

December 2012
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THE TECHNOLOGY SHOWCASE ISSUE

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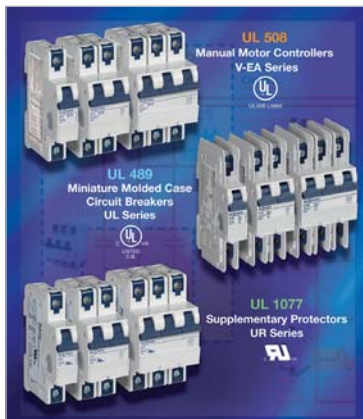
Altech Corporation Facility Flemington NJ.

One of Altech primary product lines is for Circuit Protection. In today's very competitive marketplace you need reliability, so you need to use circuit breakers that are high quality and technically correct for your application. Altech is a US leader in DIN rail mounted breakers with ratings up to 63A. Only Altech offers DIN rail mounted breakers that meet UL489, UL508 or UL1077 approvals with a short circuit interrupt capacity of up to 10kA. No

other manufacturer offers this complete line. This assures you the right product for your application requirements.

When you need branch circuit protection, Altech offers UL489 Miniature Molded Case Circuit Breakers in both AC and DC voltages. The AC version offers dual voltage rated circuit breakers at 0.2-63A/240VAC and 0.2-32A/480Y/277VAC in 1-3 poles. Altech is the only company that offers a 14kA, 20A C curve single phase breaker at 277V AC. The DC version offers 0.2-63A at 125V (1 pole) and 250V (2 pole).

If your application requires a manual motor controller, Altech is the leading US supplier of UL508 Manual Motor Controllers (MMC). In AC, we offer up to 60A in 1 to 3 poles at 480Y/277VAC. With 6 trip curves, Altech has the largest selection in the industry. This ensures you the selectivity



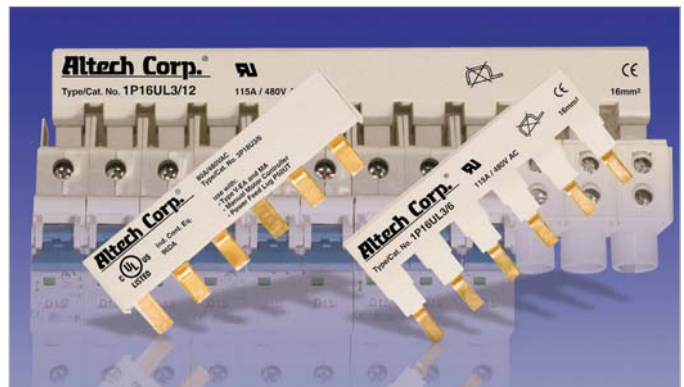
Altech Corporation / ABL Sursum UL Circuit Protection Devices

Altech Corporation is an established United States based supplier of European components and devices used in industrial control, instrumentation and automation applications. Altech is an ISO9001:2000 certified manufacturer & distributor of electrical, electronic & electromechanical components. Products include circuit breakers, busbars, DIN rail terminal blocks, printed circuit board terminal blocks, contactors, motor disconnect switches, pin & sleeve devices, receptacles, foot switches, relay modules, safety relays, slimline relays, push buttons & pilot lights. Metal detection systems, ferrules, marking & engraving systems, fuses, power distribution blocks, corrugated tubes, liquid tight strain reliefs, tower lights & wire ducts are also available. Many of Altech's parts meet UL and international standards and all are RoHS compliant.

you require for your application designs. Our MMCs have a 10kA short circuit withstand capacity, this is the highest rating in the industry. The AC version is rated up to 60A and is DC rated in 2 poles up to 80VDC.

When your application requires supplemental protection for control circuits and on the load side of branch circuit protectors Altech has solutions. We offer a competitive line of AC Supplementary Protectors, up to 63A, in 1 to 3 poles at 480Y/277VAC with a 10kA short circuit withstand rating.

To complement the line of miniature circuit breakers Altech carries a line of Busbar Systems, UL1077/508 and UL489. Altech Corp., is a leading supplier of busbar systems in the US Market. Altech has an established line of UL1077/ UL508 Busbars with ratings up to 200A. They are UL recognized and listed for use with most competitor's supplementary protectors and manual motor controllers. Altech's UL489 Busbars to its product range with ratings of up to 115A. They are also UL recognized for use with most of Altech's competitor's UL489 Miniature Circuit Breakers.



Busbars that complement the Altech miniature circuit breaker line.



Just some of Altech Corporation's extensive line of contron components.

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Contact Info:

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with the new supercharged Do-more™ PLC



If you've been using DirectLOGIC 205 PLCs, but you've been wanting ...

- More program memory
- More and flexible data type memory
- Faster program execution
- Easier-to-use instruction set
- Integrated Ethernet on the CPU
- Faster I/O for counting and motion applications
- More and easier-to-use communications

... THE WAIT IS OVER!

The new Do-more H2 series CPUs leverage the existing line of DL205 I/O modules and base units to create an incredibly powerful PLC - at an incredible bargain.

Two CPU options are available:

H2-DM1E \$399 (1) USB port for programming,
(1) full-duplex serial port,
(1) Ethernet port

H2-DM1 \$299 (1) USB port for programming,
(1) full-duplex serial port

H2-DM1E



H2-DM1

- Over 1M bytes total memory (includes program, data and documentation)
- Program/monitor/debug over any embedded communication port.
- Supports up to 256 I/O locally and thousands more with optional Ethernet remote I/O.
- Supports inexpensive serial port expansion for connection to bar code readers, printers, etc.

And each Do-more CPU comes with a coupon for a 30-day free trial of online video training.

Program Do-more with the **completely new - and FREE - Do-more Designer software.** (DirectSOFT and ladder programs developed with DirectSOFT are not compatible with these CPUs.) Download the **FREE** software!

Get started fast!

Choose a Do-more starter kit to get going fast. You get:

- Prewired, 3-slot base** with your choice of Do-more CPU
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- 8-point relay output module
- Do-more Designer software CD-ROM
- USB programming cable
- User manual
- **Coupon for 30 days FREE online video training**

** AutomationDirect reserves the right to substitute a larger base at its discretion

H2-DM1E-START \$626 with H2-DM1E CPU

H2-DM1-START \$536 with H2-DM1 CPU



Starter Kit

So visit www.do-moreplcs.com for the details, watch overview videos, and download the free software to take it for a spin.

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Visit **MACHINE DESIGN's** white-paper library for updates on a wide range of engineering technologies. Recent topics include how to lower the cost of machine design; CFD and multiphysics simulation software; basics of motor selection; and solving thermal-management problems. Learn more at <http://machinedesign.com/whitepaper>.



Show highlights

Have time constraints and tight budgets kept you tied to your desk and away from recent trade shows? Fortunately, Engineering TV has done the footwork for you! Check out what you missed at some of 2012's major engineering shows, including the IMTS, Design East, PackExpo,

Robobusiness, Intersolar, AUVSI, and even Electronica in Munich. View them all at www.engineeringtv.com/pages/trade.shows.

engineering tv

Harness-design site

TE Connectivity's interactive Web site, www.HarnWare.com, gives details on the company's harness-design software. The CAD package lets users produce wiring-harness assembly drawings, parts lists, labor estimates, RoHS compliance codes for each component, cable cross-section designs, connector drawings, and wiring schematics. It also generates 3D models of harnesses and components for "virtual" prototyping.

Conveyor configurator

Dorner Manufacturing's intuitive configurator platform lets engineers build complete virtual conveyor assemblies to their exact layout dimensions. Users can then download a single CAD model of the complete conveyor, saving the time normally spent matching up individual files. Completed projects include detailed descriptions of all components, info on RFQs, and CAD files in a variety of formats and 3D PDFs. Download the configurator at www.dornerconveyors.com.

Industrial fluid controls

Danfoss has launched a new Web site (www.danfossdirect.com) to help users configure and purchase industrial valves, coils, and accessories. Suited for OEM and process applications, the site lets engineers search for fluid controls by application, in-

dustry, or type, including solenoid, thermostatic, and pneumatic valves and specialty products such as steam valves. The configurator also makes suggestions for proper coils and accessories based on the valve selection.

Sensors and fluid management

AMETEK Sensors & Fluid Management Systems, a supplier to aircraft engine and airframe manufacturers, has a new Web site, www.ameteksensors.com. It provides product and application information on an extensive line of pressure, temperature, liquid level, flow, vibration, humidity, oxygen, speed, and air-data sensors. The site also give details on special cable assemblies and harnesses and custom sensors.

Electronic measurement

Agilent Technologies, a supplier of measurement products and services for analysis, diagnostic, electronics, and communications applications, has launched a new Web portal that lets engineers get information personalized to their products and interests. Users can register to receive firmware updates, application notes, and service notifications; connect with peers in discussion forums; and get alerts for special offers. Learn more at www.agilent.com/find/myAgilent.



OVER 80 FREE VIDEOS ABOUT C-MORE MICRO HMI

C-more micro touchscreen HMIs support easy-to-use configuration software, and these videos make it even easier to get up and running.

Access almost 85 short tutorial videos on the C-more micro product site or on AutomationDirect's Youtube channel. These informative tutorials cover a variety of topics ranging from hardware setup to animation examples, bitmaps, and project demos.

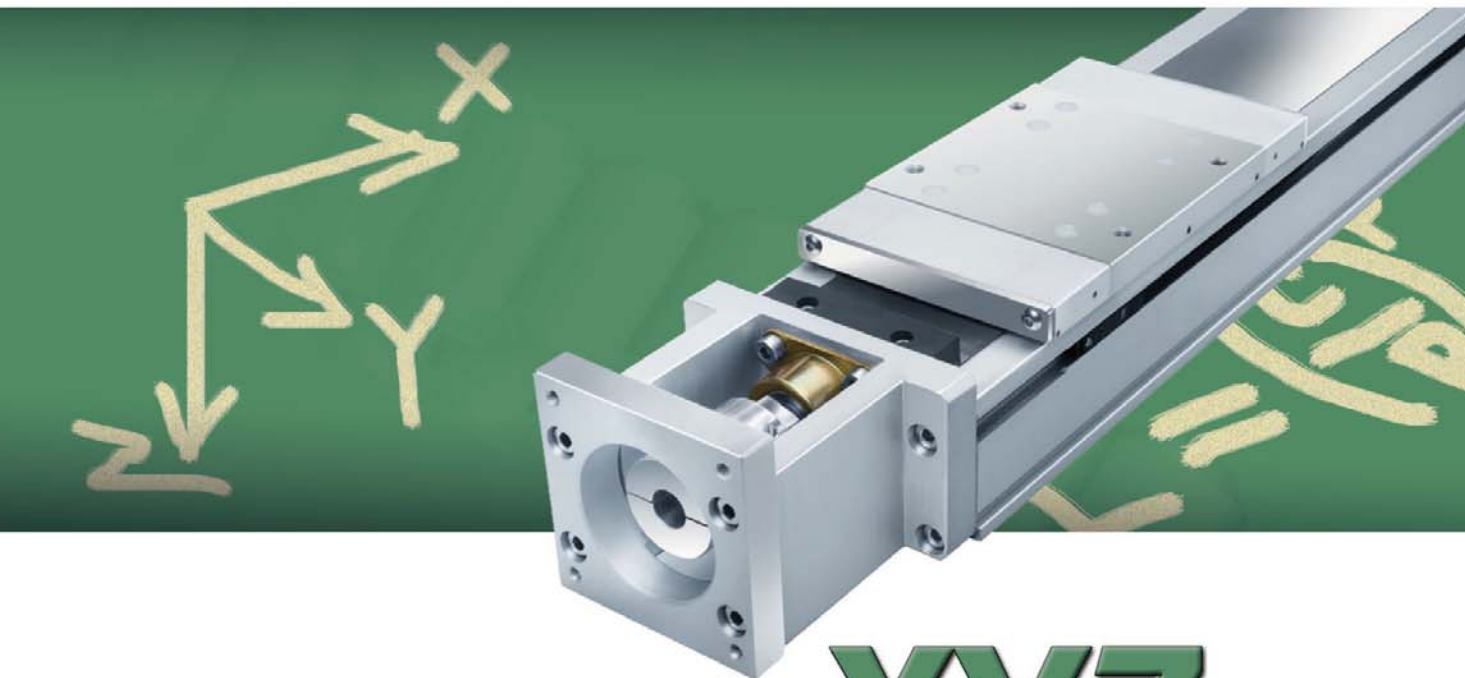
Example topics include:

- QuickStart — Getting Started
- How to Set Up the Comm Ports
- How to Calibrate the Touchscreen
- How to Import and Export Tags
- How to Use Indicators
- How to Use a Pushbutton Switch
- How to Control Beeps
- How to Use a Dynamic Bitmap
- How to Animate a Scrolling Banner
- How to Set Up Alarms
- How to Use Simulator
- How to Debug Communications

To view all C-more micro HMI video series, visit <http://bit.ly/cmicrovids>.

Or find them at: www.youtube.com/automationdirect. Become a subscriber and get alerts when new videos are uploaded.

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The XYZs of Linear Motion

Solutions for Automation That Take You Straight to the Top

Unrivaled in scope and versatility, Schaeffler's linear product line ranges from shafts with linear ball bearings and monorail guidance systems to sophisticated actuators with drives and control systems, plus special coatings and every conceivable accessory. You name it, we've got it.

But that's only the start. Our linear portfolio is based on a modular concept that goes far beyond mere components. We can design a complete system solution tailored to your specific application - from large gantry robots to intricate circuit board inspection systems. In fact, many of our linear guidance systems started out as solutions to customers' needs!

Class dismissed.

Superior-quality products.
Comprehensive reliable solutions.

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Bosch Rexroth is the world leader in the drive, motion, and control technologies that power today's most advanced manufacturing systems. We combine a passion for solving your complex engineering challenges with unmatched applications expertise across a broad range of industries and automation systems, creating custom solutions for over 500,000 customers worldwide.

Mobile Applications:

Whether it's digging construction trenches, drilling tunnels through solid rock, or practicing sustainable forest management — mobile machines provide vital tools to accomplish complex tasks, improving safety, and with less labor. OEMs developing these machines must

constantly adapt to ever-changing conditions, such as the significant emissions reduction associated with TIER 4 Final standards. With new concepts for mobile hydraulics, we ensure that mobile machines meet these standards while maintaining the highest levels of performance.



Machinery Applications and Engineering:

We are a global specialist for plant construction and unique projects, ranging from high-power forming of metal or plastic to laying submarine cables. Based in over 80 countries and with direct access to expertise in all aspects of drive and control technologies, Bosch Rexroth undertakes large-scale projects (as a project partner or general contractor) such as supplying systems for the new locks on the Panama Canal or state-of-the-art stage technology for Moscow's Bolshoi Theatre.



Factory Automation:

Machining gearwheels for mechanical clocks with 1000th mm accuracy or retooling packaging systems for new products several times a day — automating this type of manufacturing for peak efficiency requires proven technology and strong engineering insight. We understand how to combine hydraulics, electric drives and controls, mechanics and pneumatics to create energy-efficient and highly productive system solutions. As more and more functions are moved to



software-based processes, we help advance the engineering of factory platforms, so machine manufacturers can achieve their goals faster and stay one step ahead of the competition.

Renewable Energies:

Since the 1980s, Rexroth has been developing powerful and reliable transmission and drive solutions for the wind-energy sector, helping achieve an almost 50-fold increase in wind-energy plant capacity. Costs per kilowatt hour produced make wind energy a viable contributor in today's environmental protection efforts. Along with contributions to solar thermal, photovoltaic, and tidal-power technologies, we continue our commitment and strong responsibility to unlock cleaner, more-renewable energy resources for a more-sustainable future.

Rexroth

Bosch Group

The Drive & Control Company

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market-best delivery times } Exactly

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**Rexroth NFPA
Hydraulic Cylinders:
Superior Quality—Fast!**

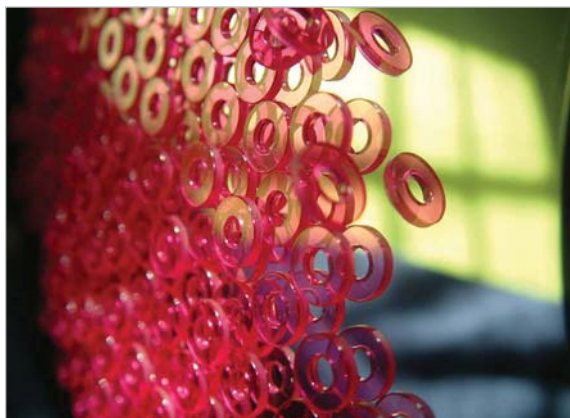
Featuring high-tensile steel tie rods and wear-resistant sealing system. One-piece extra-long ductile iron rod bearing with compression strengths up to 2½ times higher than competitive designs.



