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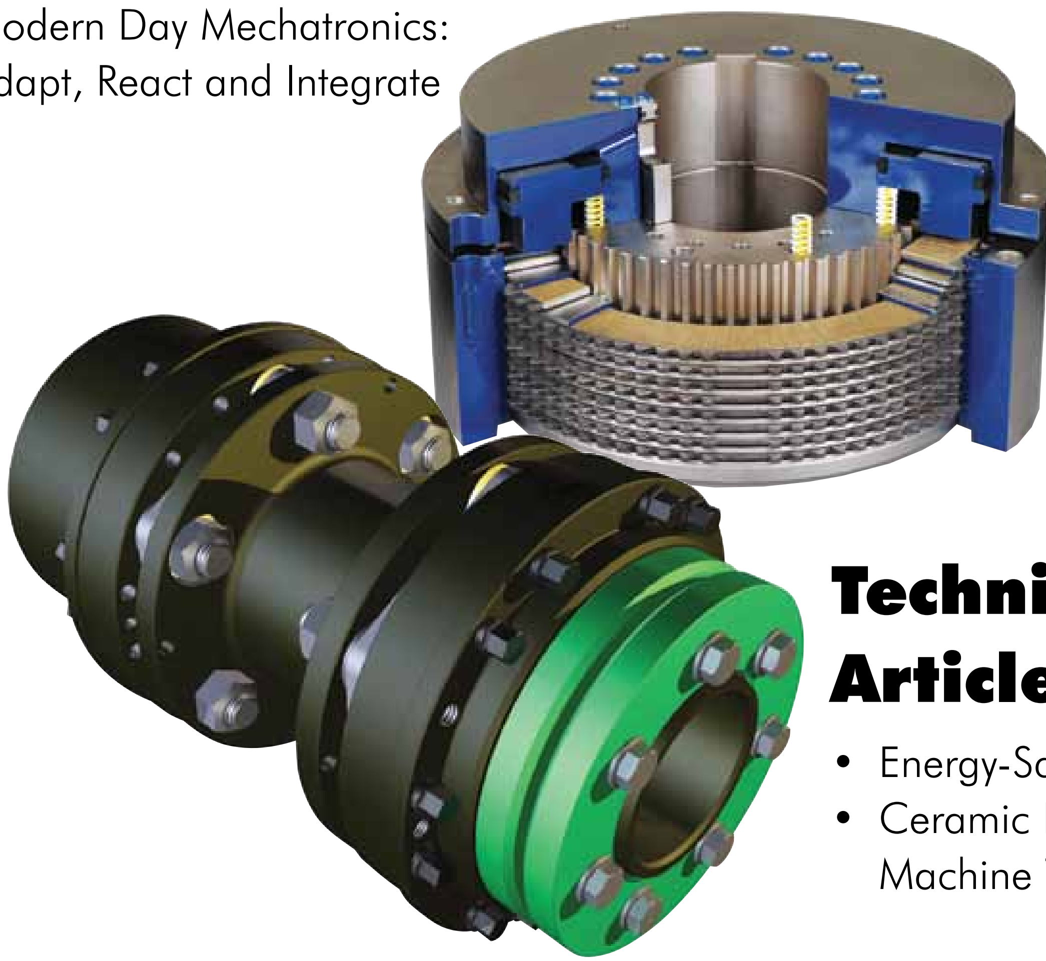
Features

- Force/Torque Sensors Automate Paper Manufacturing
- Modern Day Mechatronics: Adapt, React and Integrate



Technical Articles

- Energy-Saving Lubricants
- Ceramic Bearings For Machine Tool Spindles

Power Play

- Remembering Paul Winchell

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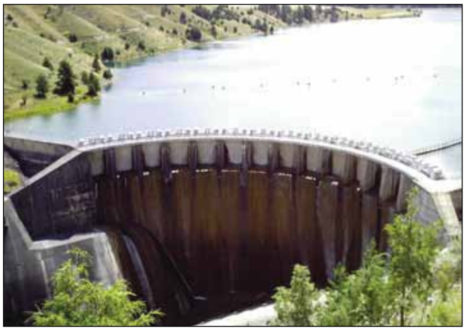
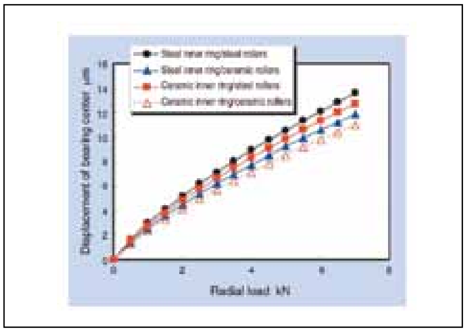
TECHNICAL ARTICLES





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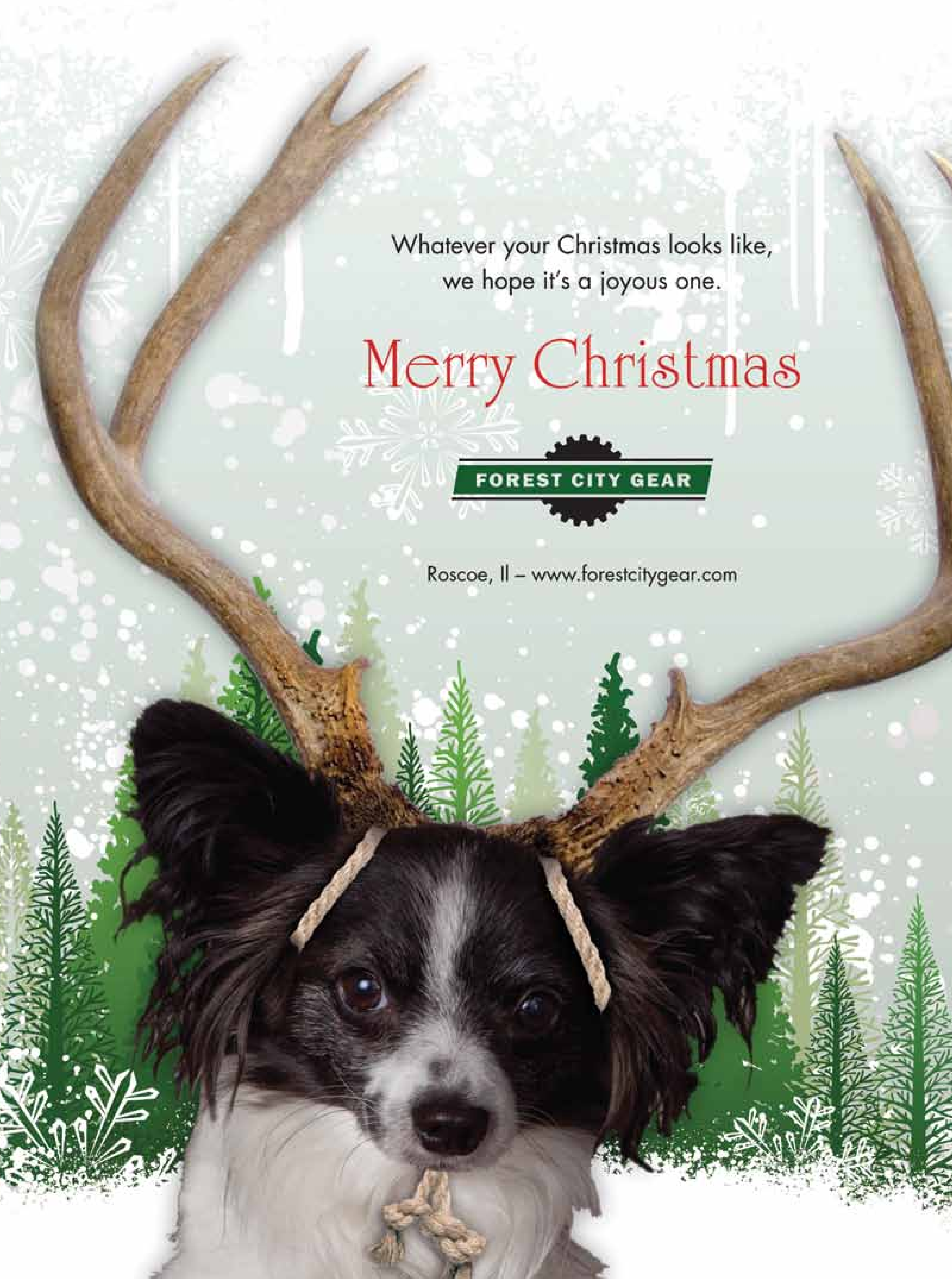
Whatever your Christmas looks like,
we hope it's a joyous one.
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Photos courtesy Ameridrives Couplings and Industrial Clutch.

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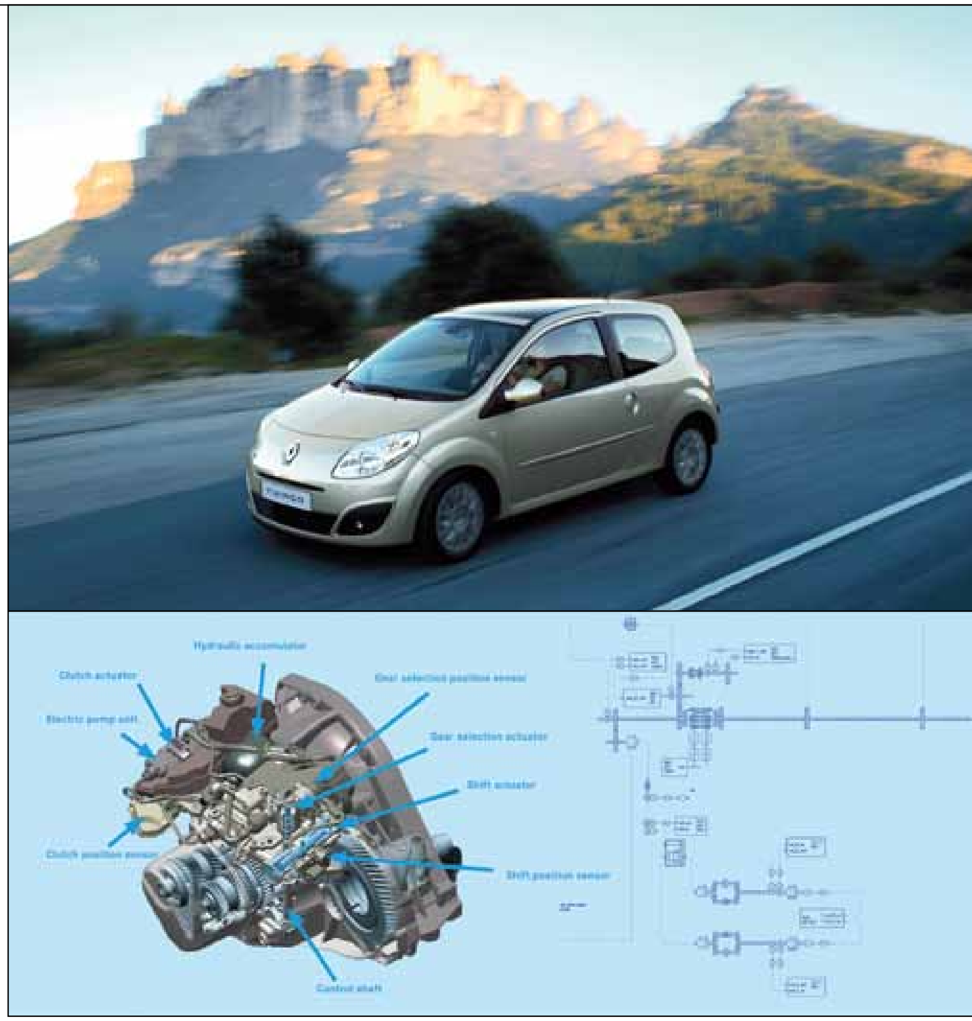
Designing the Brains for Automated Manual Transmissions

MECHATRONICS BRIDGES GAPS IN RENAULT'S AMT SYSTEMS



The Renault Twingo (top) and a schematic of Renault's automated manual transmission (bottom).

One of the features consumers worldwide increasingly look for in a new car is an automated manual transmission (AMT)—a system that behaves like an automatic, but also allows drivers to shift gears electronically using a push-button command without a clutch pedal. AMTs combine the fuel efficiency, performance and control of manual systems with the convenience of automatics—an especially handy feature in stop-and-go traffic. With the ease and convenience appreciated by many drivers facing daily traffic congestion, automakers are equipping a growing number of new vehicle models with these types of transmissions. Indeed, a report from market research firm Frost and Sullivan predicts 15 percent of small cars will likely feature AMTs by 2012.

These complex mechatronic systems are difficult to design, however, since their performance depends on the operation of three different subsystems all working together in perfect synchronization: an electromechanical actuator that shifts the gears, electronic sensors that monitor vehicle status and software embedded in the transmission control unit (TCU)—the "brains" that control the powertrain.

Ordinarily, up to a year is required to define overall functional requirements, design the actuator mechanics, develop and calibrate TCU software and validate the complete system. Software development and calibration are particularly troublesome bottlenecks, since these tasks typically require extensive trial-and-error physical testing cycles that cannot be performed until hardware prototypes are built. By then, mechanical and electronics designs are nearly finalized and cannot be changed appreciably to improve powertrain performance. Considerable time is spent troubleshooting problems near the end of design rather than refining TCU control strategies.

French automaker Renault S.A. is streamlining the AMT development process with a simulation-based approach using *LMS Imagine.Lab AMESim* 1-D simulation software to predict the performance and real functionality of complex multi-domain systems using a single unified physics-based model. Engineers drag, drop and interconnect simple icons to graphically create the model, displayed on the screen with a working sketch showing relationships of all the various elements to predict the behavior of an entire AMT system.

"Using the multi-domain simulation approach based on *LMS Imagine. Lab AMESim*, we can see early in development how all the various parts of the complex AMT system will operate together—mechanics, electronics and control software," explains Edouard Négre, senior design engineer in the Renault Powertrain Control Engineering Division. "With this understanding of the complete mechatronics system, we can readily optimize the entire design up front in development and avoid many late-stage problems and delays."

Throughout the process, the *AMESim* model evolves as the design progresses and system requirements are defined in greater detail. Renault most recently used the method to develop a new actuator for one of their existing AMT models, redefine the existing TCU control strategy and evaluate the entire AMT performance.

A simplified model was initially created to define overall powertrain load constraints and size the major mechanical components including hydraulics, electrical generator and gear reductions. Next, parameters from design drawings and technical data from engineering specifications were added to plot overall performance curves, define basic control commands and determine the overall response of the complete mechatronics system. In these conceptual phases, engineers explored the behavior of various alternative mechatronics configurations—in particular various actuator designs to provide for smooth gear shifting—until the best powertrain performance was achieved.

Based on these simulation results, the model was then used to develop control algorithms used as a basis for co-simulation between *AMESim* and the real-time software development and integration platform to develop first-order TCU logic software. In this "Software in the Loop" (SiL) approach *AMESim* was used to simulate the powertrain hardware—essentially providing a virtual engine and transmission as stand-ins while the actual hardware was still in development.

Finally, the TCU software performance was validated and calibrated using a "Hardware in the Loop" (HiL) approach to exercise the system model in real time. On a test rig, a TCU with control code embedded in the electrics sent signals to operate a physical prototype of an AMT actuator based on simulated load and sensor signals generated by *AMESim* for the rest of the powertrain. In this way, engineers fine-tuned the TCU software to achieve optimal powertrain performance according to fuel efficiency, dynamic response and other operational factors.

"Simulation-based development using *LMS Imagine.Lab AMESim* enabled Renault to shorten AMT development time considerably," Négre noted. "Refining the performance of the mechatronics system early in development avoids problems that take considerable time to resolve later in the development cycle. Moreover, using SiL and HiL approaches to develop, calibrate and validate TCU software in parallel with hardware development and fabrication constitutes an immense time savings."

"The models developed and lessons learned with this project will be used as a basis for further time and devel-

continued

opment savings in the future," Négre adds. "With this process, Renault will be launching more new vehicle models with AMTs months sooner than would otherwise be possible."

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Zero-Max ServoClass Couplings

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Design engineers looking to increase speeds in electronic assembly systems will find ServoClass Couplings from Zero-Max a viable design option. ServoClass Couplings provide high torsional stiffness, zero backlash and low hysteresis to ensure repeatable precise positioning at speeds up to 10,000 rpm. Their robust design ensures precise system operation in automated 24/7 applications. That is especially true where stresses occur at increased speeds in a servo system. Designed with 304 stainless steel disc packs and 7075-T6 aluminum hubs, ServoClass couplings are inherently strong, durable and precisely balanced. To ensure precise alignment of the assembled components, ISO 4762 CL12.9 corrosion resistant socket head cap screws are utilized with a carefully controlled assembly process. (Competitor couplings are assembled utilizing brazing, gluing and otherwise less precise methods with more variability.)

"ServoClass couplings are designed to handle the specific sensitivities of servo systems," reports Robert Mainz, Zero-Max sales manager. "The design of the coupling takes into account the mechanical as well as the electrical attributes of the system with the mechanical components keeping up with the electronic commands of the controller. The design specifications of the ServoClass coupling aid in making these two entities work far better together than other couplings when used in servomotor applications."

