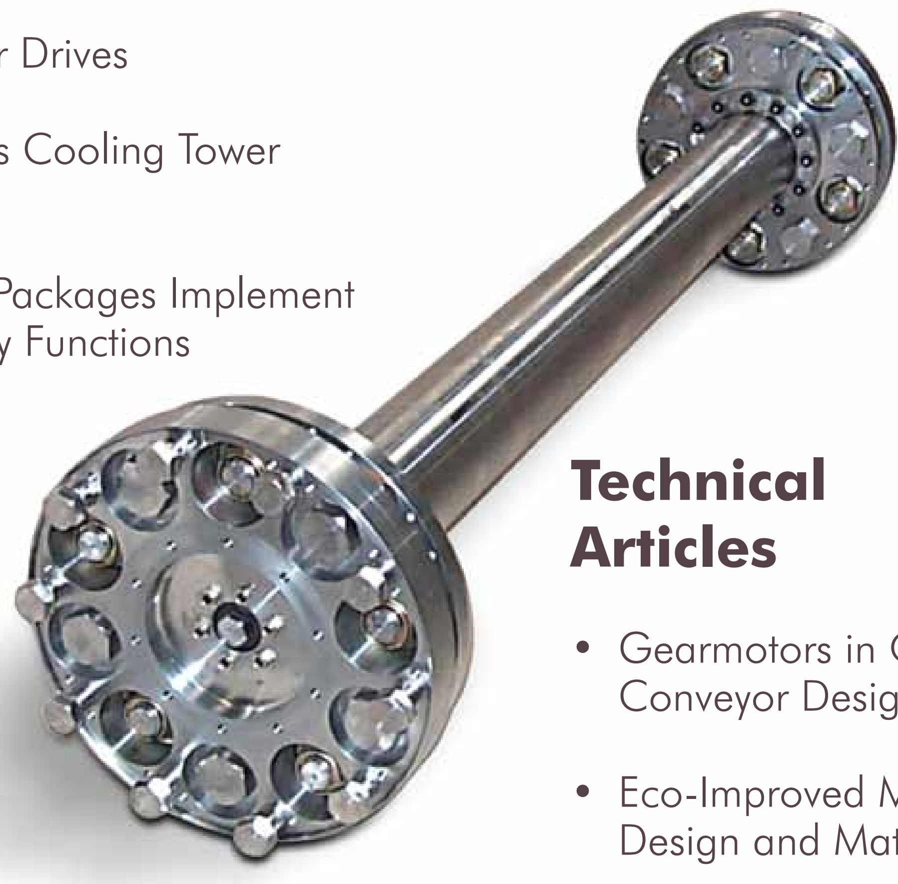
February 2011

PTE

powertransmissionengineering®

Features

- Gears and Gear Drives
- Baldor Redefines Cooling Tower Performance
- Siemens Drives Packages Implement Mandated Safety Functions



Technical Articles

- Gearmotors in Queue Conveyor Design
- Eco-Improved Motor Design and Materials
- Thin-Section Bearings: New Capacity Calculations

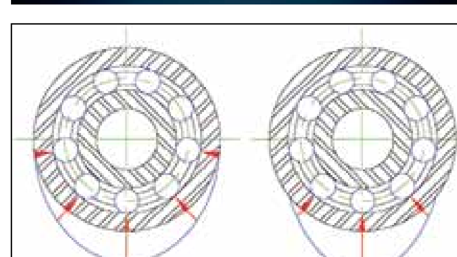
Power Play

Sneakers on Steroids

PTE

powertransmissionengineering®

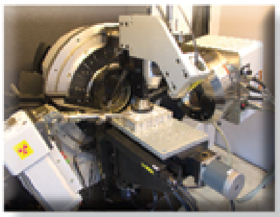
FEBRUARY
2011



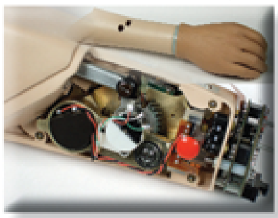
PTE
powertransmissionengineering®

FEBRUARY
2 0 1 1

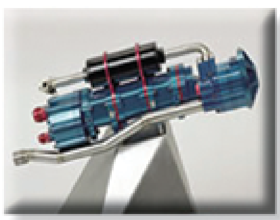
DEPARTMENTS

Brass gear and stainless worm shaft for analytical diffractometer positioning…highest diametral pitch (164) made to date by our engineers

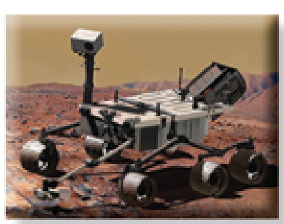



Articulating gear for the electric terminal device on the Utah Arm…patient can tie his shoes

Star gear for racecar fuel pump…every car in the Indy 500 field has our product onboard


Internal spline gear for a levelwind fishing reel…casts twice as far

Gears for the drive wheels and actuators on Mars Rover…no room for failure or a service call

Who Says You Can't Be All Things To All People?

Forest City Gear helps customers in an extremely diverse group of industrial, medical, aerospace, sporting goods, research lab and high-performance racing markets, plus many others. Some might foolishly suggest this makes us "a jack of all trades, master of none," as that old adage goes.

Boy, are they wrong.

Exactly the opposite is true. Forest City Gear is the longtime market leader in special gear solutions, precisely because we've seen and solved problems in virtually any application you can name that requires the highest geometrical integrity, superior repeatable performance, accuracy that's often off-the-charts for other gear companies and a secure, reliable line of supply. O yes, and all at an affordable price that helps keep customers competitive and viable in their markets.

Who says you can't be all things to all people? Well, we suppose the size of our machining centers is a limit, if you can call what you see here limited?

Call Forest City Gear and hear about all we can be…on your next gear challenge! Go to **www.forestcitygear.com** today.

FOREST CITY GEAR

"For high-precision gears, we certainly can!"

Fred Young, CEO

11715 Main Street, Roscoe, IL 61073 815-623-2168

PTE

powertransmissionengineering®

VOL. 5, NO. 1

Randall Publications LLC
1840 Jarvis Avenue
Elk Grove Village, IL 60007

Phone: (847) 437-6604
Fax: (847) 437-6618

Photo courtesy of Bibby Transmissions

EDITORIAL

Publisher & Editor-in-Chief	Michael Goldstein *publisher@powertransmission.com*
Managing Editor	William R. Stott *wrs@powertransmission.com*
Senior Editor	Jack McGuinn *jmcguinn@powertransmission.com*
Associate Editor	Matthew Jaster *mjaster@powertransmission.com*
Editorial Consultant	Paul R. Goldstein

ART

Art Director	Kathleen O'Hara *kathyohara@powertransmission.com*

ADVERTISING

Advertising Sales Manager	Dave Friedman *dave@powertransmission.com*
Materials Coordinator	Dorothy Fiandaca *dee@randallpublications.com*

CIRCULATION

Circulation Manager	Carol Tratar *subscribe@powertransmission.com*

RANDALL PUBLICATIONS STAFF

President	Michael Goldstein
Accounting	Luann Harrold

Bosch Rexroth 4EE

A SYSTEMATIC APPROACH TO ENERGY EFFICIENCY

Responding two years ago to customers' concerns about rising energy costs, Bosch Rexroth began leveraging its technologies to develop a comprehensive strategy to help customers maximize energy efficiency. The 4EE program (4 Energy Efficiency) involves four key areas including: efficient components, energy recovery, energy on demand and energy system design. (*Ed's note: See sidebar page 7*).

"Bosch Rexroth is able to take a more systematic approach to energy efficiency in customers' applications by factoring all technologies and the interplay of all components into the overall efficiency of the system," says Scott Hibbard, vice president of technology at Bosch Rexroth. "Considering the large scope of customers' industrial applications, our specific mission is to help customers reduce their overall energy usage and their impact on the environment, but also make them more profitable."

Bosch Rexroth's IndraDrive System.

Bosch Rexroth's KST Booster.

Other areas of energy efficient solutions include lubrication technologies and drive and control systems. Several manufacturing companies have recently weighed in on the overall energy savings achieved using elements of the 4EE program.

Lubrication. The Rapidstar Sup-ply Unit (RSU) system for cooling lubricants opens all of the advantages of a modular system for the low- and high-pressure supply. This new concept—on the basis of standardized assemblies—reduces energy needs and shortens the assembly times considerably. The KST booster moves the high-pressure generation into the hydraulic unit when internally cooled tools are used, and so the complete motor-pump supply line on the cooling lubricant side is omitted while the energy consumption is simultaneously reduced. The hydraulic unit that is available in the machine can be connected and deactivated, depending on the process; using an additional linear pump, it generates the necessary pressure of up to 120 bar with a flow of up to 50 l/min. Bosch Rexroth extends the service life of the supply unit by moving all open-loop and closed-loop control functions into the particle-free hydraulic circuit. Thus, about 90 percent of the applications can do without the cooling lubricant fine filter that has been necessary up to now and operating costs can be further reduced. The KST booster, that can also be retrofitted, reduces the average noise emission considerably and satisfies another important requirement of users.

"European customers using the KST booster report energy savings up to 80 percent, depending on the energy cycles," Hibbard says. "Customers also are saving money by not having to purchase coolant or the components for the motor-pump supply line."

Drive and control systems. Using a Bosch Rexroth drive and control system, MoCo Engineering and Fabricating, located in Spokane, Washington, converted an existing 10-axis hydraulic lumber stacker system into the world's first line-regenerative, electric servo-driven synchronized stickering stacker.

According to MoCo's documented tests, the company has had energy reductions from 40 to 75 percent, with savings of up to $45,000 per year. To obtain the suitable components, MoCo teamed up with local Rexroth automation distributor Northwest Motion, a supplier to MoCo since 2000. Based on their experience with servo designs, Northwest Motion recommended a Rexroth IndraDrive drive system, IndraDyn servo motors and a common DC bus with regenerative capabilities so excess power could be diverted from one axis to another, or onto a mill's main power grid.

Multi-axis applications are the domain of the modular system IndraDrive M. Power supplies provide the necessary DC bus voltage for the inverters. Compact single-axis or double-axis inverters and power supplies with integrated mains connection components enable compact solutions for large axis groups. Maximum energy efficiency can be achieved with power supplies that are capable of mains regeneration. Besides the power recovery encountered in regenerative operation of the drives, another outstanding feature of these devices is the closed-loop DC bus.

A combination of IndraDrive C converters and modular IndraDrive M inverters is a particularly cost-effective solution for small axis groups. The converter for the first axis supplies the inverters of the other axes at the same time. In this case, a converter with sufficient power reserve must be selected that is able to supply the smaller inverters as well.

In addition, T-TEK Material Handling Inc., located in Montgomery, Alabama, developed a new high-speed beverage palletizing machine that performs faster and more efficiently than previous models—with the help from a Bosch Rexroth servo system. The new machine has a 15 to 20 percent faster cycle time—smaller motors and regenerative energy capability results in an estimated overall energy savings of 20 percent. This energy savings was achieved using Bosch Rexroth's MSK motors, IndraDrive M servo drives and HVR power supply to take the extra energy and regenerate it. The advantage is converting usable energy for the machine by powering the other servo motors on the DC voltage bus that may be in acceleration mode, instead of burning off the energy to a resistor.

An energy efficient future. By adhering to its 4EE strategy, the company has been able to provide a wide variety of solutions for its customers including energy analysis for motion control systems, gearboxes and conveyors, mounting systems for solar panels, hydrostatic regenerative braking systems and much more. "Together with its distribution partners and integrators, Bosch Rexroth is taking a stronger approach to providing complete systems and solutions to specific industry

continued

4EE Program

Scott Hibbard, vice president of technology at Bosch Rexroth, briefly discusses the company's 4EE Program (4 Energy Efficiency), an initiative that has been in place for two years that assists customers with a variety of green drive and control technologies.

Efficient Components: From hydraulics and pneumatics to linear motion and electric drives and controls that are optimized to reduce energy consumption with every motion, these components form the basis for energy efficient mechatronic system solutions.

Energy Recovery: Energy generated in the machine can be stored and re-used. Depending on the application and general conditions, storage-charging circuits and regenerative supply devices utilize this energy to supply it to other elements in the system, store it in a buffer for the next cycle or feed it into the electricity supply grid.

Energy on Demand: Involves using only the amount of energy that is currently needed. This idea of demand-controlled energy consumption utilizes intelligent control strategies based on the respective characteristics of the drive technologies. As a result, this combines short response times with reduced power consumption while providing at least the same high productivity. For example, variable-speed pump drives use this concept to generate demand-specific energy in hydraulic systems. They manage up to 50 percent less energy—with the same machine output. Another example is electro-pneumatic pressure control valves that can be used to control air consumption on-demand and divide the motion into different phases for this purpose. The result: up to 25 percent less air consumption.

Energy System Design: The fourth element consists of the systemic overall view from analysis via simulation, project planning and consultation, up to the optimization of process flows using intelligent controls. Essentially, Bosch Rexroth looks at how much performance and energy the system will require in later operations and then calculates the ideal combination of technologies. For more information, visit *www.boschrexroth-us.com*.

Bosch Rexroth's IndraDrive Mi (top) and Indra Control-MLL (bottom).

sectors," Hibbard says.

The company has staffed its regional center in Northern California, for example, with application engineers who are experts in semiconductor and solar applications. Product examples include the use of low friction seals in linear guide applications and the use of hydraulic technologies to make utility vehicles more efficient.

Bosch Rexroth is continuing to develop new energy efficient products in the future, according to Hibbard. "Customers who have incorporated energy-efficient drive solutions from Bosch Rexroth have been thrilled with significant energy savings and lower costs."

For more information:

Bosch Rexroth Corporation
5150 Prairie Stone Parkway
Hoffman Estates, IL 60192
Phone: (847) 645-3600
www.boschrexroth-us.com

Synchrony Magnetic Bearings

HIGHER RELIABILITY, LESS MAINTENANCE

A 250 hp industrial motor supported on Fusion magnetic bearings. This motor is also fitted with a thrust bearing for those applications requiring axial force capability, such as vertical motors (courtesy of Synchrony).

Active magnetic bearings are replacing oil-lubricated bearings for new types of machines in a variety of industries. The benefits of using magnetic bearings include higher reliability with little or no maintenance, reduced frictional losses resulting in higher energy efficiency, less noise, no contaminating or flammable lubricants, reduced machine vibration and built-in machine health monitoring and diagnostics. However, despite these advantages, the application of magnetic bearings has been limited in the past by the large size of the magnetic bearings, the complexity of integrating the magnetic bearings into the machine, the need for a large external control system and the high cost. Recent advances in magnetic bearing technology, including miniaturization, simplicity and integration have overcome many of these limitations.

In a magnetic bearing system, stationary electromagnets are positioned around the rotating assembly of a machine. Typically, two radial magnetic bearings are used to support and position the shaft in the lateral (radial) directions and one thrust bearing is used to support and position the shaft along the longitudinal (axial) direction. A shaft that is completely supported by magnetic bearings is said to provide support along five axes because the bearings react to motion along the three translational axes and the two angular axes. The magnetic bearing offers little frictional resistance to motion along the rotational axis.

An active magnetic bearing consists of a stator, which contains the electromagnets and the position sensors, and the rotor, which rotates with the shaft. When the magnetic bearing is operating, each magnetic bearing rotor is ideally centered in the corresponding stator so that contact does not occur.

The position of the shaft is controlled using a closed-loop feedback system. The position sensors detect the local displacements from the shaft, and these signals are sent to a digital controller. The controller processes these signals, and calculates how to redistribute the currents in the electromagnets to restore the shaft to its centered position. Power amplifiers in the controller then readjust the currents in the electromagnets according to these calculations. This cycle is repeated approximately 15,000 times per second.

Like other kinds of bearings, the magnetic bearing provides stiffness and damping. However, unlike other bearings, the stiffness and damping vary as a function of disturbance frequency. Consequently, the stiffness and dampness can be optimized by simply changing the control algorithm.

Design innovations lead to energy efficiency. Through recent design innovations, the size of radial magnetic bearings has been reduced by more than 30 percent. The outer diameter of the stator has been reduced by splitting the flux paths and isolating the electromagnets. Using frequency-modulated sensing techniques, the size of the sensor electronics has been reduced and the signal-to-noise ratio greatly increased. Changes in design also have miniaturized or eliminated different parts of a previous bulky controller: once the size of a household refrigerator, it's been reduced to little more than the size of a DVD player. FM sensing techniques have reduced sensor electronics and eliminated the need for sensor/AD controllers; the position signal is converted using high speed digital counters. Finally, the size of the power amplifiers has been reduced through new control algorithms that make it possible to achieve stable performance of the magnetic bearing while reducing the required volt-amp rating of the amplifiers. The size reduction also means that the controller can be integrated into or mounted on the rotating machine, eliminating the need for a separate enclosure and controller.

Furthermore, it is now possible to buy magnetic bearings with the controller completely integrated into the bearing, totally eliminating the need for a separate controller. The new, compact controllers may be integrated into the casing of the machine, mounted on the exterior of the machine or integrated into the magnetic bearing. The controller may be supplied with between 48 VDC and 300 VDC of power from a power supply located far from the machine. Because the wires between the controller and the magnetic bearings are short, cabling and connectorization are greatly simplified, EMI is reduced and no special tuning of the sensors is required.

In the past, health monitoring of a rotating machine required a dedicated vibration monitoring system. However, a machine already equipped with a magnetic bearing system can also perform health monitoring without additional hardware investment. Inherent in the magnetic bearings are high resolution position sensors, digital processing and communications. Also, much of the processing of the vibration data can be performed in the magnetic bearing controller itself rather than a separate data acquisition system and processor, while only the results of these calculations are sent over high-speed Ethernet networks. Health monitoring is achieved by sampling extending the functionality with additional computer software.

Efficient design leads to lower costs. Through standardization, integration and manufacturing advances, the cost of magnetic bearings has declined. While the engineering effort to develop a new magnetic bearing system is often higher than past systems, once developed, the systems can be supplied to OEMs and end users at a much lower price than past systems. Also, the engineering effort to integrate the magnetic bearings into a machine is greatly reduced. The cost difference to use magnetic bearings

continued

instead of oil-lubricated bearings can be justified through the elimination of the oil lubrication system. The net result is that magnetic bearings have become much more economical to use in new and existing rotating machinery.

Through technical advances, magnetic bearings now offer advantages for a much broader range of machines and applications. For example, a 400 kW, 20,000 rpm drivetrain can be created with a high efficiency permanent magnet motor/generator. A stub shaft, extending from one end of the drivetrain, can be used for mounting a pump, compressor or turbine wheel. In other cases, it's possible to apply extremely compact radial and thrust bearings with completely integrated control electronics into a NEMA frame motor. By increasing the maximum speed of the NEMA motor, it can be directly coupled to a pump or fan without the need for a gearbox.

