors for some 20 years, even if these were not mounted as an integral part of the bearing but as an add-on through the housing.

"For industrial applications, use of sensorized bearings has not been as widely adopted as the opportunities and available benefits that are out there. But with higher demands on uptime and reducing maintenance costs, it is definitely increasing—load sensing (using strain gages) for paper machines, vibration- and temperature-condition monitoring for many industries, oil quality sensors for gearboxes. Today, for car applications, SKF has working prototypes of load sensing via sensor technology integrated into the wheel bearings."

Darin Davenport, product business manager for Dodge Roller Bearings, adds that in addition to the military applications, "Sensor technology was also likely improved through R&D dedicated to aerospace. We don't have proof of this though. Dodge only started offering smart products in 1995, when we leveraged Rockwell (Automation's) experience." He adds, "Sensor and monitoring capabilities are the primary value added features, but the bearing housings are modified to provide accurate sensor reading and proper sensor mounting."

Given that bearings are often one of the most important components in a machine, system, etc.—and are often one of the first to fail—having a reasonable expectation of their longevity is essential to maintaining peak performance cost. Smart bearings do just that in sensing vibration, temperature, speed, load and debris levels, to name just a few. Taken a step farther, they also are commonly used in industrial applications, in that the sensed data is extrapolated into condition monitoring systems for the monitoring of the aforementioned vibration and temperature issues. (*Ed.'s Note: For more on condition monitoring, please refer to our feature story on page 20.*)

According to the BSA, smart bearings have long played a big role in the automotive industry—in hub units, for example. That anti-lock braking system and traction control in your automobile

are made possible by smart bearings.

Beyond automotive, smart bearings address a host of industrial applications, including the monitoring of speed, temperature (thermocouple) and vibration (accelerometer) levels.

All of which begs the question—can all bearings be "smart"?

"Yes, in principle," says SKF's Wikström, "but it also depends on what parameters are key to monitor. Anything can be basically sensed—the hard part is to know what to sense and what the output signals mean. When, for example, should an increase in temperature be considered dangerous and result in a 'red light' for the user? If occurring once or twice, and without an accompanying increase in vibration, probably not at all. If at the same time as the acoustic emission signal increase—right away.

"It is, however, difficult to use traditional vibration sensors (accelerometers) or temperature sensors and obtain sufficient information in very large, slow-moving bearings (slewing bearings or plain bearings). For these types of applications, one is better off using in-line oil analysis when looking for increasing trends in metallic wear."

Dodge's Davenport concurs that "Depending upon the bearing size, mounting style and housing type, (smart bearings) may be more practical with some (applications) than others."

Given the two distinctly different (yet ultimately compatible) components—sensors and bearings—one might reasonably ask a chicken-or-egg question, i.e., Where does the design for a smart bearing begin—with the bearing manufacturer or elsewhere?

"The design starts with the manufacturer, but it is customer-driven," says Davenport. "Customer needs will dictate the features to monitor, the signal type and the sensor type. Environment and operation will also influence the design."

Asked the same question, SKF's Wikström replies, "Mostly, yes (the bearing manufacturer). Bearings are at the heart of all rotating applications, and rotational speeds, vibrations, forces and moments all go through the bearings in some way or other. Therefore, the bearing is an ideal point to monitor; there are bearings that come pre-sensorized from the factory that measure position and/or speed, temperature and vibration within a given range.

"For application-specific needs, close cooperation and joint product development between bearing manufacturer and machine builder is always a good solution."

Smart bearing technology can also play a central role in predictive facility maintenance. There remain, however, impediments to smart bearing systems in some scenarios.

"Typically, barriers to entry include the costs of the measurement equipment, software and any associated operator training," says Davenport. "These costs will also be related to the types of measurements desired, as well as the quantity and number of bearings intended for smart features. For example, installing a single thermocouple or RTD (resistance temperature detector) onto a bearing housing is fairly simple and the data retrieval and analysis software are fairly straightforward.

SKF's "smart" steering unit for warehouse and off-highway vehicles (courtesy SKF).

"However, if vibration measurements are required, then accurate results will require three accelerometers or velocity pickups per bearing or shaft-mounting location. Additionally, interpreting the results is a bit more complicated than trending temperatures. But vibration analysis provides detail of the entire machine rather than just the trend of temperatures on a bearing. The bearing is simply the most accurate location for obtaining the vibration."

Davenport goes on to explain that any decision to incorporate smart bearings must "weigh the costs of entry against the costs of downtime and costs of product replacement" due to failure, etc. He adds that often a machine component will fail, yet continue to operate and in turn wreak damage on nearby components, thus compounding replacement time and overhaul cost. All of which leads him to conclude, "A good preventive maintenance program will prolong the life of machine components as well as identify components to be replaced prior to a costly, catastrophic failure. Some smart features will also shut a system down upon alerts from the bearing that operation is faulty."

And given those start-up costs, SKF's Wikström points out that "Smart bearings with integrated sensors are not as widely deployed as they could or should be. But externally attached sensors are used in many process and manufacturing plants, as well as in mining, oil and gas, etc. All critical rotating machines are candidates—pumps, fans, motors, gearboxes, machine tool spindles, etc."

Considering for the moment that cost is no object, Wikström lays out a typical scenario for implementing smart technology in a manufacturing facility.

"Step one is to go through which applications in a plant are critical for operations. Usually, it is the 'driveline' applications: a motor, gearbox, coupling system driving a fan, pump or roll. Then, the weak links in these critical drivelines need to be identified—Which part is likely to fail first or most often? Third is to identify what can be monitored on these weakest links and to consider if relevant information (for decision making) would be obtained. Once this is done, the optimum methods for sensorizing can be decided upon—selecting pre-sensorized bearings, mounting sensors in bearing housings, or if it is just as effective and more cost-efficient to make hand-held vibration analysis instruments and/or oil analysis online or in the laboratory. The extent of a retrofit is dependent on the plant size and the above considerations.

"I find it a useful exercise to think, 'What if I knew exactly how the temperature/vibration of this point looked like all the time? What would I do with the information? Would it be data, or would it be information? And how would I make decisions based on that information."

To close the loop, we asked both

continued

contributors for examples of how smart bearings perform a specific function.

Dodge's Davenport cites a mining application in which head pulley bearings are equipped with speed sensors on a bulk material handling transport conveyor.

"A coal transport train is expected to arrive at the mine in two hours when a catastrophic failure occurred on the drive coupling at the head pulley. The speed sensors on the head pulley bearing were able to communicate through a PLC, switch or data acquisition system combined with an alarm to the mine operators. Resources were directed to replace the coupling before the train arrived, saving a $50,000/hr fine by the transportation company."

For another example, Davenport cites a critical exhaust fan in a steel processing plant using a thermocouple/transmitter in tandem with exhaust fan roller bearings.

"Trending data over the last 18 months have yielded bearing temperatures within 10 percent from nominal operating temperatures. Over the last three days, the bearing temperatures have been climbing 15 percent per day. Although these bearings were not scheduled for replacement during the next scheduled downtime, the preventive maintenance manager was able to obtain replacement bearings and include their replacement in the weekend's scheduled downtime. This helped avoid a costly delay in unexpected downtime and extended lead times."

For anyone missing the trend developing here (cost containment), SKF's Wikström offers a couple of examples of her own.

"Paper machines use load sensing to set the roll pressure, and temperature and vibration sensing to ensure all parts of the machine are OK. In a paper machine, all points related to moving forward are key—if one fails, the paper breaks and there is an expensive and undesired stop—a disaster if you are making paper for (or printing) tomorrow's newspaper. Also, because paper mills are among the most efficient plants in the world, vibration monitoring is most often applied and is done on critical drivelines and auxiliary machinery."

Wikström's second show-and-tell

Smart Bearing

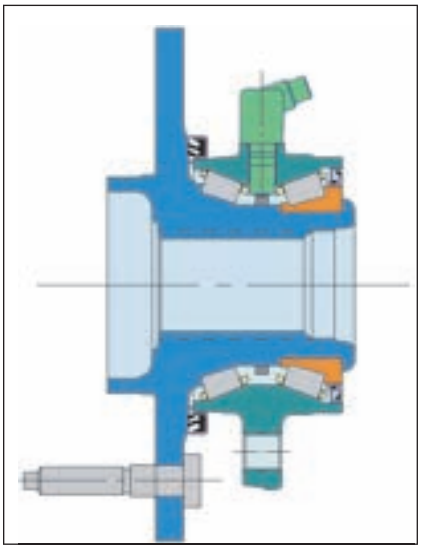

Figure 1—Gen 3 hub unit bearing with speed sensor (courtesy of The Timken Company).

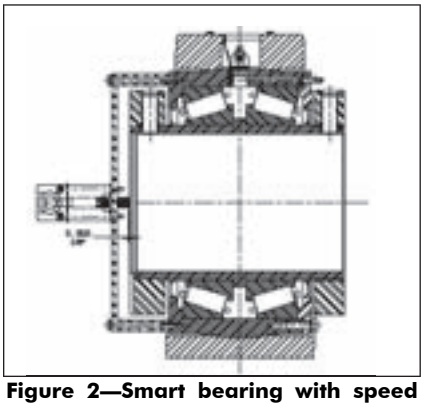

Figure 2—Smart bearing with speed proximity switch (courtesy of Baldor-Dodge-Reliance).

Proper bearing analysis is the key to keeping equipment running efficiently, reliably ,consistently and cost effectively. Monitoring for and preventing costly bearing damage can enhance productivity, ensure peak performance and ultimately affect the bottom line.

Use of "smart" bearing technology is one method manufacturers can use to monitor bearing operation. Smart bearings are instrumented with sensors to provide information about their surrounding environment, including speed, direction, temperature, vibration, load, levels of debris and other factors. The integration of sensors and bearings is what gives smart bearings their name.

Once smart bearings gather the data, they feed it to a control unit that is used to monitor the particular bearing operation. For example, smart bearings used in automotive wheel applications collect speed data used to operate anti-lock brakes.

Further, in industrial applications, the data collected by smart bearings is often matched with condition monitoring programs where being aware of temperature and vibration levels is essential to preventing bearing failures.

Smart bearing technology is used in a variety of industries, including automotive and industrial. Specific applications include, but are not limited to: automotive wheel speed and direction feedback, machine control, robotic control, printing industries, paper converting, web processing, wood processing, chemical production, textile, agriculture machinery and food processing.

Smart Bearing Types

The most popular smart bearings are found in automotive wheel applications. Most automotive "hub unit" bearings commonly include speed sensors which send wheel speed data to the ABS (anti-lock brake system) and traction control units of light vehicles. Figure 1 shows one such hub unit bearing.

In the industrial markets, housed bearing units can be equipped with sensors that monitor bearing speed, vibration, temperature or a combination of all three. Figure 2 shows a smart bearing that is using a speed pickup proximity switch. The speed pickup proximity switch senses the presence of two targets on a special collar or locknut inside the sensorized bearing housing. When a target comes into range the proximity switch closes,

involves the robotics industry.

"Robotic control and electric motors for positioning use position sensors on bearings to know where a shaft is, and for remembering where it was before shutting off power. In the near future, robotic or semi-automated excavators and motor graders will be used, making it possible for less-experienced drivers to reach desired performance levels quicker. In warehousing vehicles, SKF has produced a prototype, called the SKF E-Truck, where all functionality is powered by electric systems and the lift positioning height is displayed on a screen in the driver's cabin by virtue of a sensorized bearing."

Given the evidence to date, it appears that smart bearings provide benefits both documented and yet to be realized.

For further projections regarding smart bearings, we went to the experts.

"Wireless transmission is likely one of the next big steps," says Davenport. "Some sensor manufacturers have already been offering these features, but they are not widespread or (sufficiently) inexpensive as yet. Battery life on wireless transmitters would also need improvement."

At SKF, Wikström has a somewhat guarded take.

"Besides the examples given above, sensorized bearings are still far from being used to the extent that they could be, and the enabling technology is continually developing."

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Technology

allowing the supplied voltage to pass through. The time between the two pulses per revolution may be measured to determine the shaft speed.

Available Sensors

The types of sensors that create smart bearings also range in capabilities and usage. For industrial applications, sensors are available to measure speed, direction, temperature (thermocouple) and vibration (accelerometer).

Condition Monitoring

Manufacturers continue to further explore the benefits and uses for smart bearings in specific applications. Currently, smart bearings are evolving to have the ability to measure bearing system performance and predict the remaining useful life.

Condition monitoring units are yet another option in predictive bearing maintenance technology and can be used in conjunction with smart bearing sensors. Just as sensors are being used to transmit data to a source, condition monitoring units are external devices that can receive data on the operating conditions of equipment to ensure peak performance. Together, these devices can communicate to an operator when critical machine elements have become worn, contaminated, damaged, improperly lubricated or experience a rise in temperature or vibration—all leading to potentially costly downtime and repairs. Figure 3 shows an example of combining smart bearings into a system and feeding data to a PC as part of a condition monitoring program. Smart bearings can send the performance data via wireless or wired arrangements.

As industries continue to grow and develop, additional smart bearing sensor data is needed to more closely monitor proper bearing function, which is so essential to optimal operation. Advancements in bearing technology, including data sharing and maintenance tracking, will continue to be researched and developed for more applications.

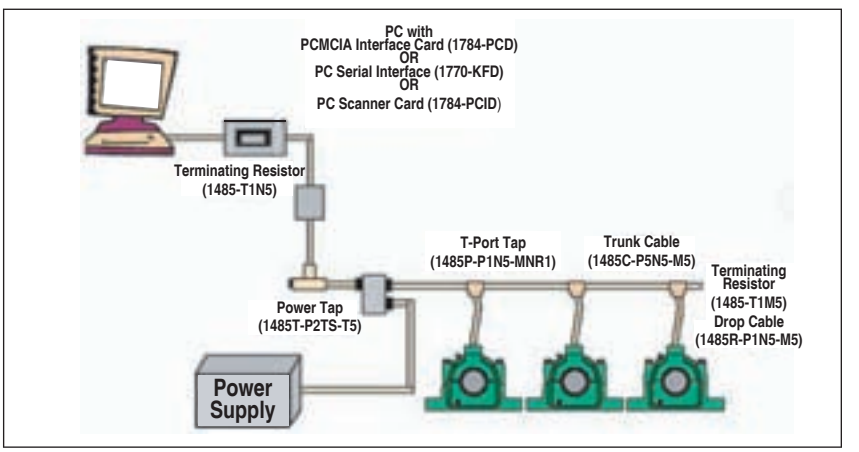

Figure 3—Condition monitoring system set-up (courtesy of Baldor-Dodge-Reliance).