In addition to electronic assembly systems, ServoClass couplings are suitable for all types of automation, packaging and other types of automated assembly including most systems using ball screws and servomotors. ServoClass couplings are available in single and double flex models in inch and metric bore sizes from 0.157 inch (4 mm) to 1.750 inch (45 mm). All models and sizes feature clamp style hubs and operate in temperatures from –22 to +212 degrees F (–30 to +100 degrees C).

For more information:

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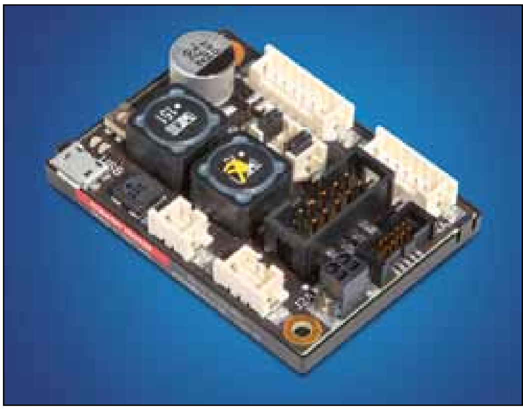

Maxon's Escon 36/2 DC is a four-quadrant PWM servo controller for use with DC motors up to 72 W. The Escon 36/2 DC is a very fast digital current controller with enormous bandwidth for optimal motor current/torque control. The drift-free yet extremely dynamic speed behavior enables a speed range of 1 to 150,000 rpm. It provides a wide range of functions, with fully configurable digital and analog inputs and outputs. When matched up with Maxon's range of motors, high demanding and dynamic drive solutions are possible. Additionally, it can be run in various operating modes speed controller (closed loop), speed controller (open loop)and current controller. This ultra-compact servo controller is controlled by means of an analog set value. The value can be specified by means of analog voltage, an external or internal potentiometer, a defined value or by means of a PWM signal with variable duty cycle. Other functions include the ability to enable or disable the power stage depending on the direction of rotation, or to use speed ramps for acceleration and deceleration. The speed can be regulated by means of a digital incremental encoder (2-channel, with/without line driver), DC tacho or without encoder (IxR compensation).

Designed to be user-friendly with an easy start-up, no in-depth knowledge of drive technology is required. When the servo controller is connected to a PC via a USB port, it can easily and efficiently be configured with the *Escon Studio* graphical user interface. During startup and configuration of the inputs and outputs, monitoring, data recording and diagnostics, the user has access to a large variety of functions and is assisted by user-friendly software wizards, as well as an automatic procedure for fine-tuning the controller. It comes fully equipped with everything that is needed. No additional external filters or motor chokes are required, and pre-assembled cables for the startup are available as accessories.

The Escon 36/2 DC has protective circuits against over-current, excess temperature, under- and over-voltage, against voltage transients and against short-circuits in the motor cable. It is equipped with protected digital inputs and outputs and an adjustable current limitation for protecting the motor and the load. The motor current and the actual speed of the motor shaft can be monitored by means of the analog output voltage. The large range for the input voltage and the operating temperature allow flexible use in a variety of drive applications. With its exceptional 95 percent efficiency, the inexpensive Escon 36/2 DC is a first-class choice for mobile, highly efficient yet consumption-optimized applications.

For more information:

Maxon Motors
101 Waldron Road,
Fall River, MA 02720
Phone: (508) 677-0520
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AVAILABLE WITH TORSI-LOCK HUBS

Developed for API 610 service, Torsiflex-i flexible disc couplings feature a robust disc pack design, allowing for greater torque load in a smaller size which results in lower weight. The couplings' lower weight and longer bearing life yield a lower cost-per-application. Max bores matched to NEMA motor shafts provide up to 60 percent weight savings. A plug-in spacer design allows installation and removal without disturbing the hubs. All models are ATEX-compliant and come standard with a zinc phosphate coating, a built-in anti-flail feature and inch series hub attachment screws (metric available).

Torsiflex-i couplings are now available with Torsi-Lock hubs. Torsi-Lock offers the ease of a slip fit with the power of a shrink fit. Ameridrives Couplings has responded to industry demand for a cold-install hub that provides the secure torque transmission and balance repeatability of an interference fit. Ameridrives combined their Ameriloc shaft-locking devices with Torsiflex-i to provide a fully pre-engineered solution that meets the balance requirements of API 610.

Cold installation of Torsiflex-i couplings with Torsi-Lock hubs means "No hot work permits," providing added safety and productivity in hazardous environments. Torsi-Lock hubs provide easy, repeatable removal and installation, and eliminate fretting of hub to shaft. The hubs compensate for variances in shaft spacing—units can be slipped on and fixed in the needed location. The hub and locking device are balanced and match-marked to assure optimum balance performance.

For more information:

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Motoman

RELEASES CONTROLLER AND MATERIAL HANDLING ROBOTS

Introduced at Pack Expo in September, the high-performance FS100 controller from Motoman Robotics is designed for open software connectivity and supports *PCI Express*. The FS100 controller supports *C*, *C#*, *INFORM III* and other high-level programming environments. "To meet the growing needs of our customers, it is often necessary to create custom functionality for the robot controller. The FS100 design leverages hardware standards and open software to allow easy extensibility of the controls," says Erik Nieves, technology director at Motoman Robotics. "It is now possible for users or system integrators to easily integrate off-the-shelf hardware or write value-added functions to the robot controller."

Designed for packaging, assembly and material handling applications, the FS100 controller is compatible with Motoman robots with payloads up to 20 kg, including the high-speed MPP3 delta-style robot also introduced at Pack Expo.

In addition, the powerful, high-speed MH80 robot has an extremely flexible design, allowing it to be used for a variety of material handling applications. The long reach of the MH80 model makes it ideal for handling large parts. Fast axial speeds and acceleration reduce cycle times and increase production output. Internally routed cables and hoses maximize system reliability, minimize interference and facilitate programming. The MH80 features an 80 kg (176.4 lb) payload, 2,061 mm (81.1") horizontal reach, 3,578 mm (140.9") vertical reach and ± 0.07 mm (0.003") repeatability. Its wide work envelope and small interference zones allow the MH80 to be placed in close proximity to workpieces and equipment, reducing floor space requirements. The robots have brakes on all axes and can be floor-, wall- or ceiling-mounted for

layout flexibility.

The MH80 robot is also suitable for dispensing and material cutting applications. The MH80 robot uses Motoman Robotics' dynamic, next-generation DX100 controller that includes patented multiple robot control technology to easily handle multiple tasks and control up to eight robots (72 axes), I/O devices and communication protocols. Featuring a robust PC architecture, the DX100 uses a Windows CE programming pendant with color touch screen. The energy-saving DX100 controller features faster processing speeds for smoother interpolation, advanced robot arm motion, built-in collision avoidance, quicker I/O response and accelerated Ethernet communication. Its extensive I/O suite includes integral PLC and HMI pendant displays, 2,048 I/O and a graphical ladder editor that can provide system level control. The DX100 controller supports all major fieldbus networks. It is compliant to ANSI/RIA R15.06-1999 and other relevant ISO and CSA safety standards.

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www.motoman.com

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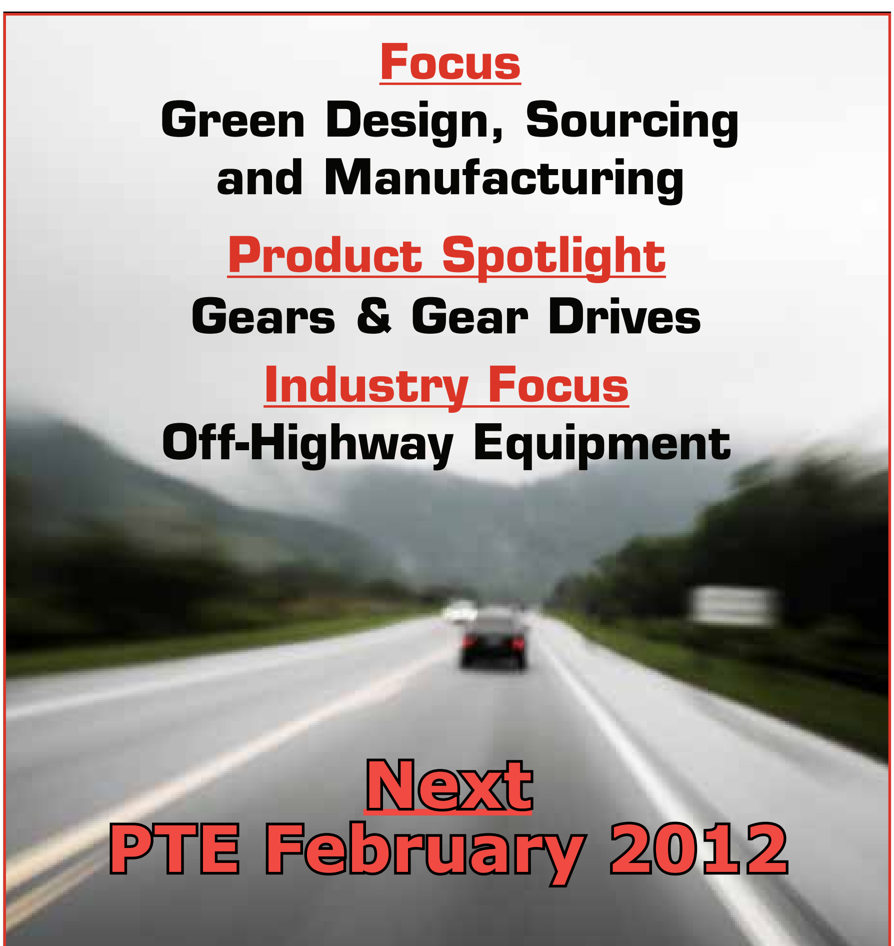
HC/CH Clutch

OFFERS PERFORMANCE ADVANTAGES IN MARINE APPLICATIONS

Industrial Clutch, located in Waukesha, Wisconsin, has introduced the Model HC/CH clutch designed for use in marine applications including draw-works, winches and propulsion. HC/CH models are drop-in replacements to competitive clutches. The HC/CH clutch features a unique, patent-pending key seal that allows for the use of standard o-rings and improves the ease of installation in current configurations using a double keyway and single drilled actuation hole. Hubs are manufactured from high quality alloy steel and include induction-hardened teeth for maximum spline life. The HC/CH is available in two styles: the EWA model for oil immersed application and EDA units designed to run as dry friction clutches. All friction materials utilized are designed to provide high thermal and smooth engagement performance. Wet friction material used in the EWA style oil immersed units allows for the use of both EP (extended pressure) and vegetable-based oils.

For more information:

Industrial Clutch
An Altra Industrial Motion Company
1701 Pearl Street
Waukesha, WI 53186
Phone: (262) 547-3357
www.indclutch.com



Cut and Print

PAPER CONVERTER INCREASES ROLL CONVERTING PROCESS BY 300%

Courtesy of ABB Robotics

Norkol Converting Corporation is one of the nation's leading independently owned converters and distributors of commercial printing papers. Founded in 1968, the company's corporate location in Northlake, Illinois has full production capabilities and state-of-the-art machinery for winding, trimming and sheeting. The company utilizes traditional slitter re-wind equipment that unwinds, slits and then re-winds paper to new dimensions. These conventional re-winders, while typically producing new widths of paper with clean cuts, work at an inefficient, slow pace.

ATI Industrial Automation offers a line of sensor products for assembly, machining and finishing tasks (All photos courtesy of ABB).

"Re-winders have been used for years in the paper converting industry and although they do the job, we are constantly researching and adopting the newest technologies to help us remain competitive," says Mike Maloy, president of Norkol Converting Corporation. "Our original re-winders take between 30 to 40 minutes to process one roll, so we were very excited when we were introduced to new technology that processes four to six rolls per hour without the need to unwind and rewind."

The company turned to system integrator Mapleroc Industries of Portland, Maine and their automation partners—ABB Robotics and ATI Industrial Automation—to implement a new cutting and finishing system to speed up their process. Together the partners developed and implemented a new fully automated cutting and finishing system using Mapleroc's RollRazor cutting technology, which features a highly engineered cut-

Mapleroc's RollRazor utilized ABB and ATI Industrial Automation to increase productivity.

ting blade capable of cutting as much as 300 percent more paper in one hour than traditional re-winders. As part of the new application, the system features a new Robotic Roll Finishing System utilizing an ABB IRB 6620 class robot equipped with a force-controlled machining package with ATI Force/Torque Sensors.

"ATI Force/Torque Sensors integrated into the robot wrist measure the forces and torques, giving the robot a sense of touch," says Dwayne Perry, PE chief sensor technologist for ATI Industrial Automation. "Robots integrated with these sensors make it possible to automate (a variety of) difficult assembly, machining and finishing tasks that previously required skilled personnel or complex assembly machines, allowing manufacturers to cut costs and improve employee safety."

The RollRazor. Developed by Mapleroc, the RollRazor utilizes a finely honed and engineered blade to cut parent rolls of paper in their rolled state in one pass, cutting them to press-ready roll sizes in three minutes, all without the need to un-wind and re-wind the paper. It is the fastest paper roll converting machine currently available. The system is capable of handling all grades of paper including tissue, napkin, cigarette, Bible, coated, uncoated, cardboard and kraft papers.

"In addition to vastly increasing cutting speed, the RollRazor's circular blade generates virtually no heat, cutting seamlessly in one pass through the roll and thereby maintaining the paper quality of the mill wound roll," says Todd Morrison, president of Mapleroc Industries. "This

continued

ATI Force/Torque Sensors gave the ABB robot a sense of touch.

The ABB IRB 6620 is a flexible six-axis robot with a compact design.

avoids possible errors inherent in the un-winding and re-winding process such as wrinkling and tension problems." Pressrooms today cannot afford upsets on press due to inconsistent roll quality. RollRazor ensures consistent mill wound rolls with all the "original" manufactured specs still built-in to the press-ready rolls."

Mapleroc estimates that mills or paper convertors can triple production output, improve efficiency by 2.7 times and reduce operating costs by as much as 72 percent using this new system.

Robotic Roll Finishing System. Traditional slitter rewinding equipment makes a clean cut and the new rolls do not require any additional finishing. The RollRazor blade cuts through the entire roll with a circular saw blade. Because not all rolls are wound the same, not all cuts come out the same. In an effort to remove the "witness lines" that are left over from the cutting process and producing a consistent looking roll, these edges then require sanding to meet the customer's requirements. To complete the robotic cutting application, Mapleroc, ABB and ATI partnered to develop a roll finishing solution to automatically sand and smooth these edges. The newly developed Robotic Roll Finishing System creates a fully automated, high precision force-controlled roll finishing station.

"We worked with Mapleroc and ATI jointly to turn the Mapleroc finishing center into a workable concept of an unmanned, fully robotized system," says Slawomir Smolec, business unit manager for robot automation at ABB Robotics. "The resulting Robotic Roll Finishing System utilizes an ABB IRB 6620 class robot equipped with a force-controlled machining package from ABB."

"The IRB 6620 robot is equipped with an end-of-arm roll finishing tool and an integrated dust collection system," added Adrian Kiss, engineering manager of ABB Robotics. "As the robot sands the rolls, an integrated dust collection system removes the excess paper using a vacuum system."

The IRB 6620 is a flexible and agile six-axis robot with a large working envelope. It features an extremely compact design, has a reach of 2.2 m and can handle payloads of up to 150 kg.

With the cut roll moved into place, the robot equipped with the sanding head smoothes the edges utilizing the ATI Force/Torque sensor technology to provide force feedback. This enables the robot to feel and have a sense of touch just as a human would. This sense of touch allows the robot to make quick adjustments in real-time to maintain a constant contact force—all while mantaining an average finishing temperature of 85 degrees. Together, the robot and sensor make this finishing task possible.

The system uses ABB's force control package featuring the force/torque sensors integrated on to the robot wrist and where the signals from the force/torque sensor are interpreted directly into the motion control of the robot. The package includes ABB's *RobotWare Force Control Machining* software with a user-friendly machining GUI. The hardware includes an axis computer, data acquisition board for the sensor, cabling between the sensor and controller and ATI's force-and-torque sensor.

Multi-Axis Force/Torque Sensors. The key to smoothly sanding the paper rolls to meet the high standards Norkol's customers require is the system's sensor technology. The multi-axis force/torque sensors measure all six components of force and torque. Each consists of a transducer, shielded high-flex cable, and an interface card specially designed to work in the ABB robot.

So how does it work? When you

apply a load to the transducer, microscopic strains develop on its internal beams. Silicon strain gages placed on these beams react to the strains, and electronics measure this reaction. Software analyzes the measurements and is able to report and transmit the information about the amount of load that is being applied. Simply put, the transducer bends microscopically; it measures that bending and the software determines and transmits that information to the robot. The sensors give the robot force feedback when the unit is pushing too hard or moving to the left or right.

Force/Torque Sensor Technology versus a Load Cell. "A common question we hear when customers are considering various force sensing solutions is how our sensors differ from load cell force sensing," says ATI's Perry. "The three important differences include the elimination of crosstalk with our product, a wide range of interfacing options making connections simple, and our product's ability to withstand overloads of greater than 20 times its capacity."