Design innovations related to miniaturization, integration and standardization continue to increase the general acceptance of magnetic bearings for many new and existing applications—setting the standard for better, smaller and greener.

For more information:

Synchrony, Inc., USA
4655 Technology Drive
Salem, VA 24152
Phone: (540) 444-4200
www.synchrony.com

Bibby

MAKES CASE FOR MANUFACTURER REPAIR

Bibby Transmissions, a designer and manufacturer of high performance couplings for industrial, power generation and process applications, is making a case for manufacturer repair by providing possible safeguards and security for Bibby customers across the globe. "Our couplings are the most reliable of their type, but there are still occasions when they need repairing, and as the original manufacturer we think that the interests of our customers are best served by our undertaking any repairs," says Steve Broomhead, business unit manager for Bibby's Turboflex Division. "A key factor is the operating environments where they are employed. Many couplings, especially our disc types, are used in critical applications like power generation, marine, oil and gas, petro-chemical and military-where adherence to specific industry standards is mandatory. When we repair one of these couplings, the customer receives a warranted unit and the security of knowing that it conforms entirely to the original OEM standard, including final dynamic balancing and testing. However, if we don't undertake the repair, then our warranty is void—and that can have serious implications for customers in the wake of any subsequent failure."

"The second major benefit for customers of our repair service is genuine Bibby parts and materials. In some sectors of engineering industry the policy of using non-standard parts and materials in repairs is common practice, due to cost savings. However, this policy is short-sighted, because third-party repairers do not have access to the original designs and material specifications. Consequently, they have to resort to reverse engineering, which is never ideal and certainly not acceptable where the coupling is used in the sort of critical applications mentioned above," Broomhead says. "Let's not forget that some disc couplings are very high value items, and you really have to know what you are doing to repair one: the process of stripping down the coupling to look for signs of damage, removing the flexible elements, replacing them and then dynamically balancing the couplings, are all very skilled tasks which need to be undertaken by experts in the workshop—not the field. The fact that we consistently get these tasks right is one of the reasons we are ISO9001 approved and trusted by some of best known global companies for coupling supply and repair."

For more information:

Bibby Transmissions
Cannon Way, Dewsbury
West Yorkshire
WF13 1EH England
Phone: +44 1924 460801
www.bibbytransmissions.co.uk

Nord

OFFERS CONNECTIVITY AND TECHNOLOGY BENEFITS

Nord Drivesystems provides a technology unit for integrating motor-mounted SK 200E inverters into EtherCAT networks and the Beckhoff control technology environment. The Ethernet-based fieldbus offers benefits particularly for distributed networks such as conveyor systems. The new EtherCAT module from Nord connects a large number of inverters to a single bus line, since there is no need for repeaters or additional bus master interfaces.

The bus module can be mounted either directly on the SK 200E's interface unit or separately from the inverter by means of an optional wall mounting kit. The EtherCAT bus line is connected to the box via an M12 plug connector. Additionally, the module features eight integrated 24V inputs and two 24V outputs. A single technology unit can address up to four inverters via EtherCAT. An integrated RS232/RS485 interface allows for on-the-spot access to the parameters of the bus module and connected inverters by means of the SK PAR manual control unit or via Nordcon PC software. The EtherCAT technology unit has a standard protection rating of IP55, and can be supplied for IP66 on request.

All SK 200E inverter models provide sensorless current vector control, a brake chopper and a control module for an electromagnetic brake. Even the basic model allows for speed control (incremental encoder input HTL signal) and positioning control by means of the integrated Posicon function. The extended range of features includes the integrated safety function "Safe Stop" and an onboard interface for the AS-Interface bus system.

For more information:

Nord Gear Corp
P.O. Box 367
Waunakee, WI 53597
Phone: (888) 314-6673
www2.nord.com

Custom Collar and Couplings

BOAST SPECIAL-PURPOSE DESIGNS

Standard and custom collars and couplings offered in a wide range of designs for building and maintaining conveyor drive systems and frame structures are available from Stafford Manufacturing Corp. Stafford Conveyor System Components feature a wide range of shaft collars and couplings that are supplied in many special-purpose designs to assist machinery builders. Included are hex and square bore collars for positive drive applications, flange collars for mounting equipment, rigid couplings for connecting motors and shafts, threaded bore collars for adjustability, mounting collars for sensors and cameras and standard round bore collars. Suitable for use in a variety of application environments, Stafford Conveyor System Components are available machined from materials such as steel, stainless steels, aluminum, brass, bronze, Delrin, nylon and high temperature alloys. Sizes can range from 1/4" to 16" I.D. and machining tolerances to 0.0005" can be achieved, depending upon material and configuration.

For more information:

Stafford Manufacturing Corp.
P.O. Box 277
North Reading, MA 01864-0277
Phone: (800) 695-5551
www.staffordmfg.com

Motor

SUITABLE FOR EXTREME OPERATING CONDITIONS

Maxon recently launched its EC22 HD (heavy duty) motor, a 22 mm-diameter brushless motor developed for the exceptionally high requirements in deep drilling technology and capable of resisting the most extreme operating conditions. The electronically commutated EC22 HD motor was developed in collaboration with the oil exploration industry and is designed to operate at depths of around 16,000 feet and in boreholes up to 36,000 feet long.

As part of the motor's development program, a high-temperature test facility was built, and extensive field trials were undertaken. The motor operated at temperatures up to 240 degrees C and under atmospheric pressure conditions from high vacuum to 25,000 psi. It has also been proven to resist impulse and impact forces of 100 G. It can operate while submerged in oil, trebling its 80 W output rating to 240 W because of the improved heat dissipation. Although developed to perform critical downhole actuation functions, Maxon believes the new motor will also appeal to other industries where reliability is essential. The motor's efficiency of 88 percent in air (and above 70 percent in oil) makes it particularly suitable for battery-powered applications.

For more information:

Maxon Precision Motors, Inc.
101 Waldron Road
Fall River, MA 02720
Phone: (508) 677-0520
www.maxonmotorusa.com

ONLINE

Visit
www.powertransmission.com
for the latest Product News

Not All Thin-Section Bearings Are Created Equal:

KAYDON NEW CAPACITY CALCULATIONS

(Courtesy Kaydon Corp. Bearings Division)

Robert Roos and Scott Hansen

Management Summary

American Bearing Manufacturers Association (ABMA) Standard 9 and ISO 281 give equations for calculating the basic dynamic radial load rating for ball bearings. These equations are based on a number of assumptions, many of which are not valid for thin-section bearings. (Thin-section bearings are described in ABMA standard 26.2.) Nevertheless, many thin-section bearing catalogs report load ratings based on these equations.

Kaydon has developed a new method for calculating the dynamic radial load rating for thin-section ball bearings. The new method uses the contact stress and the number of stress-cycles-per-revolution to calculate the capacity. The new numbers are based on five years of actual test results. These equations can also be used to calculate the dynamic radial load rating for four-point contact ball bearings, which are not covered in ABMA standard 9 or ISO 281.

Introduction

The year was 1944 and the problem that needed to be solved required the development of a new type of bearing. The U.S. Army Air Corp contacted Kaydon Engineering Corporation to engineer and build a light-weight, thin-section ball bearing for a ball gun turret to be used on an aircraft. This bearing became the inspiration for a catalog line of thin-section ball bearings known today as REALI-SLIM (*REALI-SLIM is a registered trademark of Kaydon Corporation*).

In many applications, shafts supported by bearings are lightly loaded. Shaft position with respect to the housing or other components is critical. These designs do not need big, heavy bearings and can be supported adequately by thinner bearing races manufactured to close tolerances. Kaydon had identified a need for a bearing that was capable of saving space in designs and reducing overall weight. Thinner bearing races and cross sections allowed designers to also reduce the size and mass of the shafts and housings for even greater space and weight savings.

When is a bearing thin-section? Rolling element bearing dimensions have been standardized by the ABMA so that for a given bore diameter, bearings are manufactured with different outside diameters. For a given outside diameter, bearings are made in different widths. Each bearing belongs to a dimension series that can be designated by diameter and width.

For a conventional series of ball bearings, radial cross section and ball diameter typically increase with bore diameter.

continued

Therefore, an increase in bearing weight is significant as bore diameter increases. The graph in Figure 1 compares conventional bearings with thin-section bearings, illustrating this change in radial cross section with bore diameter.

Bearing weight can be reduced with thin-section bearings because—for a given series of bearings—radial cross section and ball size remain constant. Generally, a bearing is considered to be thin-section when:

- Radial cross section is less than one-fourth the bore diameter
- Radial cross section is less than twice the rolling element diameter

Benchmarking and fatigue life testing. Kaydon has devised methods for testing the fatigue life of its REALI-SLIM bearings. Along with testing of Kaydon-produced REALI-SLIM bearings, we have also benchmarked most known major producers of thin-section ball bearings by subjecting their catalog-equivalent bearings purchased through distribution to the same testing procedure.

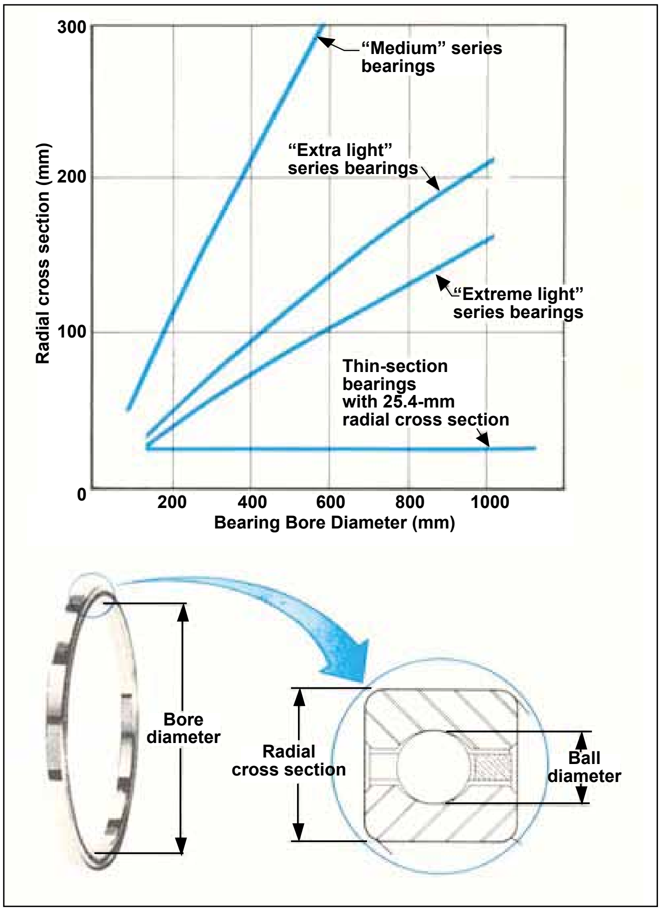


Figure 1—Bearing cross sections.

Results are shown in Table 1. Armed with this information, we set out to validate the capacity equations used in the ABMA/ISO standards.

It is also important when comparing "catalog" bearings that appear to have the same or similar part number that all thin-section bearings are not created equal. There can be major differences in things that cannot easily be seen that can cause devastating reductions in bearing life and performance. Here is a short list of those differences:

- Ball grade
- Race and ball material and microstructure, inclusion rating
- Hardness of balls and races
- Ball and ball path surface finish (roughness and waviness)
- Method of manufacture, i.e., grinding and honing of ball track (some thin-section bearing manufacturers only hard turn the ball paths)
- Truth of curvature
- Contact angle
- Conformity (osculation)
- Runouts: i.e., radial, axial
- Cleaning process
- Residual magnetism
- Cold temperature stabilization of races and balls
- Retained austenite

Objective

The purpose of this study is to develop a new set of equations for calculating the dynamic capacity of thin-section bearings. The new equations must be supported by both theory and actual test results.

Literature Review

Many thin-section ball bearing competitors calculate capacity using the methods found in ABMA standard 9 or in ISO 281. These standards define the term "basic dynamic radial load rating," which is synonymous with the Kaydon definition of "dynamic capacity." The basic dynamic radial load rating (C_r) is defined as: "*That constant radial load that a bearing could theoretically endure for a basic rating life of one*

Table 1—Test Results

TEST REPORT	BASE PART NUMBER	MANUFACTURER	B10 LIFE (hours)	EQUIVALENT CAPACITY (lbs)	CATALOG CAPACITY (lbs)	CATALOG CAPACITY COMPARISON	ACTUAL B10 FATIGUE PERFORMANCE
RP545	KC040CP0	Kaydon	76.0	1,059	880	+20%	+73%
RP487	KC040CP0	Kaydon	71.2	1,036	880	+18%	+64%
RP582	KC040CP0	Competitor (A)	23.2	713	1,290	-45%	-83%
RP487	KC040CP0	Competitor (B)	12.5	580	884	-34%	-72%
RP534	NC040CP0	Kaydon	59.9	978	880	+11%	+36%
RP529	NC040CP0	Kaydon	120.4	1,234	880	+40%	+174%
RP584	NC040CP0	Competitor (C)	19.1	668	1,290	-48%	-87%

Equation 1	$L_{10} = \left(\dfrac{C_r}{P_r} \right)^3 10^6$ million revolutions	*ISO 281 par 5.3.*
Equation 2	$C_r = b_m f_c (i \cos\alpha)^{0.7} Z^{2/3} D_b^{1.8}$ for ball size (Db) $\leq$ 1 inch. $C_r = 3.647 b_m f_c (i \cos\alpha)^{0.7} Z^{2/3} D_b^{1.8}$ for ball size (Db) > 1 inch	*ISO 281 par 5.1*
Equation 3	$f_c = 4.1\lambda \left\{ 1 + \left[1.04 \left(\dfrac{1-\gamma}{1+\gamma} \right)^{1.72} \left(\dfrac{r_i}{r_o} \cdot \dfrac{2r_o - D_b}{2r_i - D_b} \right)^{0.41} \right]^{10/3} \right\}^{-0.3} \cdot \left(\dfrac{\gamma^{0.3}(1-\lambda)^{1.39}}{(1+\gamma)^{1/3}} \right) \left(\dfrac{2r_i}{2r_i - D_b} \right)^{0.41}$ where: $\gamma = \dfrac{D_b Cos\alpha}{D_p}$	*Palmgren Table 3.2*
Equation 4	$f_c = 38.20 \left\{ 1 + \left[1.04 \left(\dfrac{1-\gamma}{1+\gamma} \right)^{1.72} \left(\dfrac{f_i}{f_o} \cdot \dfrac{2f_o - 1}{2f_i - 1} \right)^{0.41} \right]^{10/3} \right\}^{-0.3} \cdot \left(\dfrac{\gamma^{0.3}(1-\lambda)^{1.39}}{(1+\gamma)^{1/3}} \right) \left(\dfrac{2f_i}{2f_i - 1} \right)^{0.41}$	*Ref. Harris eq. 18.106*

million revolutions."

These standards also define the L_{10} bearing fatigue life as: "The basic rating life in millions of revolutions for 90% reliability."

The L_{10} life is then calculated from the load rating (C_r) using Equation 1. Please note that the basic dynamic radial load rating, as defined in these two standards, is not the maximum operating load for the bearing; it is simply a constant used in the life equation. It is often greater than the "static" radial load rating (C_{or}). Loading the bearing beyond the static rating will cause permanent deformation, or "brinelling." Both standards state:

"*The life formula gives satisfactory results for a broad range of bearing loads. (However), the user should consult the bearing manufacturer to establish the applicability of the life formula in cases where (the applied load) Pr exceeds (the static capacity) C_o or (one-half the dynamic rating) 0.5 C_r whichever is smaller.*"

(See above for Equation 1)

These two standards give the following equations for calculating the basic dynamic load rating (C_r):

(See above for Equation 2)

where:

L_{10} = The basic life rating in millions revolutions for 90% reliability

C_r = Basic dynamic radial load rating

b_m = Material factor for contemporary steels (b_m = 1.3)

f_c = Geometry factor from tables

i = Number of rows

α = Contact angle

Z = Number of balls per row

D_b = Ball diameter

P_r = Applied radial load

Both standards provide tables for the geometry factor (f_c). The material factor (b_m) was added to ISO 281 in 1990. It equals 1.3 for radial and angular contact ball bearings made of contemporary steels. The 1990 version of ABMA standard 9 does not include this factor. However, the tables for factor f_c are 1.3 times higher than the ISO 281 tables. Therefore, the two standards give exactly the same capacity.

The factor f_c can also be calculated using the equation below:

(See above for Equation 3)

where:

The units in this equation are kg and mm. For radial and angular contact ball bearings λ= 0.95. For 4-point contact bearings λ= 0.90. If we let f_i and f_o equal the inner and outer curvature ratio (*rx/Db*) and convert the units to N and mm, this equation can be rewritten as:

(See above for Equation 4)

continued

The f_c values used in the ABMA Standard 9 and ISO 281 tables are based on a number of assumptions. These include the following:

- Inner-ring raceway cross sectional radius ≤ 0.52 D_b (curvature ratio ≤ 52%)
- Outer-ring raceway cross sectional radius ≤ 0.53 D_b (curvature ratio ≤ 53%) (The f_c tables in these standards were actually calculated using 52%)
- 52100 steel per ASTM A-295
- Adequate lubrication
  - Free of contamination
  - Film thickness > the composite surface roughness
- Inner and outer races are rigidly supported and properly aligned
- Nominal internal clearance after mounting ("nominal" in this context means zero or no preload)
- Radial ball bearings are made to ABEC 1 or better tolerances per ANSI/ABMA standard 20 (thin-section bearings are made per ANSI/ABMA standard 26.2)
- No truncation of the contact ellipse

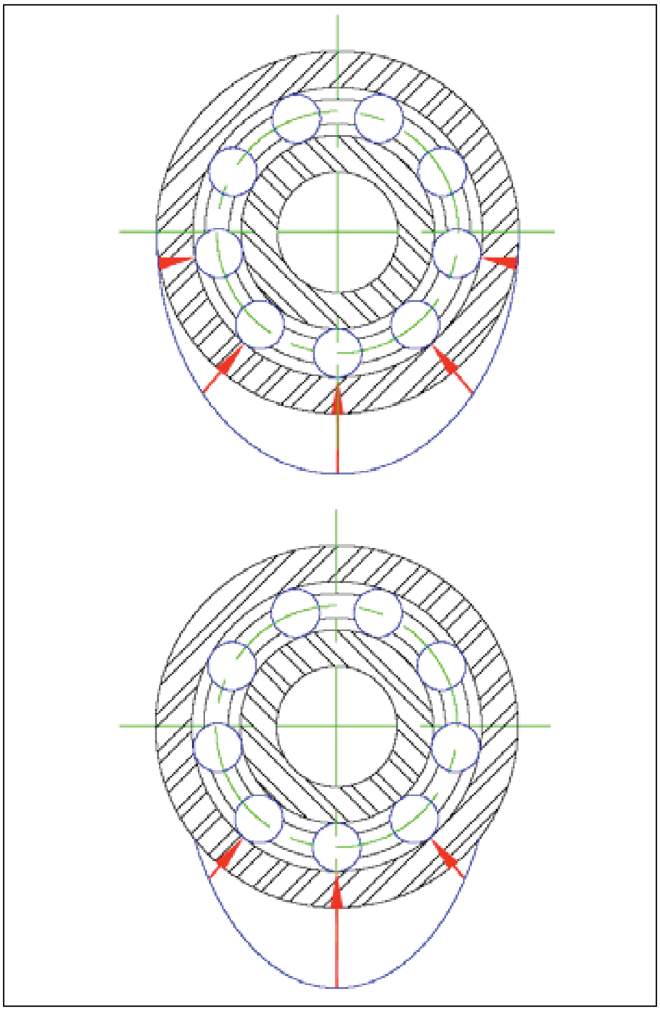


Figure 2—Ball load distribution.