CDT1 NFPA Cylinders



CDT4 NFPA Cylinders



As technology demands precision and smaller tolerances, engineers are turning to Bird

Precision micro-drilled inserts, fittings, and filter components. We offer a high-value solution in nozzle, restrictor and orifice applications, all designed with Bird Precision accuracy.

If you're involved in product design and production, you're always on the lookout for ways to improve the manufacture, performance and quality of your products. Now is the time to investigate the wide range of accuracy and workmanship Bird Precision supplies for micro miniature components and assemblies.

Bird's unique manufacturing process

Bird Precision offers a unique series of laser drilled, wire lapped Ruby and Sapphire Orifices. This unique wire lapping method insures that our orifices are round and highly polished. This method also removes the possibilities of burrs or loose particles in the orifices area.



The orifices are lapped both faces to impart a very sharp edge to the orifices. This sharp edge gives our orifices a very controlled coefficient of discharge, (cd Value.) The wire lapping also guarantee's diameter tolerances to .0001" or less, as found in our new Golden Orifice Series. It is this precise methodology that distinguishes us from all other orifice manufacturing methods, yielding production quantities of highly repeatable flows for both



liquids and gas at reasonable prices.

Orifices and filters are packaged in a huge variety of stainless, brass and plastic fittings, connectors and inserts. With extreme chemical and wear resistance these products insure precise dependable control of even the most harsh liquids and gas.

Bird Precision continues to focus on putting orifices and filters where you need them.

We also offer a number of Swagelok, Parker, Smc and Value Plastic Retrofits.

Visit us at Booth 1261 MDM WEST show February 12-14 2013
 Anaheim Convention Center, Anaheim California
 Booth 4313 Atlantic Design & Manufacturing Show June 18-20 2013



Contact info:

Bird Precision, Inc., One Spruce Street, PO Box 540569, Waltham, MA 02454-0569 USA
 T: 781-894-0160 / 800-454-7369; F: 781-894-6308 / 800-370-6308
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Properties of Bird Sapphire and Ruby Orifices

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- Will not outgas
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- Huge assortment of standard products
- Custom fits in your fitting or choose from our many Swagelok, Smc, Parker or Value Plastic Fitting retrofits.

Jewel Bearing Capabilities

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- Low starting torque
- Ability to run dry
- Operate in harsh environments
- High temperature material
- Spring loaded and cushioned shock resistance
- Custom manufacturing to your specifications
- Stainless, Titanium, Brass and Aluminum Mountings
- Proprietary shaft materials as well as carbide

Bird Precision celebrates 100 years of precision New England craftsmanship. Our roots began by supplying Ruby Ring Jewels and watch bearings for the Waltham Watch Factory in the early 1900's.

Our product later became integral to the Aerospace Industry. Precision bearings were used for satellite and lunar landing guidance systems.

With the development of new laser drilling and wire lapping techniques, we have transitioned into micro miniature orifices, nozzles, filters and connectors. We offer a whole line of micron level standard product, ranging in size from 10 microns (.0004") up to 2mm. Flow rates range from under 1cc/m.

Our orifice products are found in oxygen control devices for the medical industries. Repeatable flow controls for pneumatic regulators, hydraulic valves and analytical instrumentation.

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Advancing fluid power technology since 1958

With operations housed in 61,000 sq. ft. in Gainesville, FL, Fabco has dedicated itself to developing and providing the most advanced fluid power technology available in order to give our customers the competitive edge they need in their field. 24/7 lights-out precision machining centers drive production, assure product quality and enable reliable delivery.

**Fabco-Air solves problems.
Let us help!**

FABCO-AIR – pioneering since the early years of pneumatics

The original Pancake® Air Cylinder

was developed 55 years ago to fit and work in cramped spaces where no other cylinder could. Today that Pancake® concept has



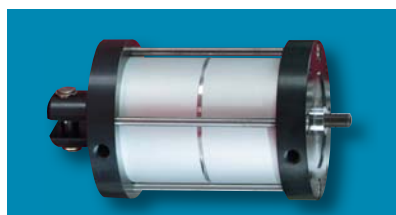
evolved into a major product line with three (3) body styles available in 8 bore sizes 1/2" to 4" and strokes to 4".

But Pancakes are only one of countless stories. Early fluid power history is filled with Fabco innovations such as Multi-Power® air cylinders.

3 body styles for Pancake® Cylinders

Multi-Power® Air Cylinders

Using only shop air pressure, **they deliver forces equivalent to low pressure hydraulic systems.** They cost far less, are cleaner, and are easy to install with only two port connections required. Available in sizes which produce forces up to 4 times that of a conventional, single piston air cylinder, these Multi-Powers can deliver tool-saving, low-impact forces from a few hundred pounds to over twenty-two (22) tons.



4 inch bore, 2-stage Multi-Power® cylinder yields forces to 24 times supply pressure.

Imagine what you could do with such forces so easily obtained in your shop!

You can now get Multi-Power® cylinders in five body styles with bore sizes from 1/2" through 12".



At the forefront of automation with engineered solutions

Sure, we have all the popular off-the-shelf pneumatic components you want, ready for immediate shipment. Everything from air preparation products through control valving to linear and rotary motion actuators. And every imaginable style of pneumatic gripper as well.

But almost 45% of our business comes from helping customers solve their design problems with special pneumatic solutions. In most cases, when asked for help with automation projects, we have been able to design, prototype and deliver custom samples within 48 hours!

We can do the same for you. We invite you to give us a try on your next project. **Fabco-Air solves problems. Let us help!**



advanced technology,
off-the-shelf pneumatics
and engineered solutions

pneumatic Rx for tricky design problems

**custom specials
prototyped
within 3 days**

Take a peek at a few approaches we have taken to help people solve their tough design challenges

Multi-Power® Linear Slide with Dial-A-Stroke®

Cylinder specifications:

4" bore x 5" stroke, Magnetic Piston, Hydraulic Shock and Speed Control.

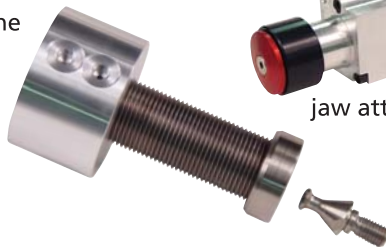
Dial-A-Stroke® enables precision adjustment of extend stroke.



Fabco-Air adapted a MULTI-POWER® air cylinder and a linear slide for high force and precision guiding in an automotive application. Capable of supplying 4,720 lbs. of force at 100 PSI, the unit has a custom mounting/bearing block with eight pre-loaded, sealed linear ball bearings supporting four hardened, precision guide shafts and a steel tool mounting plate.

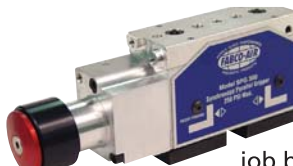
Double Acting Mold Lock Cylinder for Plastic Molding Application.

This cylinder actually pulls the stick down to the cooling platform with positive pressure rather than with a spring to give uniform cooling on overmold.



Dial-A-Stroke® Parallel Gripper for Packaging Application

This unique gripper allows the jaw opening to be adjusted on a per job basis, eliminating the need for special jaw attachments and speeding up change overs.



Round Hole-Through Cylinder for Synchronized Pick-up

Customer was trying to lift a product using 3 individual air cylinders with unacceptable results. Fabco-Air designed this "ring" cylinder that incorporates three piston rods with a single piston for smooth, non-binding actuation. Problem solved!



Dual Bore Air Cylinder

Cylinder specifications: 50 mm bore, 2" stroke, double acting, stainless steel piston rods, hard anodized aluminum body.

Unique design features integral nests machined into the cylinder body enabling precise alignment of customer tooling under tight space limitations.



FABCO-AIR solves problems. Let us help!
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Haydon Kerk Motion Solutions is the joining of two world-class brands in the field of linear motion; Haydon™ and Kerk®. Together, they offer a broad range of precision linear-motion products. Recognized as a leading manufacturer of precision Acme leadscrew and antibacklash nut assemblies, stepper-motor-based linear actuators, and linear-rail and guide systems, Haydon Kerk Motion Solutions offers high performance in demanding applications such as laboratory automation, medical instrumentation, semiconductor fabrication, electronic testing and assembly, and any other application where precision motion is critical.



The PITTMAN motor line spans a wide variety of DC motor sizes and technologies, ranging from miniature, brushless, slotless DC motors used in high-speed medical applications to large NEMA frame DC servomotors used in sophisticated automation equipment. If there's a need for precision motion, more than likely there's a Pittman solution that meets the requirements. Pittman Motors can be customized to meet just about any engineering need. Options include unique shaft configurations, various bearing systems, output devices such as pinions and gears, special lead-wire assemblies, EMI/RFI suppression networks, optimized motor windings, permanent-magnet options, and various brush materials.



Haydon Kerk Motion Solutions™ and PITTMAN® Motor brands are part of AMETEK Precision Motion Control, headquartered in Kent, OH (www.ametekpmc.com).

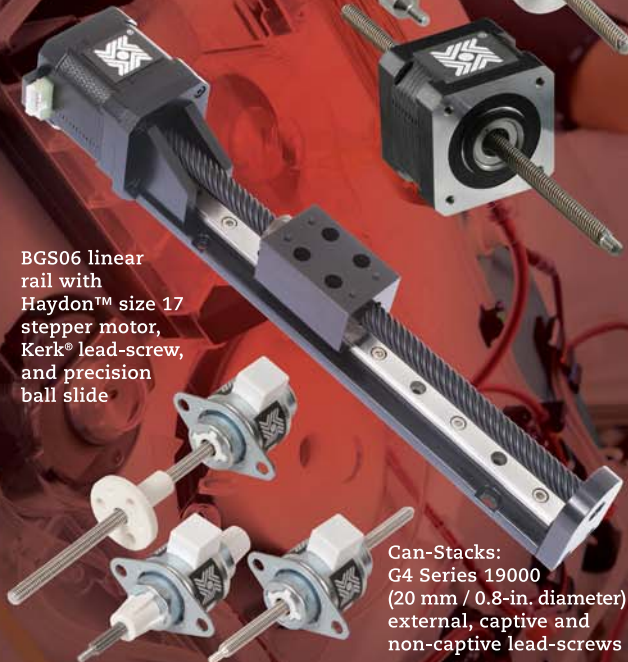
AMETEK®
PRECISION MOTION CONTROL

Haydon Kerk Motion Solutions: Experts in Linear Motion

Haydon™ Hybrid Linear Actuators: Size 17 (43 mm/1.7-in sq.) captive, non-captive, external lead-screws



BGS06 linear rail with Haydon™ size 17 stepper motor, Kerk® lead-screw, and precision ball slide



Can-Stacks: G4 Series 19000 (20 mm / 0.8-in. diameter) external, captive and non-captive lead-screws

Haydon Kerk Motion Solutions™ provides a broad range of sophisticated, application-specific precision motion control products including lead-screws/anti-backlash nut systems, linear rails and guides, linear actuator stepper motors and electronic drives. Hybrid motors range from 21 mm to 87 mm square (0.8-in to 3.4-in); Can-Stack diameters from 15 mm to 46 mm (0.59-in to 1.8-in).



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diam. DC brush
servo with
encoder



Automation
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brushless
57 mm (2.25-in)
NEMA mount,
rated IP65 with
integrated sensor
and motor
connectors



8540 Series
30 mm (1.18-in)
diameter DC
brush motor



High performance
slotless brushless
9.5 mm (0.375-in)
diameter



PITTMAN® offers a broad range of DC brush and brushless motors with various power ratings and sizes. Standard brushless motors include instrument grade, automation grade, and slotless motor configurations, and a series with integrated controllers. Options include encoders, brakes and gearboxes. Motors can be customized to accommodate any application-specific requirement.

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RS# 108



AutomationDirect sells over 12,000

feature-packed products through its Online Automation superstore and catalog. The company offers its customers high-quality automation products at prices typically below the industry average, same-day shipping on in-stock items, the best documentation in the industry, outstanding sales and technical support, and a 30-day money-back guarantee on nearly every product. Plus, orders over \$49 receive free shipping; some limitations apply.

Easier control implementation with the latest in PLC technology, plus FREE PLC programming software!

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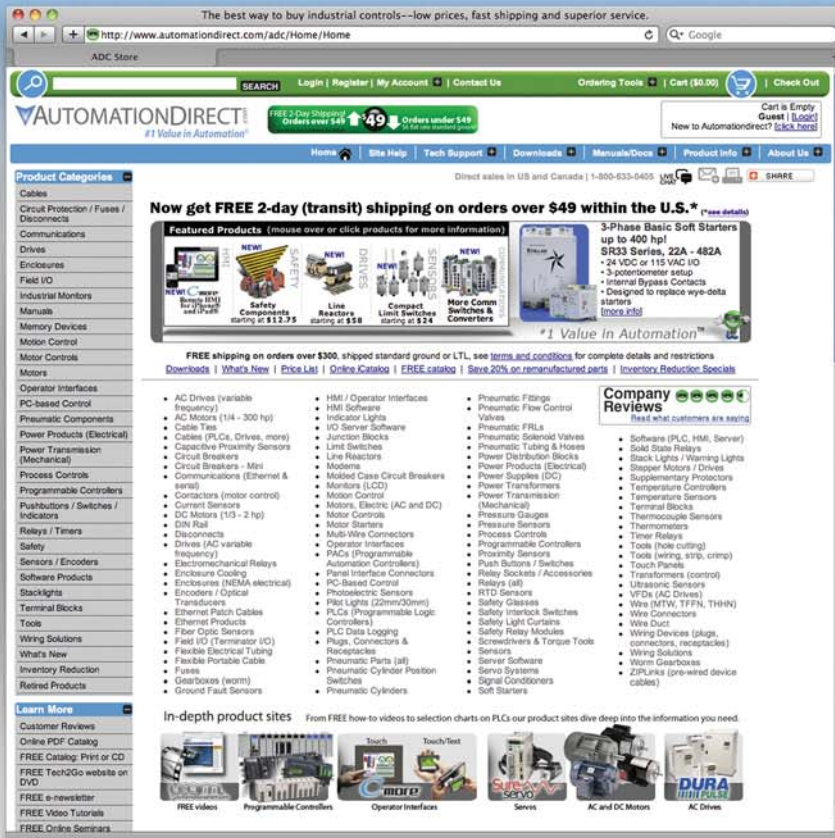
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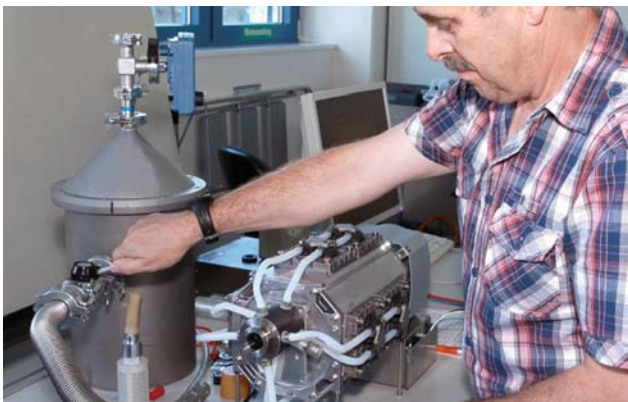
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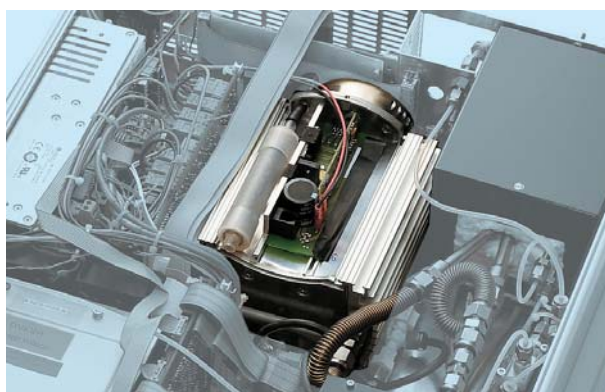
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Could gaming **revitalize** engineering **education**?