Perry elaborates that ATI's Force/Torque Sensors are largely immune to crosstalk. Load cells typically measure just one or two axes of loading, which can unintentionally react to loads on other axes, resulting in undesirable crosstalk. Six-degree-of-freedom transducers don't have this type of crosstalk problem. Another advantage with the ATI sensors is the availability of connecting to a wide range of industrial interfacing options including Ethernet, EtherNet/IP, USB, PCI bus, PCMCIA, RS-232, analog voltage and more. The sensors come as a complete system, making it simple for customers to connect to their equipment, whereas load cells usually have only one or two ways of connecting, require external electronics bought separately and usually only use analog voltages. Finally, and perhaps most importantly, Perry adds that load cells can only withstand 150 to 200 percent of an axis's rated range, thus increasing the chances of it failing. On the other hand, force/torque sensors' overload capacities generally run from five times to greater than 20 times, depending on the selected calibration.

The ABB IRB 6620 provides force feedback thanks to ATI's Force/Torque technology.

Additional Applications. In addition to the robotic roll finishing application, force control is suitable for many other applications including difficult assembly, machining and finishing tasks that previously required skilled personnel or complex assembly machines. Force/torque sensors are used throughout the industry for product testing, robotic assembly, grinding and polishing. Force control provides excellent robotic contour following, such as in grinding or deburring, to ensure the correct force is being applied. It is also used for robotic material handling to verify product weight and collision-free placement. In research, ATI's sensors are currently being used in robotic surgery, haptics, rehabilitation, neurology and many other applications.

Cutting and Finishing Benefits. Utilzing the new RollRazor cutting technology has significantly sped up Norkol's converting process and reduced their costs. The company estimates that with the new equipment they can produce one press-ready roll in six minutes where it originally would take approximately 30

continued

minutes to process. For the company this increased production lowers their cost per ton and cost of labor. The new equipment increases plant flexibility, maintains original mill roll quality, guarantees original sheet orientation and web tension and can also convert wet or damaged rolls.

The Robotic Roll Finishing System with its force/torque sensing capability eliminates safety risks for employees and offers manufacturers a quick and efficient method of finishing the roll to the standards required by the customer. The system allows the robots to address all roll sizes and unfinished surfaces automatically, eliminating the need for manual set-up. With this new system everything is embedded in the robot control, thereby eliminating the need for an expensive programmable logic controller (PLC) which typically would be used to regulate pressure and prevent the paper from burning or melting.

"Our goal at Mapleroc is to manufacture roll converting equipment with the best available technologies that improves our customers' runability and printability of their paper. We are doing this while dramatically lowering the cost of roll converting" commented Mapleroc's Morrison.

"We have been very pleased with the new cutting and finishing system as it is faster and eliminates problems for most applications. We are currently evaluating and considering replacing additional rewinders with this more efficient system," adds Maloy of Norkol.

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Often Overlooked, Lubricants

CAN HELP LOWER ENERGY CONSUMPTION

John Sander, vice president, technology, Lubrication Engineers Inc.

Management Summary

It is a simple fact: better lubrication can lead to dramatic energy savings and an improved bottom line. This ought to interest any plant manager who is looking for ways to reduce operating costs, and it is especially significant at a time when stricter government regulations are in direct contradiction to reducing costs. Lubrication reliability is the solution; this article will describe how manufacturing plants can use "lubrication reliability best-practices" to reduce their energy consumption, emissions and operating costs—all at the same time.

Introduction

Energy and its usage are the lifeblood of today's society—economic development and improved standards of living both rely upon its constant availability. According to "The Outlook for Energy: A View to 2030," by Exxon Mobil, energy usage-per-person varies dramatically around the world but equates to an average of 200,000 Btu a day—or 15 billion Btu-per-second (Ref. 1). The same study points out that each person has what it identifies as "direct" and "indirect" energy demands.

Direct demand of energy is the energy that drives our personal vehicles and operates our homes; indirect demand is the energy that heats and cools buildings, generates power, produces goods and services and provides mass transportation of goods and people.

As the lesser-developed parts of the world continue to modernize, their needs for energy will grow accordingly and result in increased costs for fuel worldwide. In addition, many of the world's governments are passing stricter laws regulating clean air and water, toxic waste, pesticides, endangered species and more. These factors—combined with the struggling economy—result in the challenge for plant operations managers, i.e.—reduce operating costs.

This often means doing more with less.

One obvious way to reduce operating costs is to reduce energy consumption. Upgrading and replacing plant equipment with newer, more energy-efficient technologies can reduce energy costs. Unfortunately, in a challenging economic environment, capital may not be available for plant upgrades.

But simple changes in habits can also create considerable savings; one such change is to improve a company's "lubrication reliability program." According to Peter Thorpe, product application specialist at Shell/South Africa, "From a cost point of view alone, lubricant costs are negligible when compared to energy costs, even before the production efficiencies of high-performance lubricants are factored in (Ref. 2)."

Indeed, electric utility bills generally dwarf maintenance and lubricant costs; all three are part of any manufacturing operation. While controlling or reducing maintenance and lubricant costs is important, reducing electric utility usage is critical. This paper will show that tremendous opportunities exist to use an improved lubrication reliability program to decrease plant energy costs and increase profitability.

Sources of Energy

There are various forms of energy (Table 1). Mechanical energy is further broken down into two types: kinetic energy—the energy of motion; and potential energy—energy associated with an object's position. Energy often transforms from one form to another for an end-use purpose. For example: oil, when combusted, contains chemical energy that converts to thermal energy and then to electrical or mechanical energy.

Energy for Work

During these conversions some useable energy is lost; these losses can be extremely costly to society. The science of physics reveals that lubrication can play a role in reducing energy losses by reducing friction.

Society uses many automated tools to perform everyday activities—what we call "work." These tools frequently include many moving parts to accomplish the chore they are designed to perform. As it happens, work and kinetic energy—also called the energy of motion—are directly related. In 1687 Sir Isaac Newton published his laws of motion in *Principia Mathematica*, which effectively determined that the mathematical expression for kinetic energy (K) is:

$K = \frac{1}{2} mv^2$ (where m is a mass and v is the velocity at which the mass is moved) (1)

It can thus be stated that energy is required to move an object.

The laws of physics also state that work is the force required to move an object a certain distance, as in:

$$W = F\Delta x \quad (2)$$

(where F is a force and Δx is the change in position)

Work is also equal to the change in kinetic energy, in that:

$$W = \Delta K \quad (3)$$

In fact, friction is a force that exists in two forms—static friction (F_s) and kinetic friction (F_k).

Friction is represented mathematically by the following:

$$F_s = \mu_s N \text{ and } F_k = \mu_k N;$$

where:

μ_s and μ_k are the static and kinetic coefficients of friction, respectively, and N is a force normal to the moving surfaces.(4)

The coefficient of friction is a unit-less number that varies, dependent upon the material composition with which the moving surfaces are made. Obviously, the higher the coefficient of friction, the higher the friction force.

Finally, the equation that describes the total change of kinetic energy (E_T) required in a moving system is the following:

$$E_T = W_m + W_F \quad (5)$$

where:

W_m is the work to move the machine
and W_F is the work required to overcome friction

Physics shows us that reduced friction would reduce the energy needed to complete the desired work. Placed between two moving surfaces, a lubricant decreases the coefficient of friction; it naturally follows that the more a lubricant decreases friction, the less energy the lubricated machine consumes.

Lubricant Formulation Basics

It has been said that "Oil's oil; just pour it in;" but this statement is far from reality. Simply described, a lubricant is composed of a base fluid and additives. However, many lubricant suppliers formulate their lubricants according to unique recipes intended for specific purposes (applications). Table 2 serves as a primer on the basic types of lubricants and their specific, ingredient-driven categories.

continued

Table 1—Forms of energy

Chemical
Nuclear
Radiant (light)
Thermal
Sound
Electrical
Mechanical (kinetic/potential)(Ref. 3)

Table 2—Lubricant types

Automotive (Transportation)	*Industrial (Factories)*
Heavy-duty diesel engine oils	Compressors
Passenger car engine oils	Bearings
Automatic transmission fluids	Gear boxes
Aviation engine oils	Hydraulics
Mobile hydraulic	Turbines
Differential fluids	Chains/wire ropes
Torque fluids	Slide-ways
Chassis lubricants (grease)	Grease

Each of the lubricant types in Table 2 is usually broken down into narrower descriptions based upon the product formulation chemistry. Table 3 lists the categories and the additive types that dictate the categorical description. These descriptions are extremely simplified as there are various base fluid types and even more additive types. Each formula category has its strengths and weaknesses, and should be chosen based upon the needs of the application.

It is a fact that lubricant formulations can be rather complex; but when searching for the best lubricant to minimize friction-induced energy loss, it is typically accepted that "you get what you pay for." This common wisdom is that an inexpensively priced lubricant does not necessarily provide maximum lubrication performance and may require a higher amount of energy consumption—sometimes at higher costs than with a more expensive, better-performing lubricant. However, simply using an expensive lubricant does not ensure maximum lubricant performance and energy savings; aside from being the right lubricant for the application, it must also be properly maintained in order for it to provide maximum performance, e.g.—proper storage and handling, filtration, oil analysis, training and more.

All electro-mechanical equipment requires periodic maintenance to operate at peak efficiency and to minimize unscheduled downtime. Inadequate maintenance can increase energy consumption and lead to high operating temperatures, poor moisture control, excessive contamination and unsafe working environments. Depending on the equipment, maintenance may include the addition or replacement of filters and fluids, inspections, adjustments and repairs (Ref. 4).

But how does the end-user know what to do? The answer is to find a lubrication partner that can help develop a comprehensive lubrication reliability program that includes lubricant selection, protection and maintenance. This partner could be a consultant, but it could also be a lubricant manufacturer that offers customized, comprehensive solutions, including lubricants and all of the related lubrication reliability products.

Table 3—Lubricant categories by ingredient

Category	*Ingredients Described*
Mineral oil	Base fluid derived from refined crude oil
Synthetic	Synthesized base fluids such as PAO, esters, PIB, PAG and more
R&O (rust/oxidation)	Contains rust and oxidation inhibition additives
AW (anti-wear)	Contains wear-reducing additives
EP (extreme pressure)	Contains extreme pressure wear-reducing additives
Multi-grade	Contains viscosity index-improving additives
DI (detergent inhibitor)	Contains detergent, dispersant, oxidation, wear and anti-corrosion additives
Others	De-foamants, emulsifiers, de-mulsifiers, pour point depressants and thickeners

Lubricants and Energy Savings

Energy savings is measured in a variety of ways, including production output, temperature changes or electrical reduction—all of which are addressed below. Yet another measurement is fuel consumption.

Production output. When we use equipment to perform work, it is possible to evaluate the equipment's energy efficiency by recording its production output. For example, if a machine is capable of producing a certain number of parts in a given amount of time and the lubricant is changed—resulting in a higher volume of parts being produced in the same amount of time—then the machine has become more energy-efficient. But one must be careful when using this technique to ensure that nothing changed in the process except the lubricant. This can be overcome by using a larger number of test units or by evaluating productivity over a longer amount of time.

Temperature changes. Monitoring temperature changes is another way to optimize lubrication program performance. Increased friction in a piece of moving equipment results in higher operating temperatures; friction is a result of metal-to-metal contact that occurs between two opposing surfaces moving relative to one another. Even between highly machined surfaces, under microscopic view, asperity contact occurs.

Indeed, the greater the amount of contact, the greater the amount of friction. As a result, more energy is required to move the surfaces relative to one another. This friction results in higher electrical power costs. Lubricants can reduce that friction. Therefore, when friction is reduced, less electricity is required to drive a gearbox, compressor, pump or other piece of equipment.

Sometimes, the bulk oil temperature is monitored in a piece of operating equipment. Another technique for evaluating lubrication performance is thermography; it involves using infrared detection equipment to look for "hot spots" on a piece of equipment that could result from insufficient lubrication, improper lubricant selection or faulty operating parts. In any of these cases, higher temperatures result in wasted energy. It is important, however, to account for ambient environmental temperatures when performing this type of energy efficiency study; obviously, a piece of equipment will run hotter on hot days than on cold days.

Case study: A knitting plant in Hendersonville, North Carolina was experiencing overheating problems in its Champion TWT-07 reciprocating compressor while using the recommended commercial-grade lubricant. Even after changing to several synthetic products, it still experienced lubricant foaming and overheating. After changing to an ash-less AW mineral compressor oil, the plant experienced an immediate drop in temperature of 15°F (8°C). Even after three months of continued service, the plant maintained this temperature drop. This study illustrates that certain equipment can have its own lubricant "appetite;" just because a fluid is synthetic does not necessarily mean that it is the best recommendation for a piece of equipment.

Electrical reduction. When most of us think about energy consumption we immediately think about *electrical* consumption, and tracking electrical consumption is a highly reliable way to evaluate improvements in plant energy use. In fact, various companies have been able to document improvements in electrical energy efficiency related to their lubrication programs. Typically, companies that upgrade their lubricants and reliability practices have been able to document a 5 to 15 percent reduction in power requirements—more than enough to pay for a better-performing lubricant. Average documented savings were 15 percent in gearboxes, 12 percent in air compressors and 4 percent in electric motors (Ref. 5).

Electric motors power most plant machinery, including gearboxes, compressors, refrigeration systems, pumps, hydraulic systems and ball mills; kilowatts (kW) are the common unit for measuring electricity. The following equation can determine the amount of electricity used by an electric motor:

$$kW = V/1{,}000 \times A \times 1.73 \quad \text{(where } V \text{ is volts and } A \text{ is amperes)} \tag{6}$$

Both are common metric measurements of electrical current, measured via a voltmeter or ammeter. For a three-phase motor, 1.73 is a standard factor. Data logging equipment is available that allows one to measure and collect data for either amperes, volts, or both. Yet most electrical consumers pay for electricity by kilowatt-hour (kWh)-per-month. The following formula is commonly used to determine the electrical-charge-per-month (ECM):

$$ECM = kW \times h \times EC \tag{7}$$

where h is hours of service and EC is the electrical charge)

Air compressors are an easy target for energy savings in that compressed air is one of the most expensive uses of energy in a manufacturing plant; approximately 70 percent of all manufacturers have a compressed air system. These systems power a variety of equipment, including machine tools, material handling and separation equipment, and spray painting equipment. According to the U.S. Department of Energy (DOE), compressed air systems in the U.S. account for 10 percent of all electricity and roughly 16 percent of U.S. industrial motor system energy use. This adds up to $1.5 billion per year in energy costs and 5 percent in emissions. Energy audits conducted by the DOE suggest that more than 50 percent of compressed air systems at industrial facilities have significant energy conservation opportunities (Ref. 6).

Following are manufacturing case studies in which lubricant changes in air compressors and other plant equipment helped manufacturers reduce their electrical consumption.

Case study 1: A western New York glass and ceramics manufacturer had instituted a program to reduce electricity consumption. The manufacturer targeted its Ingersoll-Rand ESH reciprocating compressor driven by a 440-volt, 75-hp motor because this piece of equipment operated at peak capacity 24 hours per day, seven days a week. At the start of the experiment, when the compressor contained the OEM-specified synthetic oil, the average baseline reading was 89 amps.

A week after draining the oil, cleaning the compressor and refilling with a high-performance, branded synthetic oil, the manufacturer again collected data and found that the average reading had dropped to 82 amps. Knowing that it was using six fewer amps, applying Equations 6 and 7, and knowing that the energy charge was $0.10/kWh, the manufacturer was able to calculate the annual monetary savings due to lubricant-related electrical efficiency improvements as:

$$kW = 6 \text{ amps} \times 440 \text{ volts}/1{,}000 \times 1.73 = 4.57 \tag{8}$$

$$ECM = 4.57\ kW \times 8{,}760\ h/\text{yr} \times \$0.10 = \$4{,}003/\text{yr} \tag{9}$$

Data collection continued for an entire year and the lower amperage remained unchanged. Valve maintenance was performed at the same intervals as with the previous oil—*by which the source of the energy savings was revealed*. The valves were no longer covered with sticky, carbon-varnish build-up, as was the case with the OEM oil; and the new oil appeared to deteriorate less. The manufacturer learned that not all synthetic lubricants are equal.

Case study 2: A South Dakota wastewater treatment plant was looking to reduce operating expenses by using higher-quality lubricants to achieve extended drain service and possible energy savings in three Spencer 50-hp rotary blowers that were part of a biological contactor system. The average electrical reading was 50 amps on each of the blowers while using their current lubricant. After changing to a high-performance lubricant, the average dropped to 38 amps. Based upon electrical rates at that time, the estimated yearly savings was $2,968 per blower—or $8,904 for all three.

continued

Table 4—Typical savings with 5 percent amperage reduction*

Electric Motor (hp rating)	Type of Operation	
	40 hrs/wk	Continuous
10	$74	$297
50	$372	$1,487
100	$746	$2,986
200	$1,493	$5,472

**$0.10 kWh Electricity Rate*

LE's Duolec Lubricant Helps Maintain D.J. Murray Hydro-Dam Gearboxes

Customer Profile: The customer (name withheld upon request) manages eight hydro facilities in Montana and more than 40 power generation facilities nationwide.

Application: At its Montana hydro dam, the company uses D.J. Murray gearboxes for its wicket gates, with a total of 22 gearboxes on the dam.

Challenge: The gearboxes were extremely contaminated and needed to be changed due to long-term neglect. But without a reliability program in place, the company was unaware of the extent of the contamination. They knew they needed to implement reliability best practices to prevent contamination, as well as to help the gearboxes perform reliably and last longer.