Kaydon does not use these equations to calculate dynamic capacity because most of these assumptions are not valid for thin-section bearings, and were never intended to be. Most importantly, the life calculated using these equations is not supported by Kaydon testing. Nevertheless, many Kaydon competitors use these equations anyway (Table 2).

According to the old Kaydon capacity equations, the dynamic capacity of a KC040CP0 is 880 lbs. Under a radial load of 525 lbs., the predicted L_{10} life at 1780 RPM is 44.7 hrs. If the capacity is calculated using the 1978 ABMA/ISO equations, with f_c calculated using Equation 4, (rather than the using the tables), the capacity should be 1,274 lbs. This gives a life of 133.8 hours. The actual average L_{10} life for these bearings over the last five years has been 80.2 hours. The actual life is almost double the life predicted by the old Kaydon equations, but apparently less than predicted by the ABMA/ISO equations.

However, we know that life under a radial load decreases as the clearance increases. This is because fewer balls carry the radial load (Fig. 2). The theoretical L_{10} life was calculated for the KC040CP0 bearing under a 525 lb. load at 1,780 rpm and was plotted for various amounts of diametrical clearance. The life calculations use the ABMA/ISO capacity (adjusted for curvature), in the life prediction. As shown in Figure 3, the actual measured L_{10} life falls very close to the predicted

Table 2—Comparative Capacities

Part No.	KAA10CL0	KA020CP0	KC040CP0	KF080CP0	KA120CP0	KG120CP0	KG400CP0
Kaydon Catalog Catalog 300	150	320	880	4,100	980	8,510	18,310
ISO/ABMA							
1990 f_c Tables:	558	1,012	2,321	8,081	1,904	14,133	21,630
1978 f_c Tables:	430	778	1,785	6,216	1,465	10,872	16,638
Calculated f_c:							
1990:	379	701	1,656	6,363	1,316	11,766	18,006
1978:	291	539	1,274	4,895	1,015	9,050	13,851
INA(1)	558	1,012	2,316	8,094		14,164	21,582
NSK(1)	558	1,012	2,316	8,094		14,164	
RBC(2)	300	560	1,290	5,140	1,060	10,690	16,230
SKF(1)	555	1,009	2,338	8,049	1,915	14,029	21,493

(1) INA, NSK and SKF all use the ABMA/ISO ratings taking f_c directly from the tables without adjusting for the curvature ratio or diametral clearance.
(2) RBC numbers appear to adjust for curvature, but not clearance.

Equation 5 $$L_h = \left(\frac{C_r}{P_r}\right)^3 10^6 \times \left(\frac{1}{60\ \frac{min}{hr} N\ \frac{rev}{min}}\right) = \left(\frac{C_r}{P_r}\right)^3 \left(\frac{16,667}{N}\right)(hrs)$$

values when clearance is considered.

In summary, Kaydon life testing does support the use of the ABMA/ISO (1978) capacity values, when curvature and clearance are considered. However, it does not support the modern materials factor (b_m) that was added in 1990. Therefore, it is important that the assumptions behind these equations are understood.

The purpose of a published capacity is to allow the customer to use a quick $(C_r/P_r)^3$ equation to estimate life (Eq. 1). The ABMA/ISO equations are not adequate for this purpose because they don't consider the curvature or clearance in the basic dynamic load rating. Therefore, alternate methods must be used to calculate the published ratings for these bearings.

Test Method

Preparation: The test parameters (i.e., load and speed) must first be calculated. These are selected to cause the bearings to fail by fatigue in a reasonable time period (typically less than 100 hours), while not subjecting the bearing to excessive loads. Therefore the testing speed is set to 1,780 rpm.

The desired radial test load is calculated from the life equation (Eq. 1). To get the life in hours, simply divide the life in revolutions by the rotating speed as shown in Equation 5.

(See above for Equation 5)

Where:

L_h is the L_{10} life in hours under the test conditions

C_r is the dynamic load rating for the bearing (from a catalog or calculation)

P_r is the applied radial load

N is the speed of the bearing under test, in RPMs.

We can then rearrange Equation 5 and solve for the applied radial load Pr. For an L_{10} life of approximately 50 hours, the radial load should be a little less than 60% of the rated capacity (Eq. 6). Keep in mind that the L_{10} life is based on 90% reliability. This means that 90% of the test samples are expected to exceed the 50 hours. For the Kaydon KC040CP0 bearing, a radial load of 525 lbs. was selected.

$$\left(\frac{P_r}{C_r}\right) = \left(\frac{16,667}{N \cdot L_h}\right)^{1/3} \qquad (6)$$

Bearings to be tested are randomly selected from the identified lot. At minimum of 20 pieces are used for each test. Each bearing is identified with a unique reference number.

Bearings are cleaned as assemblies prior to test by mechanical agitation in mineral spirits for at least five minutes.

Each bearing is then mounted in a suitable housing, making witness marks to indicate orientation in housings, and then mounted on a driven spindle with the axis horizontal as shown in Figure 4.

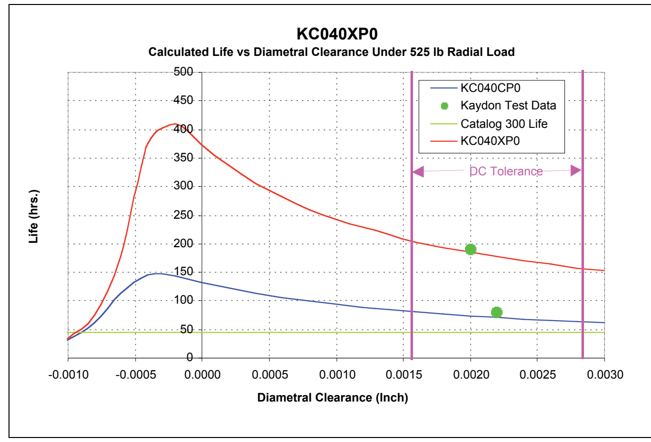


Figure 3—Life vs. diametral clearance.

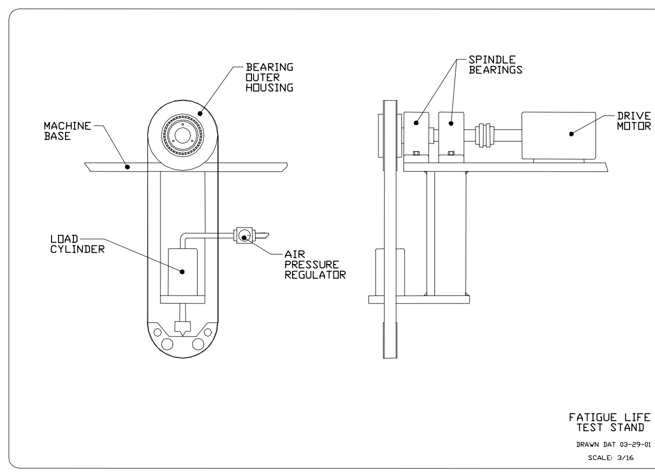


Figure 4—Test arrangement.

A steel load strap is then attached to the outer race and connected to an air cylinder arranged to apply radial load to the bearing. The centerline of the air cylinder, the steel strap and the lower tooling are aligned in the same plane as the bearing centerline.

The force exerted by the load cylinder is measured by a portable load cell and digital indicator. The air pressure to the load cylinder is adjusted to produce the desired radial load on the bearing. *Note: In calculating the total radial load on the bearing, the weight of the tooling is also considered.*

An accelerometer is mounted on top of the stationary housing with radial orientation, and is connected to the automatic monitoring equipment.

The circulating oil system is checked for adequate oil level and to ensure that filter replacement is not overdue.

Starting test. The circulating oil to lubricate the test bear-

continued

ing is connected and turned on. The cooling water to the oil heat exchangers is turned on. Air to the load cylinder is set to off.

The drive motor is "jogged" to ensure that no components are loose and that there is no unwanted interference between the rotating and stationary parts. The motor is then turned on and the reading (in hours and tenths) of the elapsed time meter is noted. All test notes are recorded on the test data collection sheet.

Oil flow to the bearing is adjusted to be as high as possible without causing excessive foaming or leakage from the bearing housing. Oil flowing to each bearing should not exceed a temperature of 130° F. Air to the load cylinder is then turned on.

The baseline radial vibration is measured. The auto shut-off system is then set for this baseline vibration level. The automatic shut-down occurs when vibration increases to 150% of the baseline level.

Stopping test. When bearing failure is suspected, either due to audible noise or to auto shut-off, the bearing rotation is stopped. The bearing is then disassembled and inspected.

If no visible signs of spalling or other failure are found on the balls/rollers or race paths, the bearing is reassembled and remounted in the test housings, noting the orientation of witness marks. The testing is then resumed (with the automatic shut-down system, baseline vibration level reset if necessary).

If spalling is found, the hour meter reading is noted and the elapsed time is calculated. Also, the location and degree of spalling is noted, and then the bearing components are bagged, identified and saved.

After all bearings in the test have been run to failure, the elapsed times are entered into the Kaydon-Weibull analysis software program. This program establishes the best-fit Weibull line for the data, calculates the slope and scale parameters and determines the L_{10} fatigue life for the sample group.

The L_{10} value obtained from the Weibull program is then compared to the theoretical L_{10} fatigue life at the tested load and speed. If the observed L_{10} value does not meet or exceed the theoretical L_{10} value, an investigation is conducted to determine the root cause.

The Weibull slope parameter gives an indication of the degree of scatter in the test results. For through-hardened AISI 52100 bearing steel races, a Weibull slope value in the range 1.0–1.5 is expected, with a lower value indicating a greater degree of fatigue life dispersion and a higher value indicating less scatter.

At least one failed bearing race is then sectioned and mounted through the failed area (spall). At a minimum the following metallurgical properties are evaluated and recorded:

- Hardness
- Grain size
- Steel cleanliness (inclusion rating)
- Carbide networking

Results

Over the last five years of testing, the Kaydon KC040CP0 radial bearing has had an average L_{10} life of 80.2 hours in Kaydon testing. The Kaydon KC040XP0, four-point contact bearing has averaged 189.3 hours. If we plug these numbers into Equation 5 and solve for the capacity (C_r), we get a radial capacity of 1,073 lbs. for the radial bearing and 1,430 lbs. for the four-point contact bearing. (Eq. 7)

$$C_r = P\left(\frac{L_{10}N}{16667}\right)^{1/3} = 525\left(\frac{80 \cdot 1780}{16667}\right)^{1/3} = 1073 \quad (7)$$

These values are much greater than the old Kaydon ratings of 880 lbs. for both. However, they still fall short of the ABMA/ISO ratings for radial bearings calculated using the fc values from the tables. (Neither ABMA or ISO publish ratings for four-point contact ball bearings.) The main reason for the apparent discrepancy is the poor assumptions these standards make regarding race curvature and diametrical clearance. Based on the results of these tests, it is apparent that a new method is required for calculated the dynamic radial capacity for thin-section bearings.

New Kaydon Equations

The new Kaydon capacity calculations are based on the contact stress and the number of stress cycles at the highest loaded point of the stationary ring. The highest loaded point is always the same spot on the stationary ring. It is variable on the rotating ring. Both the ABMA and ISO calculations assume that the inner race is rotating and the outer race is stationary. Therefore, the new equations are based on the outer ring stress. The inner ring may have a higher contact stress, but the load is distributed over the entire circumference, so there are fewer stress cycles under the max load. The new dynamic capacity is derived from the basic life equation, as shown below.

(See pg 21 for Equation 8)

where:

- C_r The basic dynamic load rating (dynamic capacity)
- P_r The radial load for a life of 10^8 stress cycles
- L_{10} The number of revolutions for 10^8 stress cycles
- f The number of stress cycles per revolution
- Q_{max} The normal ball load on the highest loaded ball for 10^8 stress cycles
- Z The number of balls per row
- i The number of rows of contact
- α The contact angle
- S The ball load distribution factor based on the diametrical clearance
- λ The stress factor: l=1 for angular (A) and radial (C) contact bearings and l= (.9/.95) for four-point (X) contact bearings

Maximum ball load (Q_{max}). The factor Q_{max} is the normal ball load that gives a mean contact stress of 262,500 psi in the outer race. This is the stress value associated with 10^8 stress cycles. This stress value was determined experimentally during Kaydon laboratory testing. The L_{10} life in revolutions is then calculated by dividing the number of stress cycles (10^8) by the number of stress-cycles-per-revolution (f) which is calculated using Equation 9.

Stress cycles per revolution:

$$f = \frac{Z}{2}\left(1 - \frac{D_b}{D_P}\cos\alpha\right) \text{.. ref. Harris eq. 25.14} \quad (9)$$

Equation for ball distribution factor (S): The relationship between max ball load (Q_{max}) and applied radial load (P_r) is calculated using the Stribeck equation (Eq. 10). The constant *S* is the load distribution factor. For bearings with zero diametral clearance, *S* equals 4.37. For bearings with "nominal" clearance, an approximate value of 5 is often used for *S*.

$$P_r = \frac{Q_{\max} Z \cos\alpha}{S} \quad \text{...ref. Harris eqs. 6.23/6.24} \quad (10)$$

In reality, *S* varies with both diametral clearance and the applied loads. For REALI-SLIM bearings, the diametral clearance increases with the nominal diameter. Therefore the factor *S* also increases with diameter. The value of *S* used in the new Kaydon capacity equations varies with the pitch diameter. It assumes that some diametrical clearance remains in the bearing after installation. Factor *S* is calculated using Equation 11:

$$S = .027D_p + 5.260 \quad (11)$$

Calculating capacity. It takes four steps to calculate the new dynamic radial capacity:

Step 1: The first step in calculating the capacity is to calculate the normal ball load (Q_{max}) that gives an outer race mean contact stress of 262,500 psi. This is calculated using the standard stress equations. This gives the ball load capacity for 108 stress cycles.

Step 2: The next step is to calculate the ball distribution factor S from Equation 11.

Step 3: The number of stress-cycles-per-revolution is then calculated using Equation 9.

Step 4: Once the maximum normal ball load, distribution factor and number of stress-cycles-per-revolution are known, the radial capacity can be calculated using Equation 8.

Derivation of Constants

A) ***The stress constant***. The 262,500 psi contact stress constant used in these equations comes from Kaydon laboratory life testing of KC040CP0 bearings. The L_{10} life for these bearings averages 80.2 hours. This equates to a dynamic radial capacity of 1,073 lbs., as shown in Equation 7.

Under a radial load of 1,073 lbs., with an estimated installed clearance of .0016 inch, the maximum ball load is 164.84 lbs. Solving Equation 10 for *S* gives a load distribution factor of 5.3769, as shown in Equation 12.

$$S = \frac{Q_{\max} Z \cos\alpha}{P_r} = \frac{(164.84)(35)(1)}{1073} = 5.3769 \quad (12)$$

The number of stress-cycles-per-revolution is calculated using Equation 9 and equals 16.75 for the KC040CP0, as shown in Equation 13. This means that there are 16.75 million stress cycles in one million revolutions.

$$f = \frac{Z}{2}\left(1 - \frac{D_b}{D_P}\cos\alpha\right) = \frac{35}{2}\left(1 - \frac{.1875}{4.375}\right) = 16.75 \quad (13)$$

We can then calculate the normal ball load for an L_{10} life of 100 million (108) stress cycles using Equation 8. The normal ball load for a fatigue life of 10^8 stress cycles equals 90.87 lbs., as shown by:

(See below for Equation 14)

For a normal ball load of 90.87, the mean contact stress in a KC040CP0 outer race is 262,500 psi.

B) ***The ball load distribution factor* S**. For the KC040CP0 bearing under an applied load of 1,073 lbs., and an assumed clearance after installation of .0016 inch, the ball load distribution factor *S* was calculated to be 5.3769 (Eq.12.).

For the KG400CP0, an outer race stress of 262,500 psi corresponds to a normal ball load of 801.23 lbs. The stress-cycles-per-revolution (*f*) for this bearing equal 60.75. As shown in Equation 8, the capacity is a function of the load distribution factor, which is in turn a function of the diametral clearance and the applied load. Equation 8 was then solved using an iterative solution for the capacity C_r and the load distribution factor *S*. For an assumed clearance after installation of .0072 inch and a radial load of 18,307 lbs., *S* was then calculated using Equation 10 to be 6.3562.

The stress distribution factor *S* varies with the installed clearance, which increases with the pitch diameter. The equation for *S* was derived using the equation of a line.

(See pg 22 for Equation 15)

C) ***Rows of contact exponent*** ($I^{(.7)}$). The number of rows of contact is raised to the 0.7 power because failure can occur on either row. This is a statistical factor that considers the possibility of either row failing. It gives the L_{10} life for the whole

continued

Equation 8
$$C_r = P_r\left(\frac{L_{10}}{10^6}\right)^{\frac{1}{3}} = P_r\left(\frac{10^8/f}{10^6}\right)^{\frac{1}{3}} = P_r\left(\frac{100}{f}\right)^{\frac{1}{3}} = \frac{Q_{max} Zi^{.7} Cos\ \alpha}{S}\left(\frac{100}{f}\right)^{\frac{1}{3}}\lambda$$

Equation 14
$$C_r = \frac{Q_{max}\ ZCos\,\alpha}{S}\left(\frac{100}{f}\right)^{\frac{1}{3}} = 1073 = \frac{Q_{max}\,35}{5.3769}\left(\frac{100}{16.75}\right)^{\frac{1}{3}} \text{ or } Q_{max} = 90.87 \text{ lbs.}$$

Equation 15

$$y = mx + b \text{ where: } \quad m = \frac{S_1 - S_2}{D_{p1} - D_{p2}} = \frac{6.3562 - 5.3769}{41 - 4.375} = .02674$$

$$b = y - mx = 5.3769 - (.02674)(4.375) = 5.2599$$

$$S = .02674\, D_p + 5.2599$$

Equation 16

$$L_{10} = \left(\frac{C_r}{P}\right)^3 \bullet \left(\frac{16{,}667}{N}\right) = \left(\frac{1417}{525}\right)^3 \bullet \left(\frac{16{,}667}{1780}\right) = 184 \text{ (hrs.)}$$

bearing and is lower than the life for the individual rows. This factor is consistent with both the ISO/ABMA calculations as well as the old Kaydon method.