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Neighborhood Watch—

ADVANCEMENTS IN CONDITION MONITORING EQUIPMENT

Matthew Jaster, Associate Editor

The XM series of machinery protection and condition monitoring modules is designed for motors, fans, pumps and blowers (courtesy of Rockwell Automation).

With all the attention given to predictive maintenance, equipment reliability, quality assurance, and machine protection, the future looks promising for the condition monitoring industry. Now more than ever, manufacturing companies are examining what steps need to be taken to ensure improvements to machine reliability by predicting system failures and minimizing downtime. Management wants to maximize profits with a minimal amount of investment in equipment.

The recent economic freefall has made account executives nervous, and they're looking for any reason to cut back programs or technologies that provide less than spectacular results. Though condition monitoring seems like a simple way to keep up with daily operational procedures, skeptics aren't always convinced it's the right investment.

"The traditional process industries have recognized the benefits for decades, to the extent where some are now treating it as a commodity item or service, which is dangerous," says Chris James, business area director for SKF Reliability Systems. "Nontraditional applications are where most reluctance is encountered. The technology is seen as costly to buy and difficult to implement. Vibration analysis, in particular, is seen as something of a black art."

For this reason, many companies are selling and marketing condition monitoring equipment in an effort to change the perception. "Organizations are reluctant to invest due to factors like technology expertise, personnel and understanding," says Scott Johnson, product business manager at Rockwell Automation. "Others are reluctant because they see condition monitoring as an additional equipment cost, but the return of investment is an easy calculation when the equipment helps improve reliability and quality."

Rockwell Automation, SKF and Emerson are three organizations that believe the advancements in condition monitoring will lead to future success in the industry. New training and implementation techniques, integrated monitoring systems and wireless capabilities are just a few of the key developments to keep an eye on.

"Modern digital technology is providing more powerful and physically smaller devices for data acquisition, and

computers are allowing us to process and display this data much better than in the past," James says. "This trend is bound to continue."

Handheld vibration sensors, for example, are available at SKF for use with portable data-collectors. The elimination of the flexible coiled cable normally used with these systems can help the user simply from an ergonomics perspective. Additionally, it removes the risk of the cable getting caught in guards or rotating components.

"The health and safety police like that a lot," James adds.

Handheld, wireless monitoring devices are getting faster and more productive at a time when many customers are under pressure to cover more data with less manpower.

"The low installation cost of wireless systems allows customers to partially automate some of their programs to better meet their efficiency goals," James says.

Wireless systems offer other advantages as well, including the ability to apply data collection to areas where wired systems are either difficult or impossible to install (e.g. moving vehicles).

"Wireless vibration devices have been around for years," says Todd Reeves, product manager for machinery health transmitters at Emerson. "The challenge has been the fragileness of the wireless networks of the past and the security vulnerabilities."

Emerson uses the WirelessHART standard which is based on the Highway Addressable Remote Transducer (HART) standard, a network protocol developed by the HART Communication Foundation that enables interoperability with other HART devices whether they are produced by Emerson or someone else. Adherence to the WirelessHART standard enables a robust, self organizing field network that delivers reliable data.

"The measurements our customers can make allow operators to see the effects of process changes on machine vibration," Reeves says. "Having this knowledge allows the operators to ensure process conditions do not cause damage to the rotating equipment and allows them to engage reliability and maintenance engineers sooner in the troubleshooting process."

Emerson provides a variety of wireless instruments such as pressure, temperature and level measurements, according to Reeves. These devices can be deployed in hard-to-reach locations where safety personnel would prefer humans not have to go. They're used in applications like cooling tower gearboxes, clean-in-place pumps, press roll bearings, pond aerator motors, load-out fans and remote pumping stations.

"Wireless systems are seen to be the future of this industry," James says. "That doesn't mean that wired monitoring will disappear; we just see distributed fieldbus-type systems replacing bulky, centralized analogue vibration systems used today. Look at it as 'less-wire' instead of 'wire-less.'"

Although Rockwell Automation does not currently provide direct wireless capability, the Rockwell Automation Integrated Architecture platform allows interface with third party wireless solutions. "This is a growing area of popularity in both the condition monitoring and control systems space," Johnson says.

Instead, the Rockwell Automation role in the industry is to provide condition monitoring equipment that focuses on integration.

"The Rockwell Automation condition monitoring system is an element of an integrated approach that can address a variety of needs for discrete, process, batch, motion, drive and safety applications," Johnson says. "It can also address enterprise resource planning needs, including quality, compliance, production management and asset management."

Johnson says the integration of monitoring data into the control system is a crucial way for engineers and operators to make maintenance decisions and identify machine degradation before a failure occurs. The challenge is to make sure the products are robust enough to handle the different environment and performance needs.

"Our customers need these capabilities for an increasing number of new applications where condition monitoring has not been traditionally applied," Johnson says. "This means developing products that meet new challenges like expanded temperature ratings, new certifications and higher speed acquisition."

Rockwell Automation's equipment is commonly used in power generation, as well as oil and gas applications. Food and beverage, pulp and paper and waste/wastewater industries have also adopted the company's condition monitoring system.

SKF's online monitoring systems cover several key maintenance strategies (courtesy of SKF).

"A ski resort even used the technology to monitor the health of an expensive gearbox that powers their state-of-the-art gondola, helping to reduce downtime for skiers and avoid purchasing costly replacement equipment," Johnson says.

SKF's condition monitoring also takes an integrated approach that covers several processes including deciding what equipment to measure, taking the actual measurements, analyzing the data, conducting corrective actions and bringing feedback and analysis back into the maintenance strategy.

"The word 'integrated' is overused in many industries," James says. "There are several different meanings to the word in regards to SKF's approach."

At a business, technology and instrumentation level, SKF can offer discrete products and services to the market. Many companies consider the type of data acquisition and process technology used for condition monitoring a "high technology."

"But is it any more 'high-tech' than the communications technology in your pocket?" James asks. "The components used to process voice and video in a mobile phone are no different than those used for vibration data processing except for one thing—volume."

While the design and manufacturing costs for mobile phones are spread across millions of units worldwide, the condition monitoring market is smaller. Therefore the cost for the same chipset is higher.

"The universal challenge of getting the right-priced product at the right time to our customer still applies," James says.

SKF's systems are used in the process industries like oil and gas, hydrocarbon

continued

Emerson offers custom monitoring products to meet the needs of each client (courtesy of Emerson).

processing, metalworking, mining and pulp/paper.

"We are seeing non-traditional applications emerging—monitoring wind turbines for example," James says. "In the future there will be more condition monitoring occurring in the transportation sector such as railways and marine."

While a total system approach is helpful to organizations that have the necessary financial capabilities, smaller companies need a more direct approach.

Reeves says that even though machines are similar from one plant to another and there are industry-best practices, each scenario is different.

"Emerson has always focused on producing vibration monitoring products and software that users can configure to meet their monitoring needs," Reeves says. "Users can also call on Emerson's service professionals to provide custom configurations."

James at SKF adds, "The 'devil is in the detail' and that's where its importance lies. The 'custom' part is attending to all the small things that need to go along with the mainstream product to make it successful—mounting studs, cables, adaptors, junction boxes, etc."

"Condition monitoring systems have changed from stand-alone, dedicated channel systems to systems which are flexible for multiple applications, distributed and multiplexed," Johnson says. "In the future, we will see this trend continue as well as even more information and networking capabilities from condition monitoring equipment to control systems."

As the technology improves, many believe it's vital that the training and implementation programs follow suit.

"Too often we've seen a first-timer buy the cheapest data-collector and software they can find, usually to address some upper management directive—and then plan to go it alone," James says. "SKF knows from experience that training and support is a must-have for a customer to get an effective system in place."

"There is always reluctance in the market to try new things, but there are also people who are eager to be on the cutting edge of new technology adoption," Reeves says. "Emerson is always working on improvements, and we will be listening to our customers and working on the changes they request in subsequent product versions."

In addition to wireless developments, integrated system approaches and training/implementation programs, what does the future hold for condition monitoring equipment?

Assetivity Pty. Ltd., an Australian consulting firm that specializes in physical asset management, recently reviewed the marketplace to identify some of the growing trends in the industry.

These trends include the development of smart sensors, the growing rate of built-in vibration sensors in motors, pumps and turbines, sophisticated software developments in condition monitoring and the integration of common standards for interfacing condition monitoring software with CMMs and process control software.

Assetivity sees traditional condition monitoring services reducing in the future due to several factors. These include the increase in "expert" software that will allow less skilled personnel to conduct condition assessments, the reduction of condition monitoring costs and an increase in the amount of equipment being monitored that will lead to new developments in monitoring technology.

While the industry was once scattered with vendors, the consulting firm sees a new trend appearing today where companies either develop their own condition monitoring equipment or acquire an existing player in the market. Experience may very well be the key to success.

SKF's approach is to offer customers root cause failure analysis and engineering consultancy with its condition monitoring equipment.

"Redesigning the correct bearing arrangement on a fan with repeated bearing failures, for example," James says. "SKF has been doing that for almost 100 years, so there's a lot of expertise in the company that can benefit our customers. (*Ed's Note: Please see our feature on smart bearings on page 15 for additional information*).

Naysayers will continue to argue that paying the right skilled workers to oversee maintenance and operation procedures is still the most financially appealing route to take. Assetivity consultants note that predictive maintenance techniques that include the human senses (look, listen, feel, smell, etc.) or statistical process control techniques are considered cheaper alternatives by many industry professionals.

But looking at the big picture—condition monitoring provides a variety of plant engineering needs at a faster, more economic rate. James argues that the use of knowledge-based "expert" software packages or embedding "smart" algorithms into the hardware will make it easier for customers to use the tools effectively. So the man vs. machine argument continues.

Regardless of your point of view, condition monitoring products aren't worthwhile if they're not used as a fully integrated part of your preventive maintenance needs.

"Predicting a failure is only one part of the total business process, albeit a tricky one," James says. "Making sure the failure does not occur again is a key

part of achieving improved reliability. It is pointless making predictions if nobody will take action."

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Condition Monitoring—Product Spotlight

Big brother is everywhere these days. He's got cameras on the streets, spies on the Internet and tracking systems on cell phones. Satellite pictures can zoom into your backyards and iTunes can tell you what kind of music you should purchase. While conspiracy theorists struggle to live in such an environment, the machines on your manufacturing floors have been dealing with this sort of scrutiny for years. These machines are poked, prodded and spied on 24/7 in the hopes of preventing machine failures and maximizing equipment life.

Unlike their human counterparts, a little surveillance and personal invasion is not exactly a bad thing. Manufacturing equipment that has to answer to vibration measurement, infrared thermography, oil analysis, ultrasonics and motor current analysis are frequently implemented for predictive maintenance measures. Here's a quick look at some of the condition monitoring products on the market that can improve machine reliability, minimize downtime and predict system failures:

SKF's *Aptitude* Asset Management System

Aptitude is a cross-communication software platform enabling collaboration between maintenance, operations and reliability teams that combines a variety of hardware and software components.

"It's the glue that holds SKF's integrated condition monitoring processes together," says Chris James, business area director for SKF Reliability Systems. "The platform can start with a maintenance strategy, move through to support a wide range of hardware for data-collection, implement decision support knowledge-base for diagnostics and then complete the cycle with interfaces to maintenance management systems (e.g. work orders)."

The *Aptitude* software platform provides tools for every part of the plant asset management process under a single umbrella. For more information on *Aptitude*, visit *www.skf.com/skf/campaign/aptitude/*.

Parker's Fluid Condition Monitoring Products

Parker offers a line of on-site fluid condition monitoring products that can prevent catastrophic failures in critical systems while providing continuous monitoring for water contamination. This includes certification of water cleanliness levels, immediate results with laboratory accuracy, new oil cleanliness testing and identification of a fluid's saturation point and/or water content. Products include the Icount Particle Detector, a laser-based, permanently mounted device for fluid management and contamination control and the IQ200 Particle Detector that provides continuous online monitoring of the contamination levels of hydraulic and lubrication fluids. For more information on Parker's line of fluid monitoring products, visit *www.parker.com*.

Emerson's CSI 9420 Wireless Vibration Transmitter

The CSI 9420 enables the cost-effective, frequent monitoring of rotating plant and/or mill machinery. The transmitter provides both overall velocity and *PeakVue*, Emerson's roller bearing and gearbox anomaly detection technology. One accelerometer with an embedded temperature sensor may be connected to the CSI 9420 allowing the overall velocity, *PeakVue* and temperature to be measured from a single device.

"When a plant is trying to produce a product, no one wants to have to shut down the process because of an unexpected machine problem," says Todd Reeves, product manager at Emerson. "Seeing problems early lets the production and maintenance groups work together to ensure plant or mill uptime is maximized."

"Customers who have tried wireless vibration systems have been extremely pleased with the ability to see vibration data that was previously unmeasurable," Reeves says. For more information, visit *www.emersonprocess.com*.

GE's Handheld Diagnostic and Data Collection Products

The Bentley Nevada line of condition monitoring products from General Electric feature numerous portable instruments designed to measure and collect vibration for field diagnostics and for test stand use. Products include the Snapshot for Windows CE, a hand-held data-collector used by machine specialists and operations personnel that supports a variety of measurement types and signal processing options and the Snapshot *Clipboard* software package that provides plant personnel with the ability to log meter and gauge readings, make inspections and jot down notes that would normally be written on a log sheet. For more information on GE's line of condition monitoring products, visit *www.ge-energy.com*.