LE Solution: Jim Pezoldt, LE lubrication consultant, recommended that the company follow best practices with a focus on the lubricant and enhanced reliability. This program included the implementation of standard operating procedures such as oil filtration and annual oil sampling. Using those recommendations, the customer developed a reliability program for maintaining its gearboxes—including the best practices listed below:

Reliability Program:

- Best possible flushing procedure (see below)
- Best possible lubricant for the application: LE's Duolec Vari-Purpose gear lubricant (1606)
- Best possible transfer and filter system: AMS model C 10150-1-6x-18DP-120
- Best possible oil analysis program: LEAP Advanced Industrial with PQ
- Appropriate target alarms
- Onsite training
- Annual status report and review of action requirements

Lubricant Recommendation and Oil Analysis

While the gearboxes run for only a few hours each year, they do so under heavy loads. And so, heavy-duty industrial gear oil is required. Duolec 1606 is a (specified) AGMA 6 EP gear lubricant that contains a premium base oil and robust additive package, making it ideal for these gearboxes. Another challenge: the oil must reside in the gearboxes for long service intervals because replacement is problematic. Duolec is designed to perform well under these conditions. And finally, one more hurdle: the necessary longevity of service time and the location of the gearboxes make them susceptible to water contamination. Duolec separates readily from water to provide effective lubrication when moisture is present. Ordinary gear oils will emulsify and foam, causing increased frictional heat and poor lubrication.

The new LEAP Advanced Industrial with PQ test slate is also a good match for this application. The particle quantifier test makes it possible to determine the cleanliness of the oil and to establish the right frequency for using the filter cart.

Flushing Procedure:

Step 1:Add 6% L-X Heavy-Duty Chemical Supplement (2300) to existing oil; run for no more than 50 hours and no less than 4 hours.
Step 2: Drain the oil while warm.
Step 3: Fill with LE's Duolec Vari-Purpose gear lubricant (1606).
Step 4: After 50 hours of service, open ball valve and drain the discolored oil. *Do this while machine is not running* (at least 20 minutes). If extensive discoloration is present, repeat process until only clean LE oil appears.

Other LE products used:

- Almaplex industrial lubricant (1275) for non-food grade bearings
- Monolec R&O com pressor/turbine oil (6404) for turbine and governors
- Quinplex foo machinery lubricant (4024) for wicket gate bear ings
- Quinplex synthetic food grade oil (4046) for waste gate hydraulic system

Results

By implementing this reliability program the customer will be able to better maintain its equipment. The conversion to Duolec 1606 was done in 2010, with follow-up results expected in 2011 or early 2012.

Summary

- Implemented a reliability program for proper maintenance of gearboxes, including an enhanced monitoring system.
- Eliminated abrasive contamination caused by the previous oil.
- Made changes that will contribute to a longer gear lifespan.

(Results based on actual user experience. Individual results may vary. Not intended to supersede manufacturer specifications. Duolec, L-X, Almaplex, Monolec *and* Quinplex *are registered trademarks of Lubrication Engineers, Inc. LE operates under an ISO 9001 Certified Quality System; SIC 4911; LI70822 12-10.*)

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Conclusion

Today there are various reasons to reduce energy consumption—conserving natural resources, reducing emissions and improving profitability among them. Governments and corporate management alike continue looking for ways to reduce energy consumption.

Indirect energy use—more commonly called industrial use—is greater in all regions of the world than direct or personal use. That makes industry the largest consumer of energy and therefore the greatest source for potential reductions. Energy use can be measured through production output, temperature changes and electrical consumption. It is possible to make dramatic gains in energy efficiency by reducing friction, and one of the best ways to do that is to employ good lubrication practices, including the use of high-performance lubricants and adoption of lubrication reliability best-practices. The key to success is finding a lubricant company that will not only provide the right high-performance lubricants for the applications, but will also recommend reliability solutions that will further reduce friction and maximize equipment efficiency.

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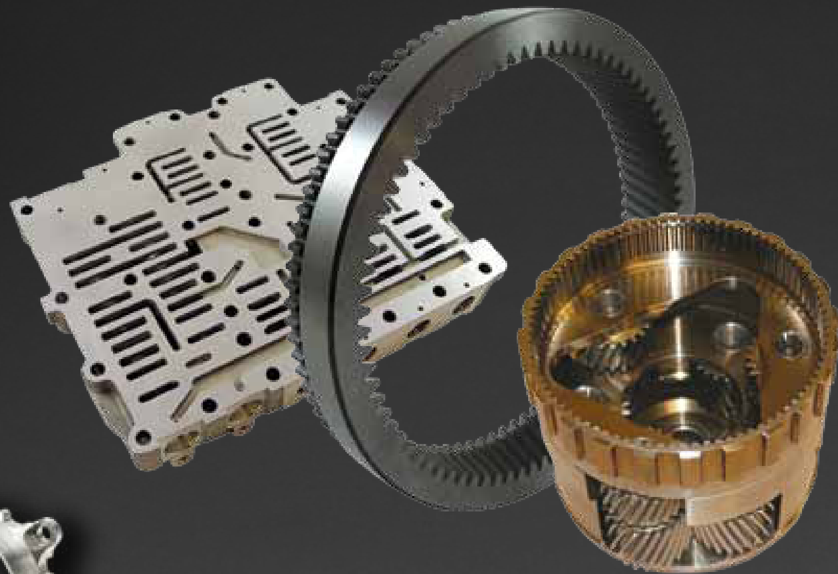
HIGH PR

DELTA GEAR

DELTA RESEARCH



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Application of Ceramics

TO NU-TYPE CYLINDRICAL ROLLER BEARINGS FOR MACHINE TOOL MAIN SPINDLES

Masatsugu Mori and Takuji Kobayashi, NTN Elemental Technology R&D Center

Management Summary

Ultra-high-speed operation of air-oil lubricated NU-type cylindrical roller bearings has been made possible by using a ceramic inner ring. A maximum speed of up to 35,000 min^{-1} is possible ($d_m n$ value of 3.25 million; inner ring bore of 70 mm). Devising the outer ring rib structure to streamline lubricant drainage resolves the occurrence of high and broad temperature rises around the mid-speed range, which is typical of conventional NU-type cylindrical roller bearings, as well as rapid temperature rises at high shaft speeds. The developed bearing will allow the practical application of NU-type cylindrical roller bearings to machine tools that require high bearing stiffness over a wide range of operation speeds. The cage made of PEEK (polyether-ether ketone) is guided on the air-oil-nozzle outside surfaces, while rollers made of steel can be used even at 35,000 min^{-1} and control the inner ring temperature below 70° C.

Introduction

Bearings used to support main spindles on machine tools must be capable of higher speed and greater rigidity. This is true in that any main spindle that turns together with a tool or work piece mounted onto it is one of the critical machine tool components that directly affects machining efficiency and accuracy of the machine tool; and, the bearings that support the main spindle are the most critical machine elements on the machine tool (Ref. 1). Other mechanical characteristics any main spindle bearing needs to satisfy include higher bearing accuracy, lower vibration and lower noise. Rolling bearings are most often used to support main spindles because they satisfy various requirements, including cost effectiveness and maintainability of balance compared with hydrodynamic (static or dynamic pressure) bearings and magnetic bearings.

Typical rolling-bearing types used to support machine tool main spindles are angular contact ball bearings, cylindrical roller bearings and tapered roller bearings. In particular, cylindrical roller bearings are preferred as non-locating bearings because they boast higher load capacity and greater rigidity in the radial direction, and their inner and outer rings are capable of moving in the axial direction relative to the main spindle. Since requirements appear to be increasing for higher speed with the fixed position preload bearing system (which features greater rigidity) for rolling bearings on machine tool main spindles, capability for much higher speed will be needed for rear-position (that is, free-side) single-row cylindrical roller bearings.

To address this challenge, we attempted to use ceramic inner rings (this topic will be described in detail later) to prevent occurrence of excessive preload that will pose a direct obstacle to achievement of higher main spindle bearing speed. In a previous paper (Ref. 2), we reported our experience in developing the N-type cylindrical roller bearings series having a ceramic inner ring (featuring double-rib inner ring); this cylindrical roller bearing type, lubricated with an air-oil lubrication system, achieved ultra-high-speed bearing operation as fast as $d_m n$ (bearing-pitch-diameter mm × inner-ring-running-speed min^{-1}) value = 3.25×10^6. This speed level is equivalent to that obtained from not-yet- mounted, ultra-high-speed, constant-pressure preloaded angular contact ball bearings (Ref. 3). However, the N-type is uniquely structured in that its ceramic inner ring is tightly fitted with steel spacer rings also serving as ribs: therefore, a simpler-structured ceramic inner ring is needed to simplify formation and mounting of the inner ring.

To address this challenge we have developed NU-type cylindrical roller bearings (featuring double-rib outer ring) that have ceramic—but no spacer—rings, and achieved ultra-high-speed bearing operation as fast as $d_m n$ value = 3.25×10^6 with air-oil lubrication. This article reports the performance of this new engineering development.

Use of ceramic materials in elements of rolling bearings has long been proposed (Ref. 4). In the technical field of machine tools, there have been an increasing number of cases (Ref. 6) where ceramic rolling elements are used in angular contact ball bearings in order to inhibit adverse effects of gyro-moment (Ref. 5) that poses particular problems for machine tool main spindles running at higher speeds. However, there have been a limited number of applications of ceramic materials to cylindrical roller bearings for machine tools. In addition to the information already presented in NTN Technical Review No. 76 (Ref. 2), we provide here additional information in order to demonstrate that by utilizing the benefits of ceramic materials, cylindrical roller bearings can offer high-speed performance comparable to that of constant-pressure, pre-load, angular-contact ball bearings.

Structure and Elemental Technologies for High-Speed Operation

Figure 1 shows a cross-sectional view of NTN's newly developed NU-type cylindrical roller bearing.

The structure of the NU-type cylindrical roller bearing (Fig. 1) is characterized as follows: the inner ring is made

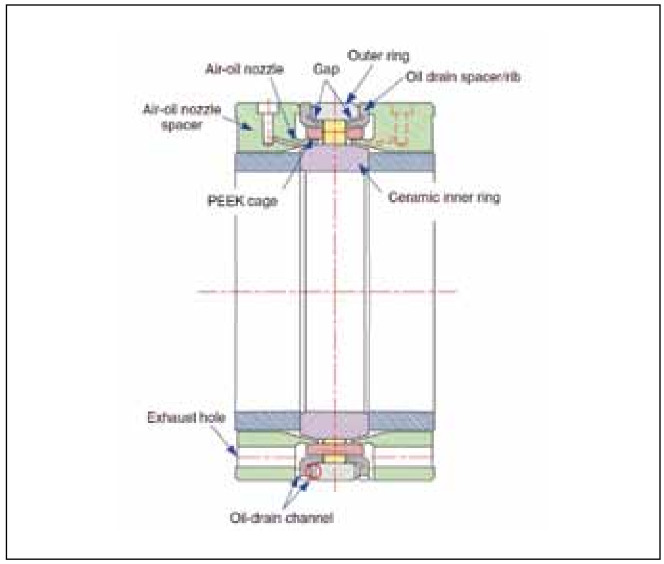

Figure 1—Developed NU-type cylindrical roller bearing.

of silicon nitride (Si_3N_4)—astructural ceramic material; the cage is made of PEEK ; the bore surface of the cage rides on the outer circumferential surface of the air-oil nozzle spacer; the rollers and outer ring are made of common bearing steel (SUJ2); the outer ring is fitted with oil drain spacers that double as ribs; and lubricating oil is drained via the gaps (marked with a red circle) between outer ring and oil-drain spacer/rig.

One characteristic that any machine tool main spindle bearing needs to satisfy is avoidance of excessive preload. On a cylindrical roller bearing, the inner ring and outer ring freely move relative to each other in the axial direction, so no axial preload occurs. On the other hand, a problem can occur in the radial direction in that the inner ring expands—owing to heat build-up and greater centrifugal force resulting, in particular, from high-speed bearing operation—leading to radial over pre-load. Heat build-up then increases between the rollers and raceway surface and the resultant, rapid temperature rise can potentially lead to bearing failure. In machine tool main spindles, jacket cooling is typically provided on the outer surface side of the outer ring—which is a stationary body—in order to prevent heat generation on the main spindle system from adversely affecting the entire machine tool. Temperature on the inner ring side will soon rise due to heat generation on the bearing and built-in motor, and, due as well to a structure that does not readily release heat. Consequently, a steep heat gradient occurs across the inner and outer ring, and pre-load on the bearing at higher speed can be excessively taxing. Therefore, problem-free, high-speed bearings operation is possible through reduction of heat generation inside the bearing and thermal expansion of the bearing.

Based on the abovementioned assumption, the elemental technologies for the elements inside the bearing that allow higher speed operation are now described.

First, the physical properties of ceramic material (silicon nitride) are compared with those of steel for the inner ring

continued

(Table 1.) A low linear expansion coefficient of the ceramic material—including 30% steel material—effectively limits thermal expansion of the inner ring. Despite the fact that the physical density of this ceramic material is as low as 40% compared to that of the steel material, the modulus of longitudinal elasticity with the ceramic material is 150% as great as the steel material. Yet, at the same time, the difference in Poisson's ratio between these two materials is very small. Consequently, the centrifugal expansion on the inner ring is limited to approximately 30%. More specifically, compared with the steel inner ring, an increase in preload is reduced with the ceramic inner ring and heat generation inside the bearing is more efficiently prevented.

As previously reported (Ref. 2), it is important to note that when using a cage riding system, controlled-temperature lubrication is always supplied to the cage lands and is promptly drained away to prevent the lubricating oil (which has become very hot from shear heat generation) from remaining on the guide surface; this arrangement helps inhibit heat build-up in the bearing. As shown in Figure 1, the lubricating oil ejected from the air-oil nozzle—with compressed air—hits the ramp of the rotating inner ring, rises along the ramp via surface tension and centrifugal force, and lubricates the rollers and raceway surface. At the same time, the compressed, air-propelled lubricating oil passes the cage riding clearance from the inside of the bearing and is drained away. In other words, fresh lubricating oil is always supplied

Table 1-Properties of Si_3N_4 and steel

	Si_3N_4	Steel
Linear expansion coefficient 1/K	3.2×10^{-6}	11×10^{-6}
Density kg/m³	3.2×10^{3}	7.8×10^{3}
Modulus of longitudinal elasticity GPa	314	211
Poisson's ratio	0.26	0.3

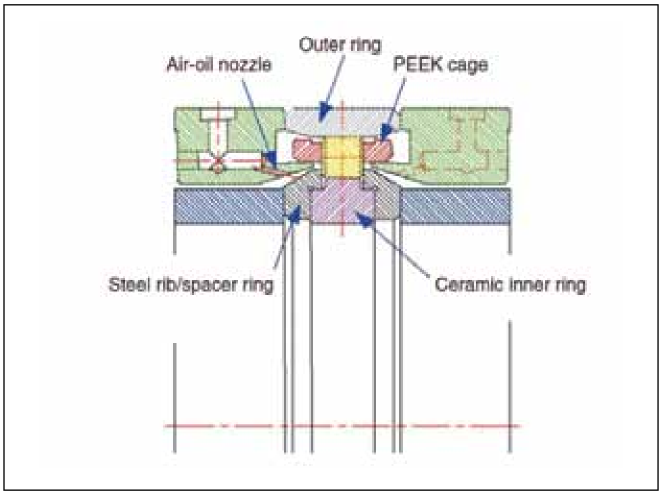

Figure 2—N-type cylindrical roller bearing with ceramic inner ring.

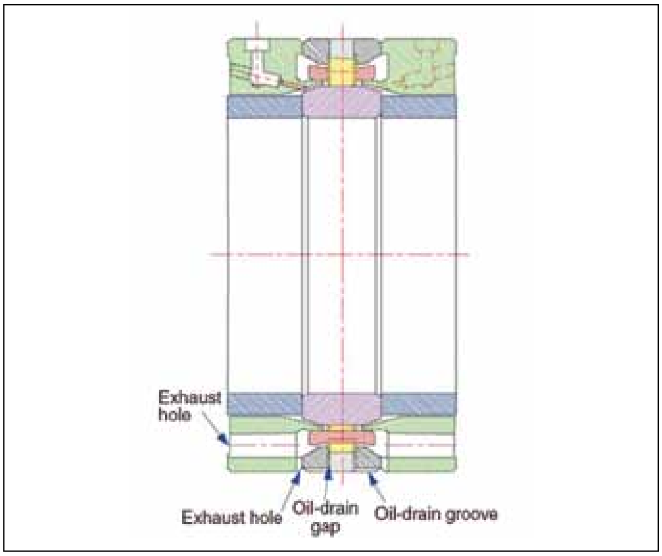

Figure 4—Oil-drain/groove-structure, NU-type cylindrical roller bearing.