I confess that in my youth, I sometimes got bored sitting in engineering classes. It usually happened as I looked at a chalkboard full of equations and listened to a dry presentation on concepts that were hard for 19-year-olds to relate to. I often found myself wondering if there were easier ways of understanding all the stuff I was expected to retain.

It turns out I wasn't the only one who thought this way. A cadre of believers in an idea called gamification claim they know how to improve the educational experience. The underlying premise of gamification is that people are more willing to do chores that are relatively unappealing if the experience can be made more gamelike.

An example of what a little gaming can do for mundane tasks comes from a recently published book on the subject called *For the Win*. It's written by two World of Warcraft players who also created what they say is the world's first course on gamification at the Wharton business school. Authors Kevin Werbach and Dan Hunter describe a competition Microsoft created among its employees to ferret out translation mistakes in a Windows operating system. Workers earned points by spotting problems, and scores were posted on a leader board for all to see. Structuring the task this way, say the two Warcraft players, enlisted two key traits of good games: instant feedback via a point system and competition to be the top dog on the leader board.

Gaming techniques like these have more utility than just for scrubbing out software bugs. Gaming, in fact, has been a popular topic at the TED conference, an annual nonprofit confab devoted to spreading ideas in technology, entertainment, and design. TED presenter Jane McGonigal, a game designer and director of game R&D at a think tank called the Institute for the Future, points out that gamers spend about 3 billion hours weekly playing online. One reason for all this activity is that people are happier working hard at playing games than when they are just hanging out, she says.

People are also happier playing games than sitting in classrooms, which is why gaming applications in education attract a lot of attention at TED.

"School... is a game, it's just not a terribly well-designed game," says Seth Priebatsch, a TED presenter and developer at a game-creating firm called SCVNGR. "There are levels: A, B, C, and so on. There are statuses. I mean, what is valedictorian, but a status? If we called a valedictorian a 'white-knight paladin level 20,' I think people would probably work a lot harder... But let's apply (game concepts) consciously. Like, why have games that you can lose? Why go from an A to an F or a B to a C? That sucks. Why not level-up? At Princeton, they've actually experimented with this: They have quizzes where you gain experience points, and you level up from B to an A."

Let's hope engineering schools embrace gaming. After all, engineering programs at many universities experience 50% dropout rates because students have so much trouble with the curricula.

Opinions on how to add gaming elements to education should abound, simply because lots of game designers have experienced boring classrooms. "There's about 350 colleges around the world teaching video game courses. That means there's literally thousands of new ideas," says game designer and TED presenter David Perry.

And out of those thousands of new ideas, hopefully at least a few about how to teach concepts like rigid body mechanics in the form of a game.

— Leland Teschler, Editor

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TECHNOLOGY: The backbone of business

Industry leaders discuss the technologies they use to design and manufacture products.

Manufacturing companies of all types rely on technologies both to develop new products and add features and performance to those products. MACHINE DESIGN asked CEOs and CTOs of several companies in a variety of industries about the technologies behind their innovations.

What technologies have been important for your company when it comes to designing, developing, and manufacturing products?

Jay Mendelson, Omega Engineering Inc.: Our most successful design technique has been 3D CAD. We plan to expand efforts in this area by incorporating the latest version of SolidWorks 3D CAD into our mechanical-design process. We also plan on upgrading our electronic CAD package to a one that can properly lay out and simulate high-speed communication circuits.

On the manufacturing side, we've relied on hard automation for assembling our broad line of thermocouple connectors. This technology lets us compete on production cost with factories in China. We intend to continue to expand this effort and invest in automated welding and laser engraving for many of our transducers.

Alan Wosky, Belt Technologies: Lean manufacturing is a widely used term, but sometimes it serves as just a catch-all phrase for businesses. At our firm, however, it has become part of the culture. It lets us meet customer demands for

quality products, on-time delivery and, for us, their supplier, to be flexible at competitive prices. Implementing Lean Manufacturing's work cells and cellular-manufacturing principles has been key to our business growth. Grouping similar products into families based on similar processes and scheduling them to be manufactured in cells has

Panel of Experts

Here are the industry leaders who contributed to this article:

KEN LECHNER, vice president of engineering at Ametek Precision Motion Control. The company manufactures electronic instruments and electromechanical devices.

JAY MENDELSON, vice president technology, Omega Engineering Inc. The company sells devices that measure and control temperature, humidity, pressure, strain, force, flow, level, pH, and conductivity. It also markets data-acquisition, electric heating, and custom-engineered products.

CHRIS NOOK, CEO, Helix Linear Technologies, a subsidiary of Nook Industries. The company designs and manufactures Acme and leadscrews.

ANDREW WERTKIN, senior vice president and CTO, Parametric Technology Corp. PTC designs and sells software for product life-cycle management, computer-aided design, application life-cycle management, supply-chain management, and service life-cycle management.

ALAN WOSKY, president, Belt Technologies. The company designs and manufactures stainless-steel belts used for product fixturing, positioning, and timing for automated assembly.

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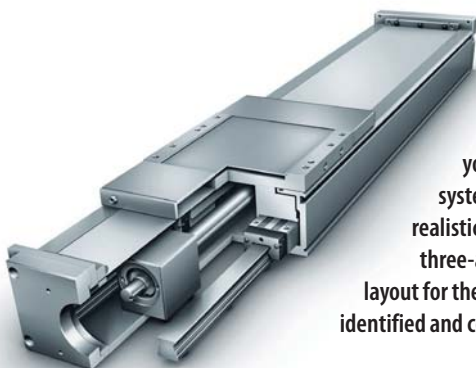
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Ken Lechner, Ametek Precision Motion Control: In recent years, we have used affordable, fast,

higher-end design tools such as magnetic, structural, and thermal FEA. They let us develop rotary and linear-motion devices and accessories that are smaller, more efficient, and cooler running than we could older design tools.

These new tools, combined with electronic document management, let engineers focus on the more-creative, higher-level aspects of design. Mechanical and electrical designers can also contribute at a higher technical level by using 3D modeling software that works with the CAD/CAM software, resulting in better use of our technical resources.

In the next few years, tools that enhance engineers' ability work collaboratively regardless of location will accelerate design as expertise from several locations can be used as needed. Ideally, this collaboration will also include customers' engineers, which would let component development be done at the same time as customer development.

Chris Nook, CEO, Helix Linear Technologies: We currently use 3D printers for rapid prototyping, FEA for evaluating new products, and laser measurement and metal injection molding to make parts. Many of our customers demand rapid-prototyped parts from us to stay on track with their product-development schedules.

What new technologies will you be embedding or using in future products and upgrades of current products?

Alan Wosky: We've been working on two primary initiatives. The first is to improve our welding to eliminate distortion by monitoring our state-of-the-art processes

and fixtures, and our employees' skills. This has let us handle new applications that require process surfaces that are extremely flat such as casting products onto belt surfaces.

The other initiative involves Teflon coatings on metal belts. We are working with suppliers to improve coating life, wearability, and resistance to corrosive chemicals. This initiative is being driven by our customers that make solar cells. They want higher productivity and increases in yield rate, and we help by supplying coated metal belts that last longer on soldering lines.

Jay Mendelson: We plan on upgrading our hardware and firmware in our transmitters, controllers, and signal conditioners to get better wireless communication and Internet access. It should also help customers get sensor information faster and make it easier to use software across the Internet.

Ken Lechner: The trend will be toward more complete systems combining motors, drives, encoders, gearheads, and brakes into the next level of customer assemblies. These cost-effective systems will make it easier for customers to focus on their own areas of expertise. Adding digital communications and user-friendly interfaces to motor drives will let customers quickly get motion products up and running in new applications.

New rotary and linear-motor products being developed will further improve circuit design, resulting in smaller, more-efficient, and more-powerful products without significantly increasing cost. However, the cost and supply of rare-earth-magnet materials will need to be taken into consideration as a major part of the cost and performance trade-offs made while developing newer permanent-magnet motors. New technologies that let motors meet efficiency and performance requirements using less-expensive magnets are key to the long-term viability of permanent-magnet motors.

"In recent years, we have used affordable, fast, higher-end design tools such as magnetic, structural, and thermal FEA to quickly develop rotary and linear-motion devices."



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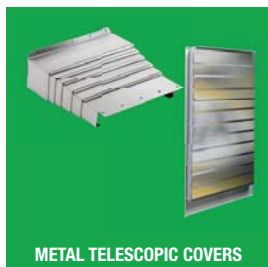
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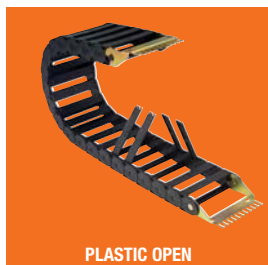
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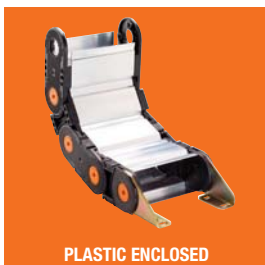
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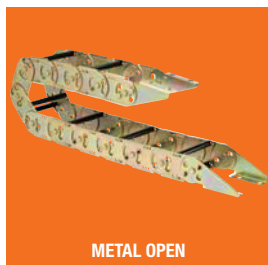
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Chris Nook: We are adding motors to more of our products, capitalizing on the rapid growth in the motor industry. For example, most of our linear actuators are currently shipped with a smart motor, letting us deliver an electromechanical actuator with a precision screw as the heart of the assembly. This gives customers an almost unlimited number of motion profiles for force, speed, and position.

And the electromechanical actuators we deliver today are truly on the bleeding edge of development. For example, we are coupling our new precision leadscrews with smart stepper motors to create a low-cost, high-performance actuator that is precise and clean for our OEM machine builders.

Where do you find the new technologies that go into new products? Similarly, where do you find the new high-tech tools to design and manufacture new products?

Ken Lechner: Staying ahead of the curve on new technologies and the design tools to implement them is essential to meet the competitive demands of the market. For motion-control technologies, participation in associations such as **SMMA** (the Motor and Motion Association), lets us network with key contacts in the industry and contribute to the future direction of motor technologies and design tools. Online resources and trade magazines are also essential for staying up to date with technologies in specialized areas such as motor design.

Andrew Wertkin, PTC: Many of our customers find inspiration for next-generation products in everyday

“Like many global companies, we communicate with customers and suppliers through trade shows, e-mail, and even print advertising.”

consumer electronics and the conveniences they provide. For instance, features that were typically reserved for smartphones are now common in devices such as cars. In fact, the car has become the ultimate mobile device, providing connectivity and “apps.” Automakers are also intelligently engineering less-expensive vehicles with fewer features. Drivers then add capability over time with small upgrades. In fact, suppli-

“We currently use 3D printers for rapid prototyping, FEA for evaluating new products, and laser measurement and metal injection molding to make parts.”

ers that were traditionally focused on consumer electronics are now seeing a tremendous demand from a broad spectrum of manufacturers trying to foster similar long-term relationships and brand loyalty.

Chris Nook: Most of the innovative technologies we leverage and capitalize on are found on the Web, in trade magazines, and by attending international trade shows. And we discover a surprising amount of innovative ideas when we explore industries outside our own.

Alan Wosky: Like many global companies, we communicate with customers and suppliers through trade shows, e-mail, and even print advertising. But working electronically through our Web site is critical. Many current and new customers come to us through our partners’ Web sites like **MACHINE DESIGN** and **GlobalSpec** to name a couple. Once a potential customer visits our Web site, they get a much better understanding of our capabilities and have a good idea on whether our products can be adapted to their applications.

Jay Mendelson. We use a variety of research tools to find new technologies. Our engineers, for example, have online subscriptions to magazines such as **MACHINE DESIGN**. Our employees in engineering societies such as **IEEE** and **ISA** use those Web sites to read articles about new technologies.

We also partner with consulting engineering firms to design some products. The resulting interaction between our engineers and consultants is one of the best ways to understand new design techniques. That’s how we get recommendations for new CAD packages. Sometimes we attend online seminars sponsored by major electronics-component manufacturers, or have their salespeople visit us to discuss their newest products. Lastly, our staff periodically attends industry trade shows such as **Design 2 Part**, or **ISA Measurement Science Conference**, attending seminars, or visiting the booths of manufacturing companies. **MD**



AL WOSKY



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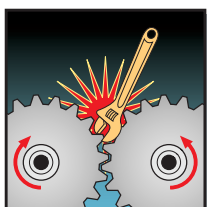
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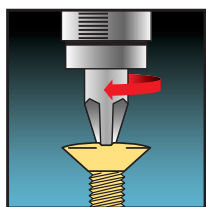


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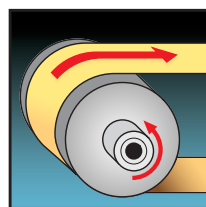
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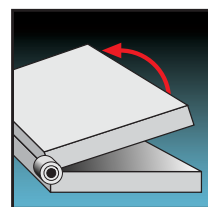
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Bimba Announces New "Blue and Improved" Original Line® Cylinders

Bimba Manufacturing Company, a provider of pneumatic, hydraulic, and electric solutions, announced a series of product enhancements to its industry-leading round line, nonrepairable Original Line® product series.

These changes include design modifications to further extend the catalog life rating of the cylinders from 1,400 miles to 3,000+ miles, as well as new product labeling and packaging.

"These design enhancements are the culmination of more than three years of product testing and communications with our customers. It will more than double the life of our Original Line®, enhancing the value to our customers of the industry's hardest-working, longest-lasting cylinder," says Jerry Scherzinger, Bimba's OL Product Marketing Manager. "Additionally, we are updating the look of the cylinder by replacing our preexisting red logo with an updated blue logo, as well as introducing new packaging that will be easier for customers to remove prior to installing our cylinders.

Scott Meldeau, Bimba's Vice President of Sales and Marketing says, "These changes reflect the aggressive corporate approach Bimba is taking to strengthen our existing products, in addition to developing new products to position us for future growth."



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* This life estimate may not include cylinders with design modifications, those exposed to harsh operating conditions or any unintended applications.



BEI Sensors specializes in speed and position sensors for extreme applications. With an extensive product offering including optical and magnetic encoders, Hall effect sensors, and potentiometers, BEI offers standard configurations to completely customized solutions. Through uncompromising quality, performance, and reliability, BEI Sensors upholds a standard of excellence in our products, customer service experience, and commitment to being a global leader in sensor technology.

Harsh industrial applications regularly expose critical equipment to mechanical stress, temperature extremes, moisture, dirt, vibration and caustic materials. BEI Sensors understands the need to have reliable encoders and sensors that offer high levels of performance no matter how severe the environment, and has engineered products to meet these challenges.



To protect encoders from corrosion in wet, salty or caustic environments, BEI has created an extensive range of stainless steel options. Several stainless steel types are available for the encoder enclosure and/or shaft, including 303, 304 and 316L. These encoders can be ordered as shafted or hollow-shaft, in incremental, absolute, and multi-turn versions. For operation in hazardous areas, ATEX certifications are also available.

In applications with extreme shock or high temperatures, BEI Sensors has utilized magnetic hall effect technology to develop its rugged position sensor line. The newly released Model 9960 rotary position sensor relies on this non-contacting Hall effect technology



and is packaged in a highly sealed (IP67) housing. With 360 degree turn capability, Model 9960 can be used over a large range of rotary motion making it extremely versatile. Available configurations include various termination options, single or dual outputs and 24 active electrical angles.

To meet today's automation requirements, BEI has developed encoders optimized for industrial

communication and available with the common fieldbus protocols including Profibus, CanOpen, and Device Net. These are ideal for industrial automation or process control such as packaging, food and beverage processing, medical equipment, transportation and building automation. BEI offers fieldbus encoders as absolute single-turn up to 16 bits and multi-turn up to 13x16 bits. A number of options for body size (58mm to 109mm) and mechanical configurations (shafted, through shaft or blind shaft) are available for ease of installation. Ingress protection ratings are offered at variety of levels (IP66 to IP69K) as well as stainless steel housing options to meet your particular environmental conditions. For those applications requiring operation within a hazardous area, BEI has developed fieldbus encoder models with an ATEX Zone 2 rating.