Rockwell Automation XM Products

The XM line can operate in stand-alone or integrated applications and is used in four key areas including machinery protection, production assurance, predictive maintenance and quality assurance. It can be integrated with the Rockwell Automation Integrated Architecture, a control and information system equipped with fully integrated control, network, visualization and information technologies.

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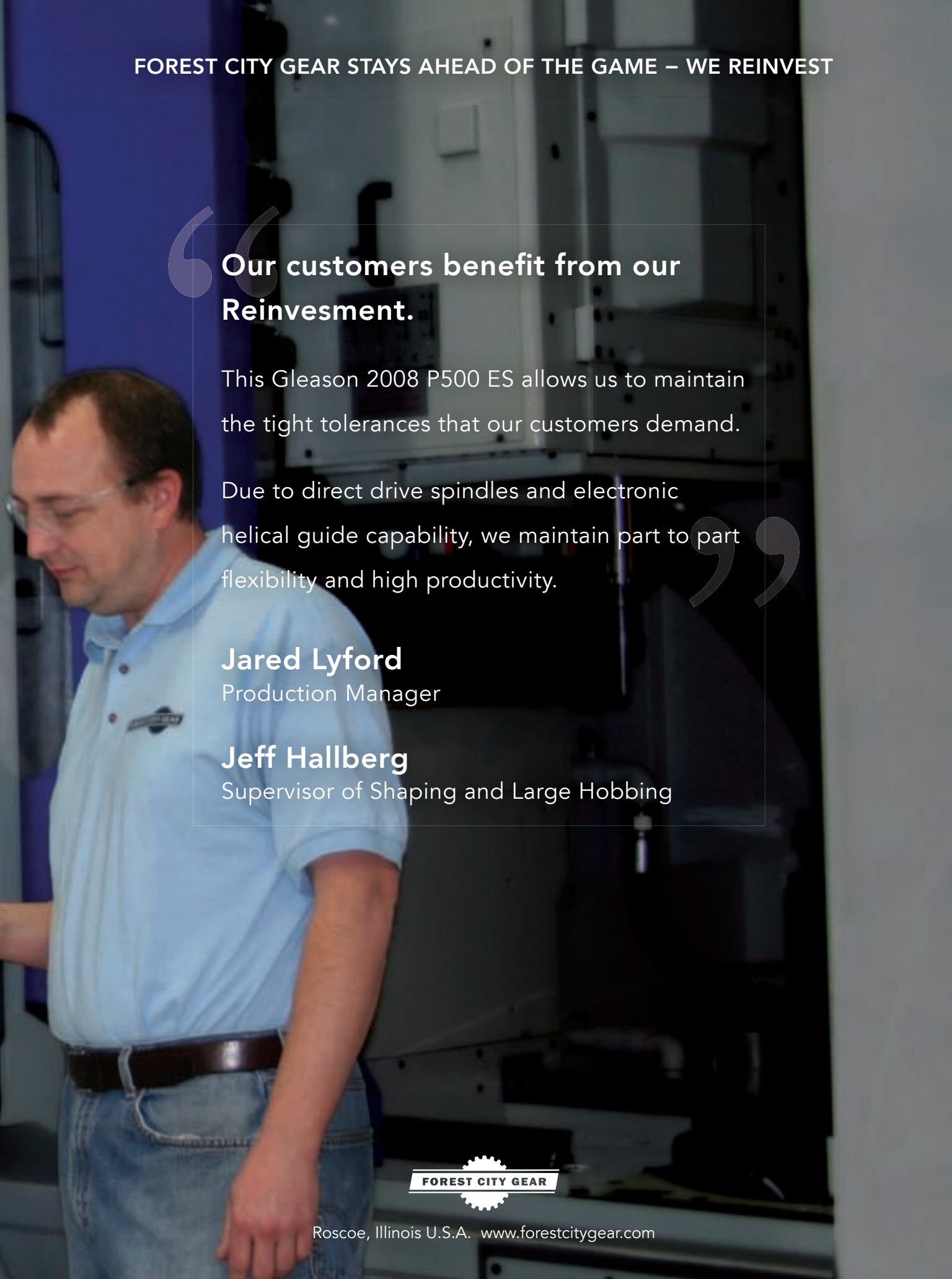

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Reducing Core Loss

OF SEGMENTED LAMINATIONS

Keith W. Klontz and Haodong (Howie) Li

(2008 SMMA Fall Technical Conference)

Management Summary

The recent trend towards using segmented laminations as a means to increase slot fill and facilitate automated fabrication of electric machines comes with a penalty of increased core loss at the segment joints. Segmentation of laminations has been reported to increase some losses by up to 50%, but there has been very little information published for medium or small motor applications. This paper summarizes the root causes of this change in loss and offers choices to reduce the effect. An advanced finite element analysis is used for calculation of the electromagnetic fields in the vicinity of the joints of the laminated steel, and takes into account the effect of the punched-edge joint and compressive stress on the core loss properties. It is shown that the increase in core loss results from several factors caused by the segmented joint, including degraded material conditions at the joint, increased amount of punched edge and compressive stress. The losses can be reduced by lamination alignment, stress-relieving the punched edges and a very small amount of core insulation at the joint. Reduction of the effect of compressive stress on the losses remains as a trade-off to be taken into account based on the user's assembly techniques.

Introduction

Motor and generator stators and rotors are usually manufactured using a stack of one-piece laminations, made by punching the desired pattern from one large sheet of steel. A variation of this manufacturing technique that has recently been gaining popularity is to punch each lamination tooth as an individually segmented piece and to later position the pieces into the desired slot-tooth pattern. After the segmented pieces are in position, the geometric pattern and magnetic circuit are approximately the same as for one-piece laminations (Fig. 1).

While the one-piece lamination method offers the advantage of assembly simplicity, the segmented lamination method also offers the potential of:

- Reduced raw material waste
- Lower capital cost for the punching equipment and tooling
- Choices in coil insertion methods and increased slot fill
- Some new choices in materials and automation

(*See Figure 2 for examples of an automated winding process and post-assembly stator.*)

A significant amount of literature has been published about losses associated with lamination joints in power transformers, and this forms a good foundation for the present work (Refs. 4–9). Similar discussion can be found for very large electric machines, where a lamination piece contains several teeth (Refs. 10–11). For both applications, the literature reports many variations of lamination joints, often with some degree of overlap employed during

core build-up. The effect on the material core loss behavior by the cutting or forming process used to make shaped laminations is less well documented (Refs. 12–13).

Minimizing power losses of the motor core is one key ingredient for high-efficiency electric machines. However, the impact on motor design, particularly core losses, for this construction method has not been widely discussed in the literature. Therefore, it is necessary to look at reports of similar fabrication techniques to gather an overall understanding of the situation in motors.

The effect of compressive stress has also been widely discussed (Refs 14–18), but is not as yet well understood by motor designers. In fact, the effect of compression of lamination joints on eddy currents at the joint edges in motors appears to be undocumented. All these factors are simultaneously present in the segmented lamination motor, and a better understanding of the total effect on core loss for this type of lamination assembly in the electric machine environment is needed.

This paper discusses the causes of these changes in core loss and presents choices to reduce the effect. An advanced, 2-D finite element analysis is used for calculation of the electromagnetic fields in the vicinity of the joints of the laminated steel, and takes into account the effect of the punched-edge joint and compressive stress on the core loss properties.

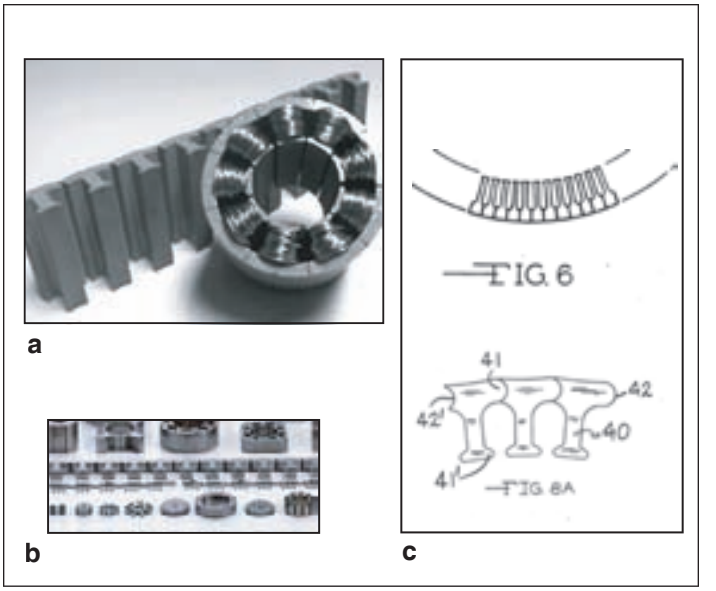

Figure 1(a)—Hinged segmented lamination, pieces rolled into position (Ref. 1). Figure 1(b)—Segmented lamination (straight row of teeth laying side-by-side) rolled into position by 'edge-bending,' narrow bridges between segments (Ref. 2). Figure 1(c)—Segmented lamination pieces, stacked for axial length, then placed in position and held by stator housing (U.S. Patent 5,212,419; Ref. 3).

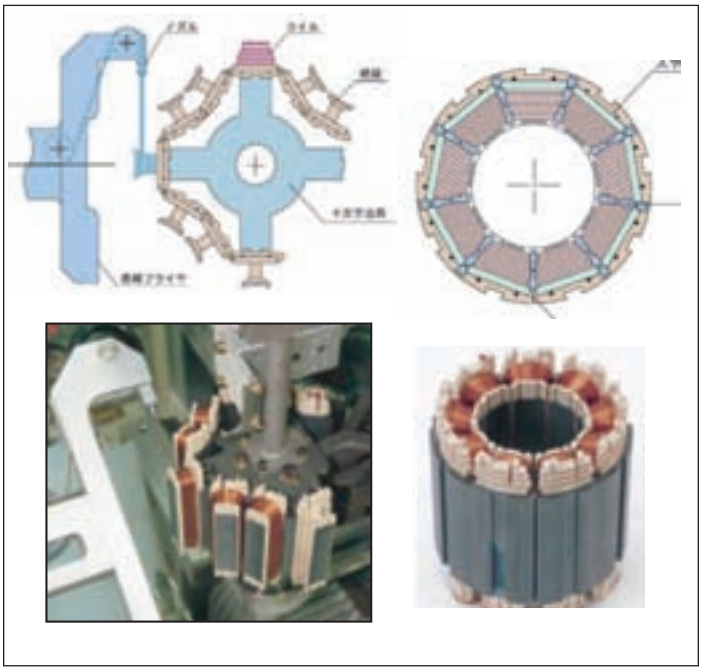

Figure 2—Segmented laminations.

Core Losses Particularly Applicable to Segmented Laminations

The segmented lamination has an additional cut edge in the back-iron area of the core, and all cutting methods cause some increase in losses. It is widely believed that laser cutting does not affect core losses, but this is not the case. In fact, laser cut laminations can have 20% higher losses at flux densities around 0.5 T, but the negative effect tends toward a negligible difference for flux densities over 1 Tesla (Ref. 13). The remainder of this paper will focus on lamination pieces made with non-oriented, fully processed electrical steel material, and using the punch and die process.

Inevitably, the punch-and-die method of making an electric machine laminated core results in an increased power loss characteristic (i.e., W/kg) because it requires metal displacement that leaves residual internal stress, cold-work regions and dislocated magnetic domains within the affected region. The inherent burr edge is a key cause of eddy current losses. For laminations made by punching sheet steel, the region of increased loss can spread up to several millimeters from each punched edge (Ref. 19). Segmented laminations always have a larger volume of degraded, higher-loss material than equivalent, unsegmented laminations.

A further potential cause of increased loss due to segmented laminations is the potential for eddy current loss at the edge-to-edge butt joint used to adjoin the segments. Any non-insulated surface or burr edges along the face of the segment joint can provide a path for eddy currents when pressed against each other, such as when under compression due to the housing. However, the amount of contact and the effective resistivity of such a joint in segmented

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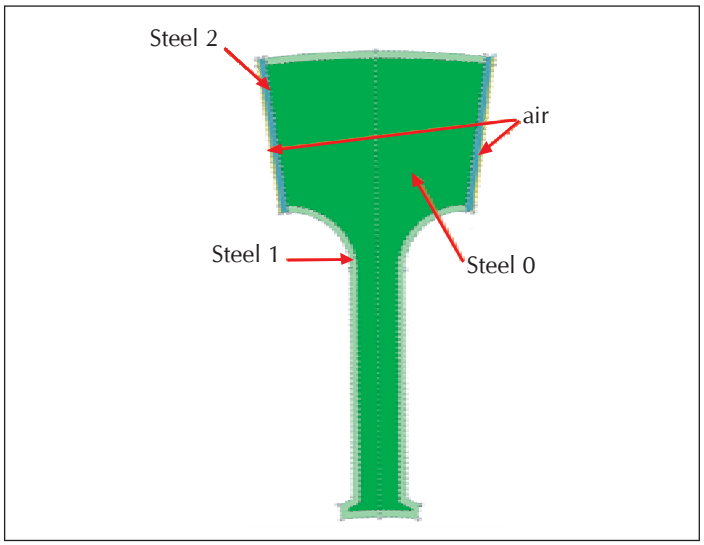

Figure 3—Model of segmented lamination.

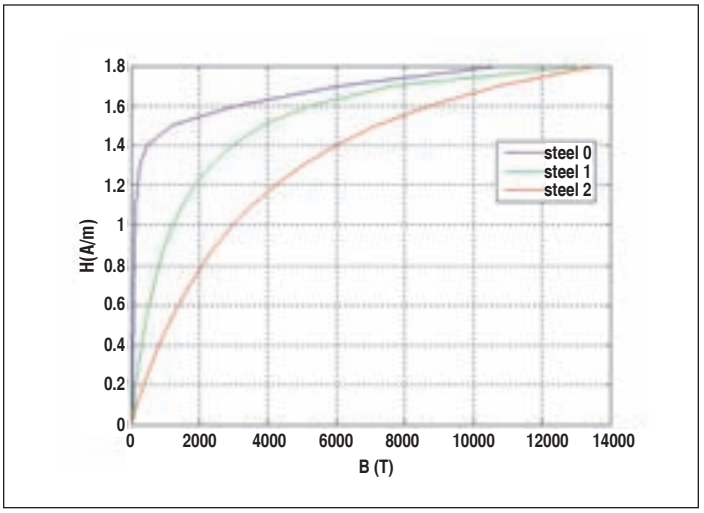

Figure 4—BH curves of:
i) Steel 0–Original, pre-punched.
ii) Steel 1–punched.
iii) Steel 2–punched and under compressive stress.