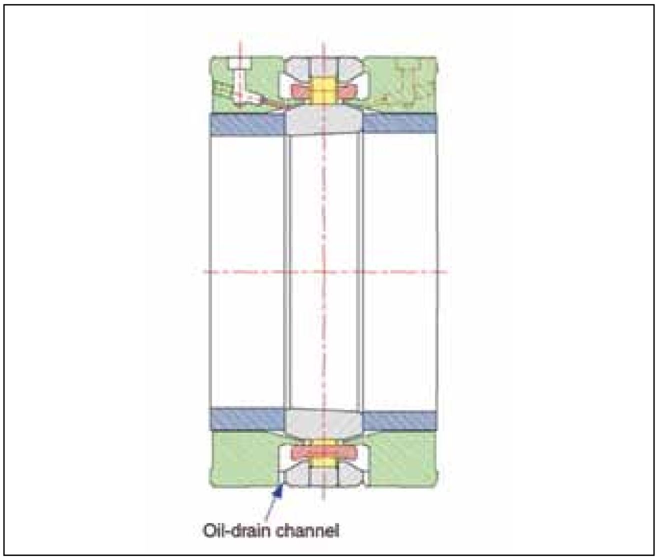

Figure 3—Standard-structure, NU-type cylindrical roller bearing.

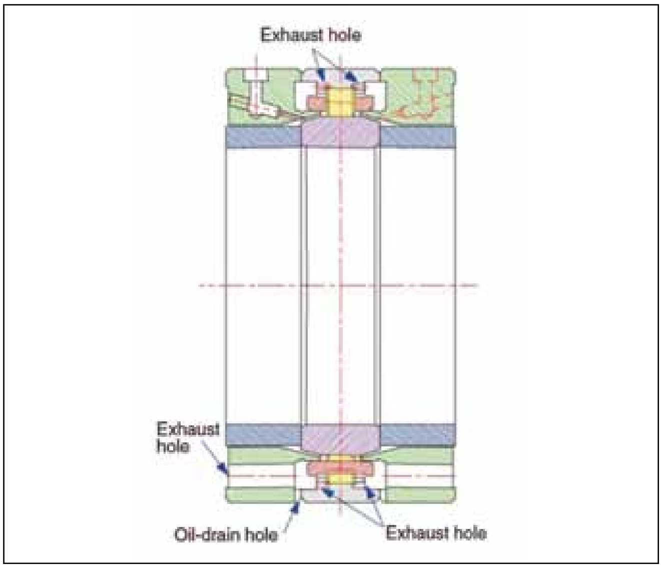

Figure 5—Oil-drain/hole-structure, NU-type cylindrical roller bearing.

to the cage lands and then promptly drained away from the bearing.

Another unique arrangement has been incorporated into the oil-drain structure in the outer ring side. When the bearing is running at a much higher speed, the fresh lubricating oil supplied to the bearing tends to remain in the vicinity of the outer ring bore due to the impact of centrifugal force. An excessive amount of lubricating oil remaining in and around the bore of the outer ring will lead to an increase in stir resistance and, as a result, heat generation inside the bearing. Compared with the N-type bearings, this tendency is more apparent with the NU-type cylindrical roller bearings, whose outer ring includes ribs. Therefore, for trouble-free, high-speed bearing operation, the oil-drain structure on the outer ring side requires a special solution.

For the purpose of comparison, the N-type cylindrical roller bearing (Ref. 2) is illustrated in Figure 2. The structure of this bearing is characterized by a ceramic inner ring fitted with spacer rings on both ends. The ceramic inner ring is interference-fit onto the shaft and the ring spacers slip-fit onto the shaft. In order to replace the steel inner ring on the N-type cylindrical roller bearing with a ceramic version, it is necessary to use a ring with integrated ribs or separate ribs. Compared with the NU-type bearing in Figure 1, either ceramic inner ring variant described above complicates the inner ring design; this "ceramic-based solution" poses a drawback of significantly increased machining costs, as ceramic material machining cost is much higher compared with steel. But to the advantage of N-type bearings, the outer ring does not tend to remain in the bearing; note that the cage riding system and material of the cage in the N-type bearings are essentially identical to those of NTN's newly developed NU-type bearings (Fig. 1).

Oil-Draining Capability and High-Speed Running Performance of NU-Type Cylindrical Roller Bearings

Encouraged by the oil-draining performance of the NU-type cylindrical roller bearings, we have developed various bearing prototypes. In this section we will describe the result of our investigation into temperature-dependent characteristics of these prototypes being run at various speeds. These prototypes are essentially NU-type cylindrical roller bearings, categorized as: "standard oil-drain structure variant," "oil-drain groove variant" and "oil-drain hole variant." Their structures are schematically illustrated in Figures 3–5.

In the standard oil-drain structure variant (Fig. 3), the inner ring is made of steel (SUJ2) while the rollers are made of ceramic material. The outer ring rib is independent of the outer ring and the PEEK cage is the nozzle outer surface riding type (Figs. 1–2); however, the oil-drain structure on the outer ring side is the standard type.

This oil-drain groove variant (Fig. 4) is unique in that a provided *separate* outer ring rib facilitates the delivery of fresh lubricating oil through the gaps on both ends of rollers as well as the gap between the outer ring and rib toward the outer surface side of outer ring; the heated lubricating oil is drained away from the bearing through the groove formed on the outer surface of the outer ring.

Regarding the oil-drain hole variant (Fig. 5), outer ring ribs on both sides—each with six equally spaced oil-drain holes toward their outer circumference to direct the heated lubricating oil to the outside of the bearing—shift the phases of both outer ring ribs with each other so that the locations of the oil-drain holes on one outer ring rib are not directly opposite the oil-drain holes on the other outer ring rib.

Note that the oil-drain groove variant (Fig. 4) and oil-drain hole variant (Fig. 5) both have inner rings and rollers made of ceramic material; the PEEK cage is riding on the outer circumferential surface of the air-oil nozzle.

Major technical data for these test cylindrical roller bearings and test conditions are summarized in Table 2, while the cross-sectional view of the spindle test rig used throughout our present development work is illustrated in Figure 6. The test results obtained from the NU-type cylindrical roller bearings of Figures 3–5 are illustrated in Figure 7.

From the graphs displayed (Fig. 7) it should be understood that apparent temperature peaks occur at around 10,000 min^{-1} with all designs—i.e., "standard oil-drain structure variant," "oil-drain groove variant" and "oil-drain hole variant."

continued

Table 2—Test bearings (Figs. 3–5) and conditions associated with Fig. 7

Standard oil-drain structure variant	Cross-sectional plan	Fig. 3
	Size	ϕ70 x ϕ110 x 20
	Pitch diameter	93 mm
	Inner ring	SUJ2 (tapered hole: 1/12 bore diameter)
	Outer ring	SUJ2
	Rollers	Si_3N_4, ϕ7 x 7, 22 pcs.
	Cage	PEEK+CF30%, Nozzle outer surface riding
Oil-drain groove variant	Cross-sectional plan	Fig. 4
	Size	ϕ70 x ϕ110 x 20
	Pitch diameter	93 mm
	Inner ring	Si_3N (cylindrical bore)
	Outer ring	SUJ2
	Rollers	Si_3N_4, ϕ7 x 7, 22 pcs.
	Cage	PEEK+CF30%, Nozzle outer surface riding
Oil-drain hole variant	Cross-sectional plan	Fig. 5
	Size	Φ70 x Φ110 x 20
	Pitch diameter	93 mm
	Inner ring	Si_3N_4 (cylindrical bore)
	Outer ring	SUJ2
	Rollers	Si_3N_4, ϕ7 x 7, 22 pcs.
	Cage	PEEK+CF30%, Nozzle outer surface riding
Test conditions	Initial radial clearance -3 – -4 μm	
	Bearing lubrication Air-oil	
	ISO VG32	
	Oil is supplied from both sides of bearing.	
	0.01cm^3/10 min x 2	
	Jacket cooling temperature Room temperature ± 1° C	

This is the major reason why NU-type bearings have not yet been used as air-oil-lubricated cylindrical roller bearings for machine tools. Therefore, the challenges for the present development work were to increase the maximum allowable bearing speed and provide a bearing that can maintain its rigidity in a wider speed range without developing heat build-up—all in an economically viable design. Our original objective for prototyping the oil-drain groove and oil-drain hole variants was to improve oil-draining performance at higher bearing speeds. Though the maximum-allowable bearing speed with the oil-drain groove variant reached 35,000 min^{-1}, the temperature peak in the medium-speed range at around 10,000 min^{-1} still persists with either variant. Note that the test for the standard oil-drain structure variant and oil-drain hole was suspended because of sudden temperature rise.

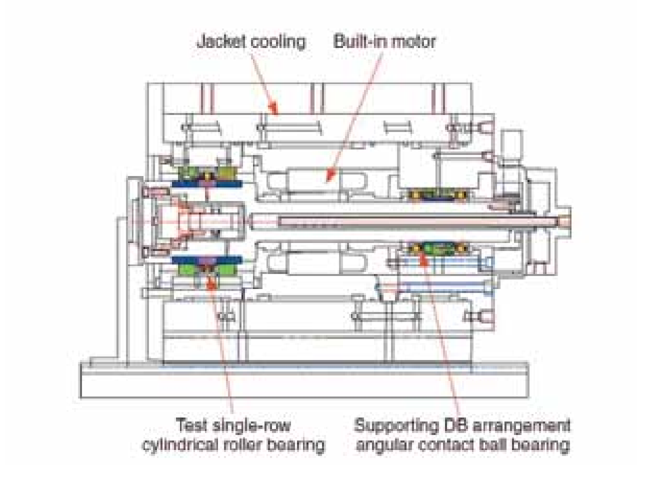

Figure 6—Section view of spindle test rig.

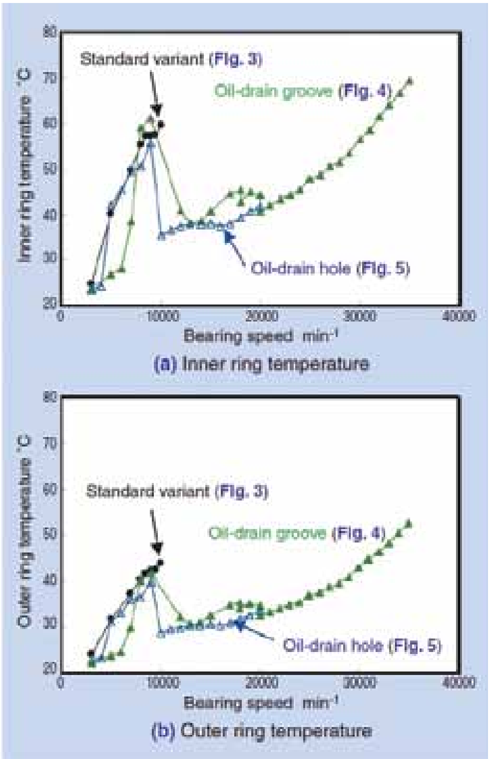

Figure 7—Inner and outer ring temperatures vs. rotational speed.

To find a solution we first assumed the cause for this temperature peak to be poor oil-draining performance and attempted to verify this assumption. Figure 8 includes two sets of data obtained from two cases of bearing operation (Fig. 4); one case corresponds with a scenario where a sufficient amount of air-oil mixture was supplied to the bearing prior to operation; in the other scenario, no air-oil mixture was supplied to the bearing prior to operation.

In the two cases in Figure 8, the test bearings were quickly accelerated to 13,000 min^{-1} while being lubricated with an oil-air flow rate of 0.01 cm^3/10 min × 2. In the scenario in Figure 8-a, air-oil mixture was supplied to the test bearing for 90 minutes prior to the test operation; in the scenario in Figure 8-b, no air-oil mixture was supplied to the test bearing prior to start of the test operation. When comparing the data in scenario "a" with that of scenario "b," the heat rise on the inner ring with scenario "a" is approximately as much as 30° C higher and on the outer ring is approximately as much as 15° C higher. From these findings we suspect the cause of the temperature peak at the medium-speed range is "residual heated lubricating oil" remaining in the bearing. Therefore, efficient oil-draining capability in both high-speed and medium-speed ranges is needed. Also, since such temperature peaks do not occur with the N-type bearings, we feel we should consider oil-draining behavior at the outer ring rib; we believe this approach will lead to improved oil-draining capability on the outer ring side of a bearing running at higher speed.

With these findings we have continued review and prototyping activities, resulting in the NU-type cylindrical roller bearing structure shown in Figure 1; test conditions associated with these activities are summarized in Table 3. Test results from the NU-type bearing and those from the N-type bearing in Figure 2 (Ref. 2) are shown (Fig. 9). Figure 9-a shows the test data from bearing samples with ceramic rollers, and Figure 9-b the test data from bearing samples with steel rollers.

As is shown (Fig. 9-a), the samples of the newly developed NU-type—as well as those of the N-type—do not show a temperature peak in the medium-speed range of around 10,000 min^{-1} and exhibit smooth temperature rise curves up to the targeted maximum running speed of 35,000 min^{-1} ($d_m n$ value = 3.25 × 10^6). Compared with the N-type, the inner ring temperature on the NU-type at 35,000 min^{-1} is 2° C lower. Also, as apparent from the test data of the NU-type samples in the data (Fig. 9-b), there is no temperature peak at around 10,000 min^{-1} and the temperature slowly increases to 35,000 min^{-1}. The inner ring temperature of 35,000 min^{-1} reads 70° C, which is 4° C lower compared with the N-type—a very favorable achievement.

These findings verified that the bearing configuration illustrated in Figure 1 (NU-type)—ceramic inner ring (no spacer rings), cage riding the outside surface of air-oil nozzle, and the outer ring having oil-drain gaps—does not exhibit temperature peak in the medium-speed range and can be run at ultra-high speeds without developing sudden temperature rise. With a variant of this bearing configuration—using steel rollers rather than ceramic—the inner ring temperature at 35,000 min^{-1} is limited to 70° C—the maximum-allowable temperature for commercially acceptable bearing operation. Compared with the N-type (Fig. 2; Ref. 2), the NU-type has the simpler-shaped ceramic inner ring as well as steel rollers, allowing this bearing to be offered at a commercially acceptable price.

It is apparent that use of the ceramic inner ring has helped achieve problem-free, high-speed operation of the bearing. However, use of ceramic material in a bearing leads to additional benefits. When a bearing having a steel inner ring is run at a higher speed, bearing fit to the shaft can loosen, owing to expansion of the inner ring bore due to heat and centrifugal force occurring from bearing operation. To prevent loosening of the bearing relative to the shaft, a rolling bearing of bore diameter 50 to 100 mm, which is often used to support a machine tool main spindle, is interference-fitted over the main spindle with an interference allowance of 30 µm or greater. Consequently, there will be difficulty when mounting the bearing by press-fitting. In contrast, use of a ceramic inner ring—with limited expansion from heat and centrifugal force—will enable the bearing to be interference-fitted over the shaft with an interference allowance of 5 µm or smaller—leading to much easier bearing mounting.

Furthermore, the ceramic material's greater modulus of longitudinal elasticity helps enhance the rigidity of the bearing, which is discussed in the following section.

Improvement in Bearing Rigidity with Ceramic Material

You'll remember that earlier in this article we stated that any cylindrical roller bearing for machine tool main spindle must be capable of not only higher speed, but also greater rigidity. Through calculation we have verified the effect of using ceramic material for improving bearing rigidity.

The internal clearance of a cylindrical roller bearing of bore diameter 70 mm was selected as zero. Combining a steel or ceramic inner ring with steel or ceramic rollers, we prepared various cylindrical bearing samples. To simulate operation of the bearing sample on an actual machine tool, the maximum radial load applied to the bearing has been set to 7 kN.

The relation between radial load and displacement of the bearing center is graphically plotted (Fig. 10). The result of bearing rigidity in the 3-to-7 kN region that features good linearity within the radial load vs. bearing center displacement is shown in Table 4. Improvement in rigidity with the sample using ceramic material only for the inner ring is 7%,

continued

and with the sample using a ceramic material for the rollers only is 19%. Use of ceramic rollers leads to greater improvement in bearing rigidity since roller to inner ring rigidity and roller to outer ring rigidity are simultaneously improved. The use of ceramic material for the inner ring exclusively results

continued

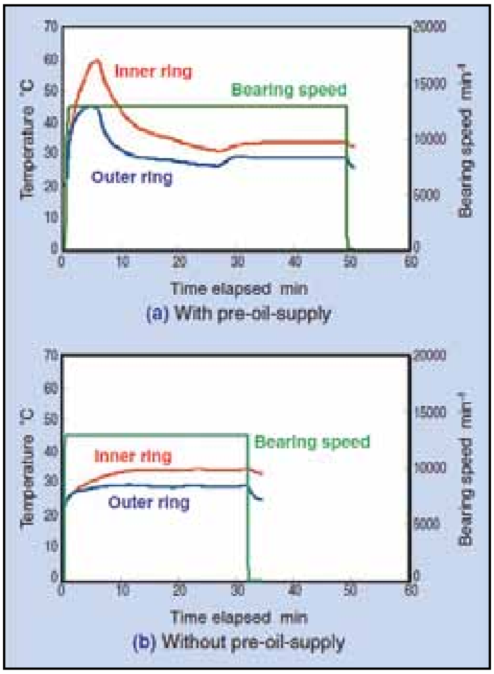

Figure 8—Pre-oil supply and temperature rise.