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The HELI-CAL Machined Spring employs the same HELI-CAL Flexure technology to provide the desired spring performance in compression, extension, torsion and lateral bending modes. The ability to produce multiple-start flexures solves many of the limitations associated with conventional springs. By design, the HELI-CAL Machined Spring can be configured to resolve moments during compression/extension, or provide pure moments when used as a torsion spring. The most demanding compression, torsion, and lateral spring applications can benefit from the HELI-CAL Flexure concept, and our ability to machine most modern high strength materials. OEM system designs can be

enhanced because the HELI-CAL Machined Spring provides increased precision, reliability and overall value.

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Flexible Couplings

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Founded in 1958 as the originator of the HELI-CAL® Flexure and located in Santa Maria, California, the company's facility manufactures the HELI-CAL Machined Spring®, Flexible Couplings and U-Joints to stringent AS9100/ISO9001 Standards. With more than 120 employees providing outstanding technical support and customer service, Helical Products Co. has become the standard for innovation by today's machine designer.

HELI-CAL Flexure is designed to transmit torque while compensating for angular misalignment, parallel offset, and axial motion between two shafts.

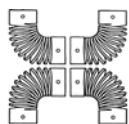
HELI-CAL Flexures are available in a wide range of standard flexible couplings to custom designed couplings, each engineered to meet the specific requirements of a unique application.

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Another significant advantage of Helical's Machined Spring, Flexible Coupling or U-Joint is the one piece construction, which enables integrating customer specified end attachments (tang, flanges, gears, removable caps, etc.) as well as unique bore configurations (D bore, hex, spline, shaft, etc.), all into a single machined piece.



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2012 Technology Showcase: Airfloat “Innovation in Movement”

Airfloat air skids offer the ideal versatile, modular system that can be customized to match practically any load configuration and weight. Utilizing our reliable air-bearing technology, air skids create a customized air pallet that allow one person to efficiently move any large, heavy load with minimal force — especially compared to heavy-duty casters.



Airfloat engineers have developed air skids from 10 to 54 in. with single-skid capacity from 500 to 60,000 lb per skid. Equipped with wear-resistant air bearings mounted on slide-out trays,

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Airfloat’s Series “L” and “XL” air platforms are ideally suited for applications requiring the movement of very large loads. These platforms have been successfully utilized within several operating environments including assembly



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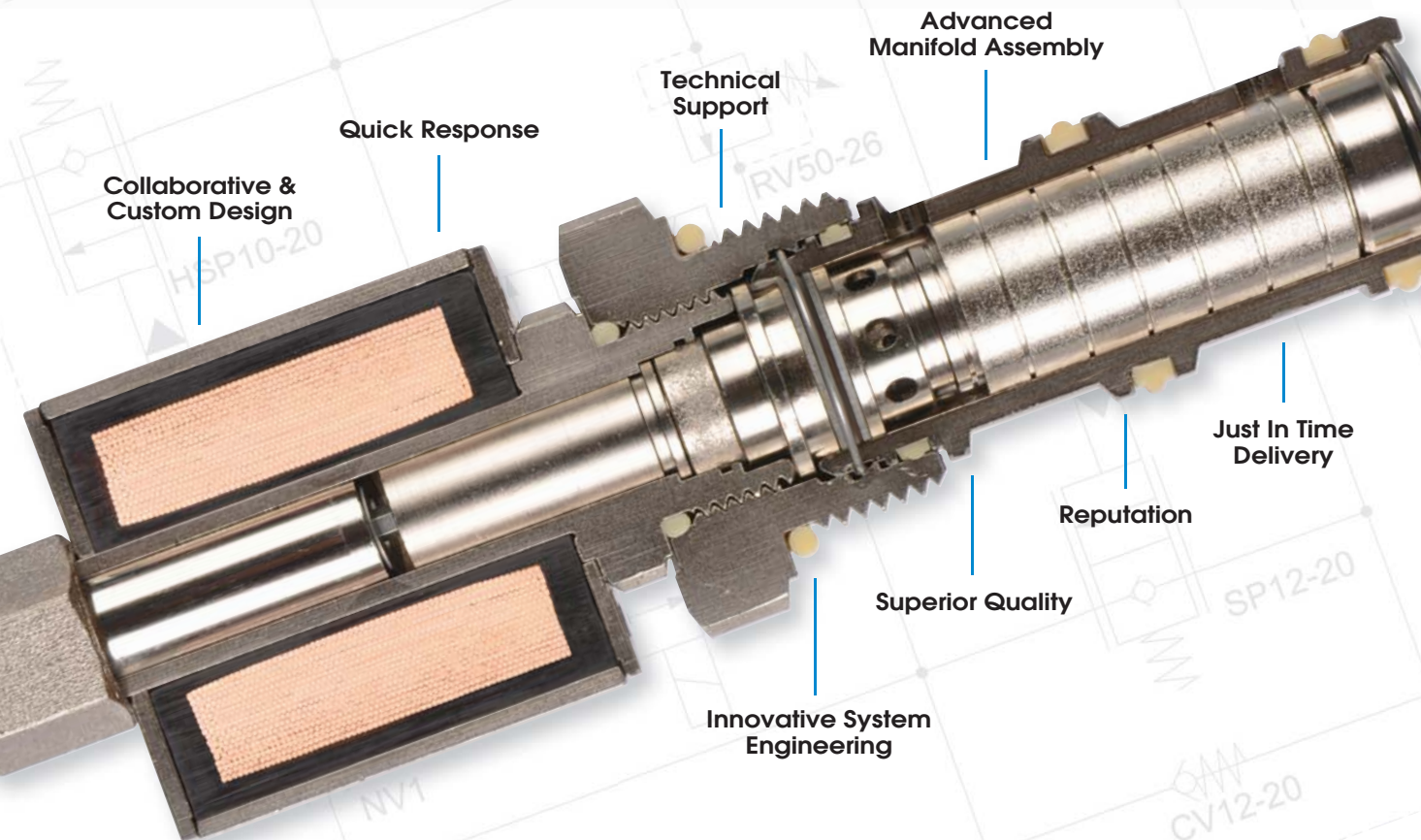
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HydraForce electro-hydraulic controllers and systems are rugged, reliable and field-proven. All their electronic vehicle control products are compatible with J-1939 and ISO-Bus, and suitable for heavy-duty operating conditions, including temperatures ranging from -40 to 85° C, and vibration up to 8 Grms (random) 24-200 HZ, 3-axis. Plus, their reliability has been proven through extensive testing, as well as years of real-world application experience in mobile, off-highway and material handling equipment.



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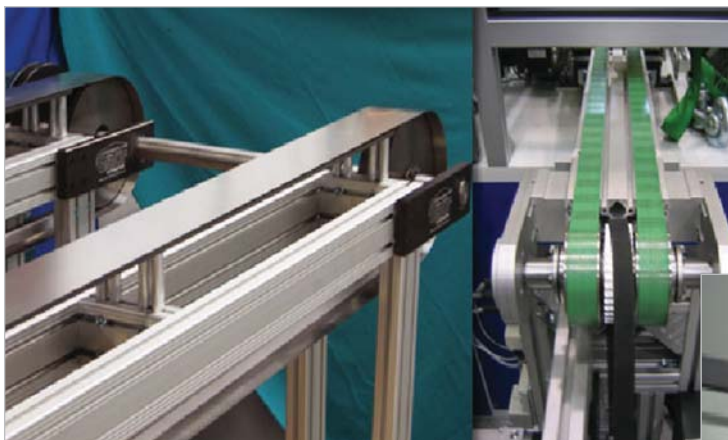
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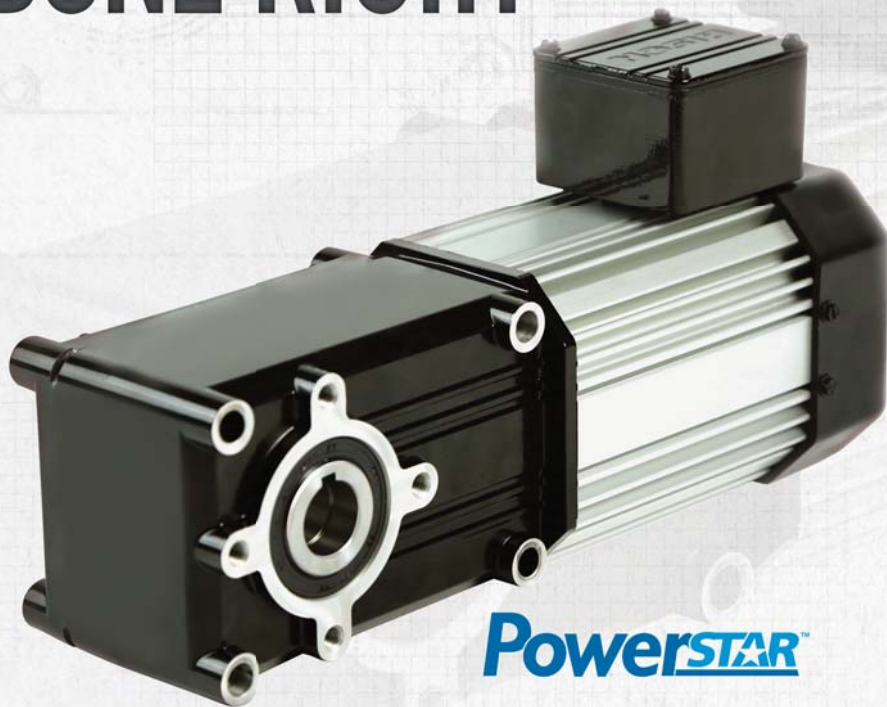


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The **Bureau of Labor Statistics** projects a need for 17,830 additional engineers each year for the next 10 years. That's about one-eighth of the total number of students awarded an engineering degree in 2011. Experts say that such a shortfall of engineering talent could jeopardize the health of American economy.

Demographics of newly minted engineers are changing but still don't match those of the U. S. population. Industry leaders say this is a problem. By many measures, Latinos are the fastest growing U. S. population segment. Yet Latino engineering enrollments aren't nearly enough to make up for a declining white engineering enrollment or the large number of retiring baby-boomer engineers. The **American Society for Engineering Education** (ASEE) data shows nearly 60% of engineering graduates in 2011 were non-Latino white. This is a 4% drop from 2010.

Meanwhile, the **National Action Center for Minorities in Engineering** (NACME) says the Latino population is expected to double and will represent one-third the U. S. population by 2050. ASEE reports only 8.5% of engineering degrees were awarded to Hispanics in 2011. The percentage of Hispanic enrollment in bachelor's degree engineering programs rose last year, but only went from 7 to 8.5%.

Latinos aren't the only minority that business leaders would like to see produce more engineers. But for other minorities, the statistics are even worse. ASEE shows the number of African American's graduating in engineering dropped slightly and only represents 4% of all engineering graduates. There is a chance this percentage could improve, but NACME forecasts no growth in the African American U. S. population through 2050. The same trend holds for American Indians who will continue to represent only 1% of the U. S. population in 2050. Statistics for American-Indian engineers are quite good. NACME says the number of awarded bachelor degrees in engineering to American Indians has more than doubled

over the past three decades. But that number is still under 500 graduates annually as of 2009.

On a positive note, the Asian-American population will help fill part of the engineering draught. Around 15% of U. S. engineering graduates are Asian American. ASEE sees steady growth for Asian Americans in engineering and NACME expects the U. S. population of Asian Americans to reach 8% in 2050.

Foreign students constitute another important source of U. S. engineers, though their enrollment has become

Authored by:

Lindsey Frick

Associate Editor

lindsey.frick@penton.com

Key points:

- Latinos will account for one-third the U. S. population by 2050, but they currently represent less than 10% of engineering students enrolled in 2011.
- Women represent about half the U. S. population and more than half of U. S. college students. However, women earn less than 20% of degrees in engineering.
- Community colleges are an untapped resource for potential engineering students.

Resources:

American Association of Community Colleges (AACC), aacc.nche.edu

American Association of University Women (AAUW), aauw.org

American Society for Engineering Education (ASEE), asee.org

The National Action Center for Minorities in Engineering (NACME), nacme.org

National Science Foundation (NSF), nsf.gov

National Society of Black Engineers (NSBE), nsbe.org

Society of Asian Scientists and Engineers (SASE), saseconnect.org

Society of Hispanic Professional Engineers (SHPE), shpe.org

Society of Women Engineers (SWE), swe.org

WebCASPAR database, webcaspar.nsf.gov

Women in Engineering Programs and Advocates Network (WEPAN), wepan.org

a political hot button. ASEE notes roughly 7% of students enrolled in a bachelor's degree of engineering programs are foreign. More importantly, these non-U. S. citizens represent about 40% of all engineering master's degrees and about 54% of all doctorates in engineering. In previous decades, it was common for many of these students to stay in the U. S. after completing their degree. Today, it is increasingly difficult for them to get U. S. visas, so many return home after graduation. Some think adding foreign engineers to the U. S. workforce depresses engineering salaries, but others say reducing the source of engineering talent is counterproductive.

Female engineers

Women represent half the U. S. population. They also represent more than half of enrolled college students. Yet ASEE data shows women earned only 18.4% of bachelor's degrees in engineering in Fall 2011. Organizations like the **Society of Women Engineers** (SWE) found the percentage of women earning engineering degrees has risen only slightly over the past few years. The million-dollar question is why more women aren't interested in engineering careers.

A coalition of the country's engineering associations conducted an interesting study called Extraordinary Women Engineers Project (EWEP) in 2004. They determined that almost equal percentages of high-school girls and boys take math and science classes. The conclusion from this data was that women's disconnect from engineering happens elsewhere.

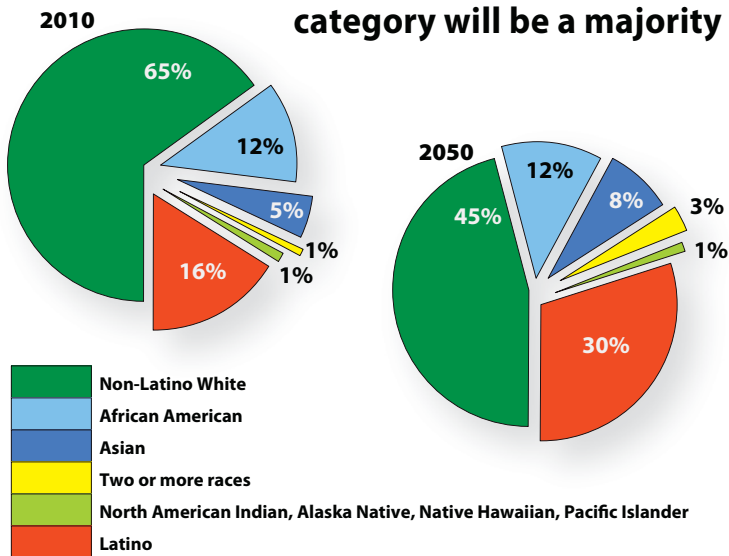
EWEP reports the problem is one of perception. Girls negatively stereotype the engineering profession because they don't know what it is about. Likewise, people like teachers, school counselors, parents, peers, media, and others who influence young girls may not understand engineering careers, either. The result is that engineering doesn't have a high profile.

EWEP polled young girls to find out what they want in a career. The findings weren't unlike what any student wants out of a career. Girls said they want their job to be enjoyable, offer a good salary, have a good working environment, be flexible, and provide an ability to make a difference.

A lack of knowledge about engineering disciplines could easily be the problem. SWE and other organizations like the **National Academy of Engineering** have been working to educate girls about engineering to break the stereotype. They do this by hosting programs such as design contests and camps, providing scholarships, and populating interactive Web sites like *engineergirl.com*.

A strong push for these outreach programs started

By 2050 no one race/ethnic category will be a majority



Source: NACME analysis of U. S. Census Bureau, 2011.

just over six years ago. Yet the percentage of females earning a degree in engineering hasn't improved more than a couple tenths of a percent. In fact, ASEE reported the 2011 percentage of women enrolling in engineering, roughly 18%, matched the percentage of women graduating with the degree. So only about 20% of women enrolled in engineering will graduate with a degree. Advocate organizations now wonder what factors could be stopping women from earning an engineering degree.