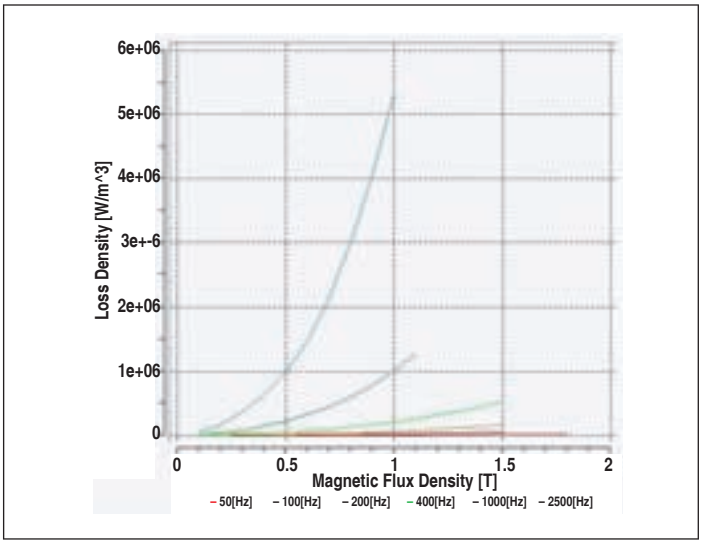

Figure 5—Iron loss of Steel 0.

lamination motors appear to be neither discussed nor quantified in the literature.

Analytic Calculation of Core Losses

The modeling and calculation of core losses has been extensively reported in the literature, including efforts to account for losses associated with the high frequency harmonics of switch-mode PWM inverters. There are two popular methods for calculating core losses, which account for the dependency of losses on flux density, *B*, and excitation frequency, *f*, including harmonic losses. One is based on the Steinmetz formulation, (Eq.1), with separate terms for hysteresis loss and eddy current loss (Refs. 20–23). The second expression is based on a single term using the product of flux density and frequency with non-integral exponents (Eq. 2; Refs. 24–26).

Steinmetz
$$P_{fe} = (K_h f B^x + K_{ec} f^2 B^2) V_{fe} \quad \text{Watts} \tag{1}$$

Non-integral Exponents:
$$P_{fe} = K_{fe} f^m B^n V_{fe} \quad \text{Watts} \tag{2}$$

The K's are coefficients experimentally obtained for each material, x varies from about 1.6 to 2.1, and V_{fe} is the core volume in appropriate units. It is very important to note that to obtain high accuracy, including for heavy saturation and for the effects of harmonics, these coefficients will vary as functions of frequency, flux density, temperature, minor loops and, especially, the localized rate of change of the flux density, *dB/dt*. When these characteristics are explicitly included in Equations 1 or 2, the expressions become somewhat more complex (Refs. 27–31), although the essence remains the same. An added term, "excess loss," is included and varies as the 1.5 power of frequency and flux density:

$$P_{fe} = P_h + P_{ec} + P_{excess} \quad \text{Watts} \tag{3}$$

$$P_{fe} = (K_h f B^x + K_{ec} f^2 B^2 + K_{excess} f^{1.5} B^{1.5}) V_{fe} \quad \text{Watts} \tag{4}$$

The effect of the segmented laminations on core loss appears to be three-fold:

- A change due to the internal stress and dislocation of domains at the additional punched edges, due to the punching and compressive force by the housing, which changes K_h
- A change in losses due to the contact of the conductive surfaces of the

edges, providing a possible new path for eddy-currents, which changes K_{ec}

- A change in the effective magnetic path due to the butt-joint interface, which varies with the circumferential compression of the segments, which changes K_{excess}

Preliminary analysis and testing results indicate each of the loss mechanisms has some influence, but, in total, they can be essentially negligible with good manufacturing technique. The effect on reluctance impacts the losses by changing the flux density magnitudes, which can change performance slightly, so the effect on the overall magnetic circuit is somewhat more important. The change in magnetic circuit due to the butt-joint edges, which can amount to a small additional air gap in the flux path, leads one to the conclusion that this technique is probably best suited for permanent magnet machines and similar machines relatively insensitive to an increase in the effective air gap.

FEA Calculation of Magnetic Field

A study was conducted of several segmented lamination configurations modeled using *JMAG Studio* (Ver 9) finite element analysis (FEA) software. For this first attempt at evaluating segmented laminations made by punching, the methodology of 'Cut Edge Length' was used (Ref. 13). This is based on the concept that the change in core loss due to the punch process can be approximated by taking account of the length of the punched edge of the lamination pieces, hence the amount of damaged volume. In particular, this high-stress, dislocated domain area has a degraded BH curve and higher losses than the pre-punched material.

For the segmented lamination, we can identify three distinct regions of differing material property (Fig. 3; Ref. 12). The region identified as 'Steel 0' has the original, undamaged non-oriented steel characteristics. The region identified as 'Steel 1' is the punched edge, has a degraded BH curve, and is modeled with 15% higher loss density than Steel 0. The region identified as 'Steel 2' is the punched edge under compressive stress, has a further degraded BH curve, and is modeled with 20% higher loss density than Steel 0. The 'air region' is initially set to be the same as Steel 2 material, and in later studies will be changed to represent an insulation coating on the edges of the laminations.

The Steel 1 region is set at 0.5 mm wide in this simulation, although a valid argument could be made, based on Ossart's work, that

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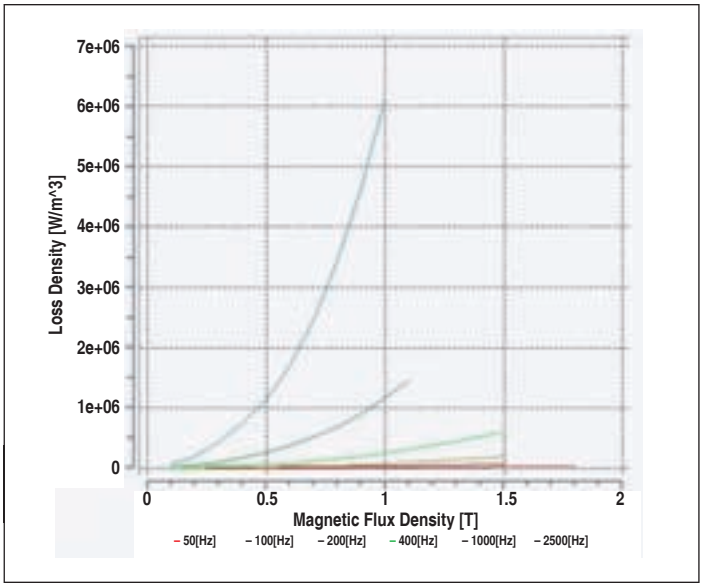

Figure 6—Iron loss of Steel 1 is 15% higher than Steel 0.

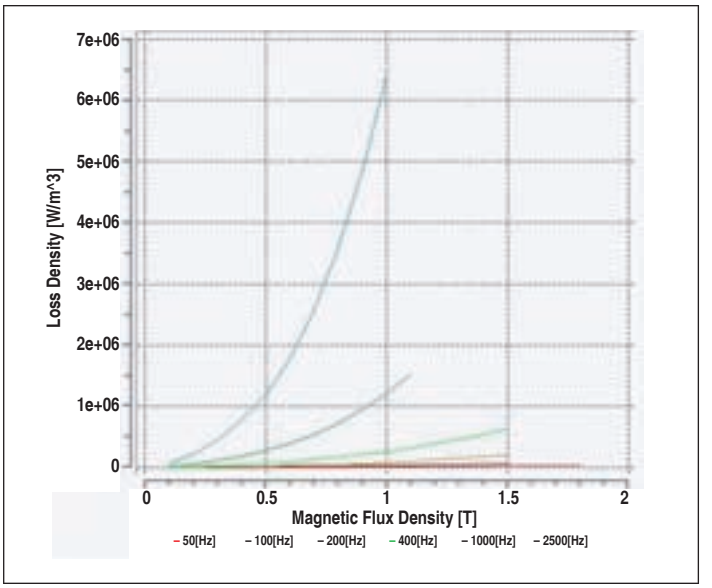

Figure 7—Iron loss of Steel 2 is 20% higher than Steel 0.

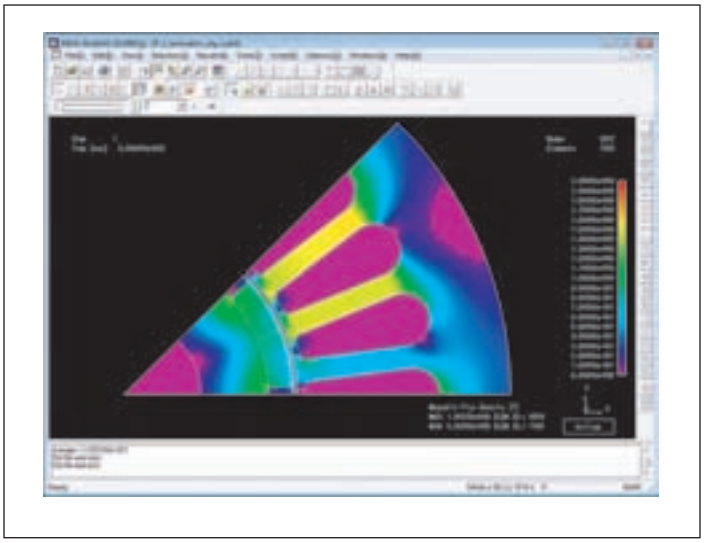

Figure 8—Flux density: original lamination, no segments.

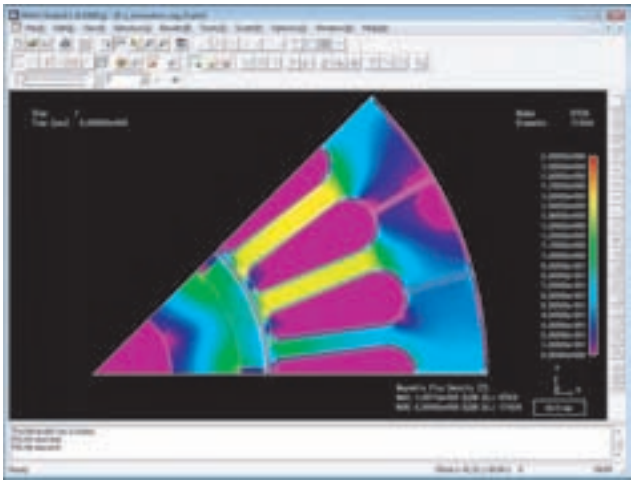

Figure 9—Flux density: Type I—Radial-line segment joint.

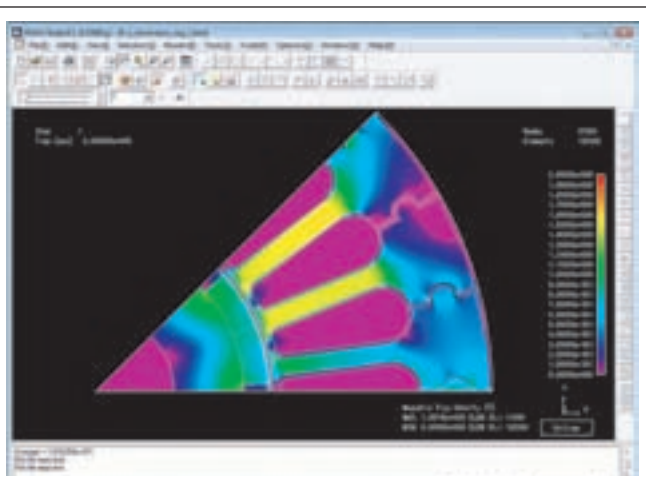

Figure 10—Flux density: Type II—Half-round segment joint.

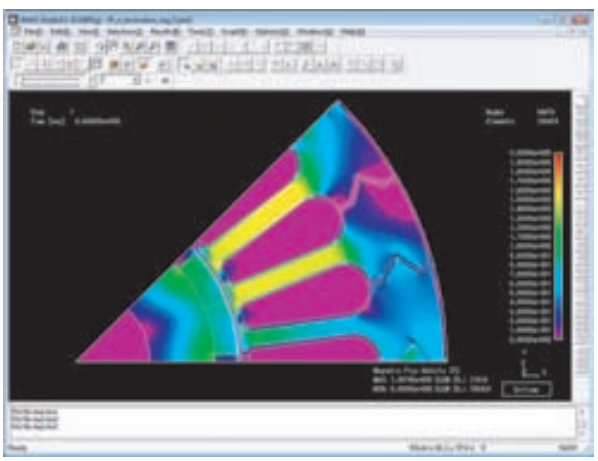

Figure 11—Flux density: Type III—Triangle miter segment joint.

Table I—Calculated Torque

Lamination	Torque	Variation from Original
Original, no segments	16.69 Nm	-
Type I—Radial-line segment joint	16.25 Nm	-2.6%
Type II—Half-round segment joint	16.30 Nm	-2.3%
Type III—Triangle miter segment joint	16.30 Nm	-2.3%

this could be up to 3 mm wide. Arshad states the width of the degraded material is approximately equal to the lamination thickness. Figure 4 shows the BH curves, and Figures 5–7 show the loss density curves, used in this simulation. The basis for the BH curves is in the references already cited. The loss curves are derived from the Steinmetz equation given in Equation 2.