Table 3—Test bearings (Figs. 1–2) and conditions associated with Fig. 9

Newly developed NU type	Cross-sectional plan	Fig. 1
	Size	ϕ70 x ϕ110 x 20
	Pitch diameter	93 mm
	Inner ring	Si_3N_4 (w/o steel spacer rings)
	Outer ring	SUJ2
	Rollers	Steel or $SiaN_4$, dia. ϕ7 x 7, 22 pcs.
	Cage	PEEK+CF30%, Nozzle outer surface riding
	Fit between shaft and inner ring	5 µm, interference-fit
N-type with ceramic inner ring	Cross-sectional plan	Fig. 2
	Size	ϕ70 x ϕ110 x 20
	Pitch diameter	93 mm
	Inner ring	Si_3N_4 (w/ steel spacer rings)
	Outer ring	SUJ2
	Rollers	Steel or $SiaN_4$, dia. ϕ7 x 7, 22 pcs.
	Cage	PEEK+CF30%, Nozzle outer surface riding
	Fit between shaft and inner ring	2 µm, interference-fit
Test conditions	Initial radial clearance	0 – 3 µm
	Bearing lubrication	Air-oil ISO VG32 Oil is supplied from both sides of bearing.
	NU type	$0.01cm^3$/10 min x 2 $0.01cm^3$/6min x 2 (steel rollers)
	N type	$0.01cm^3$/10min x 2 (Si_3N_4 rollers) $0.01cm^3$/5min x 2 (steel rollers)
	Jacket cooling temperature	Room temperature ± 1° C

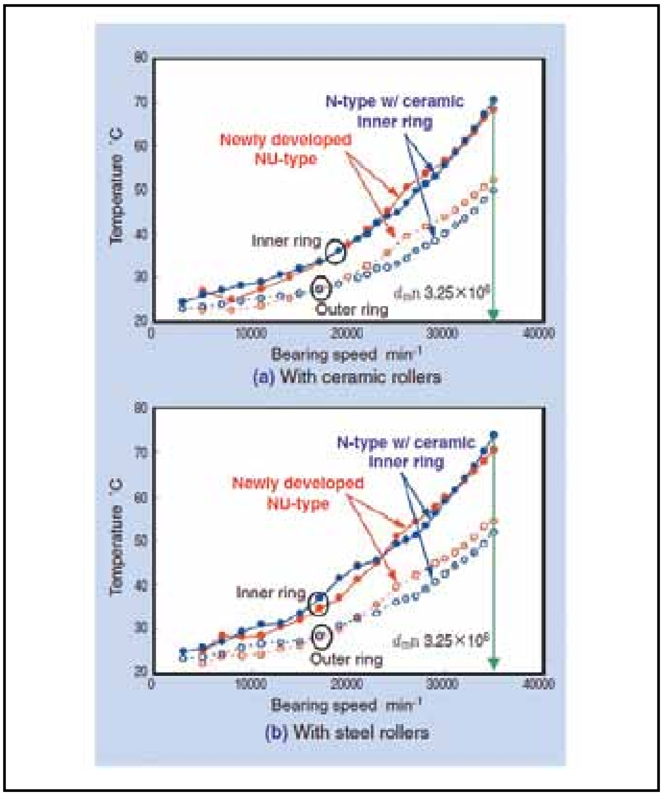

Figure 9—Inner and outer ring temperatures vs. rotational speed.

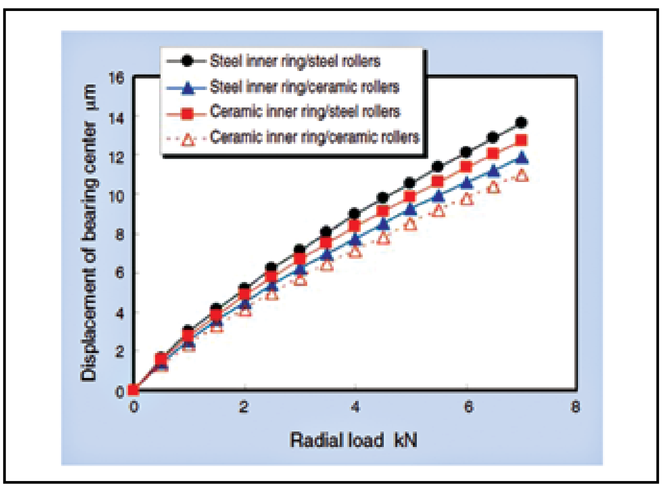

Figure 10—Radial load vs. calculated bearing deflection.

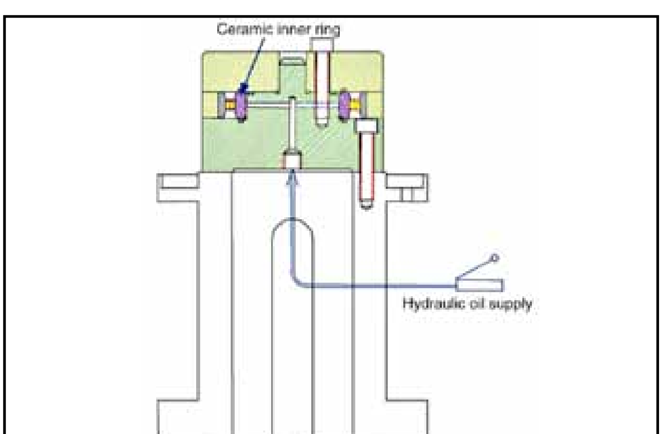

Figure 11—Hydraulic-loading test rig.

in relatively small improvement in bearing rigidity; however, this arrangement greatly contributes to improvement in high-speed performance of the bearing.

Verification of Mechanical Strength of Ceramic Inner Ring

When ceramic material is used for a bearing inner ring, it is necessary to prove that the inner ring has sufficient mechanical strength against hoop stress occurring from both heat generation and centrifugal expansion. In the axi-symmetric deformation mode, no shear stress occurs; therefore, the major stresses involved are circumferential hoop stress, axial stress and radial stress. Whereas on a thin-walled cylinder subjected to internal pressure and centrifugal force, the stress with the greatest impact is hoop stress.

Figure 11 illustrates the hydraulic loading test rig we have used to test the mechanical strength of the ceramic inner ring. The test piece used is the same inner ring used in the NU-type cylindrical roller bearing (Fig. 1). High-pressure hydraulic oil supplied from an outside hydraulic pump is uniformly distributed within the bore of the inner ring, and either an inner ring alone or an inner ring in a bearing assembly (complete with rollers and outer ring) can be tested. The test result is illustrated in Figure 12, with the hydraulic pressure applied to the bore surface of the inner ring on the X-axis, and the corresponding hoop stress occurring on the bore surface of the inner ring on the Y-axis. The inner ring has developed fracture at a hoop stress of 500 MPa when tested alone, and at a hoop stress of 640 MPa when tested in the bearing assembly. These hoop stress values are approximately three and four times greater than maximum commercially allowable hoop stress (160 MPa) for inner ring in typical cylindrical roller bearings for machine tool main spindles. When assembled with the rest of the bearing, a compressive stress is applied to the inner ring in a direction that helps the compressive stress overcome the hoop stress; therefore the inner ring in this configuration can withstand greater internal pressure than the inner ring alone can withstand.

Thus, we have proven the functionality and mechanical strength of our newly developed NU-type cylindrical roller bearing (Fig. 1). Typical photographic views of this bearing type are given in Figure 13.

Conclusion

To enhance high-speed capability of its NU-type cylindrical roller bearing for machine tool main spindle, NTN has introduced the following elemental technologies:

- Ceramic (silicon nitride) inner ring
- Cage riding on the outer surface of the air-oil nozzle
- Oil drain structure with separate outer ring rib

Ceramic materials boast a low linear expansion coefficient, low density and high modulus of longitudinal elasticity. Thanks to these features, the ceramic inner ring can resist over-preload that can result from expansion of the inner ring while the bearing is running at a greater speed. This improvement helps mitigate heat build-up within the bearing, which is the biggest obstacle to problem-free, high-speed bearings operation.

Incidentally, stagnant lubricating oil within a bearing can lead to higher bearing temperatures due to shear-heat-generation of the lubricating oil. To address this problem we improved the guide surface on the cage to promote draining of oil from its slide-way; at the same time, we introduced a draining structure independent of the outer ring rib in order to promote draining of oil from an area around the outer ring rib.

By adoption of the abovementioned elemental technologies, NTN has successfully developed an improved variant of NU–type cylindrical roller bearings that boasts an ultra-high-speed range that equates to $d_m n$ value = 3.25×10^6 (bore diameter 70 mm; bearing speed 35,000 min^{-1}). At the same time, we analyzed the mechanical strength of the ceramic inner ring and have determined that this inner ring has mechanical strength sufficient for commercial use of the new NU-type bearing.

Higher functionality and improved reliability of bearings directly contribute to better performance of machine tools and pose not-yet-solved challenges for bearing manufacturers. NTN will remain committed to further sophistication of its bearing technologies.

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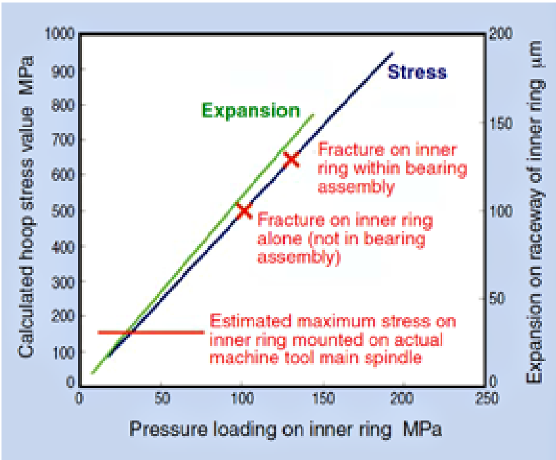


Figure 12—Inner loading pressure vs. hoop stress and inner ring expansion.

Figure 13—Developed, NU-type cylindrical roller bearing.

Table 4—Bearing stiffness improvement due to ceramic elements

Inner ring/rollers	Rigidity N/m	Increase %
Steel/steel	6.23×10^8	0
Si_3N_4/steel	6.64×10^8	+7
Steel/Si_3N_4	7.43×10^8	+19
Si_3N_4/Si_3N_4	8.09×10^8	+30

Mechatronics has evolved into a broad range of easy handling solutions, allowing customers to select tools from a menu of standard products (courtesy of Bosch Rexroth).

Project Integration

DESIGN ENGINEERS ADAPT TO MODERN DAY MECHATRONICS

Matthew Jaster, Associate Editor

Though the original definition of mechatronics derived from the Yasakawa Electric Company in the late 1960s (the company won trademark rights for the term in 1973), the word has remarkably evolved. It was originally coined as a term for electromechanical systems or control and automation engineering. Today, mechatronics combines mechanical, electrical and computer systems into an integrated solution—and that's still merely scratching the surface.

For the purpose of our *PTE* audience, mechatronics incorporates products like microprocessors, sensors, actuators, circuit boards together with mechanical components to create an integrated machine package. The software provides analysis, simulation and optimization tools. The trick is putting it all together as a single, cohesive unit. This mechatronic "magic" so to speak is developed with the engineer in mind in order to provide a better value to the end customer. The advantages of product integration with mechatronics in today's manufacturing environment are limitless.

"First, there are fewer variants to purchase—one component can perform the function of multiple mechanical variants. A second advantage is the ability for self diagnostics of components—wouldn't it be nice if your Christmas lights could tell you which bulb needed replacing? That's what self diagnostics brings. Finally, there is the inherent potential to use the feedback from the mechatronic component to dynamically improve the quality and consistency of your products," says Mark Hinckley, director mechatronics platform, SKF USA Inc.

"One of the greatest advantages is the opportunity to increase machine performance while simultaneously decreasing energy consumption. In concert with that, if a machine builder

Rockwell Automation's *Motion Analyzer* software helps machine builders evaluate design alternatives (courtesy of Rockwell Automation).

uses digital modeling and simulation to achieve these ends, they are accelerating innovation while decreasing time-to-market and mitigating risk," says John Pritchard, global marketing development manager, Integrated Architecture, Rockwell Automation. "With mechatronics, there may be a greater upfront investment of time in the initial design process but the return on investment is quickly recouped."

Software & Hardware

For Rockwell Automation, the initial mechatronic focus was to create design tools that integrated mechanical information. Today, Rockwell is still investing heavily in mechatronic design tools by integrating its *Motion Analyzer* software with Dassault Systemes *SolidWorks* solutions. Rockwell Automation offers both software and hardware mechatronic products, according to Pritchard. "*Motion Analyzer* software helps machine builders evaluate design alternatives to facilitate a reduction in motor and drive size, help maximize the percentage of power applied toward moving the load and increase the stability of the system. For mechatronic hardware, Rockwell Automation offers linear and rotary direct-drive motors, integrated drive motors, and electric cylinders."

"Over the last few years the design and analysis request from our users has evolved into a multi disciplinary requirement where the multiple impact points on a design have to be simultaneously evaluated," says Stephen Endersby, product manager at Dassault Systemes. "*SolidWorks Motion* and *Event Based Motion* are two features that can analyze mechanical systems, calculating actuator forces, motor torques etc. The motion calculation can be controlled by Rockwell Automation's *Motion Analyzer* and National Instrument's *LabView*, which can act as the motion controller. With this combination you can virtually prototype your machine, ensuring product quality and performance."

Recently, mechanical and control industries have been increasing collaboration through organic growth, partnerships and acquisitions. All evidence indicates that the trend will continue and that machines will be built using evermore highly-integrated mechatronic sub-systems. "Although the lead time for sophisticated systems might be longer, the time required to install, configure and commission a system could potentially be less overall—which is complimentary to a just-in-time environment," Pritchard says.

A Broad Range of Capabilities

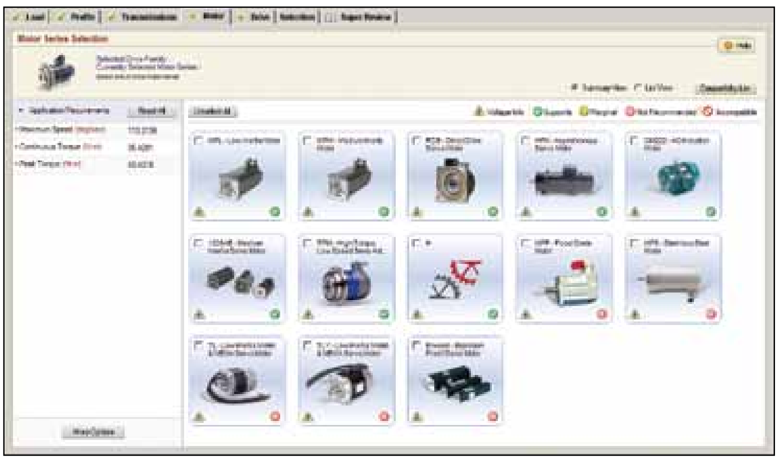
SKF's experience in the mechatronics field dates back to the late 1960s and expanded further in the late 1970s. In 1968, SKF acquired Transrol, a French company that specialized in the manufacture of ball and roller screws. Then in 1976 SKF invested in the startup of another French company named S2M,

continued

SKF's mechatronic solutions are based on the company's strength in mechanical systems that incorporate smart controls (courtesy of SKF).

focusing on electromagnetic levitation. In 1977 SKF began manufacturing industrial actuators in Gothenburg, Sweden. These early activities have been supplemented over the years with additional developments and acquisitions.

Today, mechatronics is one of five Knowledge Platforms within SKF, together with Bearings & Units, Seals, Lubrication Systems and Services. The range in each category is quite extensive, with customers encompassing a range of industries and applications.



Rockwell's *Motion Analyzer* software can assist engineers in reducing motor and drive size (courtesy of Rockwell).

"Some of our most recent products have proven popular with our customer base, including a newly designed actuator for solar applications, actuators designed for off-highway and outdoor equipment and SKF's new line of profile rail guides, just to name a few," Hinckley says. "SKF's knowledge in mechatronics is firmly based on our strength in mechanical systems while incorporating smart controls to enhance performance for our customers' value. Our portfolio of products includes mecahtronic solutions for actuation systems, linear motion, magnetic systems and sensor bearings."

These products have been well received in part due to the increased awareness among SKF customers for how environmental impact and energy costs affect SKF's decisions. Other factors driving consumer choices include the search for increased productivity and efficiency, and the desire to minimize variance and manage the total cost of ownership.

"Many OEMs who, like SKF, have made a commitment to minimizing their impact on the environment use mechatronics to deliver green solutions, such as the movement of solar panels to track the sun and thus help optimize the power generated by the panel."

There have been some significant changes in the mechatronics area over the past five years, Hinckley adds. "Some of these changes involve customer and end-user acceptance of mechatronic solutions in the equipment they build or purchase. As the acceptance of integrated electronic and mechanical systems has increased, more OEMs are able to take advantage of smart functionality and integrated packaging."

As an example, an OEM in the HVAC industry has applied SKF's high-speed permanent magnet motors which use magnetic bearings. "With this application they are able to significantly reduce the number of mechanical variants typically associated with the traditional gear drive machines. Features that would have required different options in the gearbox can now be managed by changing the programming of the variable speed motor," Hinckley adds.

A potential disadvantage mentioned earlier was the cost associated with mechatronic solutions. "There is a higher per piece price associated with mechatronics, though the total cost of integrating the solution is often equal to or less than the traditional solution's total cost."

Another argument is that in today's just-in time environment combining electronic and mechanical solutions can actually make the job more complex for the design engineer.