D) ***The stress factor*** (λ). The tables in both ABMA Standard 9 and ISO 281 show multiple columns for factor f_c. The first column is titled "Single Row Radial Contact" and "Single and Double Row Angular Contact." The second column is titled "Double Row Radial Contact" and has a lower value for fc. The reason for this is described on page 81 and table 3.3 of "Ball and Roller Bearing Engineering" by A. Palmgren (1959). Palmgren shows a λ of .95 for single-row radial bearings, and for single- and double-row angular contact bearings. He also shows a λ=.90 for double-row radial bearings. It is described as a "stress factor." This factor allows for uneven load sharing between the two rows of contact. Therefore, Kaydon has chosen a de-rating factor of (λ=.90/.95) for four-point contact (X-type) ball bearings. (The 0.95 factor for radial and angular contact bearings is already factored into the maximum allowable stress level, which was established by testing.)

E) ***Four-point contact bearing***. Using the new capacity calculation (Eq. 8), the radial capacity of a KC040XP0 (4-point) bearing is 1,417 lbs. If we plug this number into the life equation (Eq. 5), the L_{10} life under a test load of 525 lbs. at 1,780 rpm is 184 hours (Eq. 16). In Kaydon testing, the L10 life of a standard KC040XP0 was actually 189.3 hours. Therefore, there is excellent correlation between the theoretical and measured capacity.

(See above for Equation 16)

Conclusions

The new Kaydon capacity equations are based on the maximum contact stress and the number of stress cycles per revolution. They consider the actual curvature of the races. They also consider the diametral clearance. The new capacities are supported by actual test data. The new radial capacity for radial (C-type) bearings ranges from 36% higher in the KAA10CL0 to no change in the KG400CP0. The radial capacity of four-point contact (X-type) bearings increases from 31% to 77% depending on the bearing size. The new capacities are still lower than the ABMA/ISO numbers, which are based on very poor assumptions. The new Kaydon equations provide a more accurate estimate of actual bearing life when used in the basic $L_{10} = (C_r/P_r)^3$ equation.

These equations apply to Kaydon Catalog 300 bearings with standard clearance only. Preload and clearance have a significant influence on bearing life. Clearance after installation will vary depending on fits and shaft/housing materials. The Catalog 300 capacity should be used for an initial bearing selection only. Life can then be confirmed using more advanced Kaydon programs. These programs use the ISO/ABMA capacity, but also take the curvature and clearance/preload into consideration.

References:

1. *Load Ratings and Fatigue Life for Ball Bearings*, ANSI/AFBMA Std. 9, (1978).
2. *Load Ratings and Fatigue Life for Ball Bearings*, ANSI/AFBMA Std. 9, (1990).
3. *Rolling Bearings–Dynamic Load Ratings and Rating Life,* ISO 281, (1990).
4. *T. Harris*, *Rolling Bearing Analysis,* 3rd Ed., J Wiley & Sons USA (1991).
5. Palmgren, A. "*Ball and Roller Bearing Engineering*", 3rd Ed., SKF Industries, Inc., Philadelphia, PA. (1959).

Robert Roos *has been a senior product engineer with Kaydon Corporation Bearings Division for 10 years. He earned a bachelor's degree in mechanical engineering from the University of Michigan and a master's degree in mechanichal engineering from Western Michigan University. Roos is a licensed professional engineer in the state of Michigan. He holds two patents and is a member of the ASTM F34 committee for rolling element bearings.*

Scott A. Hansen *is vice president of manufacturing planning for Kaydon Corporation Bearings Division. His 30 years with Kaydon include positions in product design, manufacturing and operations. He holds a bachelor's degree from Western Michigan University and two patents—for a wind turbine pitch bearing and a robot pivot arm assembly for semiconductor wafer handling. Hansen belongs to the ASTM F34 rolling element bearings group and the ABMA engineering specification group.*

Product Focus:

GEARS AND GEAR DRIVES

In this special news section, the editors of *Power Transmission Engineering* have gathered the latest product news and information from the gears and gear drives sector. Submit your news to *publisher@powertransmission.com*.

Stöber Helical Gearing

IMPROVES FACTORY EFFICIENCY

The PHQ gear drive from Stöber Drives, Inc. of Maysville, Kentucky, is designed to help improve factory efficiency by meeting the need for higher accelerating torque, torsional rigidity and tilting stiffness.

The PHQ is part of Stöber's ServoFit line. Its design is based on a helical cut, four-planet system.

"This design enables extreme requirements to be met efficiently and effectively," says Adam Mellenkamp, ServoFit product manager at Stöber Drives, adding that the PHQ is well suited to applications in robotics, general automation, food packaging, injection molding, tube bending industries, machine tool manufacturing, material handling and many other areas.

Sacrificing torque in order to save on the size of a gear head is a major problem for some factories, but the PHQ is designed to maximize torque in the space allowed. It allows for torque increases of up to 35 percent compared with comparably sized units, Mellenkamp says.

"The PHQ is also reliable due to its life-long lubrication," says Mellenkamp. "Up to an 80 percent increase in torsional rigidity means fewer positioning errors under load and better vibration behavior."

Some factories need the option of customizing gearing units to meet their specific needs. In addition to the PHQ, Stöber offers the PHQA, which possesses the same capabilities of the PHQ in terms of being more compact and increasing torque and torsional rigidity. "The PHQA is a further advanced unit," Mellenkamp says. "It has a tighter tolerance so you can achieve lower backlash."

For more information

Stöber Drives, Inc.
1781 Downing Drive
Maysville, KY 41056
Phone: (606) 759-3615
www.stober.com

Bodine

LAUNCHES WX GEARMOTORS

The new WX gearhead is now available with two 33A permanent magnet DC (PMDC) motors. The WX is a high-torque gearhead built to provide longer life and higher performance than similar gearmotors in the same size range. These gearmotors are designed to drive applications such as conveyor systems, packaging equipment, metering pumps, medical devices, commercial appliances and solar powered outdoor equipment.

The WX gearmotors feature new all-steel gear trains and synthetic lubricants, allowing the WX to produce up to 65 percent more torque than previous models. The steel gearing is designed to meet or exceed AGMA 9 standards to assure quiet operation. The synthetic lubricant improves efficiency and allows these gearmotors to operate in a wide temperature range.

Accessories include a bolt-on adaptor to convert the gearhead to a three-point mounting pattern, as well as an

continued

"L"-bracket for flexible mounting and an IP-44 protection kit. Forty-eight new stock models feature 12 available gear ratios, ranging from 4:1 to 312:1, and rated output speeds from 658 to 2.9 RPM.

A new low-voltage type 33A PMDC motor with a winding rated 12/24 VDC and a standard 90/130 VDC motor are available to power the WX gearhead. Both motors provide high starting torque and linear speed torque characteristics. They feature permanently lubricated ball bearing construction for maintenance-free operation, as well heavy gauge steel housing and copper graphite brushes. The motors are totally enclosed, non-ventilated (TENV) and contain a Class F rated insulation system. Their windings are resin-impregnated to provide reliable performance in the most demanding applications. The motor armatures are designed to minimize cogging and to operate quietly. "Accessory ready" models allow for easy external mounting of encoders or brakes.

"With 'green' applications becoming more and more common, we're particularly proud that this new line of gearmotors includes so many low-voltage stock models with either PMDC or BLDC winding options," says Michael Gschwind, vice president of sales and marketing.

For more information:

Bodine Electric Company
2500 W. Bradley Place
Chicago, IL 60618-4798
Phone: (773) 478-3515
info@bodine-electric.com
www.bodine-electric.com

RTX Planetary Gearheads from Sterling Instrument

FEATURE
HIGH TORQUE DESIGN

A new series of RTX precision planetary gearheads from Sterling Instrument feature a high-torque design, and are offered in standard NEMA sizes 60 and 90. These 36 gearheads, identified as the S9160AMRTX and the S9190AMRTX series feature single, double, and triple gear stage configurations, optimized gear geometry, high torsional stiffness andcaptive bearing-supported input pinion. Plus, they are sealed to extend service life.

Each of the two NEMA sizes is offered in gear ratios ranging from 4:1 to 700:1. Their maximum input speed is 6,500 rpm. Their single-stage, double-stage and triple-stage minimum efficiencies are 95-, 90- and 85 percent, respectively. Operating temperatures range from –40 degrees C to +121 degrees C. The housings are made of stainless steel, with anodized aluminum mounting flanges. The output shafts are made of stainless steel, and the gears are made of alloy and stainless steel.

Detailed specifications are contained in Catalog D805, available free upon request from Sterling Instrument.

For more information:

Sterling Instrument
2101 Jericho Turnpike
P.O. Box 5416
New Hyde Park, NY 11042-5416
Phone: (516) 328-3300
Fax: (516) 326-8827
www.sdp-si.com/eStore

McGill Lunar Excavator Team

USING ALPHA GEARBOX IN ROBOT

The McGill Lunar Excavator Team at McGill University in Montreal, Quebec hopes to score big at NASA's upcoming 2011 Lunabotics Mining Competition. Wittenstein is pulling for them, as well, with the support of the alpha LP+ which is integrated into their robot design.

This is the second year for NASA's annual competition and the first for McGill's participation. Team members of McGill include Peter Radziszewski (advisor), Mircea-Vlad Rădulescu (project leader), Salman Hafeez (project treasurer) and engineers Benjamin Landon, Kyriakos Moditis, Thomas Friedlaender, Andrew Tawil, Philip Smith, Jad Hachem, Joseph Fruciano, Jerina Harizaj, Annie Wen and Saif Banimalhem.

"We continue to participate in this event because it deals with new unexplored problems encouraging innovative thinking," says Rădulescu.

The challenge McGill and the other teams face is harvesting simulated moon rock, or lunar regolith. The excavation robot must withstand a multitude of real-life expectations in the lunar environment. It must weigh 80 kg or less and collect moon rock in a 15-minute time frame and release it in a specified area. The overall design is crucial and involves much detail and coordination.

The McGill team has designed in an alpha LP+ as part of the drivetrain for their robot. Wittenstein was eager to hear of this application, which follows the company's philosophy of developing the engineers of the future through interactive education. The team chose the alpha LP+ because of its lightweight and compact design to assist in the operation of their lunar robotic mining vehicle.

Learn more about NASA's Lunabotics Mining Competition (May 23–28, 2011 at Kennedy Space Station) at *www.nasa.gov/lunabotics/*.

Rexnord

OPENS GEARBOX REPAIR FACILITY IN SALT LAKE CITY

Rexnord Industries opened a fully renovated, 29,000 sq. ft. gearbox repair and remanufacturing facility in Salt Lake City in January. The facility is part of Rexnord's Falk Renew Prager product services, which repairs or rebuilds gearboxes of all makes, brands and sizes.

"Rexnord's gearbox repair services offer our customers cost-effective solutions when downtime is critical and long-term reliability and peace of mind are a must," says Mike Stofferahn, vice president, Rexnord product services–sales and marketing. "Our services not only extend drive life, but also enhance operating performance and lower the total cost of ownership for our customers."

The new facility will operate with fully authorized and trained Rexnord technicians and field support personnel who have a combined experience of more than 75 years.

"Our customers expect Rexnord to deliver top-of-the-line performance, day after day. With over 100 years of gearbox manufacturing, repair and service experience, we deliver," Stofferahn says. "As an OEM, Rexnord utilizes OEM-quality components and the same testing methods for repaired or rebuilt gearboxes as we do for newly manufactured drives. Our expansion to Salt Lake City enables us to provide exemplary service to our customers in thriving industries in the area, such as mining, coal and power generation."

The facility will join additional Renew locations near Milwaukee and New Orleans. Rexnord's gear business serves a variety of industrial customers worldwide, including mining, aggregate/cement, wood/paper, construction, energy, food and grain, and chemicals.

For more information:

Falk Renew Prager
1930 South 4650 West
Salt Lake City, UT 84104
Phone: (801) 887-5480 or
(888) 439-7961
Fax: (801) 887-5485
FalkRENEW@Rexnord.com

Global Gears and Drives Market

TO REACH $94 BILLION BY 2015

Global demand for gears, drives and speed changers declined in 2009, owing to the global economic downturn that had a negative impact on end-use markets, specifically the automotive sector. Notwithstanding the impact of recession, the global market for gears is expected to surge in the following years, according to a new research report from Global Industry Analysts. Several factors, such as revival in the manufacture of motor vehicles, increased manufacturing output and economic recovery are expected to play a major role in market growth. Overall, the future gears market would be driven by increasing demand for reliable power, ever-increasing value in torque-per-dollar spent, smaller physical sizes and more energy-efficient transmission systems.

Additionally, end-users are increasingly switching to energy-efficient, expensive systems such as 7-speed and 8-speed transmission, a trend that is expected to add impetus to market growth. Recovery is also expected to emanate from the industrial sector. Demand is expected to receive a boost from growing markets such as solar and wind energy. Growing concerns over energy security and environmental issues are fueling interest in wind energy, which translates into increased demand for wind turbines, and consequently the gearboxes used in them.

Europe represents the largest regional market for gears, drives and speed changers, accounting for more than 30 percent share of the global market, according to the report. The United States trails Europe in terms of sales of gears, drives and speed changers. Growth-wise, Asia-Pacific is projected to be the fastest growing regional market, and is poised to increase at a compounded annual growth rate of more than 5 percent during the next few years. Major factors driving growth in the Asia-Pacific market include dramatic growth in the Chinese and Indian automobile markets, creating significant demand for automotive gears in the region.

In terms of end-uses, automotive represents the largest end-use sector and is likely to remain the dominant source of gears' demand globally due to the recovery in motor vehicle production. Major developments influencing the industry include alternative materials for the production of automotive parts such as aluminum and industrial resins, and growing application of powder metallurgy. Other end-use segments including aerospace, marine and industrial applications are likely to remain a stable source of demand.

Development of new technologies in the manufacturing and end-use sectors is redefining the gears and drives landscape. Integration of computers and computer enabled designing and manufacturing technologies into gear manufacturing methods has created improved and new types of gears that are suitable for diverse applications.

Tooth contact analysis, CNC controls, computer-aided design, and advanced metrology techniques are some of the technologies that heavily influenced the market in recent years. These technologies have expanded the range of applications for gears as well as the range of materials used to produce gears.

Major players profiled in the report include ABB Ltd., Bonfiglioli Group, BorgWarner Inc., Bosch Rexroth AG, Curtis Machine Company, Dana Corp., Danfoss Group, Eaton Corp., Emerson Industrial Automation, FLSmidth MAAG Gear AG, Haley Marine Gears Inc., Horsburgh & Scott, Hub City Inc., Rexnord LLC, Rockwell Automation Inc., Siemens Energy and Automation, SEW Eurodrive GmbH, Tomkins PLC, Twin Disc Inc., and ZF Friedrichshafen AG.

The report, titled "Gears, Drives and Speed Changers: A Global Strategic Business Report," provides a comprehensive review of the gears, drives and speed changers markets, impact of recession on the market, current market trends, key growth drivers, recent product introductions, recent industry activity, and profiles of major/niche global as well as regional market participants. The report provides annual sales estimates and projections for the gears, drives and speed changers market for the years 2007 through 2015 for the following geographic markets: United States, Canada, Japan, Europe, Asia-Pacific, Latin America, and the rest of world. Global and regional data are also analyzed for the following end-use sectors: automotive, industrial, marine, aerospace and others. A historic review for the period 2001 through 2006 is also provided.

For more information:

Global Industry Analysts, Inc.
Phone: (408) 528-9966
Fax: (408) 528-9977
press@StrategyR.com
www.StrategyR.com

Our "Sputnik Moment?"

Is this the car of the future? The 2011 Chevrolet Volt—GM's long-delayed electric-powered hybrid—is now a reality and appearing at auto shows around the country (all photos courtesy GM).

Opportunities Amidst Crises:

ENERGY-CHALLENGED INDUSTRIES—AND COUNTRIES—CAN BENEFIT FROM IMPROVED MOTOR DESIGN AND MATERIALS

(Reprinted courtesy the Motor & Motion Association)

Wally E. Rippel

Introduction

In almost every crisis, there are hidden opportunities for something good. In 1957, the Soviet Union launched the planet's first artificial satellite—Sputnik. At the time, Sputnik was seen as something bad for America. Through Sputnik, we could see Soviet influence spreading and we could see a new military threat just over the horizon. However, America responded to the challenge and we benefited greatly. Now, when a hurricane threatens, we are better able to protect life and property, thanks to orbiting satellites, which, at best, would have been delayed without the Soviet challenge. Likewise the technologies spawned from the space race of the late 1950s and 1960s have given us so many of the technological wonders we now take for granted—computers, the Internet and cell phones—to mention but a few.

Today, we now in fact face two crises—each of which is far greater than Sputnik, oil depletion and global warming. Oil is the "blood" which powers transportation and agriculture. Without it, conventional cars, trucks, tractors and airplanes would all be "dead." And without

continued

use of these machines, most people would also be dead. There would be no way to get to the store—but no matter—for there would be no food at the store for lack of transport. And even if there were a means for food transport, there would be little to ship given the absence of fuel for farm equipment and chemicals for fertilizers. While oil will not suddenly "run out," it appears that we are now at the point where scarcity factors are overpowering technological advances to the point that the real cost (hours-of-work-per-barrel-produced) is increasing. We have likely crossed the threshold commonly known as "peak oil." Two years ago, world oil production was at 85 million barrels a day. Now it is at 83 million barrels. In 2008, oil reached $147 a barrel with $5 gas close at hand. It is likely that this spike contributed to the present world recession. It is also likely that future prosperity will be limited by the price of oil.

While peak oil may be a threat to "our way of life," global warming may be a threat to life itself. Since the mid-19th century, atmospheric carbon dioxide has increased from 270 to 385 parts-per-million. This has in turn caused the average temperature of the lower atmosphere to increase by nearly one degree C—thus triggering massive ice loss around the globe. All of this is also serving to magnify weather patterns, including drought and severe storms. Unchecked, the process of global warming may lead to a runaway situation where the loss of planetary, light-reflective ice leads to further global warming and a spiraling cycle of destruction.