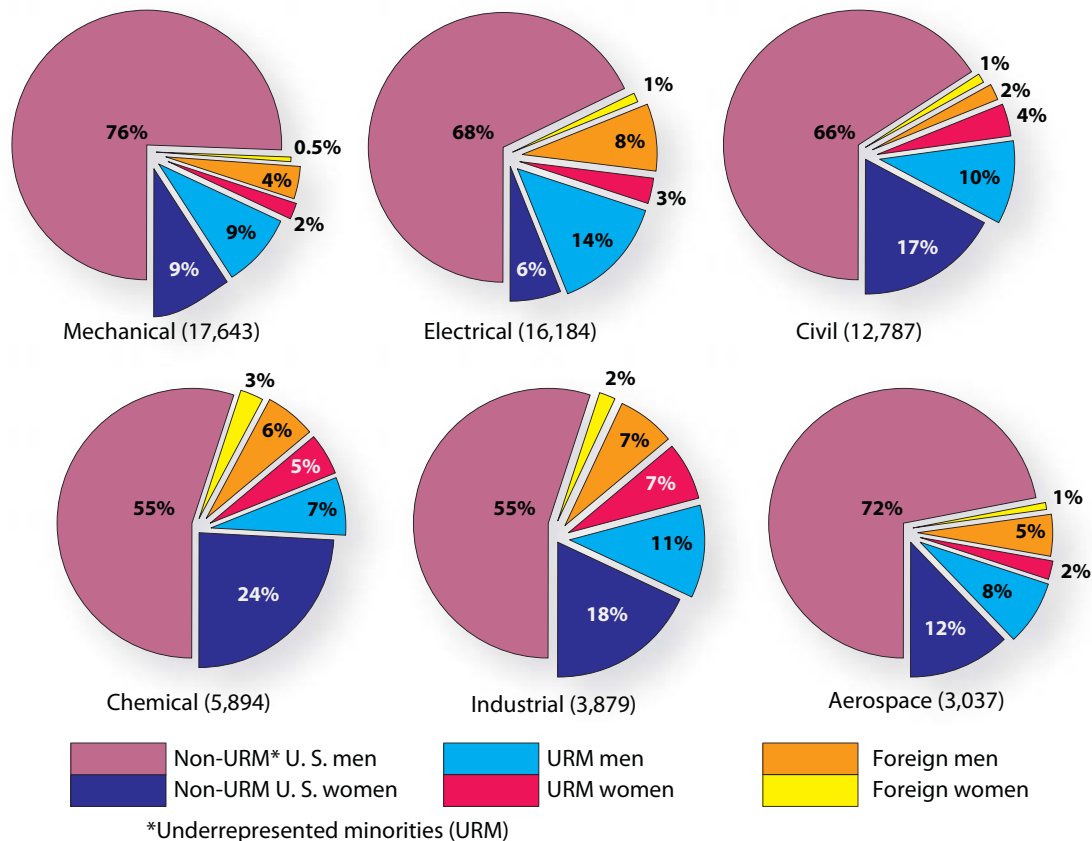
Something called a stereotype threat has been studied as a possible culprit. A paper titled "Why So Few" from the **American Association of University Women** (AAUW) says a stereotype threat can be felt as both psychological and physiological responses that result in impaired performance. The study talks about the testing performance of women and minorities exposed to stereotype threat. The AAUW paper found that over 300 studies published support findings that stereotype threat can be induced simply by asking students to indicate their gender or race before a test or by having a larger gender or ethnicity ratio in a testing room. In experiments, stereotyped individuals reread items more often and worked slower with less accuracy than non-threatened participants. In some cases, threatened students even had higher blood pressure levels.

Findings show women may be losing as many as 20 points on the math portion of the SAT simply because of stereotype threat. AAUW explains that 20 points on a test with a total possible score of 800 may seem small, but in 2008 the average score on the SAT math exam was 30 points higher for males than females. Thus, eliminating stereotype threat could eliminate two-thirds of the gender gap on the SAT math exam.

The study also shows that even high-achieving, moti-

Engineering bachelor's degree by discipline in 2009

NUMBER OF AWARDED BACHELOR'S DEGREES BY ETHNICITY AND GENDER PERCENTAGE



Source: NACME analysis of Integrated Postsecondary Education Data System data accessed via NSF WebCASPAS database system, June 2011.

vated women working towards STEM careers are susceptible to stereotype threat. This idea was tested by telling female and male students in a high-level calculus course that an upcoming difficult math test was a diagnosis of their ability. Both genders performed about the same on the test. The threat was later removed by telling students that women and men perform equally well on the test. The women performed significantly better than the men on the test.

Filling the pipeline

Engineering organizations agree students in K-12 who have access to high-quality math and science are better prepared for college. So part of the plan to get more minorities in engineering is to improve their pre-college education. This is a difficult task. NACME says fewer than 8% of Latino, African-American, and American-Indian high-school seniors take calculus versus 15% of Non-Latino whites and 30% of Asian-American seniors. Even worse, 20% of Latino males and 14% of Latino females drop out of high school.

Community colleges are another education source that have an impact on attracting and retaining engineer-

ing students. NACME says engineering schools have yet to fully tap the potential pool of community college transfer students.

Christopher M. Mullin, a program director for policy analysis at the **American Association of Community Colleges**, recently studied the importance of community college. He found that 28% of bachelor's degree earners started at a community college. Forty-seven percent of students earning a degree took at least one course at a community college. Over the past nine years, students who transferred from a community college to a private or public four-year institution are estimated to have saved \$22.5 billion in tuition fees.

NACME sees the direct link from community colleges to minorities in engineering. Fifty-five percent of all Latino undergraduates were at a two-year college in 2008, and there are similar trends in the African-American and American-Indian communities.

It will be interesting to see how organizations and schools plan to change the demographics of engineers over the next few decades. Hopefully the education, outreach, and communication they have already started will kick into gear. **MD**



Motor know-how!

TECHNOLOGY SHOWCASE

43 ... Motor know-how!

60 ... Elements of CAD

66 ... Advances in fluid-power efficiency

Think you know electric motors? Check your knowledge against these devices.

Electric motors are by far the most-common method used to convert electrical energy into mechanical motion. To provide motion, most motors use attraction and repulsion of magnetic fields to create the force needed for movement. But the generation of those fields and their method of interaction gives rise to literally dozens of motor designs.

Ac induction motors

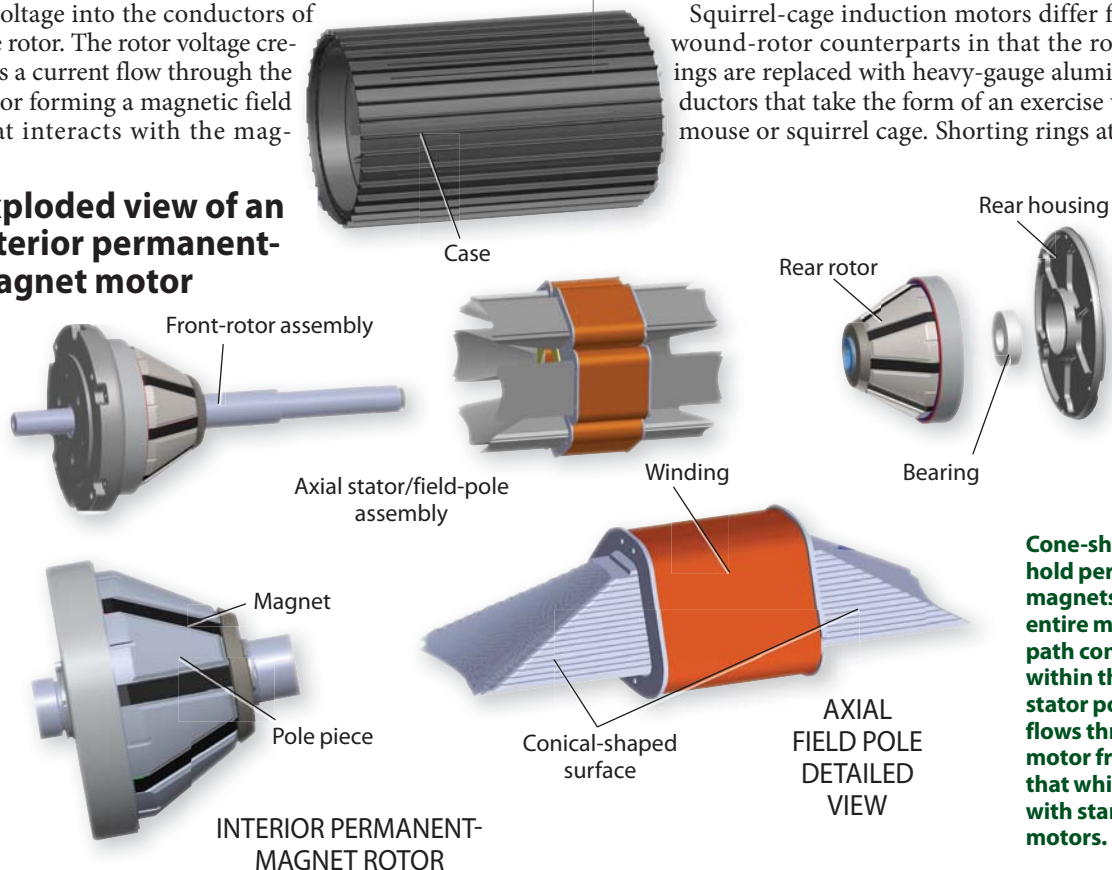
Standard induction motors have been in use for over 100 years and are reaching the limit of improvements in both performance and cost. In an induction motor, a stator winding wound on the outer frame of the motor induces a voltage into the conductors of the rotor. The rotor voltage creates a current flow through the rotor forming a magnetic field that interacts with the mag-

netic field of the stator to make the rotor turn.

Induction motors are classified by how the conductors in the rotor are formed. The two primary types are a squirrel-cage induction motor (SCIM) or a wound-rotor induction motor (WRIM). In the WRIM, the windings are actual coils of wire wrapped around the rotor's laminated core. The wire is typically brought to the outside of the motor through a series of slip rings. When starting, a resistance is placed across the rotor windings to limit start-up current in the rotor. As the motor comes up to speed, this rotor resistance is lowered until it reaches $0\ \Omega$ and the windings are shorted. This produces maximum torque in the motor.

Squirrel-cage induction motors differ from their wound-rotor counterparts in that the rotor windings are replaced with heavy-gauge aluminum conductors that take the form of an exercise wheel in a mouse or squirrel cage. Shorting rings at each end

Exploded view of an interior permanent-magnet motor



Cone-shaped rotors hold permanent magnets with the entire magnetic path concentrated within the rotor and stator poles. No flux flows through the motor frame like that which occurs with standard PM motors.



of the rotor complete all electrical connections between the conductors passing through the rotor.

SCIMs have several inherent advantages. First, they are simple to build and are robust and reliable. Second, they naturally adapt to the load placed on the motor. Current rises as the load increases while the motor's natural slip accommodates torque spikes. Through agreements between motor manufacturers, induction motors come in standard sizes and mounts that promote interchangeability.

The primary speed of an induction motor is based on the frequency of the ac power line, rather than the applied voltage. This means for fixed-speed applications, ac induction motors can be driven directly from the ac power line without the need for any electronic drive. However, most applications can show sizable energy savings through the use of an electronic drive module.

In applications where variable speeds are advantageous, a variable-frequency drive is mandatory for all but the smallest of induction motors. Once a motor drive has been added, though, the cost differential between an ac induction motor and that of a permanent-magnet motor becomes only the cost of the motor. The cost of the drive for either motor type is pretty much the same.

Induction motors operated with an electronic drive can reach speeds four times that of the motor's base speed while still maintaining a constant horsepower. This is possible because ac induction motors do not generate a fixed back or counter-EMF (electromotive force) in the rotor that builds up with higher rpms. Upper speed limits are based purely on the mechanical design of the motor, with centrifugal force being the prime limiter.

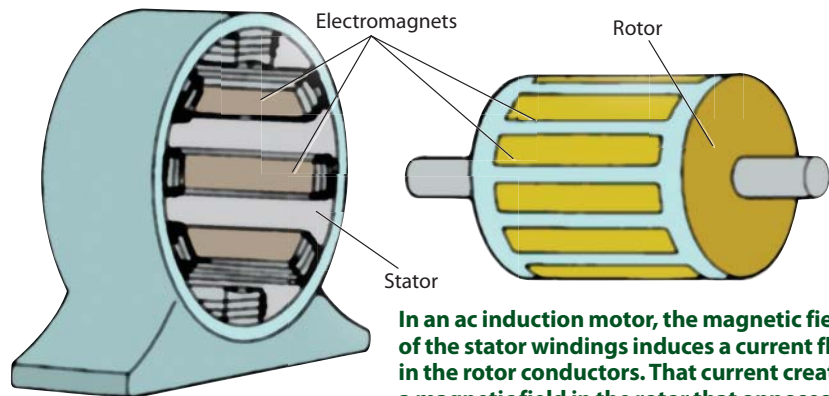
Generally, making induction motors more efficient means adding more copper and steel. The drawback is that this approach makes the a motor bigger and more expensive.

One recent move for improved efficiency replaces the standard die-cast aluminum conductors in induction motor rotors with rotors using copper as the conductor. However, both the cost of copper and the high-temperature processing of copper entails higher manufacturing costs.

Unfortunately, induction motors are not without disadvantages. One is that across-the-line starting lets induction motors draw high peak currents that can reach seven to 10 times normal operating currents. Obviously, these current surges can affect other devices on the power grid. Most modern installations use soft starters to mitigate this condition.

Induction motors also typically have a poor power fac-

Ac induction motor frame and squirrel-cage rotor



In an ac induction motor, the magnetic field of the stator windings induces a current flow in the rotor conductors. That current creates a magnetic field in the rotor that opposes the stator field, and the rotor spins.

tor in normal operation. Utility companies may require the installation of power-factor correction equipment for larger motors. And most of the power loss in an induction motor is in the rotor, which typically relies on air for cooling. The act of moving air through the motor housing for cooling leads to windage losses. Other losses can include resistive or copper losses as current flows through the stator-winding resistance, magnetic losses through stray magnetic paths, and the effect of hysteresis in the motor iron.

Dc-brush motors

This low-cost, easy-to-use motor still dominates many applications. Traditional dc-brush motors are by far the most-economical design for small devices. They're used in numerous applications including toys, auxiliary motors in cars, hand-operated devices, and other consumer items. However, industrial usage for this type of motor has been on the decline.

In a dc-brush motor, power is delivered to the rotating armature coil via a commutator, a segmented copper disk that mechanically connects the proper winding with the proper polarity to keep the motor turning. Power is delivered to the commutator through brushes typically made of carbon in small motors or copper-impregnated carbon in larger motors.

Operational issues with this motor include: brushes and commutators wear out and must be replaced periodically; most of the power loss is in the rotor, which has a poor thermal path; and, the efficiency curve peaks at one operating speed and load for a fixed-brush commutation angle. The efficiency falls off rapidly as the motor operates away from this point and is quite poor at speeds of one-half and twice the value of this operating point. Efficiency at the maximum power output of the motor is far below that of its peak efficiency.

Brushless permanent-magnet motors

The dominant design for brushless-dc permanent-magnet motors (BLDC) is a radial design specified as to

whether it's an inner-rotor-radial or outer-rotor-radial. Basically, this means the inside of the motor rotates (inner-rotor) similar to your typical motor or the outside of the motor rotates (outer-rotor) as used on some fans with the blades attached directly to the outer rotor. Permanent magnets embedded in the rotor interact with the magnetic field generated by the stator windings to produce torque. Basically, it's the exact opposite configuration of the brushed-dc motor.

The design concept of BLDC motors is mature, well developed, and supports many different applications and construction materials. Brushless-PM motors need an electronic drive controlled by magnetic sensors in the motor to replace the brushes and commutator, but this is not as big a disadvantage as it used to be. For the most part, drive costs have dropped significantly in recent years.

One issue any PM motor has is a pronounced back or counter-EMF that rises with motor speed. When motor speed reaches a point where the back-EMF matches the drive's available bus voltage, motor speed cannot rise any further. (There is a way to get slightly more speed with a timing adjustment that will be covered later.) This speed limitation presents a problem for traditional PM motors.

The electronic commutation for these motors can be altered to attain higher speeds, similar to changing the timing on a spark plug in your automobile. However, current demand increases dramatically when operated in this mode. This timing advance is most often used for applications that need high speed at low torque combined with a lower-speed/high-torque requirement. This type of operation is typical of a washing machine with a low-speed wash and a high-speed spin cycle.