Figures 8–11 show the flux density distribution for the four lamination configurations that have been modeled: 1. No segments; 2. Type I—Radial line segment joints; 3. Type II—Half-round segment joints; and 4. Type III—Triangle miter segment joints.

Analysis of FEA Results

After determining the magnetic field, the torque was calculated within the FEA software using what is essentially a virtual work method. The results are shown in Table I. As expected, there is a slight decrease in torque for the segmented lamination models, about 2–3%.

The FEA software determines the loss density for every element in the FEA model, and then sums the losses of all elements to determine the total loss in Watts. Figures 12–15 show the loss density for the four cases. Table II lists the total losses.

Conclusion

This is an initial attempt to quantify the added losses associated with segmented lamination cores, and additional simulations are ongoing. It is shown, using reasonable assumptions, perhaps even overly optimistic, that an increase in core loss results when the segmented joint lamination is used. Several factors contribute to the loss, and the methodology proposed and used here can readily be used to separate the losses. The losses can be reduced by lamination alignment to reduce eddy currents, stress-relieving the punched edges and adding a very small amount of core insulation at the joint. Reduction of the effect of compressive stress on the losses remains as a trade-off to be taken into account based on the user's assembly techniques. Results of more extensive models, with different joint configurations and conditions, will be reported in the future.

An important observation is that the segmented lamination technique is probably best suited to electric machines where the size of the effective air gap is insensitive to small variations, as in permanent magnet machines. Also, it may not be fully beneficial when the material removed to make the stator lamination is useful to make the core of the rotor, as for induction machines where the center hole can be used to make the slotted core for the squirrel cage or wound rotor.

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Table II—Calculated Stator Core Loss

Lamination	Loss	Variation from Original
Original, no segments	840.5 W	-
Type I—Radial-line segment joint	912.4 W	+8.6%
Type II—Half-round segment joint	925.5 W	+10.1%
Type III—Triangle miter segment joint	926.3 W	+10.2%

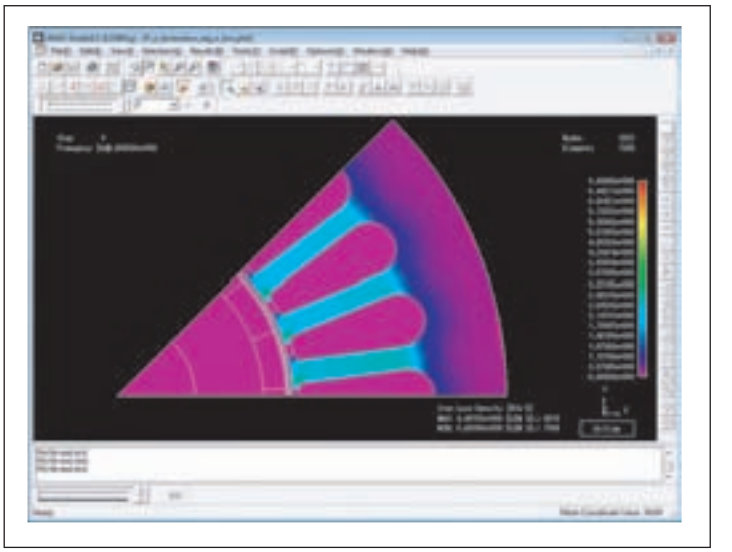

Figure 12—Iron loss density: Original lamination, no segments.

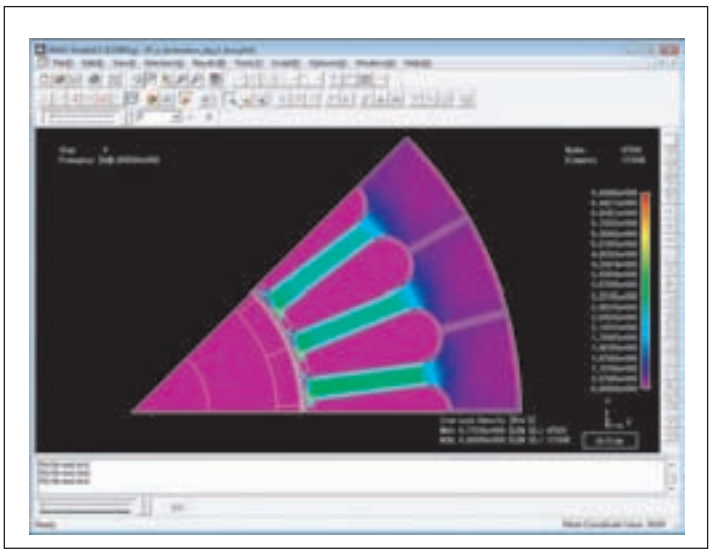

Figure 13—Iron loss density: Type I—Radial-line segment joint.

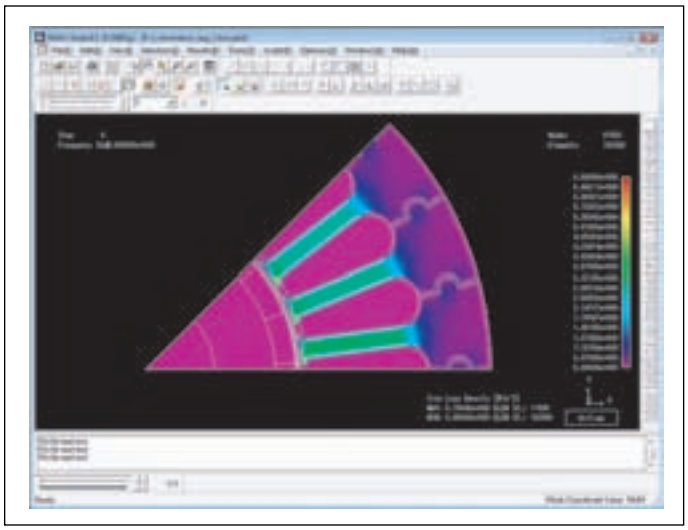

Figure 14—Iron loss density: Type II—Half-round segment joint.

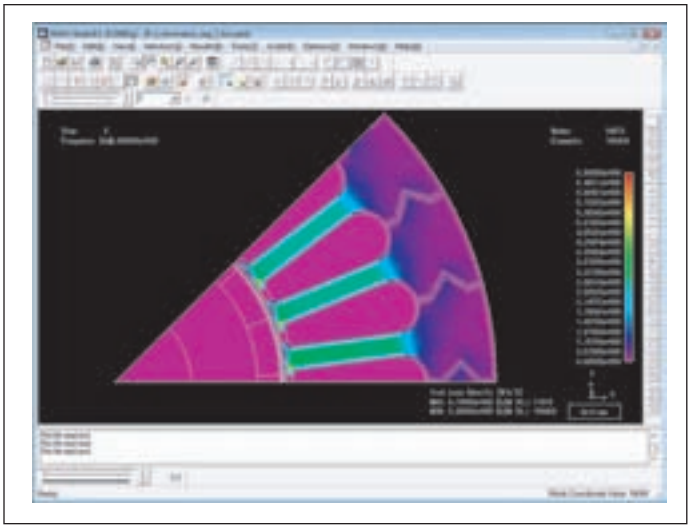

Figure 15—Iron loss density: Type III—Triangle miter segment joint.

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Electronic Control for Hydraulic Applications—A CASE STUDY

Andrew J. Smith and Brian Van Batavia

Management Summary

This paper presents how electronics and software can be applied to a mobile hydraulic application—what the benefits are and how electro-hydraulics design has evolved over time. The specific system serving as the basis for this paper is a timber-logging trailer. The paper describes the components of the system, as well as the structure implemented for the electronics and software. The benefits provided by particular components and the system architecture are explained, and pictures of the trailer are included to show integral elements. Diagrams related to the software control algorithms show what is enabled using software and electronics that couldn't be implemented hydro-mechanically. Throughout the paper, it is explained how an open architecture and modular approach were utilized, and that this approach is key to a flexible, scalable and efficiently developed electro-hydraulic system.

Introduction

As the mobile industry evolves toward more sophisticated systems, it is integrating more electronics with traditional hydraulic systems to address end-user demands for higher performance and greater efficiencies. The trend of increasing electronic content in mobile applications has been apparent for years now, but the initial adoption has been somewhat slower than one would expect. Two issues that may have kept electronics from becoming more mainstream until now were uncertainty in regard to which standards (or lack of standards) to apply, and whether an open or proprietary architecture approach was best. At the onset of this case study, analysis was performed and a decision was made on the approach to

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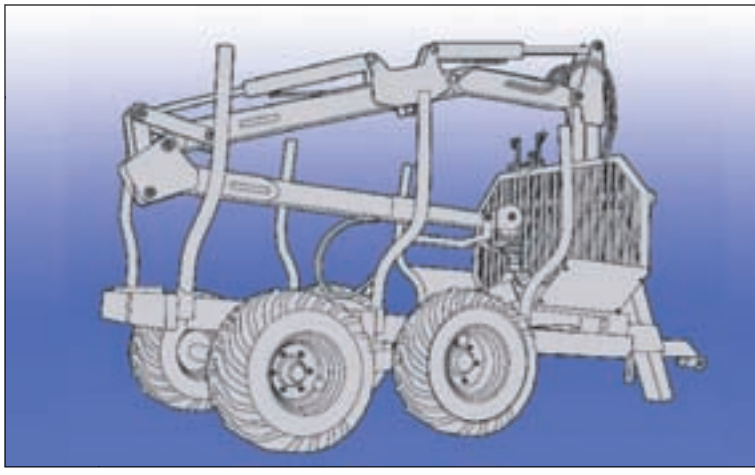

Illustration 1—The original timber-logging trailer, with manual hydraulic controls.

take regarding these issues. An open architecture that leverages existing industry standards was the position taken, as it offers the most flexibility and scalability to the final solution. An additional factor that gated the use of electronics in mobile hydraulic solutions was the harsh environment that mobile equipment faces during normal daily use. This has to be considered, and addressed as well, before any electronics can be used with confidence. A mobile piece of equipment—a timber-logging trailer (see illustration)—was chosen to develop, test and showcase a mobile electro-hydraulic solution using industry standards, an open architecture and extremely durable electronics. In this study, great attention was paid to the hardware and software architecture implementation, where distribution of control and reusability of software functions were key goals for effective and efficient development of the system. Using these specific architectural elements as a foundation, it is possible to demonstrate multiple types of specialized control functions on the machine. The use of an open architecture and predefined industry standards is credited with making this electro-hydraulic implementation a success, and is selected as the preferred approach for implementation of electronics and specialized software control for any application in the mobile industry.

Approach

Open Architecture/ Industry Standards

Utilizing industry standards for both software and hardware was an important element of the approach to the case study. Utilizing these standards provided a much wider selection of components to choose from to create the application and helped to ensure the interoperability of the different components as a system.

Software platform. All system control software that exists in the main system controller was developed using a standardized software platform. The software platform, Eaton *CONTROL F* (x), leverages the IEC 61131-3 programming standard. This standard provides five graphical and textual languages for the programmer to choose from. The choice of multiple languages helps to better match the experience of engineers from different backgrounds. Someone with an industrial background can use *Ladder Diagram* for their programs, while a software engineer with a background in "C" programming may prefer to use *Structured Text*. Working hand-in-hand with this IEC standard is the concept of an open architecture. In using the IEC 61131-3 programming standard, along with an open architecture, the combination of different components to build the system is facilitated. There are no restrictions that the core components or the other devices have in order to be produced from the same, or any specific manufacturer. Any standard devices can be chosen as components for this system. Because an open architecture was used, a large variety of devices were available to meet the control needs of the timber-logging trailer. Standard devices have an additional benefit in that they are often less expensive because their production is not limited to serving a certain proprietary system, but rather they support any system leveraging an open architecture. Utilizing the IEC 61131-3 standard also helps the programmer create high-quality programs with fewer defects, as the programming system itself alerts the user to syntax and other errors. This standard facilitates program code reuse as well, which reduced the time and effort required to develop the software for this application.

System bus communications. Another dimension of the vehicle design where it is critical to adhere to standards and an open architecture is with the communication bus chosen for the timber-logging trailer. The bus structure implemented is the CAN 2.0B hardware layer, supporting the J1939 message protocol. The CAN hardware layer is widely used for bus communications in both the mobile and industrial markets, and the J1939 protocol is the messaging standard used by suppliers of components and systems in the mobile market, including many engine manufacturers. Similar in effect to the standards and open architecture implemented in the software, this approach to bus communications opens up the supply base for components that can be leveraged in an electro-hydraulic system. The use of standardized communication interfaces create a pool of component hardware to choose from that exhibits high quality levels at reduced per-unit cost. This provides a stable environment so that new development can be focused on higher levels of functionality. The degree of interoperability of components that leverage a standard is very important in the eyes of the end-users, as they desire to retain flexibility and scalability in their applications without being locked into a single supplier.

Environmental Resilience/Ingress Protection

Solutions for the protection of electronics in harsh environments are necessary before electronics can be considered to enhance mobile applications. Shock and vibration are obvious requirements, but just as important is how an enclosure protects the electronics from dust, dirt, humidity and fluids.

Housings that demonstrate an ability to provide protection from the ingress of foreign material are critical to electronics utilized in the mobile application space. An IP (ingress protection) 67 rating has become an expectation for the electronics that are used. This rating translates to a total resistance to dust and to temporary immersion in water. Some mobile electronic integrators are setting their sights on IP 68 and IP 69K ratings that indicate a component is protected to indefinite submersion down to 10 m deep and can withstand high pressure washes up to a pressure of 140 bar. The development of electronics and enclosures that can withstand environmental extremes has been critical to their adoption in the mobile market, and components that met these requirements were chosen for use on the timber-logging trailer application.

Case Study: Timber-Logging Trailer

In order to illustrate the benefits of electro-hydraulics outlined above, Eaton created a demonstration vehicle that showcases the potential benefits of supplementing traditional hydraulic components with electronics and software. The vehicle combines several innovative Eaton products that are particularly well suited to electro-hydraulic systems.

System Architecture

Physical description. The machine being discussed is a logging trailer equipped with a hydraulic arm and grapple. The primary function of the machine is to pick up logging timbers from the ground and place them on the trailer for transportation. The construction of the hydraulic arm resembles a typical three-link, articulated robot arm with three revolute joints

and grapple end effector.