Humanity's response to these two crises will determine our future. We have some choices—just as we did five decades ago with Sputnik:

- We can pretend that the problems do not exist.
- We can accept the problems as real, but choose to not respond because of the difficulty.
- We can respond, but without the needed commitment.
- Or we can meet the problems head-on with the required response.

Should we choose the last option, there will of course be expense, just as there was with the space program. There will also be benefits, such as the development of new technologies and new markets. If the future is anything like the past, the benefits will far outweigh the costs.

It is interesting to see how and where we, the designers and developers of electric motors, relate to these two crises. Let's first consider oil. While approximately half of the electrical energy generated in the United States is delivered to electric motors, only about 1.5 percent of the generated energy comes from oil. Therefore, it appears that electric motors have little to do with oil consumption. On the other hand, we are now beginning to see electric motors used significantly in connection with hybrid, plug-in hybrid and electric vehicles. In all of these cases, the use of electric motors enables either a more efficient use of oil—as in the case of hybrids, or the direct replacement of oil—as is the case with plug-in hybrids or pure electrics. So, when it comes to oil, we may be part of the solution. After decades, this is now being recognized. Federal and private investment funds are now becoming increasingly available for the development of hybrid and electric vehicles. This will mean new opportunities for the development of electric motors—which are already reducing manufacturing costs—combined with increased power densities and

continued

The cost, availability and accessibility of charging stations like the one pictured above will dictate the acceptance and popularity of electric vehicles. GM recently announced that "more than 5,300 home and workplace" stations will be installed throughout Michigan in the coming year.

Many say that the planet's very survival and economic well-being will soon dictate the need for alternative energy sources to fuel the world's economy.

increased energy efficiencies.

In the case of global warming, electric motors have some "guilt by association" in that more than 10 percent of the world's CO_2 generation is associated with the generation of electric power specifically supplied to electric motors. The key to solving this problem will be the replacement of coal-fired generation with carbon-free generation such as wind, solar and nuclear. However, to a lesser extent, the development of more energy-efficient electric motors will also play a role. Accordingly, there will likely be expanded opportunities in connection with the development of high-efficiency electric motors for all sorts of applications, ranging from air conditioning systems, refrigerators and washing machines to large industrial applications such as steel rolling and water pumping.

In the following, we will focus on the challenges and opportunities for electric motors in connection with the transportation sector, i.e.—electric and hybrid vehicles.

Trade-Offs Involving Electric Propulsion Motors

For every application, the ideal electric motor would be one that costs nothing to manufacture, weighs nothing and has unity (or higher) energy efficiency. Unfortunately, none of these attributes can be attained in the real world. Like it or not, we have to settle for machines that cost money to make, and, once made, have mass and lose energy. The issue at hand is to quantify the trade-offs between these and other parameters.

Trade-off numbers differ widely, depending on the application. In industrial applications, cost and efficiency may be crucial, with mass relatively unimportant. Conversely, for aerospace applications, mass and efficiency are usually the key drivers—with cost taking a back seat. For all those involved in the design process, it is important that readily available trade-off numbers are at hand. Without this, it is possible, for example, that one designer will focus on achieving low mass but at high manufacturing cost, while a second designer might do just the opposite. When two such efforts are merged, the worst of all worlds happens and the product is both heavy and costly; the "bad" overpowers the "good." Indeed, it is better for all designers to be working to a common set of flawed trade-off numbers than to have no trade-off numbers at all.

Of course, the best situation is to have the right trade-off numbers. Using these, rational decisions can be made concerning candidate approaches for reducing cost (at the expense of mass or efficiency), or for reducing mass (at the expense of manufacturing cost or efficiency), etc.

All of this is quite important for electric and hybrid vehicle applications. Manufacturing cost of the motor will of course have a direct impact on the cost of the vehicle–which in turn will determine how many vehicles can be sold. Mass, size and efficiency are also critical as they, too, relate to cost. As efficiency drops, the battery must be up-sized, which means that the rest of the vehicle must be enlarged, and which further means more money up front and more money over time in the form of energy costs. The story is much the same concerning size and mass, which cost money up front and over time. With that, step one in the design process should be the evaluation of the trade-off numbers for the specific environments associated with electric and hybrid vehicles.

Determining the cost-efficiency trade-off for motors in EVs and HEVs. The economic impact of efficiency is determined primarily by battery depreciation and, to a lesser degree, by the cost of electrical energy. With state-of-the-art lithium ion batteries, the high-volume, packaged manufacturing cost is approximately \$400 per kWh—with an average life corresponding to about 500 (100 percent depth) cycles. It then follows that the depreciation cost is therefore about \$400/500 = \$0.80 per kWh throughput. The cost of electricity varies from location to location and, in some cases, with the time of day. Given the fact that rates are rising, a moderately high cost is assumed—$0.15/kWh. Finally, an account must be given for energy loss in both the battery and the battery charger. For the present, state-of-the-art charger efficiency (averaged over a complete recharge) is approximately 87 percent (including energy losses associated with blowers, etc.). For the lithium ion battery, the round trip energy efficiency is typically 92 percent. Taken together, the combined charger-battery efficiency is about 80 percent. Thus, when battery depreciation, electricity cost and energy efficiency are combined, the total cost of energy delivered at the battery terminals is approximately $1.00 per kWh.

In the case of a mid-sized, 1,500-kg electric or plug-in hybrid vehicle, the electricity use averages about 0.3 kWh per mile. And, over an assumed vehicle life of 150,000 miles, the energy use is 45,000 kWh; based on the above, the value of that energy (including battery depreciation) is $45,000. Approximately five percent of this energy is used for non-propulsion functions such as lights, air conditioning and power steering; the remaining energy, valued at approximately $43,000 is applied to the drive system. Accordingly, a one percent improvement in the energy efficiency of the drive system can be valued at $430. Accordingly, the motor cost efficiency trade-off is determined as $430 = 1 percent.

The meaning of this trade is that one who specifies and purchases the motor should be willing to spend up to $430 to gain one percent efficiency, provided other factors—such as weight— remain constant. When the "cost of money" and various sales issues are considered, this number will likely revise downward.

Determining the cost-mass trade-off for motors in EVs and HEVs. For each kg of added mass, the vehicle structure and drive system mass must increase by a total of about 0.3 kg in order to maintain range and performance. Likewise, the battery mass must increase by about 0.2 kg. Thus, adding 1 kg results in a total mass gain of 1.5 kg. For each kg of added mass, the vehicle energy use (at the wall plug) increases by approximately 0.06 Wh/mile. With the addition of 1.5 kg, the energy use (at the wall plug) would increase by 0.09 Wh/mile. Since the battery output energy is 80 percent of the wall plug, the energy increase at the battery would be 0.072 Wh. Thus, over the 150,000-mile vehicle life, energy use (at the battery terminals) will increase by 10.8 kWh. As noted earlier, the value of battery-delivered energy is

2011 Chevrolet Volt Delayed Charging Screen - The 2011 Chevrolet Volt allows owners to program charging times based on departure time from the Volt's center stack 7-inch LCD touch screen.

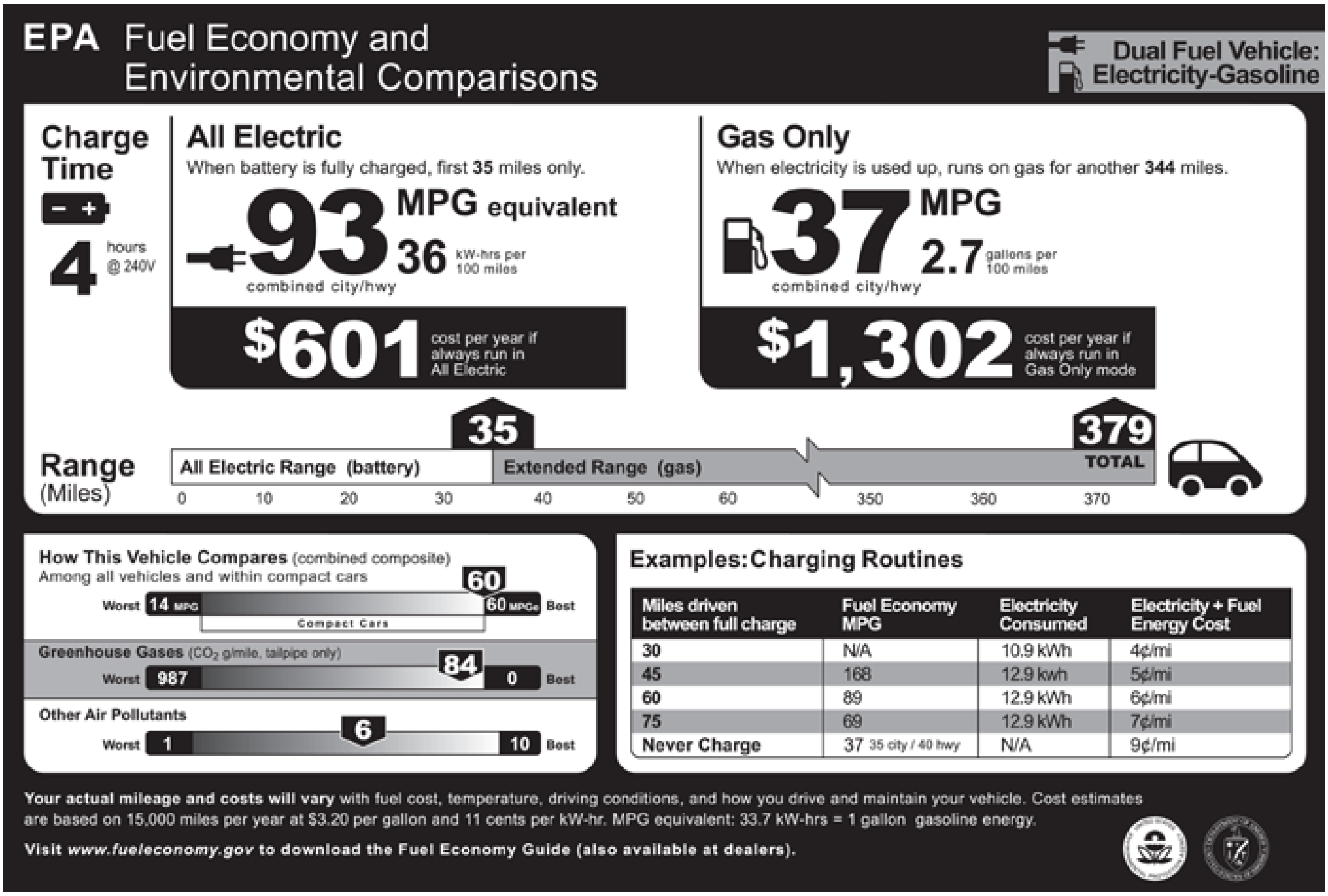
2011 Chevrolet Volt Climate Control screen: Volt owners can control the in-vehicle climate through the Volt's center stack 7-inch LCD touch screen.

The guts of the 2011 Chevrolet Volt.

approximately $1.00-per-kWh—which brings the energy-related costs to $10.80. To this we must add the cost of the added vehicle structure, added propulsion and added battery. The added vehicle structure and propulsion cost approximately $4/kg. For an added 0.3 kg, this cost component comes to about $1.20.

The battery-specific energy is typically 150 Wh/kg, and the battery cost is $0.40/Wh., which means that the added-battery-cost associated with 0.20 kg of battery is approximately $12. The three costs sum to $24. Accordingly, the motor cost/mass trade-off is determined to

continued



New battery technology is essential to the Volt's or any other electric vehicle's success. Design trade-offs regarding battery size vs. power (charging) duration are still up for debate. For now, drivers will have the option of employing either electric- or gasoline-powered energy.

be $24 = 1 kg.

The meaning of this trade is that specifiers and purchasers of motors should be willing to spend up to $24 to reduce mass by 1 kg—provided other factors, such as efficiency, remain constant. When the "cost of money" and various sales issues are considered, this number will also revise downward.

Determining the mass-efficiency trade-off for motors in EVs and HEVs. The mass-efficiency trade (where cost is held constant) is simply the quotient of the cost-efficiency trade and the cost-mass trade. Accordingly, the mass-efficiency trade is determined as ($430/one percent)/($24/kg) = 18 kg/one percent, or 18 kg = one percent. This means that the one who specifies and purchases the motor should be willing to accept a mass increase of 18 kg in order to gain an efficiency of one percent.

Efficiency is of course a function of both speed and torque, and so for a vehicle application, where speed and torque are continually changing, some sort of weighted average is required. The weighting should be with respect to energy, not time. The weighting factors are based on how vehicles are driven and therefore may change some from vehicle to vehicle. In the end, all that is needed is a characteristic speed and torque under which one efficiency point is measured. From experience, it appears that for most on-road applications, the speed and torque associated with 60 mph on a two-percent upgrade work reasonably well.

Applying the trade-offs to the AC Propulsion EV motor. AC Propulsion builds complete drive and recharge systems based on induction motors using copper-cage structures. For their 150-kW system, the inverter-motor system has a peak rating of 150 kW (shaft) at 6,000 rpm. The continuous rating is approximately 40 kW. The measured peak-point efficiency of the inverter-motor combination is 92 percent (at 30 kW, 6,000 to 8,000 rpm); the motor itself achieves a peak-point efficiency of 95 percent. The motor mass is 46 kg and the estimated high-volume production cost (rough estimate) is $1,000.

Since the cost-efficiency trade is $430/one percent, it follows that for the ACP motor, one should be willing to increase the manufacturing cost by something approaching 43 percent to gain one-percent average efficiency (assuming mass is constant). Likewise, with the cost-mass trade at $24/kg, it follows that one should be willing to increase the manufacturing cost by 1.1 percent in order to reduce the mass by one percent (assuming efficiency is constant). Finally, using the mass-efficiency trade of 18kg/one percent, one should be willing to increase the ACP motor mass by 39 percent in order to gain one percent in efficiency (assuming the manufacturing cost is held constant).

As mentioned, one of the main purposes in establishing these trade-off numbers is to determine which developments make sense and which do not. For example, in using the cost- efficiency trade-off it can be determined whether the added cost of the copper rotor cage is justified. Likewise, using the cost-mass trade, one can determine whether a candidate lightweight power cable might be justified.

Making Ever-Better Motors for EVs

The quest will never end for designing and building ever-better motors—ones that have lower manufacturing costs, are smaller and lighter and yet are more energy-efficient. The question is what to focus on. Which areas of development stand to yield the greatest "bang for the buck?" We start with some basic equations which deal with power conversion and heating:

$$P = K_1 * S^4 * (J * K_p) * (B * f) \qquad (1)$$

$$P_d = S^3 * [K_2 * \rho * (J * K_p)^2 / K_p + K_3 * B^{\alpha} * f^{\beta}] \qquad (2)$$

$$\Delta T = \theta * P_d \qquad (3)$$

$$M = K_4 * S^3 \qquad (4)$$

In the Equation 1, P is the shaft power; S is a characteristic linear dimension of the motor, such as bore diameter or stack height; J is the current density; K_p is the winding packing factor; B is the magnetic flux density; f is the applied electrical frequency; and K_1 is a constant that is based on details of the motor design.

In Equation 2, p is the resistivity of the winding averaged with the resistivity of the rotor cage; K_2 is a constant based on design; K_3 is a constant based on design and is proportionate to the magnetic loss; and α and β are magnetic-loss constants (typically, α is around 2.2 while β is around 1.5).

From Equation 3, ΔT is the temperature difference between the "hot-spot" and ambient; P_d is the motor loss; and θ is a fictitious thermal-impedance constant relating to these two quantities.

Finally, in Equation 4 M is the total-machine mass and K_4 is a constant (that changes somewhat with machine design).

Achieving increased specific power. From Equation 1 we see that if either J, K_p or f are increased, the shaft power will also increase. When we do any of these, the power dissipation P_d will also increase—as noted by Equation 2. This then means that the hot-spot temperature will rise unless the critical thermal impedance is lowered via improved cooling. In most cases, it will also mean that the machine efficiency drops due to either rapidly increasing J^2 losses or rapidly increasing magnetic losses. If, however, both J and f are increased in near-proportion, the rate at which losses increase may be similar to the rate at which shaft power increases—and energy efficiency is maintained while specific power increases.

If, for example, current density and frequency (and so shaft speed) are doubled, the shaft power will increase by a factor of four, while the heat dissipation will increase by a factor of four (in fact, a little less than a factor of four since β is usually less than 2.0). Accordingly, the efficiency remains constant (or slightly increases) while the specific power increases by some 300 percent. If the critical thermal impedance is then reduced by a factor of four, the hot-spot temperature rise will remain the same as for the baseline case—which is definitely a good thing.

In order to carry out the above algorithm, it is clear that several areas of design improvement must be tackled at once.

One needed improvement is that thermal impedance must be improved. In the case of induction machines this generally means that an improved means of rotor cooling must be achieved. For both induction and brushless machines, it also means that an improved means of stator cooling must be employed, i.e.—end-turn cooling must be improved; heat transfer within the winding must be improved; and heat transfer through the slot liners must be improved. The list goes on. The good news is that present designs present much room for improvement, especially when fluid cooling means are implemented. Reducing θ by a factor of ten for many designs is in fact realistic.

Item two is that the machine must be capable of operating at increased mechanical speed. In many cases this means that design modifications are required, such as the addition of end-ring captures and a stiffening of the rotor stack. It may also mean that modified gearing and bearing lubrication must be used.

One direct means for increasing P is where a copper rotor cage is used in place of the conventional aluminum cage. This enables J to increase without increasing P_d, meaning that

continued

Inside the 2011 Chevrolet Volt.

2011 Chevrolet Volt Driver Information Center charging screens: Even when the vehicle shuts down, Volt vehicle charging information is accessible through the reconfigurable 7-inch LCD driver information center.

both rated power and efficiency can be simultaneously increased. (The efficiency increase is typically around 1.5 percent at the rated power point). Copper-cage fabrication, however, comes at a price. Per unit volume, the cost of copper has ranged between five and fifteen times that of aluminum over the last decade. (The ACP motor rotor uses 13.6 lb. of copper per rotor. In 2008, copper reached a high of $4.00 per pound. At this price, the copper cost for the rotor was $54.40. If the same cage were structured from aluminum, the cage mass would be 3.63 lb. In 2008 aluminum also reached its high of $1.75 per pound. At this price, the aluminum cost would have been only $6.36.) In addition to the large difference in material costs, the casting of copper is also much more expensive than aluminum, due in part to the higher melting temperature of copper. Other copper-cage fabrication techniques—such as where extruded bars are inserted into the rotor stack and then welded within the end-ring structure—are even more expensive. But when the trade-offs are considered, the copper cage appears to be justified for most EV applications.