A relatively new design which gets around this speed limitation problem is called an interior permanent-magnet (IPM) motor design. IPM motors typically employ less-expensive rectangular magnetics rather than magnets curved to fit the circular rotor surface. The magnetic blocks are slid into slots in the laminated rotor core. Magnet retention is enhanced and it simplifies the manufacturing process. IPM motors use both the permanent-magnet torque and reluctance torque. This reduces or eliminates the limitation of motor speed imposed by back-EMF and drive-bus voltage.

The standard radial motor has a single stamping for the stator that includes slots for the windings. Recently, the development of segmented or cut-core designs with concentrated windings has produced motors that perform better than the standard design. High-pole-count motors with radial-facing magnets and poles are also gaining acceptance. High-pole-count brushless motors need control electronics that switch at higher rates to maintain the same rpm as lower pole-count motors.

Some radial BLDC PM motors have their rotor on the outside. This design was first introduced in small fans operating on a low dc voltage, such as the 12-Vdc cooling fans commonly used to remove heat from computers and other electronics. In these small fan motors, the rotor con-

sists of magnets or a magnet ring inside a cup. The cup fits over the stator. This same concept has been used for disc-drive spindle motors for almost 30 years. Putting the rotor magnets on the outside intensifies the total magnet flux and also enlarges the air gap diameter for greater torque density.

Though torque density improves due to the larger radius of the rotor, the stator with the heat-generating windings is now on the inside of the motor, where it is more difficult to cool. This configuration works best with short axial lengths having enough surface area on the stator and a conduction path to remove the heat. Long stack lengths prove a challenge to cool when the only heat path from the stator is through the stationary shaft.

An application that is well suited for this type of motor is the direct-drive washer motor which is about 12 in. in diameter and 2-in. long with ferrite-magnet arcs on the inside diameter of the outer rotor assembly. The stator bolts to the stationary part of the washing machine and the rotor is attached to the rotating drum. The stator mounting provides a good heat path to the washer, and there is a large surface area, so it's not difficult to cool the motor. This direct-drive approach keeps motor speed and noise low, even with spin-cycle speeds over 1,200 rpm. A belt-drive motor running at 15,000 rpm for the spin cycle is noisier than the 1,200-rpm direct-drive motor. The quiet operation and elimination of belts, pulleys, and transmissions has made direct-drive washer motors the preferred design of most Asian appliance manufacturers.

Standard axial permanent-magnet motors

Axial permanent-magnet motors have been around for several decades and typically have a form factor like a pancake: large diameter and short length. The advantages of axial motors over radial motors include an output torque that rises with the cube of the motor diameter while the length of the motor has no appreciable effect on output torque. This gives axial motors a big volume advantage for high-torque, higher-power applications.

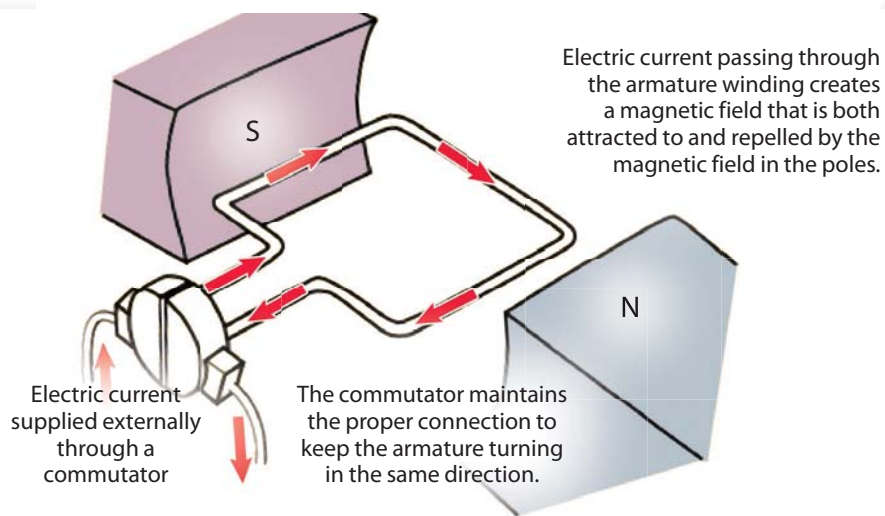
Axial motors have their windings exposed to the outside boosting thermal performance. In addition, they can use a relatively inexpensive bobbin-style winding while substantially enhancing motor reliability. The flux path is straight through the poles of an axial motor without intervening case metal as seen on standard motors. This reduces flux leakage and lets motor designers use better performing grain-oriented magnetic steels. The winding incorporates a more-optimal shape in that the winding perimeter is small for the enclosed area. More winding volume may be added by extending the length of the motor to boost efficiency.

Despite all these advantages, axial motors are still a limited niche, mostly because they need rare-earth magnets. Until the price of neodymium-iron-boron (NdFeB) magnets dropped to reasonable levels, these motors were far too expensive for most applications.

The pancake form factor of standard axial motors limits them to applications where that form factor is advanta-



Commutation in a dc PM motor



A dc motor passes current through the armature winding that creates a magnetic field that is both attracted to and repelled from the field poles. A commutator keeps the current flow proper through the armature winding to maintain proper polarity of the magnetic fields.

geous. Most applications need (or, are typically designed for) a motor with a radial form factor, where the motor is longer than the diameter. The axial forces developed on the rotor of this motor forces both axial and radial rotor positioning by the bearings. Also, many axial motor designs use a high pole-count that produces many individual parts to manufacture, inventory, and assemble.

Switched-reluctance motors

While reluctance motors were one of the first types of motors to be developed in the early to mid 1800s, they fell out of favor as newer designs provided greater power and efficiencies. This class of motors was revived in the 1970s with the promise of performance equal to that of permanent-magnet motors without the cost of permanent magnets. However, several problems arose that hampered their development.

First, to boost power density, these motors must operate at high flux levels and need to use small rotor air gaps. These two conditions created a noisy motor that was difficult and costly to manufacture. A second factor is that standard motor drives won't power switched-reluctance motors. The drive and motor must be an integrated design as drive characteristics greatly influence motor performance. This also leaves the user totally dependent on a single manufacturer, because the motors and drives are not interchangeable. Induction motors and permanent-magnet motors can use the same standard commercially available drives with a simple software switch, many alternative motor and drive sources are available.

The switched-reluctance motor has found some specialized applications, but even now is rarely used. SR motors are designed for specific needs or applications, so they

are not available in standard sizes. But advances in IPM designs, which take advantage of both permanent magnet and reluctance torque, eliminates many of the reasons for using SR motors.

Stepper motors

Stepper motors are yet another version of variable-reluctance motors. They are high-pole-count motors, on the order of 50 or more poles. The most commonly used stepper motor carries 200 poles. The most widely used type, the hybrid stepper motor, contains a permanent-magnet assembly in the rotor. This type of motor takes discrete steps of motion and is generally limited to speeds below 2,000 rpm.

The advantages of stepper motors include high torque for the size of the motor, a simple low-cost drive and motor, and simple position control. Disadvantages include low speed, significant loss of torque as speed rises, strong resonances at specific frequencies, high noise, and low efficiency with respect to load variations. To get high torque, stepper motors are constructed with small air gaps, often in the range of 0.1 to 0.2 mm (0.004 to 0.008 in.).

In-hub wheel motors

Many axial motor designs are focused on in-hub wheel motors for vehicle traction applications. The natural pancake form factor of standard axial motors has led to this focus. The in-hub simplicity appeals at first look, but there are significant challenges to its implementation.

First, remember that electric motors develop power as a product of torque times speed. As wheel rotations rarely exceed 1,000 rpm for normal vehicles, motors would need significantly higher torque to produce a reasonable power output. Therefore, low-speed wheel motors must be substantially bigger, use more materials, weigh more, and cost more than high-speed motors. While higher-speed motors do need a gear drive to reduce speed, gear drives are reliable and relatively inexpensive.

Second, electric motors are precision devices with closely controlled mechanical air gaps which are sensitive to dirt and particles collecting in the gap. PM motors are especially prone to this issue because any magnetic particles (steel, for example) are directly attracted into the gap by the magnetic fields. Brake rotors on the wheels generate these magnetic particles as they wear, which means the motor must be perfectly sealed while still allowing free rotation.

Motors are also sensitive to water damage through

wear and corrosion. Bearings especially do not take well to water and, therefore, need special sealing.

The amount of heat generated by these motors mean all need at least forced-air cooling, and some require liquid cooling. In fact, many automotive motors require liquid cooling and all need forced-air cooling at a minimum. How this cooling is to be accomplished when mounted on the wheel is also unclear. In addition, the power and control leads must be cabled out to the wheels.

The handling of a car depends on the sprung weight of the wheels. Motors are relatively heavy components and placing them on the wheels adds to the sprung-weight problem.

Radial motors designed with very-short stack lengths and relatively large numbers of poles can create high-torque pancake motors that can be used for low-speed, high-torque applications such as in-hub wheel motors. But the disadvantages of this design are similar to the axial configuration. High torque requires the use of rare-earth magnets. The high-pole count also produces a large number of discrete parts that need assembly.

Other motor types

There are other special motors that are worth mentioning. Homopolar motors find interest in very-large motor applications, typically greater than 1,000 hp. The Navy has investigated this motor in a superconducting version for ship power, but the motor currently does not have any commercial applications. The name homopolar indicates that the motor has only one electrical polarity. That is, the magnetic polarity of the motor does not change so no commutation is needed.

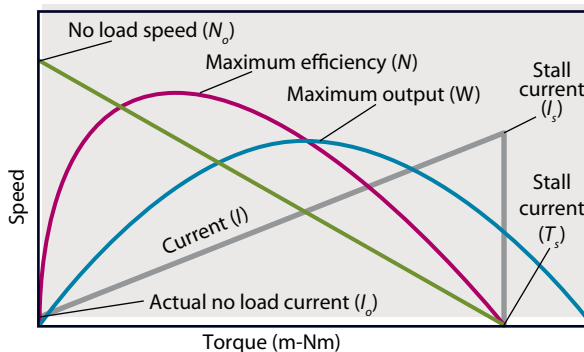
Linear motors take a traditional motor design, either radial or axial, and essentially unroll it so motion follows a straight line rather than circular. Linear motors are the fastest-growing area within motor applications, and they are being used for machine automation, conveyors, and moving parts through factory warehouses.

Magnetic levitation (mag-lev) motors are a special version of linear motors. The magnetic field of the motor not only provides motion, but lifts or suspends the armature (the part that moves) such that it no longer touches the fixed windings of the guide track. The primary use of this type of motor is in transportation vehicles such as trains and monorails. However, today it's also finding new applications in factory conveyor systems.

A word about rare earths

Rare-earth materials, such as those used in samarium-cobalt and neodymium-iron-boron magnets, dropped dramatically in price from their development in the late 1980s. Many companies started to introduce motors incorporating these high-performance magnet materials. Because of their high energy product, rare-earth motors

Torque versus speed dc-brushed motor



This chart shows the typical response of a brushed-dc motor using a fixed brush commutation angle. Note that motors don't operate at maximum efficiency when at maximum output power.

were smaller and weighed less than equivalent-sized induction motors. In addition, they used less copper and steel for a lower materials cost. Even as copper and steel started going up in price, the cost of rare-earth magnets continued to drop, offsetting the other expenses. Rare-earth motors could still be made less expensively than induction motors and ferrite-magnet PM motors.

Trends in efficiency improvements

The traditional way to improve motor efficiency is to use more and better materials. For example, using higher-quality steel with lower core loss or thinner laminations for motor construction raises efficiency. Another approach is to use more steel, thereby lowering flux density, losses, and allowing room for more winding material to reduce resistance and conduction losses. Any of these approaches mean higher manufacturing costs.

For induction motors, one of the most notable changes is the move from cast-aluminum rotors to cast-copper rotors. This can raise efficiency by about 1% at 3 hp. However, the cost of cast-copper rotors is significant.

Another approach uses an electronic drive to operate motor systems at variable speeds. For many applications, this has the greatest energy savings potential. Some systems can save 50% or more of the total energy consumed by a fixed-speed system without an electronic drive. The cost of adding the electronic drive to vary motor speed is quickly recouped with the savings from lower energy consumption.

There is currently a strong trend in product design to change from induction and universal motors to using permanent-magnet motors with electronic drives, even in some fixed-speed applications. This is because permanent-magnet motors can have higher efficiency and smaller size for the same output power. This saves on energy costs and can reduce overall product size and weight. **MD**

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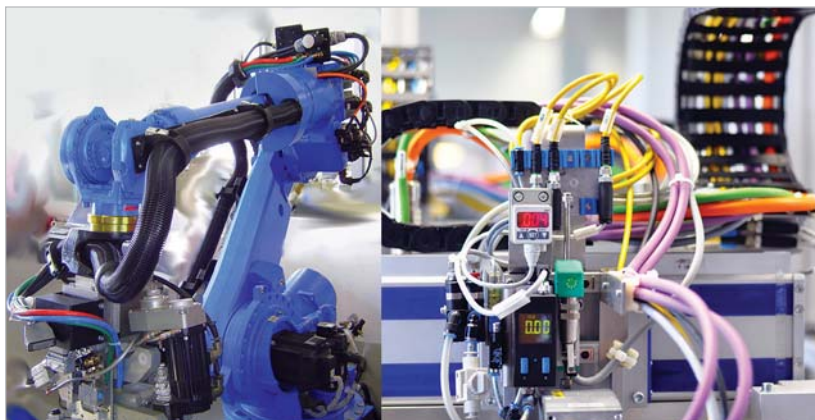
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TRAYCONTROL® 600 & 600-C



TRAYCONTROL® 600:

This flexible, oil-resistant PVC power cable is designed for open installation (TC-ER) in machinery and industrial plants. It is UL/CSA and NFPA 79 approved, UV resistant and flame retardant, and is suitable for Class 1 Div 2 or outdoor applications. It comes in gauge size 18 AWG – 500 kcmil.



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This multi-norm control cable has five international approvals, UL, CSA, HAR, CCC, and GOST-R, and can thus be used in machinery intended for the USA, Canada, Europe, China, and Russia. It was specifically designed for machine-tool manufacturers who export, allowing them to seamlessly integrate one control cable into equipment

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Since launching the world's first digital DC drive over 30 years ago, Control Techniques also introduced the first fully-integrated, easy-to-program servo drive, the first universal AC and Servo drive, and was among the first to offer an AC flux vector drive.

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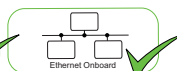
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EPIC® ULTRA features an integrated brush-style cable gland, which provides a fast and easy method to terminate a cable shield with a 360-degree, low resistance contact area. Along with the nickel-plated housing, this forms a conductive shell—or Faraday cage—around the electrical contacts to virtually eliminate electrical interference.



New ÖLFLEX® VFD Cable For Reliable Precision Control

Nowadays, variable frequency drives often serve in mission-critical process control applications, and when they go down, they can bring production lines to a standstill. Our engineers have recently taken steps

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They have developed a new cable that creates extremely robust power connections between VFDs and motors. Called ÖLFLEX® VFD XL, this shielded motor cable offers mechanical and electrical properties beyond those offered by standard AWG motor cables. Among the improvements:

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- Cross-linked polyethylene insulation provides a lower dielectric constant to improve the purity of the signal.
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- Shielding Resists Noise.
- Combination of triple-laminate foil tape and 85% braid coverage offers enhanced shield effectiveness that eliminates external noise problems and internal signal disruptions.

ÖLFLEX® VFD XL has UL and CSA TC approvals. Recommended applications include VFD drive and motor connections for web presses, HVAC systems, conveyors and many other types of industrial machines.