- The first revolute joint affects hydraulic arm rotation about an axis that is perpendicular to the ground (east-west shoulder rotation).
- The second revolute joint affects overall angle of the arm relative to the ground (north-south shoulder rotation).
- The third revolute joint affects the amount of arm extension (elbow movement).

Each arm link is fitted with a hydraulic actuator. All actuators are connected to an Eaton Ultronics valve system. An Eaton EFX1624 electronic control unit (ECU) controls the system. Two electronic joysticks, five rocker-style switches, five proportional proximity sensors and three traditional on/off mechanical limit switches provide control inputs. Each of these components is available from Eaton. A photo of the hydraulic arm with an inset diagram of the link and joint layout is shown in Figure 1.

Functional description. The end user operates the machine from a control chair and manipulates two electronic joysticks and several rocker switches in order to achieve the desired functionality. The operator may select from two distinct modes of operation—open-loop control or closed-loop control. Open-loop control refers to user input routed directly to the valve system for vehicle control. The user input is directly related to the flow demand that is routed to the valve system, and therefore the user has direct control over movement of the system. If the desired movement is not immediately obtained, the operator simply makes an adjustment to the input to achieve the desired result. The term closed-loop control refers to the system managing the flow demand routed to the valve system to achieve the desired movement or desired position. Instantaneous errors may exist between the desired position and the actual machine position for a very brief period, but over time the system controller will automatically adjust the demand routed to the valve system to reach the desired location.

When the machine is operated in open-loop mode, the relationship between the user input and the amount of flow requested can be adjusted (flow gain). The system allows for three preset gain adjustment settings—off, economy and power.

- The "off" setting will force all flow commands to zero, regardless of any joystick input.
- The "economy" setting will result in a flow demand that is 20% of the max system flow for a corresponding maximum input command from the joystick.
- The "power" setting will result in a flow demand that is 80% of the max system flow for a corresponding maximum input command from the joystick.

At any given time, the user may also modify the preset gain adjustment setting in increments of 1% via one of the rocker switch controls. The operator may also command movement of the three major machine axes from one of the provided inching control rocker switches. For any given flow gain setting described above, the corresponding inching control will result in a flow demand for a given work circuit, which is one tenth of the corresponding joystick input for the same circuit.

When operated in closed-loop control mode, the operator is simply required to press and hold the closed-loop control activation button on the joystick and the machine is automatically controlled to the pre-programmed home position. This function is enabled by the position feedback provided by the proportional proximity sensors. The position information from these sensors is processed by the system controller. The controller then makes adjustments to the machine position by directing flow demands to the Ultronics valve system. The three major axes of motion are also fitted with mechanical limit switches. The system controller monitors these inputs and prevents movement by any work circuit whose limit switch has been activated. A photo of the control chair with two Eaton Ultronics joysticks is shown in Figure 2; and a display/control panel with a programmable Eaton VFX display

continued

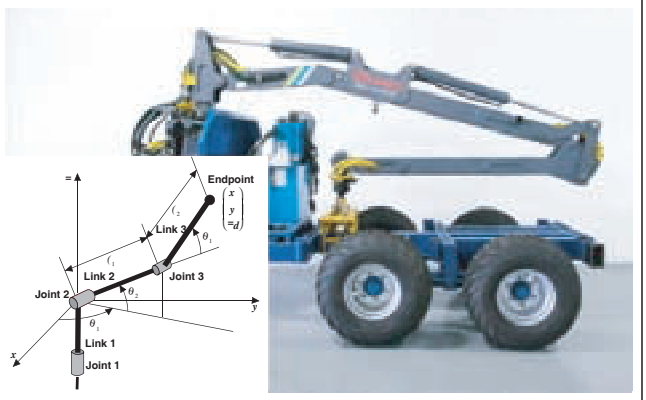

Figure 1—Hydraulic arm and diagram of joint layout.

Figure 2—Control chair.

and Eaton CAN-based eSM and eVU rocker switches/display is shown in Figure 3.

Hydraulic description. The system uses a vented hydraulic reservoir at atmospheric pressure. Hydraulic flow is generated by a fixed displacement hydraulic pump driven by electric motor. A pressure relief valve is fitted to the output side of the hydraulic pump in order to control maximum system pressure by providing a regulated flow path back to the reservoir. The primary hydraulic flow path is from the pump to the Ultronics control valve. The electrically actuated control valve is equipped with a pressure-conditioning input section, followed by six highly configurable work sections. Each valve section is equipped with a mechanical pressure relief that regulates maximum pressure in each work circuit. All valve sections are spring-centered to block flow in the center position; this prevents flow to/from the double-acting cylinders in the absence of a valid command signal. A hydraulic schematic of the system is shown in Figure 4.

Figure 3—User interface.

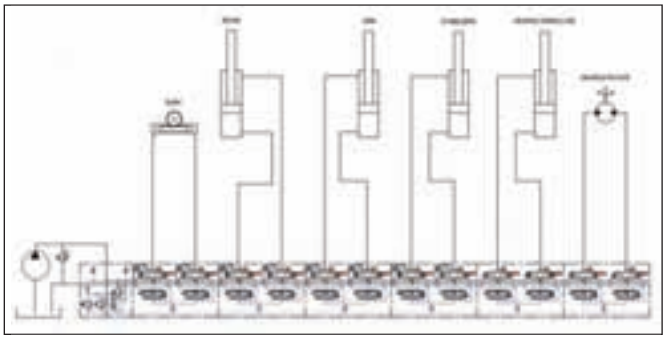

Figure 4—Hydraulic schematic of the work circuit.

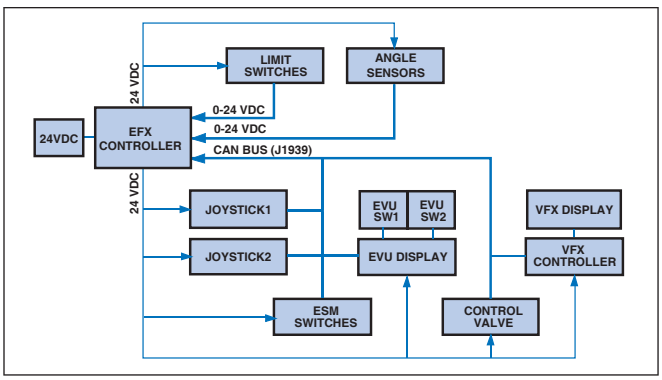

Figure 5—Electrical interface drawing.

Electrical description. The machine is powered by 240 volt AC power. Incoming AC power is routed in parallel to the hydraulic pump electric motor and to Eaton's Cutler-Hammer 160-watt DC power supply. The power supply ensures that system voltage is regulated to 24 volts DC. The system voltage is routed through an emergency power shut-off switch to the sectional control valve, joysticks, machine control rocker switches, LCD display controller, LCD display module, proximity sensors, limit switches and system electronic control unit. All operator control inputs are sent from the respective input devices to the system control ECU through a digital Controller Area Network (CAN) communications bus. All system control signals are likewise sent from the system control ECU to the sectional control valve via CAN bus. The sectional control valve in turn provides several feedback signals to the ECU by sending messages back to the system controller over the same CAN communication bus. The CAN bus is also utilized to send system status and feedback data from the ECU to each of the electronic visualization devices. Electrical control signals from the proportional proximity sensors and mechanical limit switches are routed directly to the ECU as traditional analog and digital control inputs. A simplified electrical interface drawing is shown in Figure 5.

Distribution of control. The Ultronics control valve is configured to provide inner-loop control of the flow through each work circuit. The Ultronics control valve is a standalone system capable of a wide variety of application-specific control tasks. Each valve section contains an electronic digital signal processor that executes proprietary software control algorithms. In the system being discussed, the valve inlet section is configured to sense the load on each work section and control system pressure in order to meet the instantaneous pressure requirements of the system. This function enables the hydraulic system to use all power available when required and yet maintains optimum efficiency by minimizing power consumed to only that which is required by the system at any given moment. Each work section of the control valve is configured to control the flow that passes through that section. The electronics and software algorithms that are executed on the control valve provide an inner-loop flow control function that provides consistent performance despite continuously changing system conditions. The system control ECU provides outer-loop control of system movement. The primary function of the system control ECU is to interpret the inputs from the user and select the appropriate commands to send to the valve system. The system control ECU is also responsible for monitoring system feedback information and taking appropriate action when necessary. Another critical func-

tion the system control ECU performs is providing system information to each of the available visualization devices for display to the operator.

Software Architecture

Application description. Eaton *CONTROL F(x)* was used to create the software application that coordinates all system functions. Eaton's EFX1624 electronic control unit (Fig. 6) executes the software program. The software is written, compiled and downloaded to the controller using built-in features of the *CONTROL F(x)* programming system. The programming system connects to the controller through RS232 serial or CAN bus interfaces.

The EFX controller executes the software application as a single program task. The controller reads system inputs, executes the software control logic, and then writes the results to system outputs. At the end of each cycle, execution of the program is started once again; the application will repeat this process indefinitely and as quickly as possible. An exception to this process could be utilized in other applications where specific programming logic is implemented so that counters, interrupts or user intervention control the timing of the program execution. The application created for this system runs as a freewheeling task and typically completes in about 5 milliseconds.

The *CONTROL F(x)* programming system gives the user the choice of several programming languages—ladder diagram, instruction list, structured text, sequential function chart, function block diagram and continuous function chart—with each having certain advantages and disadvantages. For this system—i.e., visualizing the control strategy as a continuous flow of signals that stream into the application as inputs, which are processed by the control algorithm, and finally flow out of the application as outputs—seemed particularly fitting. To accomplish this, the continuous function chart language was chosen as the primary programming language for nearly all program modules.

The software application is split into several subprograms, each with specific responsibility to interface with the main system functions. A high-level block diagram of the application organization is shown in Figure 6.

Abstraction for reusability. One of the significant strengths of the *CONTROL F(x)* programming system is the built-in support for code reuse. Any program or program component that is created can easily be captured in a program library. These library files can then be easily folded into other applications by simply creating a library reference. One example of the use of a function library is the hardware function libraries that are provided by Eaton to accompany each EFX controller. These libraries contain function blocks that enable users to quickly and easily interact with the controller. For example, function blocks are provided that enable initialization of key hardware components such as the CAN interface. By providing function blocks that are well tested and documented, the user is able to concentrate on programming at the application level rather than implementing the specific details of a hardware interface. Eaton has taken this concept one step further with the introduction of function libraries that handle all necessary interface details between the EFX controllers and a growing list of complementary products. Examples of products that are already supported include Ultronics ZTS16 control valves, Ultronics joysticks, eSM switch modules and eVU display modules. The software application developed for control of the demonstration vehicle makes use of several of these function blocks.

Another technique used in this application that promotes code reuse is the creation of function blocks that are generalized to the highest extent possible. For example, general-purpose function blocks have been created to perform all of the control logic for control of a work circuit. Specific functionality of each particular work circuit is achieved through the ability of each instance of a work circuit function block to operate on a distinct set of data items. Every work circuit provides some translation of user input to valve flow demand through the use of a gain factor. The specific value used by each function block is unique, even though the general algorithm used inside each block is identical. This philosophy minimizes the effort required to test and validate the control application and improves the maintainability of the code.

Specialized Control

One of the primary advantages of using software to implement system functions is the fact that algorithms can be easily changed and adjusted. Even though it is possible to implement a proportional control circuit using only hydraulic and electronic components, the ability of a software implementation to be much more easily adapted makes it the logical choice. A software implementation can be changed from a proportional controller to a proportional-integral controller, for example. Software implementations are also commonly cheaper to develop from the start, since a control algorithm can be easily copied and multiplied as many times as required for the task at hand. Finally, as any algorithm begins to grow in complexity, it becomes more and more useful to describe the algorithm using a combination of symbols and text that can be quickly tested and corrected if problems are found. Several functions of the timber trailer demonstration vehicle that are particularly suited to this type of expression in software are described in more detail below.

Single degree of freedom closed loop control. One type of advanced functionality that has been incorporated into the system being discussed is the ability to control the absolute

continued

Figure 6—Eaton EFX 1624 electronic control unit.

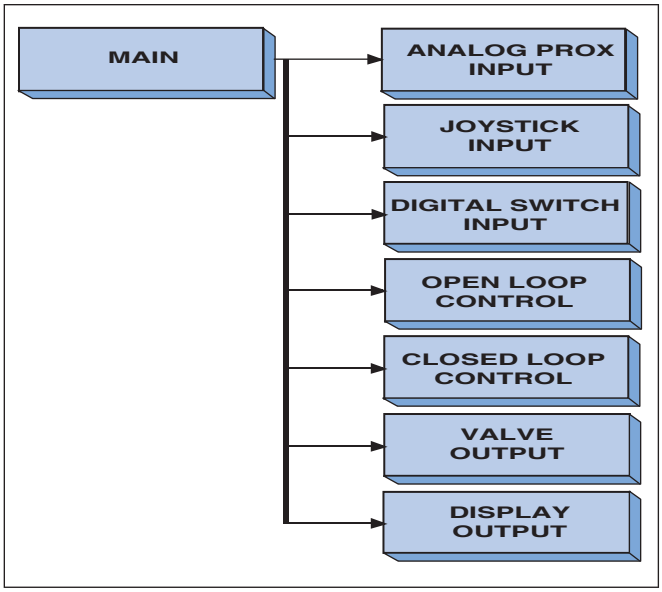

Figure 7—Software application organization.