Achieving increased efficiency. In Equations 1 and 2 we note that if the packing, K_p, is increased, that shaft power P will increase more rapidly than the P_d losses. Thus, one means for improving efficiency is to find a way in which the packing factor can be increased. One approach is where machines are hand-wound, but in most cases the cost trade-off numbers rule this option out. Another means is to use rectangular "bus conductors" in place of stranded conductors. This approach is typically used for large machines, but generally requires hand labor. Recently, techniques have been developed where segments of bus windings are machine-inserted in slots and then welded together using automated processes to form the completed winding. While these approaches can achieve very high packing factors combined with good heat transfer and good manufacturing economics, they have one imperfection when compared with conventional multi-strand windings, i.e.—increased skin and proximity losses. This problem is amplified in the EV environment where relatively high excitation frequencies are involved (up to 400 Hz).

Considering the combination of issues, the ultimate answer for achieving a low-cost winding that achieves a high packing factor but does not suffer from AC losses is where a pre-formed multi-strand winding is pre-formed and then applied to a two-piece stator stack; the winding can then be easily inserted in fully open slots. However, further development is required before these approaches are ready for manufacturing.

Improvements in the stator and rotor magnetic cores may offer even greater opportunities for improving efficiency. While global efforts will surely continue to provide lamination materials that have reduced losses and better cost effectiveness, it is unlikely that any major materials breakthroughs will suddenly occur. Despite this, there may be some "low-hanging fruit" that has yet to be picked.

One idea is using different lamination materials for the stator and rotor. For the stator, the ideal material is thin, low-loss silicon steel. For the rotor, the fundamental frequency component is quite low (equal to the slip frequency), so with the exception of harmonics due to tooth and slot interactions (and harmonics due to the inverter), low-loss characteristics are not nearly as important as with the stator laminations. Then, thicker, lower-cost materials can be used where the saturation flux density is higher than for the stator. This in turn allows narrower rotor teeth that serve to increase the cage bar cross sections. This will of course lower R_2 and may make cage casting a bit easier. It is also true, however, that the economic gains may be compromised if the stator lamination centers are lost; but in cases where the "donut" holes can be used for other products, the economic penalty can even be a plus.

Another idea currently being investigated is where grain-oriented material is used—either exclusively or in combination with non-oriented materials. One design approach that might benefit from the use of oriented steel is where each lamination is replaced by several equal sectors that join together to substitute for a conventional lamination. By systematically misaligning the joining points of contacting laminations, a rigid core structure can be provided while possibly achieving improved loss and permeability characteristics. While the manufacturing-costs-per-unit frame size will surely increase, it is nevertheless possible that the reduced losses will be justified by the trade-offs discussed earlier.

How Good Can it Get?

One of the things that makes engineering exciting is the contemplation of radical, technical improvement. While it is hard to see the future, we can gain some insights based on the laws of physics. Physics tells us that we cannot make motors that are 110 percent efficient, telling us what is impossible. But, where the laws of physics do not indicate impossibility, there is always the implication of possibility. For example, with batteries, power electronics and electric motors, there are no laws setting ultimate limits on specific power.

Today we have the T-Zero and the Tesla Roadster, both of which demonstrated accelerations of under four seconds to 60 mph. Today we have the ACP-150 induction motor that boasts a measured peak-point-efficiency of 95 percent. Surely there is room for improvement.

So we ask: How good could we make batteries and motors? What are the physical limits? If we start with existing materials such as silicon, steel, copper or aluminum, what horsepower (or kW) could one expect per pound (or kg) of machine on a continuous basis? Could we beat jet engines that produce out something like six-horse-power-per-pound?

Using some of the principles presented here—in which state-of-the-art heat transfer is combined with high speed—the results are quite surprising:

- For both induction and brushless machines (in the 20-cm-diameter class), continuous, specific torques of better than four Nm/kg should be possible in the near-term.
- Likewise intermittent, specific torques above ten Nm/kg should also be possible.
- For the same machines, peak efficiencies above 97 percent should also soon be attainable.
- And where speed is pushed to material limits, continuous power levels above 3,500 W/kg should be also be reachable in the near-term.

Fifty years ago, it seemed that induction motors were a mature technology. Today, it seems that we are just getting started.

Wally E. Rippel *received a bachelor's degree in physics from Caltech in 1968 and a master's degree in electrical engineering from Cornell University in 1970. While a sophomore at Caltech, he became interested in electric vehicles as a means for combating air pollution—which in turn led to his converting a 1959 VW bus to electric drive. During his senior year, in an attempt to focus university research on the technical problems of electric propulsion, he challenged MIT to a cross-country electric car race. The MIT students accepted and the result was the "Great Electric Car Race"—won by Caltech. Between 1976 and 1990, Rippel was a member of the technical staff at Caltech's Jet Propulsion Laboratory, where he focused on the development of batteries and electric vehicle drives based on induction motors. In 1985, he initiated a joint effort between JPL and AeroVironment for the development of a high-performance electric passenger vehicle—code named Santanna. But requested funding from General Motors was not obtained and the effort was shelved. In 1987, Rippel consulted for AeroVironment in connection with the development of a solar-powered "race vehicle" for GM—the Sunraycer. This vehicle zoomed to victory in the first Australian cross-country solar race and paved the way for AeroVironment to re-propose the Santanna development. This time, GM granted the funds and the result was the development of the Impact vehicle, which then led to the EV-1. The rest of the story can be seen in the film, "Who Killed the Electric Car?" Rippel is now with AC Propulsion, Inc., a San Dimas company he co-founded in 1992, which develops and manufactures high-performance induction motor drives for electric vehicles. He is currently working on the next-generation development of induction motors and inverters for electric vehicles. Rippel holds 26 U.S. patents with four more on the way.*

Airport Baggage Handling:

QUEUE CONVEYOR DESIGN FROM A GEARMOTOR PERSPECTIVE

Rintaro Takasu,
Sumitomo Machinery Corporation of America

Introduction

The events of 9/11 and other terrorist threats have caused governing bodies around the world to heighten air travel-related security. In the United States, every piece of baggage that is checked in at an airport is now required by the Aviation and Transportation Security Act to be inspected for prohibited and hazardous materials by an explosive detection system (EDS) machine or by an alternative method. EDS machines utilize X-ray technology to inspect and detect explosive materials in baggage. In many airports, the baggage is checked in at the airline's ticketing and check-in counter, and then travels via a conveyor system through the baggage hall for inspection and delivery to the appropriate aircraft.

Depending on the configuration of the airport's checked baggage inspection system, the EDS can be of the inline type—where the EDS machine is integrated into the conveyor system (Fig. 2); or the EDS machine can be of the standalone type—where the EDS machine is separate from the conveyor system. Typically, in larger airports with higher baggage throughput, inline EDS machines are used.

The queue conveyor is a relatively short conveyor that transfers the baggage that travels from the check-in counter via the conveyor system to the EDS machine. Because baggage is introduced to the handling process once a bag is checked in by the passenger at the airline check-in counter, the spacing of the bags is typically non-uniform. However, an EDS machine requires the bags to be fed uniformly and at a designated rate. Therefore, the primary function of the queue conveyor is to control the baggage flow into the EDS machine. In order to do so, the queue conveyor is required to start and stop with high frequency.

As EDS machine manufacturers develop faster and more accurate products, the primary driver of the queue conveyor must be able to operate under the increasingly demanding operating conditions of frequent starting and stopping. The selection of the primary driver of the queue conveyor is dependent on multiple criteria, including dimensional requirements and durability characteristics.

Common Queue Conveyor Design Specifications

The design specifications of queue conveyors vary amongst different conveyor system manufacturers; however, comparing several manufacturers' specifications reveals several common features, as listed in Table 1.

Conveyor Dimensions

Based on available specifications, the dimensions of the queue conveyors were listed as having lengths ranging from 36 to 136 inches (0.92 to 3.45 meters), and widths between the sidewalls of the conveyor ranging from 26 to 56 inches (0.66 to 1.42 meters). The pulley diameters of the queue conveyors vary amongst the different conveyor system manufacturers. Because each airport and conveyor system is different, the dimensions are listed as ranges.

Conveyor Belt Speed

The conveyor belt speed is varied amongst the manufactur-

Table 1. Common Specifications from 4 Airport Baggage Handling Queue Conveyor Manufacturers

Dimensions	Conveyor Length	Ranges from 36" to 136"
	Conveyor Width	Ranges from 26" to 56" between frames
	Pulley Diameter	Various
Speed	Belt Speed	Variable (Ranges from 90-350 fpm)
	VFD Control	Typically Available
Driver	Motor	Various (Ranges from 3/4 HP to 3 HP, 3-phase AC-Induction Motor)
	Speed Reducer Type	Various (Helical bevel, helical shaft mounted, motorized pulley, belt drive, etc.)

ers with a minimum listed speed of 90 feet per minute (0.46 meters per second) and a maximum listed speed of 350 feet per minute (1.78 meters per second). The determination of the belt speed of the conveyor depends on multiple factors that can be independent of each conveyor system. These factors include the maximum desired throughput of the EDS machine as well as the ability to handle the fluctuations in throughput for different levels of baggage traffic.

One method of providing this flexibility in conveyor belt speed is the variable frequency drive (VFD). The VFD is an electrical controller that manipulates the frequency of the electrical signal supplied to the electric motor, which can alter the rotational speed and other operations of the motor. This method of conveyor belt speed control is available as an option for many queue conveyors.

Primary Driver of the Queue Conveyor

The primary mover of the queue conveyors is typically a 3-phase AC induction motor in combination with a speed reduction component. The sizing and the load capacity requirements of the motor and the speed reducer are dependent on the configuration and operation of the specific conveyor system. The typical motor powers listed by the four manufacturers ranged from ¾ to 3 horsepower (0.55 to 2.2 kW).

The speed reducers specified by the surveyed manufacturers are of a geared speed reducer or a belt drive variety. Several possible configurations of the geared speed reducer include a shaft-mounted, right-angle type (hypoid, helical-bevel) and a shaft-mounted, parallel-shaft type (helical shaft-mounted, motorized pulley).

Dimensional constraints in the baggage hall—such as the available spacing between multiple conveyor lines—may restrict the sizing and configuration of the speed reducer and the motor. In such cases, a more compact design for the motor and the speed reducer becomes necessary. Two ways that this can be achieved are by:

1. Direct-mounting a hollow-shaft speed reducer to the conveyor pulley
2. Utilizing an integral gearmotor design or a motor that is direct-coupled to the speed reducer

Employing one or both of these design options aids in reducing the space required of the drive components and also minimizes the number of components in the design.

The performance specifications of the queue conveyor create challenges for both the speed reducer and the motor because of the frequent starting and stopping of the conveyor that is required in order to index the baggage appropriately for the EDS machine. Frequent starting and stopping is strenuous on the motor because the in-rush current at startup is typically six to ten times higher than the rated operational current. This leads to temperature rises in the motor that can push the limits of the thermal insulation.

The speed reducer is subject to greater fatigue wear due to the frequent starts and stops. Each time the speed reducer is started, it endures a shock load, which over multiple cycles can lead to fatigue wear and eventual failure. Therefore, the durability of the speed reducer is of great importance in terms of selection criteria.

Sumitomo Drive Technologies Hyponic Gearmotor

Sumitomo Drive Technologies' Hyponic gearmotor is a hollow-shaft mounted, right-angle gearmotor that employs a hypoid gear design to provide a compact and durable solution to drive the queue conveyor.

The hypoid gear set design places the driving pinion at a right angle to the driven hypoid gear, but differs from a worm gear set or a straight bevel gear set in that the pinion contacts the driving gear at a position that is in between the tangential contact of the worm gear set and the isoplanar axes of the straight

continued

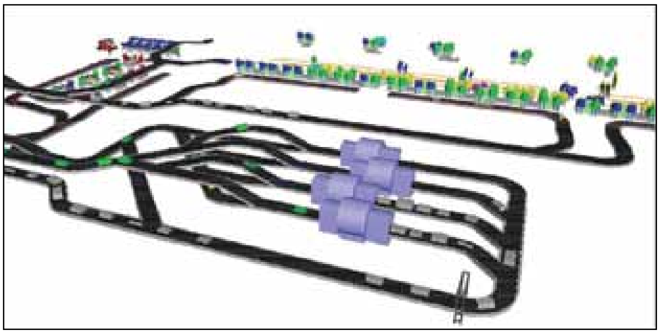


Figure 1—Schematic visualization of a medium-volume inline system (Ref. 9).

Figure 2—Inline EDS and queue conveyor (Ref. 10).

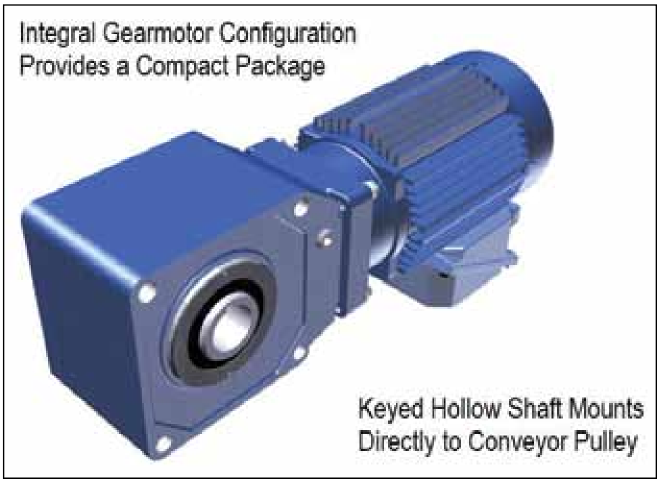


Figure 3—Sumitomo Drive Technologies' Hyponic integral gearmotor.

bevel gear set (Fig. 4).

The positioning of the hypoid pinion allows for a larger tooth contact surface between the pinion and the driven gear than a straight bevel gear set. This larger tooth contact surface area allows for smoother, quieter operation. The offset positioning of the hypoid gear set is also theoretically more efficient than a worm gear set because there is less transmission loss due to the sliding that occurs between the pinion and the driven gear.

The Hyponic gearmotor is supplied with a keyed hollow-shaft output that allows the unit to be installed directly on the pulley shaft of the conveyor, and an integral motor that is assembled directly to the speed reducer section, thereby providing a compact package.

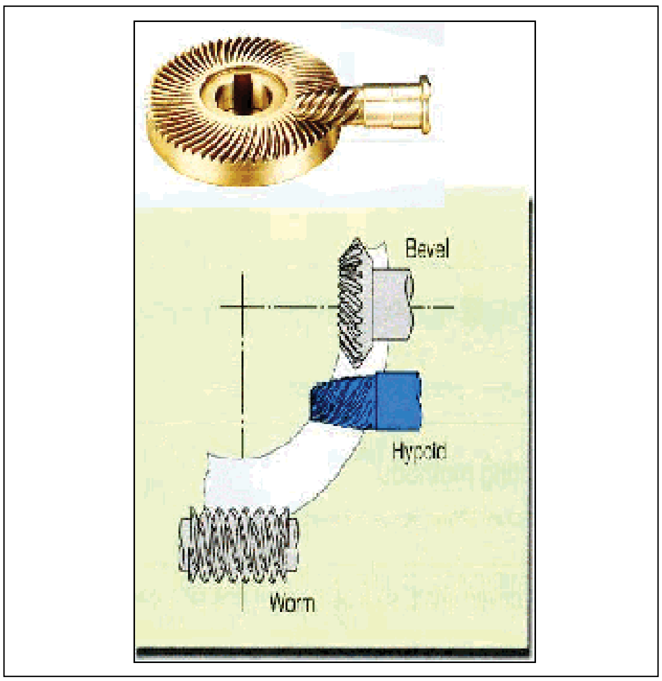


Figure 4—Pinion position: hypoid vs. worm vs. bevel.

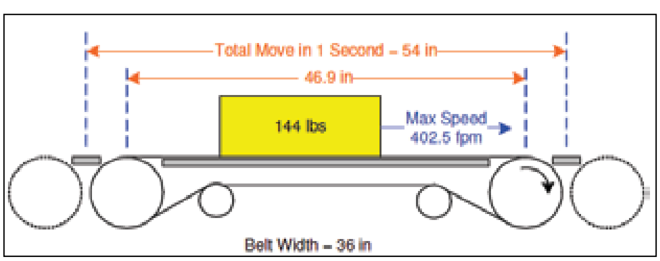


Figure 5—Simulated conveyor (Ref. 2).

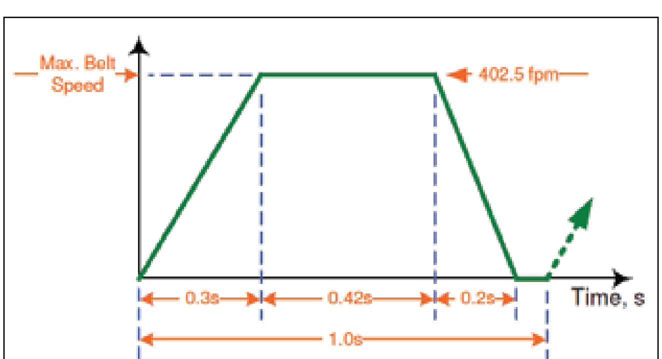


Figure 6—Simulated conveyor speed profile (Ref. 2).

The durability of the Hyponic gearmotor as it applies to the queue conveyor application was studied by Sumitomo in the research paper "Applying Hypoidal Gearmotors in High-Cycling Queue Conveyors" (Ref. 2). In the study, a Hyponic gearmotor was driven by a VFD and programmed to simulate maximum-capacity operation of a queue conveyor. To simulate the load conditions, a separate gearmotor was coupled to the output of the Hyponic gearmotor and driven backward. The initial objective of the study was to observe the gear surface wear characteristics and other effects to the Hyponic gearmotor as it was subjected to 2,500,000 start/stop cycles.

The simulation configurations and conditions consisted of the following:

- ***Hyponic model: RNYM2-1520YA-AV-10***
    - Integral Motor: 2 hp, 4 Pole, 3-phase, 1,750 rpm, Class H Insulation

- ***Simulated conveyor dimensions:***
    - Belt width: 36 in.
    - Distance between the centerlines of the pulleys: 46.9 in.
    - Total displacement of the queue conveyor: 54 in.
    - Pulley diameter: 6.75 in. (6 in. diameter + 0.325 in. lagging)

- ***Simulated load:***
    - 144 lbs.

- ***Simulated conveyor speed profile:***
    - Cycling Rate: 1 cycle per second

- ***Number of cycles:***
    - 2,500,000
    - To failure

The testing of the unit resulted in minimal gear surface wear and no motor failure after 2,500,000 cycles. The minimal wear consisted of "a polished appearance where the teeth made contact" (Fig. 7 and Ref. 2).