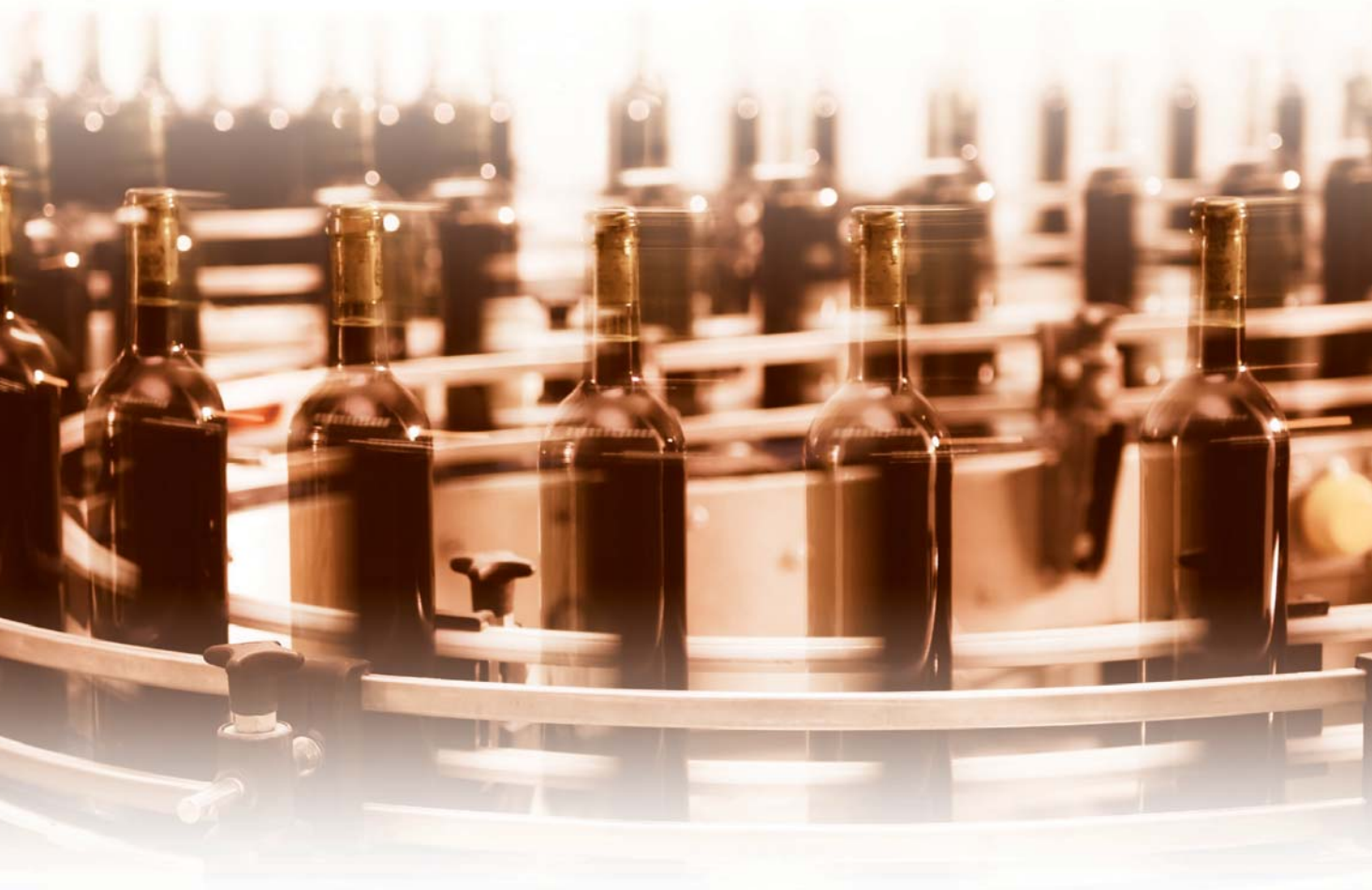


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Elements of CAD

The math behind CAD

Understanding how mathematical concepts apply to CAD can help you design visually appealing products that evoke an emotional response. Regarding a product's "good looks," the most important aspect of any design geometry is its surfaces. Creating attractive surfaces requires the application of curves. Recall that taking the derivatives at points along a curve tells a lot about its shape. Derivative properties are often referred to as continuity.

The first derivative of a curve is the tangent, a straight line drawn along the curve that tells the direction of the curve at that point. The first derivative is useful for seeing if the curve is level or matches another curve's direction at a particular point.

The second derivative provides the curvature at any given point, useful for knowing the precise shape of the curve. Where curvature changes from positive to negative or concave to convex there is an inflection such in as the middle of an "S." Curvature and inflection are important in the aesthetics of a surface because they influence how light is reflected to the eye.

The third derivative describes the acceleration or the rate of change of curvature along the curve. Even attributes as subtle as how smooth the changes are in the 2nd or 3rd derivative can have an effect on the curve and overall aesthetics. Smooth changes are more desirable from an aesthetic point of view.

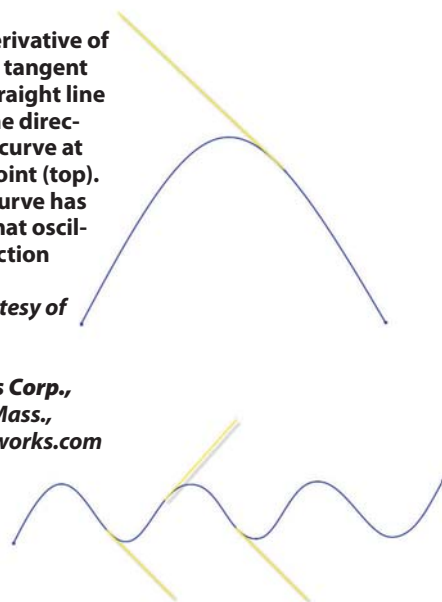
The same concepts that apply to curves apply to surfaces. Surface shape is characterized by size and position, as well as the way the surface flows, the rate at which its curvature changes, and the manner in which surfaces connect to each other. Think of a square surface with lines drawn across from boundary to corresponding points on the opposite boundary, similar to a tic-tac-toe game. The lines are called isoparametric curves.

Surfaces can be evaluated in several ways but the simplest is looking at the derivatives along the isoparametric curves. Recall the first derivative tells the direction of the tangent at any given point. Imagine placing a ruler on the surface parallel to one of the isoparametric curves. The ruler sits in the direction of the surface tangent at the point of contact. This information is useful for determining if the surface is level at that point.

The second derivative is also commonly used because it shows the degree of curvature at a particular point in relation to the direction of the isoparametric curve. Looking at the second derivatives along a surface tells where the surface is flat and where it is curvy. Again, when the second derivative changes from positive to negative, or vice versa,

The first derivative of a curve is a tangent vector, a straight line showing the direction of the curve at a certain point (top). A rippled curve has tangents that oscillate in direction (bottom).

Image courtesy of Dassault Systèmes SolidWorks Corp., Waltham, Mass., www.solidworks.com



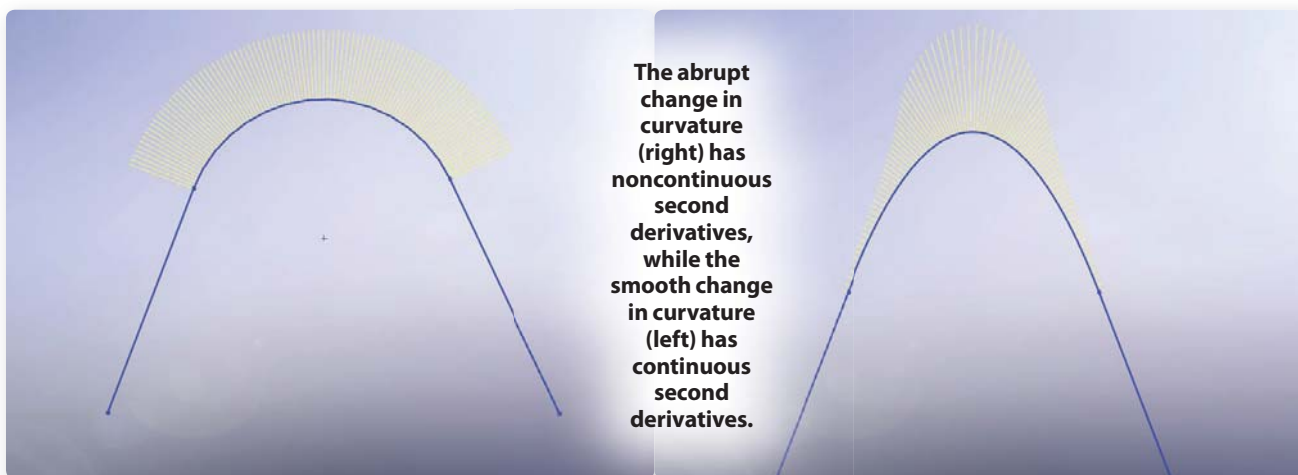
there is an inflection.

These attributes greatly affect the overall attractiveness of a design. In fact, automotive designers, for example, spend a lot of time working out curvatures and inflections of car bodies to get a desired aesthetic. They might, for instance, evaluate the transition of second derivatives and inspect third derivatives to help detect uneven transitions, which the human eye generally finds less attractive.

Design tips from the shop floor

Many designers and engineers learn solid modeling in school and then enter the business world to design machines and components. But some newer (and even some more-experienced) designers never consider whether the 3D CAD component they have just created is actually manufacturable. Hence, shops often face unnecessarily difficult or even impossible machining tasks. A lack of exposure to machine-shop settings and machining processes can result in costly designs and final products. Pointing out just a few of the problems machinists face should give designers insights into how to make designs economical to manufacture.

Try to design around standard material sizes in the coarser fractional dimensions such as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ in. Avoid the $\frac{1}{16}$, $\frac{7}{16}$, and, $\frac{9}{16}$ -in. sizes because most



mills either don't stock them, or require a special run.

Also, try to design long, thin parts around more readily available material sizes to avoid or minimize machining large surface areas, which can cause the material to distort.

Whenever possible, design your part to have at least two opposing parallel flat surfaces or a truly cylindrical surface, so it can be gripped by conventional vises and tooling. Otherwise, expensive custom fixturing or additional anchor material will be needed to control the part.

There are hundreds of ways to model a part, but treating your design as if you (the designer) were actually machining it yourself within the computer is the best way to avoid costly pitfalls.

Keep in mind that a standard off-the-shelf end mill has a length-to-diameter ratio of 2 to 1. Although many cutters exceed this ratio, there are good reasons for maintaining this standard. Small internal corner radii necessitate using small cutters with the associated risks of tools breaking, longer machining time, and higher costs.

Should you need to design an angle on a feature such as a square or rectangular pocket, remember that the radius in each corner will increase the higher it goes up the sides when using angle cutters. When your design requires constant corner radii, it will require more-expensive 3D machining.

Avoid undercuts, which are any angle that creates a blind pocket or slot with an opening that is larger at the bottom than the top. These so-called reverse drafts on blind pockets cost more to produce than straight wall or conventional drafts.

Every feature added to a part adds to the cost. It is less expensive to fillet a corner where two planes are perpendicular. It is more expensive to fillet a face where the two planes contain contours or are not perpendicular, such as when an angular face and a perpendicular edge intersect. Be prepared to pay for the 3D machining operations that will be required to create those types of irregular features. Often, the only way these kinds of feature can be accommodated is by some sort of hand finishing. Only spec them in if you absolutely cannot do without them.

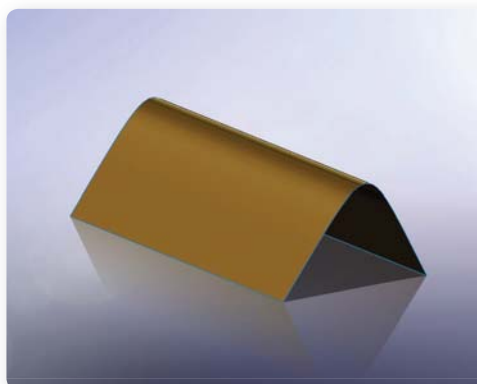
Deep holes with small diameters, extreme straight-

ness requirements, and off-center intersections with other holes or features tend to be more costly.

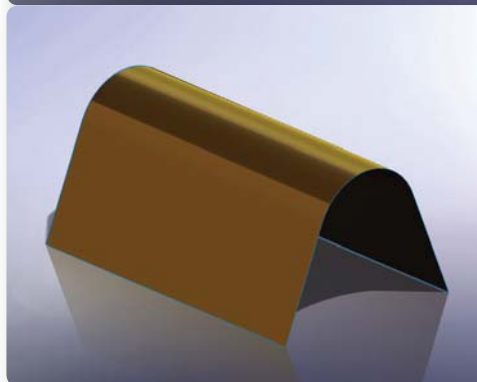
Nontraditional CAD modelers

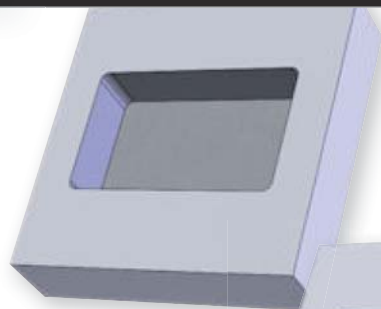
The lines between different types of geometric modeling software have blurred over time. Nontraditional approaches have accelerated this trend. For example, some packages combine polygonal and voxel modeling. Some programs let users model with solids, surfaces, and polygons. Other programs combine voxels, solids, surfaces, and polygons. These modelers typically complement traditional CAD packages.

For a better understanding, let's take a look at different

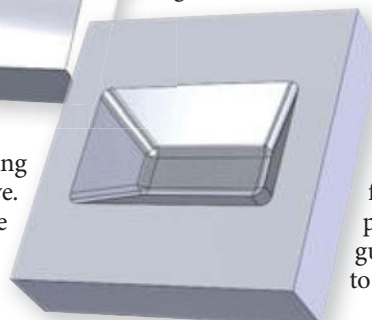
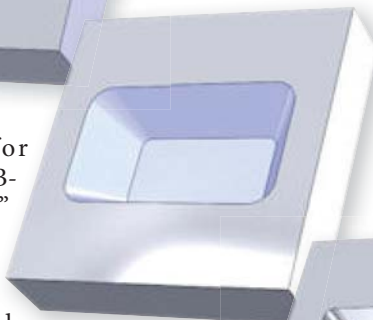


A surface with a nonsmooth curvature transition has harsher reflection lines (top) than does a smooth surface (bottom).





A well-designed pocket feature (left) is a straight side pocket with corner radii that uses conventional machining and is the easiest to produce. A tapered pocket created with tapered cutter (middle) does not require bottom radii but the corner radius varies. A tapered pocket with equal radii corners (right) requires 3D machining and is most expensive to machine. *Images courtesy of Tooling Research Inc., Walpole, Mass., www.tooling-research.com*



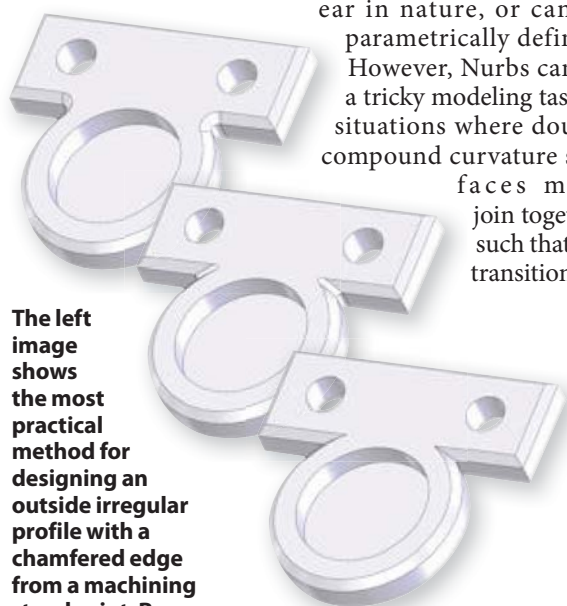
geometry types.

Nurbs is short for “nonuniform rational B-splines,” with “B-splines” being the important bit. In 1959, French engineer Pierre Bezier and French physicist and mathematician Paul de Casteljau, working independently, came up with a way of using control points to define and control a free curve.

Methods were also invented to control the curve with control points directly on the curve as opposed to on a control net. This made the definition and control of these curves more intuitive. The method works well to define straight lines, arcs, and circles as well as curvy shapes. Defining a 3D surface just extends this principle.

When you need rectilinear, typical engineering models, Nurbs are great. Nurbs suit products that have well-defined edges, are inherently smooth, rectilinear in nature, or can be parametrically defined.