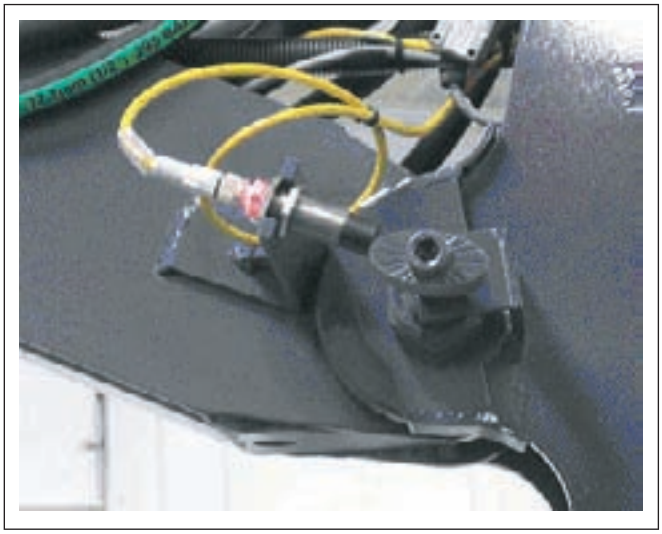

Figure 8—Sensor and elliptical target for measuring boom joint angle.

Figure 9—Sensor configuration for determining boom rotation.

position of a particular machine axis. Each of the three major axes of machine motion is equipped with highly accurate proportional proximity sensors. These sensors are products of Eaton's electrical product division and are able to sense the distance between metallic objects and the sensor face. An elliptical target is mounted to each machine joint, which rotates with the joint. By mapping the distance between the sensor face and the rotating target to physical joint angles using a calibration instrument, a low-cost, angular-position feedback mechanism is created. Figure 7 illustrates the sensor configuration for the joint of the machine that allows raising and lowering of the boom.

The sensor layout described above is limited to a physical range of motion of about 90°. In applications where a larger range of motion is required, it is possible to use an array of sensors whose information is consolidated through software. An example of this type of sensor configuration also exists on the machine being discussed (Fig. 8).

The physical range of motion for this axis of machine motion is about 180°. Although two sensors would theoretically satisfy the requirements for this function, three sensors have been utilized to allow for the mechanical variations that inevitably occur during fabrication of the mounting components, and the need for flexibility in mounting orientation that is required for this axis of motion.

With all angular position sensors in place and calibrated, the system software is able to determine the orientation of the three primary machine joints at all times. This feedback information enables closed-loop control of the joint angles. With this type of control in place, the user can enter joint angles directly from a user interface to position the machine at any given location by simply entering the desired joint angles. However, to prevent the addition of a more complicated user interface to this demonstration machine, a simple home function was implemented. When activated by pressing a single button on one of the joystick controls, this function automatically moves the machine to a preset home position. For the sake of simplicity, an arbitrary target point was chosen within the range of motion of the machine. The joint angles were noted and programmed into the software algorithm as command inputs to three separate position controllers, one for each axis of motion.

When these position controllers are activated by the user by pressing and holding the activation button on the joystick, the angle position controllers begin to automatically generate flow demands to each affected section of the Ultronics control valve. This has the effect of moving the machine autonomously from any arbitrary starting position to the home position without any further input from the user, other than the continuously active enable signal. This type of function could be used to automatically return a machine to a ready position with minimal user input and maximum efficiency. It should be obvious how this type of function can significantly reduce operator fatigue and increase the level of reliability and safety related to this phase of the process. What may not be as obvious to the casual observer is the ability of the machine to be easily adapted to slightly different variations in the application. For example, the speed of movement could be easily adapted to suit the particular material involved in the process

by simply adjusting a few parameters in the software. This allows an identical set of mechanical and electronic components to be used to achieve significantly different results.

Multiple degree of freedom coordination control. This type of coordinated control of multiple, related axes of motion has not yet been implemented on the machine discussed throughout this paper. However, it is an obvious extension of the existing control capabilities of the machine and will likely be developed in the near future. This type of control algorithm is similar to the features mentioned above in that they would be extremely difficult to implement with only hydraulic components and/or electrical circuitry. The ability to have software executing within the system opens up a broad area of advanced functionality that brings enhanced value to nearly any product. One significant example of this type of feature is the ability of a machine to coordinate several axes of motion to achieve precise control over the movement path. This concept is well demonstrated in the discussion of the capabilities of a common telescopic lifting system. On these types of vehicles, it is common to find one hydraulic circuit which controls the angle of the boom with respect to the ground, another circuit which controls the amount of extension of the boom, and yet another circuit which controls the angle of the tool at the end of the boom relative to the boom itself. These types of vehicles are commonly used to move materials on and off vertically stacked shelving. Previously, in order to move materials from the ground to a particular storage location the operator was required to manipulate several user input devices simultaneously. Precisely coordinated movement of two or three input devices was very common in order to achieve a movement path that not only kept the material parallel to the ground but also moved along a path that was the most efficient in terms of speed and power consumed. However, with the addition of software controls the user input can be reduced to a single simplistic input. The user would only be required to move a joystick in a single direction, for example, while the software monitors the position of the machine and moves all related circuits in unison to achieve a desired movement that is perfectly vertical while maintaining an orientation of the end tool that is exactly parallel to the ground.

When this type of coordinated control is combined with the natural ability of software to be scripted, the result is even more powerful. Indeed, a machine could be programmed to automatically lift materials from the ground to the first shelf when the geometry of the shelving and material is known. Or, if the machine is commonly moved through a repeatable path of movement like in the case of a hydraulic arm for loading and unloading railcars or cargo ships, these movements could also be automated through the use of software. It is quite possible that the range of applications that could benefit from these types of software controls is practically limitless.

Conclusion

Specialized control of mobile applications has become more and more important to suppliers and customers alike. Traditionally, hydraulic mobile application components were chosen to attack space constraints, with the components with the most force-per-area winning out. As specialized system control and efficiency gain greater focus, it has become possible to supplement the power of hydraulics with electronics and software to attain new performance goals. This case study of the timber-logging trailer is a great example of taking an existing application and advancing its functionality by implementing an electro-hydraulic control system. New capabilities are now available on the trailer at the flip of a switch, and the vehicle can accommodate efficient operation by users of different skill levels. Specific, differentiating capabilities of certain components are packaged and distributed in on-board electronics.

These electrical and hydraulics components retain a standard interface to the rest of the application, however, to ensure they can be leveraged in a modular and scalable open architecture. Rugged, programmable standalone electronics are implemented for supervisory control. These, too, leverage standards so that they have the flexibility to be cooperatively developed, modified and serviced by the supplier, customer or end-user. All of these concepts proved to be key elements to the rapid and successful development of the timber-logging trailer, and should be used on any mobile machine development project in order to meet both internal as well as external market requirements for electro-hydraulics in mobile applications.

Additional Sources

1. CAN in Automation, *www.can-cia.org*, the international group that supports CANopen and other CAN protocol layers.

2. PLCopen, *www.plcopen.org*, the global organization focused on support of the IEC 61131-3 programming standard.

Latin America

MIGRATES TO MIAMI FOR MATERIAL HANDLING EXPO

Mattech, in its second installation, expects 2,000 - 2,500 qualified industry buyers and 100 exhibitors (courtesy Dean Millius).

Tap into the Latin American and Caribbean market at perhaps the material handling industry's newest trade show Mattech 2009: the international material handling, manufacturing and packaging technology, logistics and supply chain expo. Coming off a successful inaugural Mattech 2008, president and show organizer Ian Howard expects 2,000–2,500 qualified industry buyers and 100 exhibitors. The show intends to reach a broad range of professionals.

"This is not solely material handling. This is not solely packaging. We are combining a little of material handling, packaging, manufacturing, logistics and supply chain into one, and there is no other trade show like that in the world," Howard says. "And the reason we do that is because the main core, the main attendee we invite—the buyer—is the manufacturer of every industry. And if they come to our show, we want it to be where they won't just see manufacturing products, such as nails and screws and drill presses, but they might see material handling equipment to move their products in their warehouse. They might see logistics companies that can help them ship their products; they might see packaging companies that can help them package their products. As such, it's a combination like that to get someone to see a little of everything at one time and save trying to go to all different shows."

In addition to the exhibition, Mattech will feature two, possibly three educational sessions. At the Manufacturing/Fabricating Solutions Forum, attendees will discuss issues and trends set to impact logistics, supply chain and manufacturing/fabricating industries, including budgeting and planning, the impact of current economic conditions and the industry outlook for 2009. There will also be an educational session about the procedures and regulations involved in doing business and exporting to Brazil.

The forums will be led by a moderating panel, which includes Dean Millius, general manager of *Material Han-*

dling Wholesaler; David Colby, publisher of *Material Handling Management* and *Outsourced Logistics* magazines; Chizoba Okey-Ikeri, managing director of Aerologistics, in Lagos Nigeria; Andrew Reese, editor of *Supply and Demand Chain Executive*; and Ejaz ul amin Mughal, technical director of Jeco Private Limited Manufacturing, in Pakistan.

The show is held in Miami in the summer, which is the key to its Latin American appeal. "One of the reasons we hold Mattech in the summer, in August, is due to the fact that it is summer here, but it's winter in South America—though it's not very cold, it's still winter—and the business people in Latin America love traveling to Miami in August," Howard says. "We've done other trade shows here in August and it's proven a very successful time of year for bringing business people to this area. A lot of the bigger business people in Latin America have second homes in Miami. Miami is the gateway to Latin America. No other city can claim that in the U.S."

Feedback from last year's Mattech was overall very favorable and can be found in several videos on the show website. "We found that people that were here are the right people to talk to," said Brian Downes of NBB controls in Virginia. "We need to keep broadening our spectrum of clientele, and with a show like Mattech, we are able to do that.

"We have seen just in our booth alone a lot of diversified clientele that normally would not get to see a lot of products without a show like this."

Exhibitors like Systems Material Handling of Olathe, KS, which distributes and manufactures lift truck replacement parts and accessories, including hydraulic and electromagnetic brakes, were drawn to Mattech by their Latin American customers. "We decided to participate when we learned from our customers in Central and South America that they were going to visit, and they were asking us if we were going to be there," said Annemie Dunn, international sales manager.

"It's interesting to meet other companies that plan to do business in Latin America and to talk with them and about their planning," Dunn said. "We have met a couple of new leads here—new companies that are interested in working with us."

Some of the confirmed exhibitors for Mattech 2009 include DC Velocity, Power Electronics International Inc., Automation Tech Support, Flow-Rite Controls Global Sensor Systems, Inc., Power Automation Systems and Eureka Chemical Company.

Although Mattech emphasizes the South American and Caribbean market, the show is promoted around the world. Howard explains the show's broad appeal. "Mattech is a global trade show that benefits two different types of people. Those people who are already doing business with Latin America and the Caribbean, and want to further their business with those companies, and use Mattech as a central jump off point. They can bring their distributors, dealers or clients right here to Miami, to Mattech and have what you call a showroom for themselves right here at our show. The other type of person is the person who has not yet begun doing business with Latin America. They can come up here and establish new contacts with businesses who want to make contact with American, Caribbean and Canadian international suppliers."

Mattech 2009 takes place August 5–6 at the Miami Beach Convention Center, Miami Beach, FL. For more information, visit *www.mattech.us* or call (941) 320-3216.

Summertime in Miami has proven a successful time to bring Latin American business people to the area for Mattech (courtesy Dean Millius).

calendar

June 22–26—Time Compression Expo. McCormick Place, Chicago. The TC Conference and Expo brings together an array of technology experts dedicated to the proposition that in today's market, there are the quick and the dead. Co-located with NPE 2009: The International Plastics Showcase and the MoldMaking Expo, the inaugural TC Expo and Conference is an event where attendees see, hear and learn about both emerging and established processes, hardware, materials, and tools in design, software, prototyping, tooling, and direct manufacturing in an effort to reduce time to market. For more information, visit *www.timecompressionexpo.com*.

June 3–July 1—Transmission in Vehicles 2009. Kultur- und Congress-Centrum, Friedrichshafen, Germany. This international conference is organized by the VDI, The Association of German Engineers, which is a financially independent and politically unaffiliated, non-profit organization of 132,000 engineers and natural scientists. More than 50 exhibiting companies are expected with 1,000 participants. The conference addresses manufacturers, developers, engineers, designers, researchers, users and suppliers of transmissions in vehicles, their components and materials. It provides a professional forum for all experts who are working in these fields to exchange experience and ideas. The event includes an exhibition and a technical program. For more information, visit *www.getriebekongress.de*.

July 27–29—Powder Metallurgy Basic Short Course. Penn Stater Conference Center Hotel, State College, PA. This intensive three-day course is designed for people starting out in the PM field looking for an introduction, looking to learn about recent developments in the industry or trying to broaden a PM background and users of PM parts. Attendees will learn the history of PM, why it is viable, why use is so widespread, design points, production, injection molding, standards and the latest technologies. It is not required for attendees to have a technical background. It is designed specifically for engineers, tool designers, product designers, metallurgists, technicians, QC personnel and more. For more information, visit *http://www.mpif.org/meetings/2009/2009_basic_sc.pdf* or call the MPIF at (609) 452-7700.

August 4–6—NIWeek. Austin Convention Center, Austin, TX. This graphical system design conference and exhibition is hosted by National Instruments and is expected to attract 3,000 engineers, educators and scientists for three days of interactive technical sessions, workshops and exhibitions on new developments for design, control, automation, manufacturing and test. The conference also features keynote presentations and demonstrations that highlight how engineers and scientists can use NI graphical system design to test, measure and fix inefficient products and processes to improve everyday life. For more information, visit *www.ni.com/niweek*.

September 20–23—CanWEA 2009: Infinite Possibilities. Metro Toronto Convention Centre, Toronto, Ontario. This year, more than 2,000 delegates and 225 exhibitors will come together for the Canadian Wind Energy Association's annual conference and exhibition to explore the possibilities of wind energy in the country. Canadian and global industry leaders will be in attendance at Canada's largest renewable energy conference. The main conference speaker sessions will be divided into four tracks reflecting different areas of interest within the wind industry: project financing and economics, business development, project development, and technical and wind R&D. In addition, on Sunday September 20th, there will be a half-day pre-conference session covering the technical, practical and policy aspects of small wind energy systems.