The unit was reassembled and placed back in the simulation until after 14,500,000 cycles— when the thermostat installed in the motor tripped and the simulation was concluded. The inspection of the unit that followed revealed initial signs of pitting on the hypoid pinion, while general appearances suggested that the gear teeth could continue to handle many more millions of cycles (Fig. 8 and Ref. 2).

Conclusion

As EDS machines continue to improve in terms of increased baggage throughput and accuracy, the primary mover of the queue conveyor is subject to greater demands in design and durability performance. Sumitomo Drive Technologies conducted a series of tests on its Hyponic product to simulate continued high-cycling, maximum-capacity loading. After 14,500,000 cycles, limited wear was found on the gears (Ref. 2). The combination of a compact, shaft-mounted, right-angle integral gearmotor design and its proven durability characteristics suggests that Sumitomo's Hyponic product line is a suitable selection as the primary driver of airport baggage handling queue conveyors.

References

1. S. 1447–107th Congress: Aviation and Transportation Security Act (2001), In *GovTrack.us* (database of federal legislation), Retrieved January 4, 2011, from *http://www.govtrack.us/congress/bill.xpd?bill=s107-1447*.
2. Asai, J. and R. Robinson. "Applying Hypoidal Gearmotors in High-Cycling Queue Conveyors," *ASME 2010 International Mechanical Engineering Congress and Exposition* (*IMECE2010-39196*), Vancouver ASME.
3. G&S Airport Conveyor. *Sortation Solutions*, Section 5.4: "Queue Conveyor," 2005, Wichita, KS, Retrieved January 4, 2011, from *http://www.gandsmechanicalco.com/pdfs/5.4%20-%20Queue%20Conveyor-05.pdf*.
4. G&T Conveyor Company. *Queue*, 2009, Tavares, FL. Retrieved January 4, 2011, from *http://www.gtconveyor.com/pdf/images/product_images/queue.pdf*.
5. The Horsley Company. (2004). *Specification: Queue Conveyor*. Ogden, UT. Retrieved January 4, 2011, from *http://www.horsleyco.com/products/queue.pdf*.
6. Jervis B. Webb. (2005). *In-Line Baggage Screening*. (Bulletin #9263 111306). Farmington Hills, MI. Retrieved January 4, 2011, from *http://www.jervisbwebb.com/Brochures/Bul-9263_In-line_Baggage%20Screening_Conveyors.pdf*.
7. Logan Teleflex. (2008). *Model 571 Series III Queue Conveyor*. Hull, United Kingdom. Retrieved January 4, 2011, from *http://www.loganteleflex.com/files/97a1f770b70637525a49b09c71ec9951M571%20Series%20III%20Queue%20Conveyor1.pdf*.
8. Transportation Security Administration. (2009). Planning Guidelines and Design Standards for Checked Baggage Inspection Systems. (Version 3.0). Pentagon City, VA. Retrieved January 4, 2011, from *http://www.tsa.gov/assets/pdf/pgds_v3.0_113009.pdf*.
9. Transportation Security Administration. (2009). Planning Guidelines and Design Standards for Checked Baggage Inspection Systems. (Version 2.0). Pentagon City, VA. Retrieved January 4, 2011, from *http://www.tsa.gov/assets/pdf/pgds_v2.0_013009.pdf*.
10. Photo of Inline EDS Machines and Queue Conveyors Retrieved January 4, 2011, from *http://www.airportimprovement.com/images/200903_Page_32_Image_0001.jpg*.

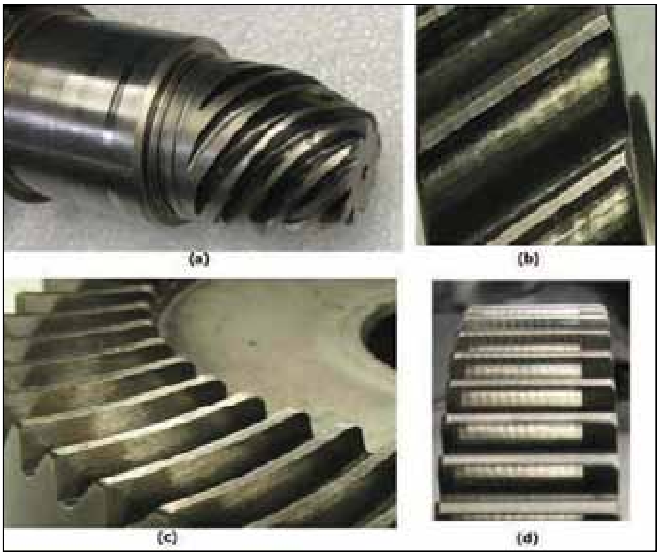


Figure 7—Hyponic gear components after 2.5 million cycles: a) hypoid pinion; b) spur gear; c) hypoid gear; d) spur gear pinion (Ref. 2).

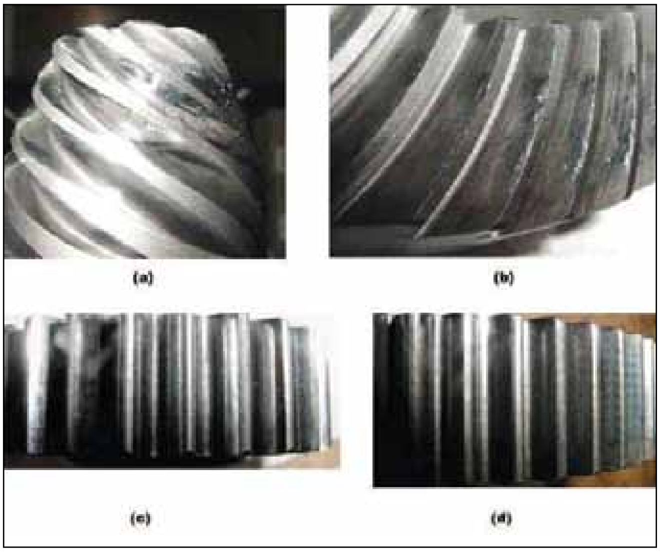
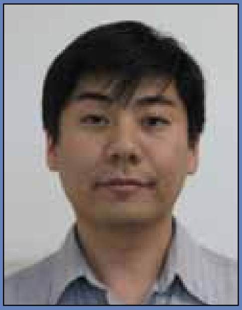


Figure 8—Hyponic gear components after 14.5 million cycles: a) hypoid pinion; b) hypoid gear; c) spur gear pinion; d) spur gear (Ref. 2).



Rintaro Takasu *is an applications engineer for Sumitomo Machinery Corporation of America. He has held this position since 2007, upon graduating with a B.S. in mechanical engineering from the University of California, Berkeley.*

Drive-Based Integrated

Safety monitoring in a drive must be continuous and integral, according to John Krasnokutsky (courtesy of Siemens).

Drive-based integrated safety can save external component cost, additional wiring and overall machine footprint.

Safety


John Krasnokutsky

MANDATED SAFETY FUNCTIONS IMPLEMENTED THROUGH ADVANCED DRIVES PACKAGES

John Krasnokutsky, Siemens Marketing Manager, Motion Control Business

While safety functions have been integrated into drives packages for some years now, the current trends are very exciting, from many angles. Today, a full complement of safety functions can be implemented at the front-end of a system design on all types of production machines, including printing, packaging, converting, materials handling and other equipment used throughout American industry. This can be accomplished in full compliance with all the current regulations for machines used worldwide.

Furthermore, machine designers can look to a drive-based safety integrated protocol that has greater flexibility than ever before, both in terms of its mechanical footprint and component savings, owing to the various ancillary devices such as external contactors and redundant electromechanical safety devices, with all their inherent wiring, cabinet space and related cost.

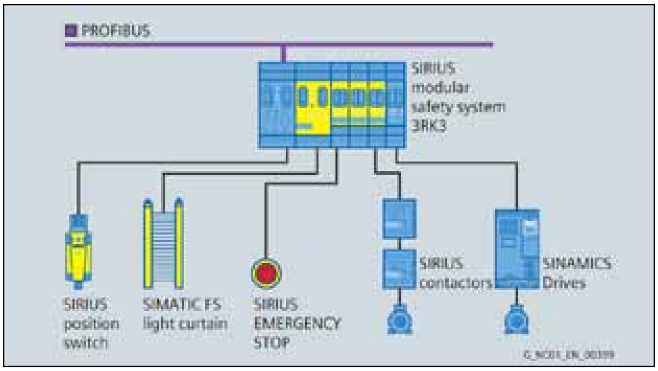
Lastly, and perhaps most important to the designers working on that factory of the future, with an eye on lean, green and expandability, the safety integrated features on today's drives allow additional functionality to be included without excessive rework. Combined with the current state of safety communication capabilities over protocols such as Ethernet/Profinet and Profibus, plus the rapidly emerging and already utilized automation platforms of wireless communication of critical safety function data in a manner isolated from non-deterministic information, these are not your father's drives, to put it mildly.

In the past, the common practice for monitoring drive reaction to shutdown requests came through the machine controller, be it a PLC, CNC or other motion controller hardware. Current safety requirements, especially Category 3 of NFPA 79 and the corresponding category of EN 954-1 and its recently implemented upgrade, ISO 13849-1, now allow drive-based safety functions to be utilized independently. Drives are now performing the continuous safety monitoring with control-reliable safety action inside the drive, through dual channel safety inputs.

Coupled with a safety controller, safety monitoring in a drive must be continuous and integral, so the drive no longer needs to "wait" for a periodic signal from the machine controller to detect, for example, an over speed condition, a break in a light curtain, or even improper inputs that may have resulted from welded contacts or other off-normal conditions. In this manner, the loss of productivity to your machine is radically reduced, while the drive can also send a signal directly to an HMI screen, identifying the fault, in sharp contrast to bygone days when this was not possible without lengthy breakdown and analysis. Troubleshooting and maintenance costs are further reduced by the safety-integrated drives.

Dual benefits derive from these drives for the practical execution of machine control, as well. First, safe stop of the drive without disconnecting the low-voltage power means faster

continued



Drives can now accept inputs directly from various safety devices such as e-stops, laser scanners and light curtains, without need of external devices or a PLC.

Safety concerns on many types of machinery vary considerably and today's advanced safety-integrated drives can accommodate.

Designers will achieve substantial savings through the use of safety-integrated drives on manufacturing floors.

restart and less degradation over time. Additionally, motion safety is achieved by monitoring drive speed through functions such as safety limiting speed, safe brake control and safe speed monitoring functions, which in some drives can be achieved without encoder feedback. These are the more recent advancements beyond the basic safe stop, torque off and safe operating stop functions.

These drives are typically available in variable frequency, vector and servo control models to accommodate induction, servo, linear and torque motors from the subfractionals to the megawatt variety. For inputs, safety incidents from light curtains, laser scanners, position switches and other machine hardware are routinely accepted. Output signals processed in the drive CPU are sent via wire or bus to higher level safety controls or available upgrade modules that activate the drive functions.

During commissioning, the safety functions are set by the password-protected relevant parameters in the drive architecture protocol and triggered for single- or multi-axis groups. Therefore, these drives are finding applications in every type of basic point-to-point linear or rotary motion scheme from a pump or fan to a packaging line up to the highly sophisticated interpolation of multiple axes on machine tools. Highly reliable circuitry controls the output of the low-voltage power that runs the rotational speed output of the drives, so the machine can retain drive power without shutdown to remain more productive. This contrasts sharply with the old three-phase contactor technology of the past. For installation simplicity, many of these drives further feature plug-and-play connectivity for implementing all functions, either at start-up or subsequently, as the manufacturing protocols or monitoring requirements change in the field.

The new thought process for engineers in this area must now be to build monitoring of safety functions into their systems at the front end, knowing they can add I/O with more design work done in the software than the hardware without redundant external devices and custom safety wiring on every job.

Machine designers will realize substantial engineering savings, component cost reductions and improvements in footprint configuration through the use of these safety-integrated drives, while building compliant machines for worldwide use to protect equipment, manufacturing integrity and, most importantly, workers in the process.

For more information:

Siemens Industry, Inc.
Drive Technologies
Motion Control — Production Machines
390 Kent Avenue
Elk Grove Village, IL 60007
Phone: (847) 640-1595
Fax: (847) 437-0784
SiemensMTBUMarCom.sea@siemens.com
www.usa.siemens.com/motioncontrol

The Green Spin

BALDOR REDEFINES COOLING TOWER PERFORMANCE WITH MOTOR AND DRIVE TECHNOLOGY

The Baldor Reliance RPM AC Cooling Tower Direct Drive Motor is designed exclusively for the cooling tower industry. This motor combines the technologies of the power-dense, laminated frame RPM AC motor with high performance, permanent magnet salient pole rotor designs (photos courtesy of Baldor).

For the past 20 years, Rod Applegate, owner and president of Tower Engineering, Inc. of Fort Worth, Texas, has been searching for a better method of driving fans in cooling towers. He says he has finally found what he's been looking for in Baldor's new RPM AC Direct Drive Cooling Tower Motor controlled by a Baldor VS1 Cooling Tower Drive. Since 1986, Applegate's company has been designing and installing high-quality cooling towers for the large institutional market, including hospitals, universities and airports. They all use an air conditioning system that requires a cooling tower to exchange heat and return cooled water back to the chiller.

These towers use large, high-inertia fans to pull air over a water soaked media to cool the water as part of the process. The most common method for driving the fan in modern cooling towers has been

continued

a right-angle gear reducer, drive shaft and disc coupling arrangement, along with a standard foot-mounted AC motor. "I have always wanted to get rid of these gearboxes and all of the other moving parts," says Applegate. "Misalignment, excessive vibration and noise are all inherent problems with this system. With the high speeds, the gearboxes generate too much heat, and the seals and bearings can have very short lives. There are just too many things that can go wrong."

There is also a significant maintenance issue for the owner. "Keeping up with regular oil changes of the gearbox and inspections of the flexible elements are critical," says Applegate. "Ignoring either of these two can, and has, resulted in the catastrophic failure of equipment." Gearboxes are also prone to oil leakage around the high-speed input shaft, contaminating the tower cooling water.

A traditional cooling tower fan drive features a right-angle gearbox mounted under the fan powered by a drive shaft attached to an induction motor.

Turning an idea into new technology. A couple of years ago, when a Dodge engineer called on Tower Engineering to discuss gearboxes, Applegate explained, in no uncertain terms, that he didn't need another gearbox. What he needed was a direct drive fan motor.

"To his everlasting credit, this engineer took the message back to the company, where it was determined that this was a project they would take on," says Applegate. "In subsequent meetings at Baldor's research and development lab, I was able to share with a group of engineers all the things that the cooling tower industry was looking for in a product. Once all the parameters were set, they went to work."

In the meantime, Applegate had a patent pending on a cooling tower motor of his own, but he soon recognized that his design was not the way to go. "I am not a motor manufacturer, and frankly I could see that the Baldor design was going to be far superior. So, now I have a nice patent on display in my office, and that's exactly where it's going to stay."

Eliminating many of the components of the right-angle geared system, the Baldor Reliance RPM AC Cooling Tower Direct Drive Motor is available in either flange mount or foot mount.

Rod Applegate, owner and president of Tower Engineering, Inc., says the Baldor engineers were smart enough to create a low profile motor design that fits in the same space and mounting footprint as the gearbox.

The result of the research and development is the Baldor Reliance RPM AC Cooling Tower Direct Drive Motor which features a power-dense, laminated steel, finned-frame construction. A proprietary Permanent Magnet Rotor (PMR) design using high-flux magnets allows the motor to be manufactured in a compact form, similar to the gearbox it replaces. The combination of these technologies has allowed the company to build a high torque, low profile motor, with the fan mounted directly on the motor shaft. It's a synchronous machine that runs at precise speeds without slip in combination with a Baldor Permanent Magnet Cooling Tower Drive.

With Baldor's release of the new cooling tower motor, Applegate says he finally has the solution he has long been searching for. He describes it as a product that neatly sidesteps all of the issues of a traditional system. "If you don't mind the phrase, I think it's a simple and elegant solution," says Applegate. "It's elegant in the sense that you have traded all of the components for one moving part."

A greener technology. Eliminating the troublesome gearbox maintenance issues with a simplified direct-drive motor is just the beginning. The Permanent Magnet Motor and Drive package provides high system efficiency. The variable speed control allows the tower to operate at optimum performance, which results in a considerable amount of energy being saved.

The energy efficiency story of the Baldor package is one that Applegate is eager to tell. "This is an important discussion to have in a time when everyone is concerned about reducing the amount of energy they consume," says Applegate. "When gearboxes run at these high speeds, they generate a lot of heat, and that's energy being lost. Based on the test data, we anticipate that the Baldor solution is 13 percent more efficient than a conventional drivetrain."

The motors also run quieter, and the reduction in noise level is important, especially in towers that are located near "people-dense" buildings. In addition, by replacing the gearbox, the potential for environmental contamination is eliminated.

The solution for the 21st century. Applegate describes the Baldor Reliance Cooling Tower Motor as a revolutionary product but predicts that five years from now this solution will be the norm. His company is already installing these motors in new cooling tower construction. He also believes this is an ideal solution for existing cooling towers. "We will be doing as many retrofits as we can because they're just so darn easy," says Applegate. "The Baldor engineers were smart enough to create a low-profile motor design that fits in the same space and mounting footprint as the gearbox. It's so simple; it's almost just a drop-in replacement."

Over the past 20 years, Applegate has seen potential cooling tower fan drive solutions come and go, with none working any better than the gearbox drivetrain design. But this time he's convinced he's found a superior performing, user friendly and green solution. "I am confident that this is a real and permanent solution for the industry," says Applegate. "My confidence was strengthened after meeting and getting to know the engineers who designed and worked on the project. I was constantly blown away by their intelligence. I've also visited the plant and watched the product being manufactured. This is a company that will stand behind the product, and that's why I know it will be a success."

These new products are being built in Baldor's Gainesville, GA, motor plant and Fort Smith, AR, drives center. Baldor expects this new technology to transform the traditional cooling tower fan motor and gearbox design to this new high-efficiency "green" direct-drive motor and control solution in the near future.

For more information:

Baldor Electric Company
5711 R.S. Boreham, Jr. St.
Fort Smith, AR 72901
Phone: (479) 646-4711
www.baldor.com

Tower Engineering, Inc.
2821 Lackland Road Suite 340
Fort Worth, TX 76116
Phone: (800) 759-6600
www.tei-usa.com

New Cooling Tower Technology Helps Emory University Achieve Green Energy Savings

The timing of Baldor's launch of the RPM AC Cooling Tower Direct Drive Motor couldn't have been better for Emory University of Atlanta, Georgia. The university was beginning a project to replace two cooling tower units that had been in service since 1988. These two towers are part of a system that provides air conditioning to classrooms and offices in seven buildings on campus, including the new Claudia Nance Rollins School of Public Health.