"Certainly the systems are different. But whether they are more or less complex depends on your past experience and the way you choose to integrate the mechatronic solution. Many times our engineers, who may have traditionally interacted with the mechanical designer, will find they are working with an electrical engineer at the OEM," Hinckley says. "This highlights the importance of partnering with a company like SKF that has a strong mechanical foundation behind our mechatronic solutions. It allows the OEM to be able to focus on the electrical interface, without needing to be so concerned over the selection of the mechanical components."

A Focus on Cost Savings

Mechatronics first came onto the scene in Bosch Rexroth under Rexroth Automation Systems (RAS). The charter of RAS was to combine the technologies of the different divisions of Bosch Rexroth to provide customers with integrated multidiscipline solutions. Mechatronics at Bosch Rexroth today has evolved into a broad range of easy handling solutions, allowing customers to specify custom mechatronic solutions from a menu of standard products utilizing online selection tools like Easy Select.

"Our newest offering in mechatronics solutions is our Easy Handling product line," says Joel Galliher, director—mechatronic systems at Bosch Rexroth. "Customer response on our Easy Handling offering has been very positive as it gives them the tools to be able to specify, order, install and commission mechatronic solutions to meet their application needs with cost savings of up to 80 percent."

Galliher points to recent economic conditions, saying that many companies have downsized their engineering resources in recent years. "Trends are to utilize the limited resources on core competencies that are market differentiators for the OEM. The integration of electronic and mechanical products for part handling has been outsourced to the motion industry experts."

He feels that leaders in the motion industry will need to respond to provide this competency to the market. Additional trends toward more online engineering tools, "apps" and E-commerce will force the mechatronics suppliers to develop more "easy to use" interactive tools. Additionally, the customer base wants one company to be responsible for the complete system performance. "One part number—one person to call," Galliher adds.

Solidworks **can analyze mechanical systems by calculating actuator forces, motor torques, etc. (courtesy of Dassault).**

"One of the biggest advantages in exploring a mechatronics solution on the manufacturing floor is the increase in productivity. Properly selected mechatronics solutions can increase capacity and throughput without increasing fixed cost. Today, energy efficiency is a key decision factor when adding equipment in the production environment. The cost of energy continues to rise and environmental concerns all are considerations in the total cost of ownership. Mechatronic systems that utilize regenerative power drives are examples of energy efficient solutions."

And the best way to get these mechatronic solutions into the hands of the engineers?

"More traditional organizations have a clear separation between the electronic and mechanical engineering disciplines. Highly integrated mechatronic solutions may make it difficult to decide who does what," Galliher says. "My counter argument is a properly selected highly integrated mechatronic solution will far outperform a segregated solution."

The Mechatronic Message

So, what does the industry itself need to do to get more engineers onboard and create a more unified mechatronic approach on the shop floor? "Certainly there is a need for more education

One of SKF's recent mechatronic solutions included this newly designed actuator for solar applications (courtesy of SKF).

in this field starting with the basic definition of mechatronics today," Galliher says. "As mentioned before, the education and the tools need to be provided in the environment young engineers operate in today…via the internet and apps."

Dassault Systemes have found that the investment into the educational space (universities and school) is time well spent in creating a generation of 3-D aware engineers, according to Endersby at Dassault Systemes. He believes a similar effort is required for mechatronics.

"While some universities offer mechatronics courses, it is still not common across campuses. The modern world is mechatronics, and young engineers need to be exposed to it. The possibilities of a mechatronic design approach are exciting, and it's important that the next generation of engineers has exposure to how it can be used and the resources and opportunities available," Pritchard at Rockwell adds.

SKF is actively involved in many programs that encourage and help develop the next generation of engineers. SKF is a main sponsor of the Shell Eco-marathon. This is a global competition that encourages technical high schools and universities to design and create vehicles that achieve the highest miles per gallon in one of three engine categories: standard combustion, hydrogen or solar. As part of this program, SKF also supports university Society of Automotive Engineer teams (Hybrid, Solar, Baja and Formula) with technical advice as well as products.

"More recently we have been approached by students who

continued

are working on new engineering robotic projects such as the RoboSub competition that will incorporate more mechatronic products as well as traditional bearings," says Hinckley at SKF. "RoboSub is a competition sponsored by the Association for Unmanned Vehicle Systems International (AUVSI) and the U.S. Navy Department to provide opportunities for students to experience the challenges of system engineering, to develop skill in accomplishing realistic missions with autonomous vehicles and to foster relationships between young engineers and the organizations developing and producing autonomous vehicle technologies."

While the technology is available and young engineers have the proper skills to further enhance the mechatronics platform, today it falls on the design engineers to adapt, react and integrate—full speed ahead.

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www.boschrexroth.com

DS SolidWorks Corp
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890 Forty Foot Road
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Lansdale, PA 19446
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A Mechatronics Solution

One of Rockwell Automation's machine builder customers recently created a high-speed, cutting edge rotary saw for their machines using mechatronic products. The OEM was seeking a step forward in its saw cutting technology to significantly increase the speed and throughput of its converting machine. The company decided to take a mechatronic design approach early in order to validate the performance of new concepts and save testing time going forward. "This was the first time that the customer had applied some of the latest mechatronic design tools, so again it was faced with the challenge of applying new technology in order to provide greater value to their end users," says John Pritchard, global marketing development manager, Integrated Architecture, Rockwell Automation. "The company turned to Rockwell Automation to help deliver the advanced design software and automation technology needed to achieve its aggressive goals."

Early in the machine design process, they modeled the new application by virtually linking models created using *SolidWorks* design software from Dassault Systemes with control designs in *Rockwell Software RSLogix 5000* software using *Allen-Bradley Motion Analyzer* software. Engineers leveraged *Motion Analyzer* to evaluate a variety of gear ratios, inertias and mechanical alternatives that would further enhance the system. The integration between *SolidWorks* and *Motion Analyzer* helped designers quickly simulate a variety of mechanical alternatives, motor-drive combinations and more profiles in order to help the customer choose a solution optimized for the saw application.

They used Allen-Bradley RDD-Series Direct Drive Rotary servo motors to help eliminate the need for power transmission devices such as timing belts and pulleys required in its previous saw cutting technology. This reduced the number of items on the bill of materials and simplified installation and maintenance support. Kinetix servo motors were combined with the Kinetix servo drives to help meet the demanding requirements of their high performance motion control system. "The new rotary saw is the highest speed saw cutting application on the market today. Cutting at speeds in excess of 500 cuts per minute, compared with 300 cuts per minute previously, the new saw has significantly increased the throughput of the customer's machine," Pritchard adds.

"We feel mechatronics can help us in the future, saving test time in assembly because it will help eliminate rework of replacing drive and motor combinations. We'll also save time by fully testing our applications in a simulation environment before we get to the plant floor," said the Rockwell customer.

Electric Automation Trends

DISCOVERED AT SPS-IPC-Drives 2011

The automation industry was in full force at SPS-IPC Drives 2011 with increased attendees and exhibitors (courtesy of SPS-IPC Drives).

SPS-IPC Drives 2011, which took place in Nuremburg, Germany in November, covered all components down to complete systems and integrated solutions in the electric automation industry. The trade fair and its adjoining conference provided information on products, innovations and current trends with products and services presented in control technology, IPCs, drive systems and components, human-machine-interface devices, industrial communication, sensor technology, industrial software, interface technology, electromechanical components and peripheral equipment. Trend topics for the exhibition included energy efficiency, safety and security, and industrial identification.

Approximately 56,321 visitors filled the halls to gather information on the latest products and solutions in electric automation (52,028 at the 2010 show). The exhibitor numbers increased as well with 1,429 compared to 1,323 in 2010. Here are a few of the products and technologies featured at the exhibition:

Moog Industrial Group. Moog offered its latest developments in hybrid solutions combining hydraulic and electric technology. The company displayed a prototype design concept for Electro Hydrostatic Actuation Systems (EHA). Moog's EHA can be utilized for applications that require high force, energy savings and advanced fail-safe functionality. Typical applications include actuation for wind turbine blades, gas or steam turbines, injection molding machines and metal forming presses. Moog's innovative EHA concept is a self-contained unit combining several high performance Moog products including a servomotor, hydraulic pump, servo valve, controller and software. Unlike an electric actuator, EHA technology requires no screws or gearing, and it differs from hydraulic actuators in that it requires no hydraulic piping. One important advantage is that all hydraulic and electric components are integrated in the actuator assembly. Moog's EHA design offers machine builders high energy efficiency and reliability, reduced envelope size, less wear on components and up to 40 percent less weight. For many applications such as wind turbines, the potential for hydraulic leaks is eliminated, thereby improving environmental impact.

Pepperl+Fuchs. The newly designed multichannel LB Remote I/O modules dramatically reduce the required space for analog I/O in the cabinet. Four-channel 20 mA analog inputs and outputs are 50 percent smaller than the previous modules, allowing for more I/O per backplane. This energy-saving design concept lowers the heat dissipation and increases reliability, and was on display at the Pepperl+Fuchs booth

The conference sessions at SPS-IPC Drives provided a platform for discussions between product developers and users (courtesy of SPS-IPC Drives).

during the exhibition. The multichannel remote I/O modules can be combined with single-channel modules for high-integrity applications and single-channel loop integrity where needed. Communication gateways can be upgraded to communicate with the new remote I/O modules, and the existing LB backplanes support the new modules. Each module has one diagnostic LED per channel, so on-site diagnostics can be easily identified.

The universal I/O module is a field-configurable, all-in-one multipurpose module. It accepts analog and digital inputs and outputs.

Nord Drive Systems. Energy-saving motors were on display at the Nord Drive Systems booth. Motors that have a greater efficiency than previous EFF2 motors, produce less waste heat, have a longer operating life than previous motors and enable "safety reserves" to be dispensed with due to the shift of the operating range or the safety range above the nominal rating. Additionally, the company featured its frequency inverter series SK 500E, a flexible modular system for automation. The development of the series does not concentrate on replacing traditional PMSM servo applications (permanent magnet synchronous motors) but rather places the emphasis on permanent magnet synchronous motors as energy saving motors for S1 applications. Where asynchronous motors are no longer adequate due to limitations in their dynamic characteristics, Nord now offers a solution which is compatible with the SK 520E/SK 530E, and uses permanent magnet synchronous motors for S1 applications. Features include: new microcontroller platform with higher performance and larger memory, open-loop and closed-loop operation of PM synchronous motors, integrated SPS functionality for the implementation of simple automation applications or technological functions.

For a full recap on the SPS-IPC Drives 2011 exhibition, visit *www.mesago.de*.

January 9–10—AWEA Wind Environmental Health and Safety Seminar. San Diego. As the wind industry has evolved, so have the responsibilities of the environmental, health and safety (EHS) professional. From reducing incidents and preventing accidents to ensuring environmental compliance, EHS managers are facing new challenges in an uncertain regulatory and standards environment. Join the AWEA for a seminar that examines the issues facing occupational environmental, health and safety professionals in the wind industry and how others are solving issues to some of the industry's most important challenges. Attend and learn directly from industry experts, interact with other EHS professionals and suppliers, and develop valuable new relationships to help support current and future projects. Discuss current EHS trends in the wind industry including topics on building and improving safety behavior, emerging technological issues and safety best practices. For more information, visit *www.awea.org*.

January 18–20—MCA Business Conference. Orlando. The Motion Control Association (MCA) Business Conference brings together top executives from motion control industries. It is co-located for the second year with the Automated Imaging Association (AIA) Business Conference and the Robotics Industry Association (RIA) Industry Forum. Combined, these events will attract some 350 industry leaders from the robotics, machine vision and motion control industries. Speakers include Alan Beaulieu, economist and principal from the Institute for Trend Research, Mark Lewandowski, controls technology leader at Proctor & Gamble and Terrence Southern, supply chain senior project engineer at Frito-Lay North America. Panel discussions will be led by experts from Yaskawa Electric, Parker Hannifin and Kollmorgen. You must be a paid member of the MCA in order to attend the MCA Business Conference. For more information, visit *www.motioncontrolonline.org*.

February 2–5—WIN-World of Industry 2012 Part 1. Istanbul, Turkey. Exhibitors of WIN-World of Industry have the opportunity to display their products directly to top decision makers in the growing markets in Eurasia and the Middle East. Part 1 will include exhibitions on metal working, welding and surface treatment. WIN-World of Industry Part 2 will be held from March 29-April 1 and will include exhibitions on automation, material handling, hydraulics/pneumatics and energy and electronic technologies. The Industrial Activities Summit 2011, held parallel with WIN 2012, features well-attended conferences, seminars, roundtable discussions, panels, company and product presentations and forums. For more information, visit *www.win-fair.com*.

February 9–11—IPTEX 12. Bombay Exhibition Center, Mumbai, India. IPTEX is an exclusive exhibition focused on gear engineering and power transmission technology. The show features products and services in gears and gearboxes, gear machines and tools, linear transmission and drive systems, metrology products, software, bearing, belts and other mechanical transmission products. Supported by AGMA and organized by Virgo Communications and Exhibitions, IPTEX 12 will help attendees learn the latest trends in gear and power transmission technology and provide solutions for an array of manufacturing needs. Visitors to the 2010 show included industry leaders from the aerospace, automotive, machine tool, material handling, sugar, textile and thermal plant industries. For registration information, visit *www.virgo-comm.com*.

February 14–16—ATX West. Anaheim Convention Center. The Automation Technology Expo features the latest products and technologies in assembly systems, custom automation, material handling, motion control, motors and drives, sensors and much more. "Automation and Cost Control in Packaging" is a scheduled conference session that will examine practical strategies and technologies while instructing attendees how to cut costs and streamline their production process. ATX West is a Canon show, co-located with eight trade shows including WestPack, MDM West, Electronics West, Pacific Design and Manufacturing, Aerocon, Plastec, SensorTec and Sustainability in Manufacturing. Registration will provide access to all nine exhibitions. For more information, visit *www.canontradeshows.com*.

March 6–8—Expo Manufactura. Cintermex, Monterrey, Mexico. The largest event in Mexico for the processing and manufacturing industries boasts more than 600 national and international brands. The exhibition offers technological solutions in aerospace, medical devices, automotive, metallurgical, aeronautics and electrical appliances. Innovation topics for the 2012 show include cloud computing, connectivity, micro and nanotechnologies, automation and micromachining. More than 9,000 industry professionals will visit the show looking for industry insights, new technologies and networking opportunities. The exhibition was conceived to bring together all industry professionals with the most innovative technology solutions, so that they can implement them in their internal processes, which will allow Mexico to benefit from and further promote the competitive advantages of its manufacturing industry. For more information, visit *www.expomanufactura.com.mx*.

PTDA

CELEBRATES SUCCESSFUL INDUSTRY SUMMIT

Carlos Ingram (top) was the 22nd recipient of the PTDA's Warren Pike award for lifetime achievement in the power transmission/motion control industry.

The PTDA's Industry Summit recently took place in Washington D.C. This networking and educational event provided networking opportunities, programming and various social events. Attended by top-level decision-makers from leading distribution and manufacturing firms, the Industry Summit is a unique mix of educational sessions on industry trends, distributor-manufacturer meetings and peer networking forums. It is designed to help distributors and manufacturers work together to move their companies and the industry forward. Keynote and educational sessions help attendees grow their businesses and bottom lines by focusing on using existing capabilities and careful planning to tap into new markets and capture new opportunities.

More than 530 industry professionals registered and attended the conference including international delegates from Belgium, Brazil, Canada, Columbia, France, Germany, Italy, Mexico, Russia, Trinidad and the United Kingdom. Highlights of the summit included the opening keynote address by Alison Levine, "Ascending from Summit to Summit," the second keynote address by economist Alan Beaulieu of the Institute for Trend Research, "The Beaulieu Report" and a panel discussion: "Effects of Mergers and Acquisitions on The Distribution Channel," moderated by Barb Ross, vice president sales and marketing, Timken Drives LLC, with participating panelists Chris Bursack, director marketing, Industrial Supply Co., Inc.; Jay Greyson, principal, Supply Chain Equity Partners and co-founder, Vetus Parnters; George Rizza, president, Rossi Gear Motor Division, Habasit America; Steve Smidler, president, Kaman Industrial Technologies Corporation; and Ed Ralston, executive vice president, Baldor Electric Company, a member of the ABB Group.

The PTDA Industry Summit features invaluable networking, learning and social events including the signature event, the Manufacturer-Distributor Idea Exchange (MD-IDEX), where distributors and manufacturers efficiently bring together existing and potential channel partners to strategically plan for the upcoming year. The 2011 program featured well over 600 meetings through pre-scheduled appointments and open times.

For the sixth year, the Industry Summit included a Motion Control Showcase, featuring 20 motion control suppliers with live demonstrations of the latest hardware. The showcase is targeted at members considering expansion into the motion control arena, looking for additional suppliers to support current offerings or interested in networking with other market players.

The closing event of the Industry Summit included a private social event at the Smithsonian's National Museum of American History, where delegates and their spouses/companions and families enjoyed dinner and the opportunity to wrap up their convention activities, in addition to the chance to get up close with some true American treasures.

During the event the PTDA named Carlos Ingram, former vice president of business systems, Kaman Industrial Technologies Corporation, the 22nd recipient of its Warren Pike Award for lifetime achievement in the power transmission/motion control (PT/MC) industry. The award is named for the PTDA's co-founder and first president and was established in 1984 to honor individuals who have demonstrated outstanding, continuous, long-term support of PTDA and the PT/MC industry.