September 22–24—Design and Manufacturing Midwest. Donald E. Stephens Convention Center, Rosemont, IL. Promoted as the Midwest's premier event for advanced design and manufacturing professionals, Canon Communications expects to see more than 400 exhibitors and 10,000 visitors seeking to source and supply services and technology. The show features CAD/CAM/RP, contract manufacturing, enterprise technologies and plant engineering. Exhibitors will meet senior-level design and manufacturing attendees responsible for the purchase of design, plant, enterprise/IT, automation, process, quality, assembly and controls products and systems. For more information, call (310) 996-9427 or visit *www.canontradeshows.com*.

September 23–25—EPTDA Annual Convention. Rome Marriott Park Hotel, Rome, Italy. The 12th annual European Power Transmission Distributors Association brings its 200 distributor and manufacturer member companies together to network around the theme "excellence in relationships." The goal for this year's convention is to restore confidence and inspire the PT/MC industries to overcome economic challenges and create business opportunities. World class experts will address topical issues such as risk and cash flow management, opportunities of the global economic situation and human resource retention. The convention also features a day of private meetings for open discussions on the latest product offerings, innovations and industry developments. A Manufacturer-Distributor Idea Exchange is considered a major highlight. For more information, visit *www.eptdaconvention.org*.

Bosch Rexroth 2008 Sales

UP 9.8 PERCENT


Albert Hieronimus

Sales in the Americas were up almost eight percent for Bosch Rexroth AG while total sales for the parent company of Bosch Rexroth Corporation in North America reached $8.3 billion, which is a 9.8 percent increase from the 2007 figures. The most significant growth levels were achieved in the mobile and industrial hydraulics areas while gearboxes and drive solutions for wind energy plants experienced the highest rates of growth.

"Despite some shortages in raw materials and key semi-finished products, our associates worked to the limits of capacity during the first six months of the year, showing great commitment and working numerous additional shifts," said Dr. Albert Hieronimus, chairman of the Bosch Rexroth AG executive board, during the annual press conference in Frankfurt.

The company does anticipate weaker numbers for the current year, but Bosch Rexroth will maintain investment in research and development at levels exceeding the industry average. Bosch Rexroth spent around $364 million on research and development in 2008, which is 4.5 percent of sales. The company maintains business planning in the short and medium term is difficult to predict due to the loss of stable planning foundations.

"That's why we're taking things one day at a time, as are most of our customers," Hieronimus says. He emphasized that "The long-term growth trend in our markets remains intact."

In an effort to safeguard as many jobs as possible in its core workforce, Bosch Rexroth may reduce normal weekly working hours to avoid all-out job losses. At the end of 2008, 35,300 people were employed worldwide by Bosch Rexroth, with 3,500 of those employees in the Americas.

The company plans to be active in all phases of the supply chain to take advantage of all market opportunities. This includes expanded capacities for wind power gearboxes. Production capacities will be increased by a new plant for gearboxes in Nuremberg, Germany for and expanded production at the Chinese site in Beijing. "The global push to expand facilities for generating renewable forms of energy is helping our business," Hieronimus said.

Bonfiglioli

OPENS ELECTRIC MOTOR FACTORY IN VIETNAM

A $16 million Bonfiglioli Riduttori SpA electric motor factory was officially opened in the southern province of Binh Duong, Vietnam at an opening ceremony January 19. The 190,000 square-foot plant features state-of-the-art equipment and is almost fully automated. Over 100 people are employed there, including 80 manufacturing personnel and 20 office workers. SIMEST, an Italian government-owned company specializing in supporting Italian businesses' international expansion programs, serves as Bonfiglioli's investment partner in the project.

"This new motor factory is part of our continuing international development strategy," says Garry O'Neill, industrial solutions sales manager for Bonfiglioli USA. "The facility allows us to continue our commitment to value, service and engineered solutions, for the industrial market. Producing our own motors, in both Italy and Vietnam, allows us to control the motor manufacturing process and provide a high value product. Our significant market share in Italy and Europe and this new Vietnamese plant, provides Bonfiglioli USA with a strong platform to capitalize on and to become a U.S. gearmotor market leader."

Engineering and Service Center

PROVIDES 24/7 MAINTENANCE

A Sumitomo Drive Technologies Engineering and Service Center (ESC) was opened in Chesapeake, VA. The new division will be responsible for after-sales services including predictive and preventive maintenance services, quick repair, warranty extensions, part and kit handling and other services. The idea behind Sumitomo's ESCs is to provide service on a regional basis, with this one focusing on Virginia, North Carolina, West Virginia, Maryland and Delaware. Service will be available 24/7 and free plant surveys are included.

"Our goal is to provide quick, high-quality service and repair with original Sumitomo Drive Technologies' parts and engineering expertise," says Matthew Roberson, national sales manager. "The ESC program will offer our customers prolonged gearbox life and the option to maintain these components

continued

Left to right: Allen Whiteford, ESC sales manager; Mateus Botehlos, strategic marketing director; Matthew Roberson, national sales manager; and Ron Smith, president and CEO perform the ribbon cutting ceremony for Sumitomo's new Engineering Service Center.

through the support of our engineers. The sole purpose of our after-service program is to make our customers' business more competitive. The flexibility of the programs allows our customers to continue their operations as our field engineers survey their facility to offer service and repair recommendations.

"This type of program goes a long way—especially when consistently executed and supported—in improving customer satisfaction, retention and relationships. It also allows us to be engaged with our customers so that we can better understand their needs to become their dependable partners in business."

Sumitomo plans to expand three to four ESC branches across the United States in 2009.

Timken

SUPPLYING CHINESE WIND GEARBOX MANUFACTURER

The Timken Company signed a long-term, multi-year agreement with Nanjing High Speed Gear Manufacturing Co., Ltd. with wind turbine gearbox bearings. NGC manufactures gear transmission equipment for wind power, marine, construction and industrial equipment in China.

The agreement determines that Timken will supply tapered and cylindrical roller bearings for use in NGC's wind power gearboxes. Initial revenue is estimated at $30 million for Timken.

"This is another great success for Timken in the China wind energy market sector. NGC is a globally recognized brand and a leader in the industry," says Mike Connors, president of process industries at Timken. "Our strategy is to work with leading companies in the industry, companies that compete on product performance, durability and reliability and that demand the highest level of expertise in friction management and power transmission from their suppliers."

High Fault Testing at 80VDC

CONDUCTED AT COOPER BUSSMAN FACILITY

The Paul P. Gubany Center, developed by Cooper Bussman, offers both AC and DC testing to help OEMs meet user demand for new electrical products and comply with global safety standards. The facility conducts high-fault testing at 80VDC for telecommunications overcurrent protective devices and offers a wide range of testing services for electrical components and assemblies.

"With the widest range of AC or DC voltage, amp and frequency combinations, the Gubany Center makes it possible for manufacturers to conduct confidential product evaluations under high-current conditions to quantify the reliability and performance of their products under the most extreme fault conditions," says Todd Lottmann, product manager of services for Cooper Bussman. "We specialize in high short-circuit testing of components and assemblies, both AC and DC."

The Gubany Center uses custom-designed power generating equipment to replicate power systems found worldwide, according to the company's press release. The

Cooper Bussman's Gubany Center features an observation deck that allows customers to watch the technicians perform tests in real time.

center is an ANCE designated test facility and is accredited by UL, ASTA and CSA. An observation deck permits customers to watch technicians perform tests in real time or view footage from video monitors.

The test facility is equipped to provide short-circuit current ratings (SCCR) for components and assemblies in AC testing. It is capable of performing three-phase testing from 5kA to 300kA at up to 600VAC; single-phase testing up to 300kA at up to 760VAC and single-phase testing up to 100kA at 1,450VAC; and DC testing up to 100kA at voltages ranging from 24VDC to 1,000VDC. For more information, visit *www.cooperbussmann.com/services*.

Bishop-Wisecarver

APPOINTS VP EMPHASIZING CONTINUOUS IMPROVEMENT

Mike Citro

Mike Citro has been named vice president of operations for Bishop-Wisecarver Corp. Citro will lead the manufacturing, quality, purchasing and engineering teams at the company. He emphasizes continuous improvement in manufacturing operations and plans to identify opportunities to implement strategies designed to maximize resources and process standards.

Citro spent 11 years as the director of operations for Micropump. He then worked as an independent consultant for several years where he worked with major corporations to implement lean manufacturing standards and boost productivity. He worked for nine years as director of operations and general manager at Tuthill Pump Group, where he oversaw on-time orders more than double.

"I am encouraged by Bishop-Wisecarver's employees' willingness to embrace change, an attitude I have seldom encountered at previous projects," Citro says. "I am a fanatic about customer service, and I look forward to implementing Toyota product principles to support that conviction and take the company to the next level."

Citro has been an advocate of career technical education. He has taught manufacturing technology night classes at junior colleges and for the National Tooling and Machining Association, where he served as a national officer for 12 years.

continued

Power Up!

If you have a background in gears, bearings, motors, belts, couplings, sensors or actuators, we'd like to talk to you. Power Play, the back page feature in *PTE*, is all about your industry. If you've got a funny anecdote, an interesting observation or perhaps a limerick on motion control, feel free to send it our way. This column is dedicated to the stories too radical to make the cut in industry or product news. We need story ideas, and we're confident you can provide them.

The rules are quite simple: submit a story idea about the power transmission industry, make it entertaining as well as informative, and become a *PTE* magazine editor-at-large today (salary not included). Submit your award-winning material to:

publisher@powertransmission.com

He met Bishop-Wisecarver founder Bud Wisecarver more than 30 years ago at the Diablo Valley College (DVC), where Wisecarver was a member of the Machine Technology Board, and Citro taught classes.

"I signed up for the first class Mike taught at DVC, a computer programming course," Wisecarver says. "I knew right away that we had a lot in common. He demonstrated a real passion for helping kids develop technical skills and ensuring they had the necessary tools to put those skills to action."

Citro and Wisecarver worked together to acquire equipment for the school through government programs.

"Mike comes to us with a wealth of knowledge and a track record of past successes," says Pamela Kan, president of Bishop-Wisecarver. "He is a hands-on person who thrives on discovery by 'doing,' and teaching by example, two ideals he shares with my father [Wisecarver]. We look forward to the benefits of learning from Mike's valuable insight."

National Oilwell

MAKES TWO ACQUISITIONS

National Oilwell Varco, Inc., announced it has acquired ASEP Group Holding B.V. and Anson Limited.

Netherlands'-based ASEP develops and manufactures well service equipment that includes automation products, pressure control products, coiled tubing, cranes and wireline units. ASEP employs 555 people at four manufacturing locations and operates in nine countries.

British-based Anson manufactures valves, flowline equipment, manifolds, swivel joints, hammer lug unions and wellheads. These products should complement National Oilwell Varco's pump and fluid expendable products. Anson has 443 employees, one manufacturing location and operations in five countries.

"We are pleased to add these fine organizations to NOV and believe each enhances the level of service and technology we can provide our customers," says Pete Miller, chairman, president and CEO of National Oilwell Varco. "We continue to focus on long-term fundamentals of the oil and gas business as we seek to improve our strategic position, and we're pleased that our strong balance sheet enables us to capitalize on attractive opportunities."

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Gear Manufacturing

Gear Manufacturing

Gear Manufacturing

Power Transmission—Behind the Scenes

MOTION CONTROLLER GETS ITS 15 MINUTES IN ENTERTAINMENT APPLICATIONS

Building a mast that extends as high as a 12-story building with the capability to support a full-size 50 kg camera in potential high winds is no easy task. So when professional cameraman Matthew Gladstone developed the Vortex Aerial Mount Camera System in England, he turned to Trio Motion Technology for position and stability control.

Trio, a niche source for motion control technology, provided its MC206X motion controller to assist Gladstone in creating a portable, remote camera system that can be rigged and de-rigged in minutes—making it suitable for a wide range of camera shots for television and film work. The Vortex camera system can capture high angle shots with a minimal amount of equipment. It's a beneficial alternative for filming sporting events like horse races, golf matches or marathons where organizers prefer less noise and fewer distractions from busy film crews.

The camera mast is constructed using lightweight carbon fiber with each section rigidly interconnected through linear bearings. A central Kevlar cable runs through each section on an internal pulley system using a servomotor geared winch that moves the mast from its horizontal position to its vertical operating position. The servomotor then axially separates each section to lift the camera system up or down during filming.

Ed Novak, U.S. sales manager for Trio, says the MC206X controllers are capable of controlling 1-5 servo or stepper motors in full coordination. These designs allow customers to select their preferred drive, feedback and motor technologies in combination with a wide choice of factory and drive communication networks.

For the camera system, the MC206X provides the mass stiffness and stability control to capture the final turn of a horse race or aerial shots of the London Marathon. It can lift the camera from the ground level to a height of 30 meters in 15 seconds, allowing for multiple camera setups in the course of a single day.

"Few motion controllers have the performance and flexibility in such a cost effective, compact module," Novak says. "This allows many of our customers to get their applications up and running very quickly."

When London-based Windmill Studios needed synchronized graphics and motion for an exhibition that showcased props, costumes and creatures from the popular science fiction series, *Dr. Who*, they also chose Trio's MC206X.

"Trio's development software is easy to use for configuration and programming," says David Black, a project manager at Windmill Studios. "The project-based approach along with the axis and I/O monitoring and the simplicity of the Trio *BASIC* language allowed for really fast application development."

Although the controllers are featured in several entertainment applications, Novak says the equipment has also been used in industries like food packaging and labeling, window making machines, textile machines, automotive, medical, sign making and extrusion machines.

"These are multipurpose, programmable units that can be used in dozens of different industries."

For more information on the Vortex Aerial Mount Camera System, visit *www.cammotion.co.uk*. For information on Trio's motion controllers and equipment, visit *www.triomotion.com*.

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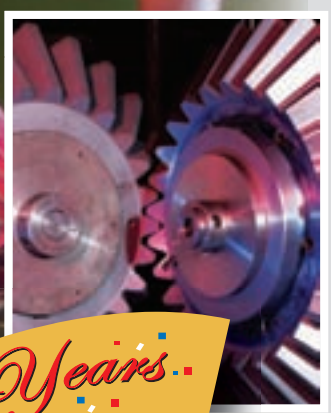

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