Rob Manchester with Emory's Engineering Services is the mechanical engineer in charge of the project. He says he learned about the new technology from Tower Engineering, a company the university has been doing business with since 1992. Tower Engineering had just finished a cooling tower retrofit at Clemson University and invited Manchester to visit the site and take a closer look at the new direct-drive technology.

Tower Engineering was confident that Baldor's cooling tower motor was the optimal solution for the Emory project. After learning more about this simplified drivetrain, Manchester agreed, and was ready to move forward with a solution that would help him eliminate costly maintenance and reduce energy consumption.

"We were eager to move away from the traditional gearing units because most of our cooling tower maintenance problems related to the gearbox," says Manchester. "It needed regular oil changes, and the drive shafts also required ongoing regular attention. It's been a burden for our maintenance staff because the units are suspended in the middle of the cooling tower, which makes them very difficult to reach. We wanted a solution that would remove all the maintenance issues."

By combining the power density of the RPM AC motor with the added advantages of permanent magnet rotor technology, Baldor has designed a motor, driven by a Baldor H2 drive, that is highly efficient. Manchester says the university has a goal to decrease energy usage by 25 percent by 2015, and adopting this new technology will help in that effort.

"We have seen the studies that show us that this technology will provide some fairly significant energy savings," says Manchester. "I'm excited about reducing the amount of energy we consume, and because the product is maintenance free, we'll achieve a cost savings on two fronts."

Being an early adopter of new technology can sometimes raise additional concerns, but as the project moved forward, Manchester had the opportunity to visit Baldor's Gainesville, Georgia, motor plant and actually see his two motors being built.

"I have to admit that I felt much better embracing this new product technology after visiting the plant and seeing how these motors are manufactured," says Manchester. "I also feel very good about Baldor's involvement and their commitment in making sure this project goes well for us. I know I can talk directly with engineers who will be willing to help me if I have questions, and it makes me feel confident about adopting the Baldor solution, because I know I can count on their support."

Hannover Messe 2011

13 TRADE FAIRS EXAMINE SMART EFFICIENCY

Hannover Messe, established 60 years ago, ranks as one of the leading international exhibitions for industrial technologies, materials and product ideas. Over the years the focus has shifted from stand-alone components to end-to-end solutions. Technical innovation is one key to the exhibition's success; another is its sharp focus on the creative application of existing knowledge. The international exhibition examines innovations and new developments, technologies and products as well as efficient processes and materials in energy technology, subcontracting and services, industrial automation as well as drive systems and fluid power.

"Efficiency within individual industrial sectors has been a predominant topic for years," says Dr. Wolfram von Fritsch, chairman of the management board at Deutsche Messe. "Designing industrial processes requires more than just mere efficiency, however, it requires the intelligent interconnection and exploitation of all the individual efficiency factors. 'Smart efficiency' integrates the factors of cost, process and resource efficiency."

For this reason, Smart Efficiency has been chosen as Hannover's main theme during lectures, congresses and forums. The 13 flagship fairs featured at the 2011 show include Industrial Automation; Motion, Drive and Automation; Energy; Power Plant Technology; Wind; MobiliTec; Digital Factory; ComVac; Industrial Supply; CoilTechnica; Surface Technology; MicroNanoTec and Research and Technology.

For *Power Transmission Engineering* (*PTE*) readers, key areas of interest include the Industrial Automation; Motion, Drive and Automation; and Energy fairs. Below is a summary of these trade fairs and some of the special events and pavilions featured during the exhibition:

Industrial Automation: For many years Industrial Automation has ranked as the leading flagship fair for process automation, factory automation and related systems. It showcases all the relevant areas of industrial automation from production and process automation to universal automation technologies. The focus here will be on sector-specific solutions for industries such as chemicals, pharmaceuticals, biotechnology and food, as well as the metalworking sector, the car industry, the energy industry and electrical engineering. The production automation section will present a wide array of integrated automation solutions, as well as innovations in mechanical engineering and electric power transmission and control. Also featured at Industrial Automation are the information and communication technologies, without which industrial automation could not function. These include industrial communications as well as automation-related IT hardware and software. The special display, "Robotics & Automation" will demonstrate mobile robotics for industrial production, public undertakings and the service industry.

Motion, Drive & Automation (MDA): Takes place once every two years as part of Hannover Messe. It showcases the complete spectrum of electrical and mechanical power transmission and control technologies as well as all the latest innovations in hydraulics and pneumatics. The headline themes for 2011 are Energy Efficiency, Lifecycle Management and Condition Monitoring Systems. The new trade fair Mobilitec completes the line-up in Hall 25. More examples of power transmission and control technology can be seen at Industrial Automation and Wind. More than 1,300 manufacturers of gears and transmissions, roller bearings, electric motors, pumps, cylinders, filters, hoses and seals, as well as many other components used in power transmission systems, will be exhibiting at Hannover. Additionally, the AGMA pavilion at MDA will showcase gear products and services at Hannover Messe and offer an exclusive exhibitor turnkey package to AGMA members (contact *website@agma.org for more information*).

Energy: Energy and its three companion trade shows—Power Plant Technology, Wind and MobiliTec—document the complete energy cycle, from generation, supply, transmission and distribution to transformation and storage. Among the topics covered extensively at Energy are smart metering, smart grids, smart building and information and communication technologies for the energy industry. All these are featured at the E-Energy Centre. The group display "SuperConductingCity" is another highlight of Energy, where high-tech companies will be demonstrating examples of superconductor technology in action. This technology makes it possible to conduct electricity without electrical resistance. Also returning in 2011 is "Hydrogen and Fuel Cells," Europe's largest joint presentation for these cutting-edge technologies. Here specialist firms will be presenting systems for hydrogen production, fuel cell components, stationary, portable and mobile fuel cells, and their applications.

For more information and full schedule of Hannover Messe events, visit *www.hannovermesse.de.*

March 1–3—Expo Manufactura. Cintermex, Monterrey, Mexico. The largest event in Mexico for the processing and manufacturing industries boasts more than 350 companies representing more than 600 national and international brands. Expo Manufactura brings professionals together with technological solutions in aerospace, medical devices, automotive, metallurgical, aeronautics and electrical appliances. More than 9,000 industry professionals will visit the show looking for industry insights, new technologies and networking opportunities. For more information, visit *www.expomanufactura.com.mx*.

March 21–24 2011—Automate 2011. McCormick Place, Chicago. Automation technologies such as robotics, machine vision and motion control help companies in every industry become stronger global competitors. Automate 2011 brings together a broad range of integrated solutions while examining the latest technology advances in these fields. Formerly the International Robots, Vision and Motion Control Show held once every two years, Automate 2011 has partnered up with ProMat 2011, a leading trade show for the material handling and logistics industries, to bring guests new ideas that can be put to use immediately. One badge gets you into both shows. For more information, visit *www.automate2011.com*.

March 22–26—IFPE 2011. Las Vegas Convention Center.. IFPE is the leading international exposition and technical conference dedicated to the integration of fluid power with other technologies for power transmission and motion control applications. Held every three years, the exposition showcases the newest innovations and expertise in fluid power, power transmission and motion control. More than 100 education sessions focus on the newest technologies, best practices and the latest research and developments including: The National Conference on Fluid Power, Innovations Theater and college-level courses in hydraulics and pneumatics. For more information, visit *www.ifpe.com*.

March 30–April 2—PTRA Annual Conference. Destin, Florida. The focus of this year's Power-Motion Technology Representatives Association (PTRA) conference will be industry economic trends, customer relations and sales skills. The conference features Alan Beaulieu, senior economist for the Institute of Trend Research presenting "See the Future before Your Competition Does" and Paul Pease of The Pease Group with "Keep Your Salespeople Selling." Also speaking will be Steve Turner of Turner Time Management on "Maximizing Your Technology Productivity When on the Road" and Peter Zafiro of The Pease Group on "Mutual Action Planning-Not a Cookbook Approach." There will also be a panel discussion "What Does a Customer Really Want? Tough Questions, Real Answers." The PTRA annual conference has long been recognized as one of the signature networking events available to independent manufacturers' representatives and manufacturers serving the power transmission and motion control industry.

April 5–7—AeroDef Manufacturing. Anaheim Convention Center, Anaheim, California. AeroDef Manufacturing is designed to meet the manufacturing challenges in the entire aerospace and defense manufacturing segment. Organized by the Society of Manufacturing Engineers (SME), AeroDef Manufacturing offers a comprehensive exposition and technical conference that includes demonstrations of innovative, enabling technologies and advanced, integrated systems for manufacturing in the military and commercial aerospace, defense and space industries. Educational sessions will have a heavy emphasis on what the industry needs to know to move forward in advancing U.S. aerospace and defense manufacturing.

April 14–16—2011 ABMA/AGMA Annual Meeting. San Antonio, Texas. For the first time the American Bearings Manufacturers Association (ABMA) and the American Gear Manufacturers Association (AGMA) will meet in Texas to discuss topics including, "Recovery from the Great Recession," "Department of Defense Spending: Impact for the Manufacturing Sector," "The New North American Auto Industry," and "Opportunities in the Wind Energy Sector." While the economy and politics are the focal points, members will also be discussing manufacturing, products and end users. Special events include a silent auction, golf tournament and barbeque dinner. This meeting is open to ABMA and AGMA members. For more information, visit *http://abma.site-ym.com/ or www.agma.org*.

May 6–8—Gears, Motors and Controls Expo. Bombay Exhibition Centre, Mumbai, India. GMC 2011 is a showcase of gears, motors, controls and allied products scheduled to be organized from the May 6–8, 2011. The 3rd edition of the event builds on the success of the earlier editions held in Chennai & Mumbai. It will be held in conjunction with Pumps, Valves & Compressors Expo 2011. The three-day event will be promoted extensively across India and the region, and visitors will comprise key decision makers from nearly every industry segment. With customer satisfaction at the heart of the trade show's strategy, GMC 2011 hopes to build on previous efforts and deliver maximum rewards to the participants. Bonfiglioli and Elecon are industry partners for the 2011 event.

Photos courtesy of AMT.

Manufacturing for Growth

FOUR ASSOCIATIONS CHART COURSE FOR U.S. MANUFACTURING

Four leading associations of small- and medium-sized manufacturing companies recently announced that they are combining resources to host the inaugural Manufacturing for Growth (MFG) meeting, a gathering of hundreds of manufacturing leaders, March 3–6, 2011, in Chandler, Arizona. Collectively representing a cross-section of the industry, the Association for Manufacturing Technology (AMT), the American Machine Tool Distributors' Association (AMTDA), the National Tooling and Machining Association (NTMA) and the Precision Metalforming Association (PMA) will combine their annual meetings to pursue the common goal of building sustained U.S. economic growth by strengthening the country's manufacturing sector.

Together, the four associations comprise more than 4,000 small and medium-sized manufacturers from all 50 states that provide products for the aerospace, automotive, construction, energy, medical and many other industries in the United States and abroad. By sharing resources, the Manufacturing for Growth conference will provide an opportunity for more than 500 top manufacturing executives to exchange best practices as the industry seeks to reassert and expand its U.S. economic footprint.

In a letter to the four groups acknowledging the significance of the industry gathering, U.S. Department of Commerce Secretary Gary Locke wrote: "Your four trade associations are to be commended for recognizing that collaboration and cooperation among industry stakeholders are vital to the future of America's manufacturing sector."

"The MFG meeting represents a unique opportunity to collaborate with manufacturing technology providers, builders, integrators and users," AMT president Douglas Woods said. "By combining the resources of our four premier manufacturing associations, the MFG Meeting will have exceptional program content and networking opportunities."

AMTDA president and CEO Peter Borden added, "The MFG meeting represents a sea change for the industry. The collaboration involved with this meeting coincides with the shift in the industry itself towards a greater emphasis on interconnectivity—from the manufacturer to sales distribution to customer—making [it] an ideal forum for industry professionals to discuss common issues."

"To have four great associations collectively coming together to support manufacturing and promote its awareness shows the positive effects of collaborating around a common goal. This event is the first step to promote manufacturing awareness and educate our country on its importance to

America's economic infrastructure," NTMA president Dave Tilstone said.

"This new collaboration among the major industry associations represents a milestone in strengthening business relationships within the supply chain of the metalworking and forming industries," said PMA president Bill Gaskin. "By joining together for the MFG Meeting, members of these associations can develop new opportunities to work together to assure a strong manufacturing base in North America." For more information, visit *www.themfgmeeting.com*.

Electric Vehicle Manufacturers

CHOOSE UNIVERSAL TRANSMISSION

VMT Technologies recently announced that two electric vehicle manufacturers—Kentucky-based Vision Motor Cars and Korean-based Leo Motors—have requested the use of VMT's new transmission technology for their cars.

VMT recently unveiled its Universal Transmission, claiming it could replace many of the current transmissions—including continuously variable transmissions—and improve gas mileage. The company is selling licensing agreements to original equipment manufacturers. VMT, a technology development and licensing company, began working on its new transmission technology in 2005.

According to VMT, Universal Transmission functions as a positively engaged, infinitely variable transmission with an engaged neutral, and it eliminates the need for a clutch or torque converter. VMT Technologies CEO Richard Wilson said the Universal Transmission is particularly beneficial to the hybrid and EV market because it eliminates the need for the controller. In addition, the transmission can allow EVs to use much smaller battery configurations, resulting in cost savings for manufacturers, he added.

Vision Motor Cars, based in Williamsburg, KY, has

continued

submitted five years' worth of purchase orders totaling $348 million for its new line of all-electric drive delivery vans, mini-vans and sports cars. "VMT technology, coupled with our power system, will be the best EV combination in the world, increasing efficiency and range of our trucks by 30 to 50 percent," said Vision Motor Cars President Brooks Agnew.

VMT is also considering an offer from Leo Motors, whose purchase orders would total more than $480 million. Vision Motor Cars has offered to perform final assembly to make its high-efficiency motor an integral part of the lightweight design of the Universal Transmission. "In addition to multiple business and technology review meetings in Korea for the past year, we have also met with many U.S. companies," said Mark Stoddard, VMT managing partner. "We're entertaining offers from several of them to fulfill the orders for these electric vehicle applications, as well as many other non-electric applications in our leapfrog technology."

VMT speculates that the Universal Transmission may be able to help automakers meet government CAFÉ requirements ahead of the 2017 deadline. "Our new transmission, with an engaged neutral, allows engines to run closer to their 'sweet spot' right out of the hole," Stoddard said. "According to electric vehicle experts, the potential benefits of the Universal Transmission technology are the reduction of the drain on the electric motor controllers and battery packs, and less power surges due to the engaged neutral."

VMT said it expects more automakers will show interest in licensing the Universal Transmission technology for other classes, sizes and ranges of vehicle applications. For more information, visit *www.moongears.com*.

ABB

Completes Acquisition of Baldor Electric

ABB Ltd. has completed its acquisition of Baldor Electric Company. The transaction, which was originally announced on November 30, 2010, was valued at $4.2 billion, including $1.1 billion of net debt. The acquisition of Baldor advances ABB's strategy to become a leader in the North American industrial motors business and a global leader for movement and control in industrial applications. The combination provides an even stronger growth platform from which ABB can increase its penetration of North American markets by building on Baldor's strong presence while at the same time facilitating the sale of Baldor's products globally through ABB's worldwide distribution network.

ad index

classifieds

With These Shoes—Some Say—

EVEN WHITE MEN CAN JUMP!

"Banned by the NBA!" the headline screams. What are we talking here—Steroids? Gambling? Methamphetamines? Black socks?No—we're talking shoes. Specifically, $300 Concept 1 basketball shoes from Athletic Propulsions Labs (APL), with its patented Load 'N Launch technology and claims that the shoes will add a minimum of three, and up to five inches to a player's vertical leap. Whether they work or not still appears to be an open question, but the NBA was sufficiently impressed with their performance that it took the rare step of banning the shoes just prior to the beginning of the 2010–2011 season.

The NBA proclaimed: "League rules regulate the footwear that players may wear during an NBA game. Under league rules, players may not wear any shoe during a game 'that creates an undue competitive advantage (e.g., to increase a player's vertical leap).' In light of that rule, players will not be permitted to wear the APL shoes during NBA games." (The last time the league banned a specific shoe was in 1985, when it restricted Air Jordans, citing an unacceptable color combination.)

How do they work? (After all, there has to be some kind of power transmission relevance here, or the Power Play Team wouldn't be reporting it.)

As APL 23-year-old founders, brothers—and twins—Adam and Ryan Goldston, describe it, their Load 'N Launch concept seems simple enough.

"When you apply pressure to it, it compresses," Adam Goldston says. "And when you go to jump it propels you upward and releases. It's a mechanical device. There's no other technology in shoes that works that way."

Or as the APL site states, "The Load 'N Launch device is implanted in a cavity of the shoe's forefoot, which serves as a 'launch pad' by taking the energy exerted by the player and increasing lift with the aid of an intricate, spring-based propulsion system."

The "technology" is in fact a spring incorporated in the front of the shoe. The Goldstons have compared the effect to that of a diving board—the more pressure exerted on the spring, the higher the leap.

But one thing cannot be denied—news of the NBA ban has provided a mother lode of free advertising and publicity for the shoes, even if there doesn't quite seem to be a market out there for them.

"In terms of marketing, this is probably the greatest thing that could have happened to our company, because it basically blew us up overnight," says Adam Goldston.

But who will buy them?

"No player has asked to wear these shoes, so it's a non-issue," NBA spokeswoman Kristin Conte announced. "However, we determined that they don't conform to our rules, based on the company's representation of what they do."

Nevertheless, upon news of the ban, Google was soon tsunamied by Concept 1 search queries of where to buy the shoes. However, no college athletic programs have yet to reach out to APL, due, the Goldstons say, to their existing contracts with other shoe brands.

But there is also a *Jerry Maguire* "show me the money" dynamic at work here. Just ask Adam Goldston.

"I think the major problem the NBA has to deal with is the fact that the majority of NBA players are under contract to other footwear brands, and would be at a competitive disadvantage to players who would wear the Athletic Propulsion Labs shoes, Adam Goldston stated in a press release. "The intriguing question is what would NBA players choose to wear if they were spending their own money, and there were no footwear endorsement contracts?"

So, is the controversy all about the money, or about preserving the competitive integrity of the sport?

If it is the latter, here's a solution the Power Play Team is certain will please the Goldstons:

Why not outfit every NBA player with Concept 1s?

Short of that, maybe there's a practical household use for the "Load 'N Launch" technology. Perhaps for washing those hard-to-reach windows around your place? Or cleaning the gutters? (*For more information, go to www.athleticpropulsionlabs.com*)