Upon receiving the award, Ingram took the podium and said, "As I look over past award winners, this is such an elite group that I feel honored. I look at other leaders who have done so much and haven't won this award, and I think maybe a mistake has been made. I want to thank the association staff and all the members. I especially want to thank Kaman Industrial and Jack Cahill, who supported me so much over the years. I also want to thank my beautiful wife Darlene for all her support."

Ingram has been a leader for PTDA for the past 20 years. Beginning as a member of the Business Information Systems Committee in 1991, he has served on committees ranging from marketing to industry relations. He joined the PTDA board in 1998 and served as president in 2003. He continued to serve the association right up until his retirement in May 2011.

Kevin McCloskey, a colleague of Ingram's at Kaman and a fellow past PTDA president, heaped praise on Ingram for his forward-driving influence over the entire industry. In the '90s, Ingram was part of a core group of people who saw what was coming and made sure the association helped the industry take advantage of new systems for handling data and new processes. He was a champion for emerging technologies

continued

before that term was in vogue. One of his core contributions was the development of PPIF, which gave the entire power transmission/motion control market a framework for sharing price and product information. It's impossible to calculate how much time and money the PPIF has saved both distributors and manufacturers.

Barb Ross, Timken Drives, LLC, served as chair of the Manufacturer Council when Ingram was president in 2003 and spoke of Ingram's involvement with PTDA. "I have been fortunate to work with Carlos over the years. He is a true professional who understands the industry and is a true partner," said Ross. "He is a man of integrity and is respected in the industry. While Carlos was president, the industry was going through some tough times. Carlos was an inspiration. He was always smiling and charging forward with a positive attitude."

PTDA's 2012 Industry Summit is scheduled for October 18–20, 2012, at the Hyatt Regency Dallas in Dallas, Texas. For more information, visit *www.ptda.org*.

Altra

ACQUIRES BAUER GEAR MOTOR

Altra Industrial Motion recently acquired Bauer Gear Motor, a privately held company headquartered in Esslingen, Germany. Bauer is a European manufacturer of high-quality gearmotors, offering engineered solutions to a variety of industries. As part of Altra Industrial Motion, Bauer Gear Motor joins Boston Gear, with a broad offering of gearing products, including the industry standard 700 Series worm gear speed reducer. "With strong expertise in both integral gear motor technology and C-face gear drive engineering, Altra now offers a comprehensive suite of application-dedicated products," said Craig Schuele, Altra vice president of marketing and business development. "Bauer Gear Motor, together with Boston Gear, provides our customers with the reliability of two world-class brands and more than 200 years of combined experience." Both Boston Gear and Bauer Gear Motor have extensive experience and application knowledge in industries including material handling, food processing, packaging, bottling and metals. Bauer Gear Motor is a globally recognized brand of quality integral gear motors. Known for streamlined geartrain designs, market-specific features, motor manufacturing expertise and a broad offering of drive packages, Bauer is the preferred choice of many major original equipment manufacturers. Boston Gear is a trusted brand with experience in developing and manufacturing many types of enclosed C-face gear drives, including worm, bevel and helical. For more information, visit *www.altramotion.com*.

Wittenstein

ACCEPTS INDUSTRY AWARD

Dr. Manfred Wittenstein

Top business elite were recently honored for Germany's prestigious 15th annual "Entrepreneur of the Year" competition. Dr. Manfred Wittenstein, president of the Wittenstein Group with global headquarters in Igersheim, Germany, won the award in the "Industry" category. The jury was impressed by Wittenstein's foresight: "He inherited a small sewing machine business and turned it into the world's premier manufacturer of drive technology. Wittenstein is a visionary among machine builders," cited a jury member.

Of the 300 companies nominated, 65 qualified for the final round. The category winners won with criteria focusing on clear employee focus, proven innovative vitality and a policy of responsible growth. Select winners, including Dr. Wittenstein, were also nominated to represent Germany in the international "World Entrepreneur of the Year" competition. The "Entrepreneur of the Year" is a global competition organized by Ernst & Young and seeks to identify and honor extraordinarily successful business people on a national level around the world. The "World Entrepreneur of the Year" will be announced in June 2012.

EPTDA Convention

REPORTS RECORD-BREAKING ATTENDANCE

The European Power Transmission Distributors Association (EPTDA), a strong voice for the mechanical Power Transmission and Motion Control (PT/MC) indus-

continued

The EPTDA board of directors for 2011-2012 were appointed during the EPTDA Annual Convention.

David Harrow, EPTDA president, speaks to the members at the Annual Convention in Budapest.

try, reported record-breaking attendance at its 2011 Annual Convention in Budapest. With more than 350 participants featuring 32 companies joining for the first time, and with over 700 individual meetings between distributors and manufacturers at the signature MD-IDEX sessions, EPTDA re-established its position as a leading association in Europe for PT/MC decision makers.

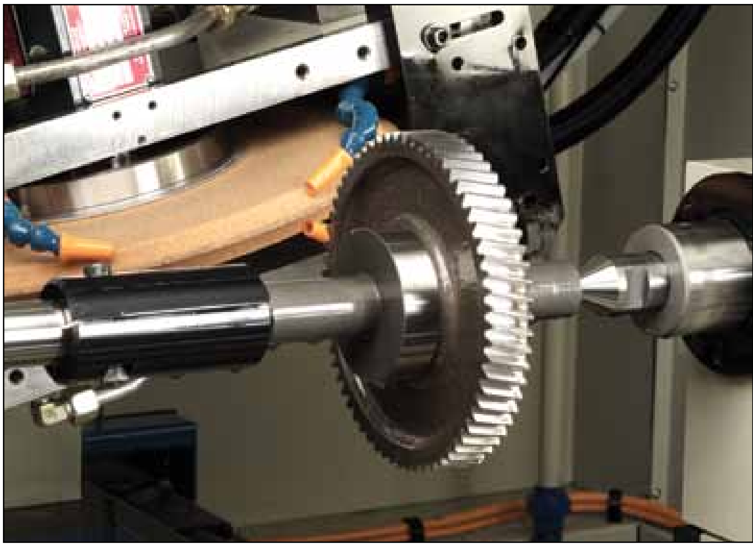
Signalling its commitment to personal training and development, at the Budapest 2011 Annual Convention EPTDA also launched its much-awaited EPTDA Academy in collaboration with Nyenrode University of The Netherlands. The EPTDA Academy will host its first Executive Training program in June 2012 focusing on strategy and leadership.

The 2011 Annual Convention featured Connie Podesta discussing leadership skills, Alan Beaulieu on global prosperity and Ben Legg on the future of the Internet. From the "Next Generation Event" to the "Distributor Forum," delegates interacted and engaged in formal and informal levels to address the future of the industry and areas of mutual growth and mutual issues. The EPTDA Annual Convention also featured a dedicated session on the association governance, including an update on the bylaws and appointment of the new board of directors for 2011–2012: David Harrow, EPTDA president—Godiva Bearings, U.K.; Meino Noordenboos, EPTDA vice president—Biesheuvel Groep, B.V., the Netherlands; Manfred Beitel, EPTDA past president—WLB Antrieselemente Handels GmbH, Germany; David Bassas, EPTDA secretary treasurer—Tecnotrans Bonfiglioli S.A., Spain; Stewart Booth, EPTDA manufacturer council chair—PIX Europe, United Kingdom; Lars Akerberg, EPTDA board member—Nomo Kullager, Sweden; Christian Collignon, EPTDA board member—IPH-Orexad, France; Roberto Cugnaschi, EPTDA board member—Mondial S.p.A., Italy; Elisabeth Meister, EPTDA board member—Ludwig Meister GmbH & Co. KG, Germany; Mustafa Özkara, EPTDA board member—Bilya-Sanayi, Turkey; Moris Romi, EPTDA board member—RIMA, Italy; and Dick Winkelhuis, EPTDA board member—Spruit Transmissies, The Netherlands.

In 2012, EPTDA Annual Convention will be held in Lisbon, Portugal on September 26–28. For more on the EPTDA 2011 Convention, visit *www.eptdaconvention.org*.

Micro Precision Gear Technology

INCREASES MACHINE CAPACITY



Micro Precision Gear Technology of Hemel Hempstead is bucking the current trend of a flat market for U.K. manufacturing and increasing capacity both for its precision gear component business and its high-precision assembly service, both driven by orders from motorsport teams and subcontract work for civil aerospace and military related hardware. Terry Grubb comments on the move, "Micro-Precision has been in business for over 30 years quietly supplying sub-contract and make complete engineering work to some of the highest profile commercial engineering operations in the world, from the latest generation of aircraft to Formula 1 cars. We have grown organically by providing an absolutely top-class service and this has now allowed us to make this latest investment in new machinery and factory expansion in order to satisfy demand."

"As engineering production becomes ever more streamlined and tolerances and materials become ever more exacting our value to our customers is on the increase, mainly because of our quality and our flexibility," he continues, "If a customer requires just one part, manufactured to the same tolerances and put through the same test regime as a larger batch would, then we can do it. Low-to-medium volume production is our current forte and having continually invested in the very latest high accuracy machines we have always been ahead in terms of accuracy and production economies."

The new machines include precision CNC Hofler gear grinding machines and five-axis S and T gear hobbing machines, alongside specialist measurement and finishing machines, all of which will be kept busy with orders from the U.K. and increasingly international customers operating global manufacturing businesses. For more information, visit *www.microprecision.co.uk*.

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State/Province: ____________________

ZIP/Postal Code: ____________________

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6) How is THIS LOCATION involved with power transmission products? (Check all that apply)

- ☐ WE MAKE power transmission products (10)
- ☐ WE BUY power transmission products (12)
- ☐ WE SELL power transmission products (Distributors, sales reps. etc.) (14)
- ☐ WE DESIGN products with power transmission components in them. (16)
- ☐ Other (please describe) (15) ____________________

____

7) Which of the following products and services do you personally specify, recommend or purchase? (Check all that apply)

- ☐ Actuators (30)
- ☐ Adjustable-Variable Speed Drives (31)
- ☐ Bearings (32)
- ☐ Belting and Belt Drives (33)
- ☐ Brakes (34)
- ☐ Clutches (35)
- ☐ Controls (36)
- ☐ Chain & Chain Drives (37)
- ☐ Couplings & U-Joints (38)
- ☐ Gears (39)
- ☐ Gear Drives (40)
- ☐ Gear Mfg. Services (41)
- ☐ Hydraulic Power (42)
- ☐ Linear Motion (43)
- ☐ Motors (44)
- ☐ PT Accessories (45)
- ☐ Sensors (46)

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

- ☐ Corporate Management (1)
- ☐ Plant Engineering (2)
- ☐ Design Engineering (3)
- ☐ Marketing & Sales (4)
- ☐ Manufacturing Engineering (5)
- ☐ Purchasing (6)
- ☐ Quality Control (7)
- ☐ Factory Automation (8)
- ☐ Maintenance (9)
- ☐ Other (10) ____________________

____

9) What is the principal product manufactured or service performed at **THIS LOCATION?**

____

10) How many employees are at THIS LOCATION (Check one)

☐ 1-19 ☐ 20-49 ☐ 50-99 ☐ 100-499 ☐ 500+

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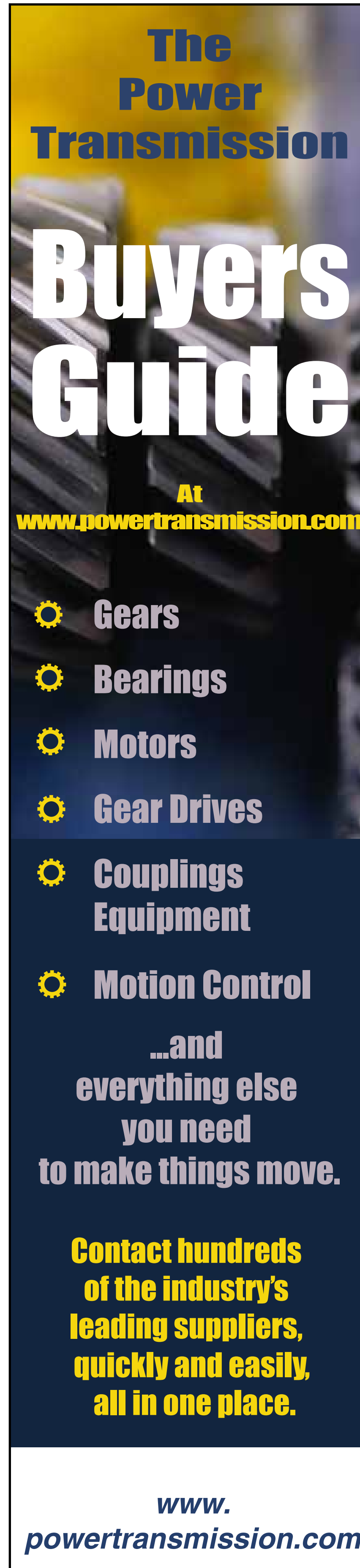

Remembering Paul Winchell—A Man With Heart To Spare

(Courtesy Roger Passero).

Remember Paul Winchell? Sure you do—if you are a child of the '50s. Who of that period does not recall ventriloquist dummies Jerry Mahoney and Knucklehead Smiff—the "headliners" of Winchell's popular NBC Saturday morning kids show (*The Paul Winchell Show*)? Later generations of kids have no clue of him, but millions of them have heard him—whether they know it or not—as the voice of Tigger in the Disney animated kid classics Winnie the Pooh and the Blustery Day and *Winnie the Pooh and Tigger Too*, for which he received a Grammy in 1974. Son of an immigrant tailor, a shy child with a pronounced stutter and a polio survivor, Winchell (formerly Wilchinsky) went on to voice other familiar cartoon characters, including Gargamel (*The Smurfs*), Fleegle (*The Banana Splits Adventure*) and many, many more. Also a talented, sometimes actor, Winchell appeared on hit TV shows including *The Beverly Hillbillies, The Dick Van Dyke Show* and *The Brady Bunch*.

And not to bury the lead, but here's something that almost nobody knows: Winchell, who died in 2005 at age 83, was also an inventor and the holder of some 30 patents.

That is impressive on its own, but among those patents was U.S. Patent # 3097366 for the design—with assistance from noted physician Dr. Henry Heimlich; yes, that Heimlich—of the first implantable, artificial heart. Other medical patents awarded include those resulting from Winchell's humanitarian work for what is now known as the Leukemia & Lymphoma Society and the American Red Cross. Patents awarded for a blood plasma defroster and a piezo-electric diaphragm were a direct result of his work for those organizations. And, Winchell, then in his 50s, found time to attend and graduate from The Acupuncture Research College of Los Angeles in 1974; he also worked as a medical hypnotist at the Gibbs Institute in Hollywood.

And while some may think it a stretch to cite Winchell in Power Play, his heart pump design and aforementioned piezo-electric diaphragm are concrete examples of power transmission accomplishment.

Quoting (regarding his artificial heart design) from the Winchell website (*paulwinchell.net*):

"I applied for a patent and then I awaited the examiner's report. The initial search revealed that the device was cleared for patent and no prior art had been found. I filed in the summer of 1956. It took me almost eight years to convince the examiner of the device's possibilities. He, too, thought I was wacky, but he finally acceded, making me the first inventor to ever receive a U.S. patent for an artificial heart."

Winchell, upon request, subsequently donated his patent to the University of Utah. However, a debate eventually arose over how much of Winchell's design was actually used by Dr. Robert Jarvik—commonly credited as the originator of the artificial heart. Jarvik at that time was working with a team at the school on his own heart device. Over the years, Jarvik has long denied that any of Winchell's design elements were incorporated into the device he fabricated for humans—the Jarvik–7—which was successfully implanted for the first time in human guinea pig Barney Clark in 1982.

But the plot thickens, according to the *Internet Accuracy Project* website (*accuracyproject.org*):

"After Jarvik was repeatedly—and erroneously—referred to as the inventor of the artificial heart, Heimlich made a television talk show appearance (*The Merv Griffin Show*) alongside Winchell to confirm not only the story of Winchell's early work and patent of his artificial heart device, but also to verify the fact that Winchell's work had occurred many years before Jarvik's artificial heart was produced. (During the appearance Heimlich stated): 'I saw the heart. I saw the patent and I saw the (application) letters. The basic principle used in Winchell's heart and Jarvik's heart is exactly the same.'"

And this, too, from the *Internet Accuracy Project:* "Contrary to popular public perception, the artificial heart was not invented by (Jarvik). Documents from the United States Patent Office show that February 6, 1961, Paul Winchell filed for a patent on his artificial heart. He was granted a patent on July 16, 1963. (The patent paperwork explains in part): 'This invention relates to an artificial heart and, more particularly, to an artificial heart capable of substituting for a natural human heart in moving blood through a human body…and in which the moving parts are sealed within a container made of a material which is non-toxic and non-irritating to the human or animal body and inert with respect to body fluids, the several moving parts being made of tough, durable material which will not wear out in use, such as nylon, and the like.'"

And did we mention his invention of the first disposable razor?

Not bad for someone perhaps best known as Knucklehead Smiff's alter ego.

And so, as Tigger would say: "Ta-ta for now."