However, Nurbs can be a tricky modeling task in situations where double compound curvature surfaces must join together such that the transition



The left image shows the most practical method for designing an outside irregular profile with a chamfered edge from a machining standpoint. By increasing the corner radius of the profile at the inside corner, it becomes a simple matter to machine the component using an angle cutter. The middle design is good, but will require 3D machining to create the internal corner blends. The least-practical design is on the right. Note all of the sharp internal corners on the profile and the chamfer.

between them is aesthetically smooth.

Polygons are another way to model 3D objects by creating 2D triangles and then connecting the triangles together. Increasing the number of polygons and reducing their size allows the accurate modeling of any shape below any reasonable manufacturing tolerance.

Polygons are also common in design and manufacturing work that relies on additive manufacturing (AM) for production. In AM workflows, polygons are used as the translation language that lets the CAD software “talk” to the AM machine.

Another common use of polygons is in scanning. Scanners export point-cloud data, but this is almost immediately translated into polygons for import into CAD software. Polygons generate a shape which will later be converted into a Nurbs model for further use in a traditional CAD system. However polygons have numerous downsides. They are less accurate and less precise than Nurbs, although boosting the resolution can partly resolve this. In addition, files can get so large that models become unusable. Polygons are not easily and randomly created on-the-fly, which limits applications such as scan cleanup. And polygon models are not necessarily manifold or watertight solid models. They can have overlapping open shells, which can cause problems in downstream processes such as AM and must typically be fixed before the workflow can continue. Lastly, converting polygon models into Nurbs is often the only way to reuse these models later. The act of converting polygons to Nurbs is not trivial, giving rise to the need for specialty software.

Voxels — Just about everyone is familiar with how 2D pixels define a photograph. Voxels can be thought of as 3D, volumetric pixels. They can be arranged randomly in 3D space — like shifting grains of sand — to create different shapes. This means that designers modeling with voxels are not limited by the same rules that apply to Nurbs modeling, for instance, by the constraints of topology.

As with polygons, when voxels get smaller and smaller, the relative accuracy of a sphere, for instance, represented by voxels will rise to the point that any deviation is smaller than the tolerances of the manufacturing technique being used to produce the product. Voxels let users perform a 3D version of the antialiasing commonly found with 2D pixel images such as adding triangles to the diagonals of a block model. The net result is that users can generate smoother models without taking the voxels down to micron sizes. An additional benefit of 3D antialiasing is that the soft-

ware wraps the voxel model in polygons for import into additive manufacturing machines.

Voxel models are also inherently solid, manifold, and watertight. All the checking required when using polygon models — to ensure downstream manufacturing processes will not fail — is not required with voxel models. Also voxel models let users randomly add (or subtract) voxels on-the-fly, giving designers the creative freedom to simply push, pull, smooth, and carve models of “virtual clay.”

In addition, voxels work well for modeling textures. This is rarely done in traditional CAD software because the complexity of the Nurbs model would slow the software and make the model unusable. Because voxels are not bound by the same solid-modeling and surface limitations as Nurbs, creating textures is simple. And these textures are not just visual in nature, they are actually part of the model.

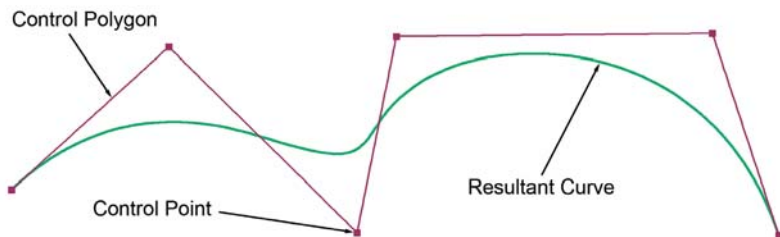
Voxels are well suited for modeling highly organic-shaped products and performing complex modeling operations such as shelling intricate shapes — operations which typically fail in Nurbs or polygons.

Like any modeling approach, voxels also have downsides. For example, currently available voxel modelers do not support sharp edges well. And because accuracy and smoothness is driven by the size of the voxel, dimensionally precise and smooth models can get large in data size. In addition, voxel modelers are not history based or parametrically driven, so some design changes can take longer than when done on a correctly defined Nurbs parametric model.

The Catmull–Clark algorithm for subdividing surfaces (subD) was developed in 1978. At the basic level, subD is a method for representing a smooth surface by continually refining a mesh.

By continually subdividing the control net, the software increasingly smooths the model. As the localized subdivision continues, it is possible to model details such as pockets. This lets subD modelers make smooth continuous models faster and more easily than traditional Nurbs-based CAD. Another benefit, especially over Nurbs models, is that users can create complex models without trimming.

No modeling technology can address every modeling scenario for every workflow. Fortunately CAD/CAM companies are adding more representations to their core functions to overcome the fundamental



A Bezier curve is defined using control points. Image courtesy of Geomagic Sensable, Wilmington, Mass., www.geomagic.com

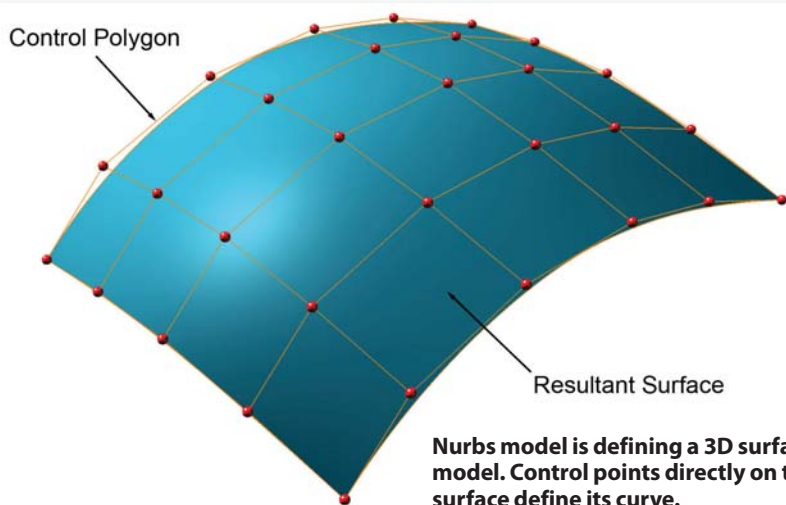
limitations of the different technologies.

For example, not long ago, most CAM software could only use Nurbs. Now, most programs can create toolpaths on top of polygons as well, effectively eliminating the need to convert a finished polygon model to a Nurbs model.

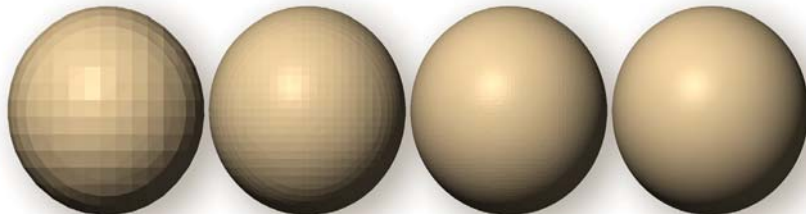
And what are known as organic voxel modelers have evolved to provide poly-representational modeling. This lets designers move freely between surfaces, solids, polygons, and voxels. For example, a designer could scan a manually sculpted design that cannot be modeled in Nurbs, import the .STL file for clean up, integrate CAD components and further modify the model, and then either create mold inserts or export directly for manufacturing.

A hands-on way to create and edit solid models

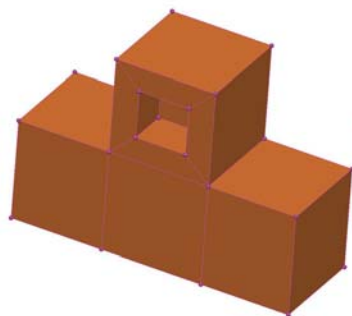
A technology called “direct modeling” provides a different way to interact with solid models. Traditional feature-based programs create solid models by storing a “recipe” of instructions that generate the model. That recipe, like software code, must be executed to produce a result. Thus, changes to early instructions can cause later instructions to fail. This is known as rebuild or regeneration failure. Therefore, designers using feature-based software must put significant thought into design intent.



Nurbs model is defining a 3D surface model. Control points directly on the surface define its curve.



Polygons of increasing number define a smoother sphere.



On the other hand, direct modelers forgo instructions and instead simply store the solid model itself. Although the direct approach was developed before feature-based modeling, recent advances in solid-modeling technology and increases in computing power have fostered a new generation of direct-modeling tools.

Some direct modeling is now included in most CAD systems. It is also available in stand-alone tools. These tools help companies augment monolithic CAD systems for detailed design and drafting.

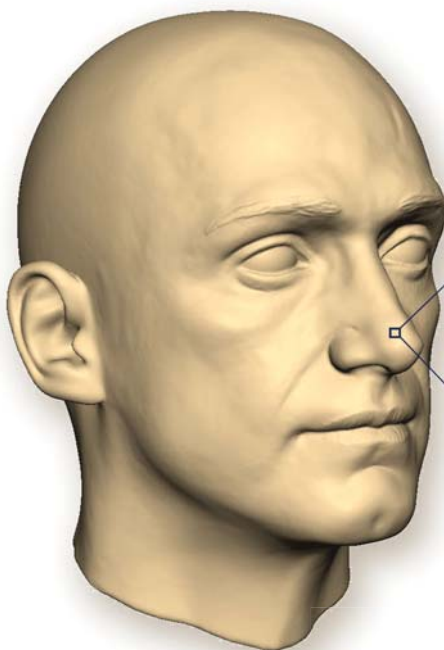
Solid modelers can be classified according to two technological differences, how the user interacts with the model, and how the solid model is stored.

The constraint-driven approach — employed by both feature and direct modelers — uses underlying constraint solvers to manage a model's varying degrees of freedom and make edits that conform to those constraints. Constraints can be contained in the model's sketches, between different components, and on the solids themselves.

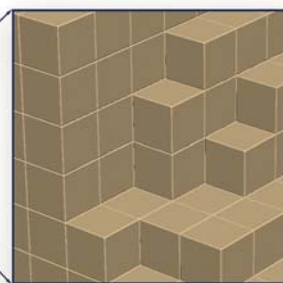
Constraints form a set of governing rules that dictate how a model may and may not be changed. They bind the model together so a change to one part, for example, can move many other parts and features. To change a model in a way that's inconsistent with a given constraint setup, a designer must first reconfigure the system of constraints.

Traditional feature-based systems are powerful tools in the hands of experts. Their sequential nature suits design problems that are already well understood and documented by concept models or 2D drawings. Feature-based modelers make a good choice for generating families of parts. Manufacturers can benefit by the ability to program business and engineering logic into model recipes.

However, designers must have a well-thought-out game plan before they start modeling. Otherwise different users cannot edit each others' designs. Also, in the past, the user experience was relatively noninteractive. Edits mainly involved typing in dimension values, reprogramming



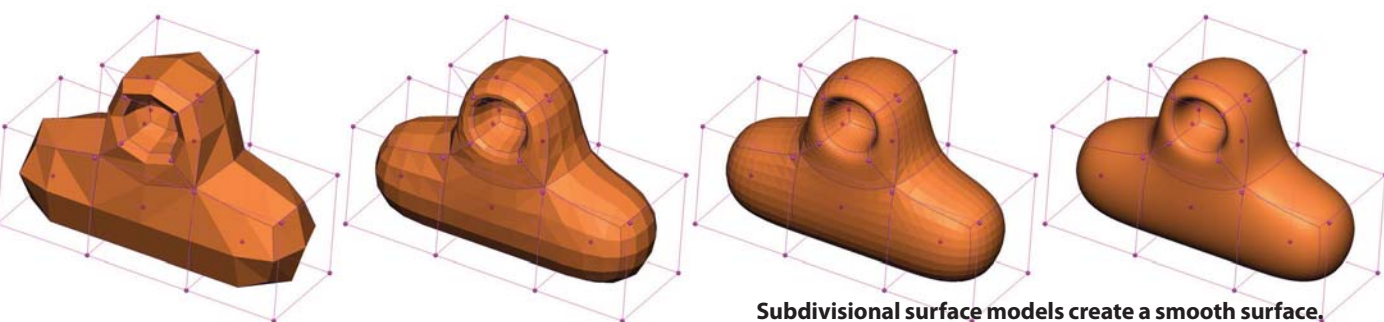
This example shows voxel model of a human head.



Note: voxels shown as representative only



These are examples of voxel models of cell-phone covers with and without textures.



Subdivisional surface models create a smooth surface.

placement constraints, and seeing if the model regenerated. Some CAD developers have since created user interfaces that allow direct manipulation using interactive tools to modify underlying histories.

These interactive feature-based modelers make model creation and editing more hands-on than traditional systems. For example, previously, editing the position of a hole entailed rolling back the design feature to the point where the sketch existed but the extrusion didn't. The trouble was that users couldn't see ramifications of edits until the model regenerated. Interactive feature-based modelers let designers modify sketches by directly moving the faces of the features, helping designers better visualize what they are doing.

Design intent or modeling intent?

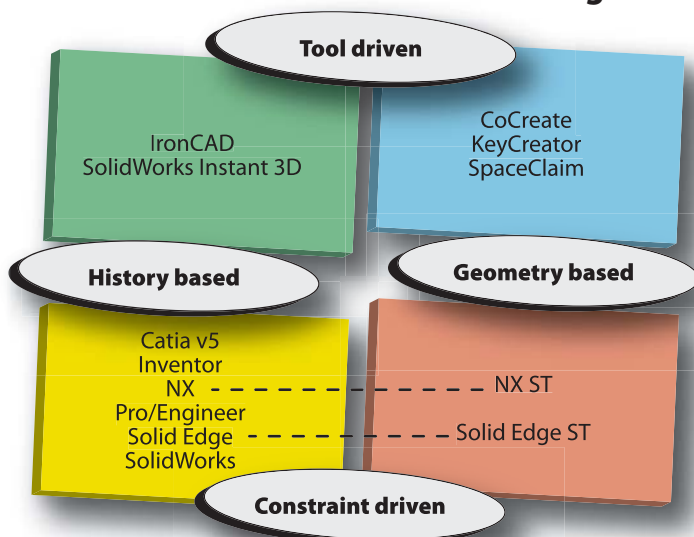
The meaning of the term "design intent" varies with who you ask. Different CAD systems give users varying degrees of rigor for specifying modeling intent. But there is little connection between a modeler's ability to capture modeling intent and whether it is tool driven or constraint driven. For example, consider a simple assembly where a shaft goes through a hole. In most constraint-driven modelers, there are different high-level strategies designers might use to manage that relationship:

- There is no relationship between the shaft and the hole.
- The shaft feature follows the hole.
- The hole feature follows the shaft.
- The shaft and hole are made concentric using a simultaneous assembly relationship.
- A third "skeleton" or "layout" component describes the boundary between the hole and the shaft and drives both parts.

Also, there are many different techniques that can be used to capture the relationship including annotations, Boolean features, multibody modeling, and validation criteria.

In the simple case above, the design intent seems pretty clear: The shaft and the hole need to coexist. One part doesn't necessarily "deserve" to drive the other. However, there are a myriad of different implementations of model-

The flavors of solid modeling



Solid-modeling tools can be classified according to two technology trends, shown here on the graph axes. One trend involves whether a geometry model is based on an ordered feature, or an explicit, "dumb" geometry. The other trend involves how designers interact with the model, either by driving it using hands-on tools or by editing constraints. With the exception of traditional feature-based, constraint-driven modelers, all the different modeler types can be labeled direct modelers. Image courtesy of SpaceClaim Corp., Concord, Mass., www.SpaceClaim.com.

ing intent, all of which have their own trade-offs and none of which perfectly capture the actual design intent. Different users and different companies will choose different approaches, and there is no clear right and wrong.

Some companies have a policy that parts cannot have relationships to each other, because an innocuous edit to one part can destroy an assembly that uses the part. In this case, the only way to find out is to open every assembly that uses the part and regenerate it. Other companies have CAD architects that do nothing but think about the right way to build relationships into their models. Constraint-based modeling techniques span the full rigor spectrum. **MD**

Hydraulic and pneumatic components with advanced controls and software make equipment more efficient.

Advances in fluid-power efficiency



Rexroth's Sytronix SvP 7000 servopump drive combines a permanently excited synchronous servomotor with an internal gear or axial-piston pump. It can substantially reduce energy consumption in applications like presses and injection-molding machines.

Energy efficiency has become a major consideration for anyone operating industrial or mobile equipment. Power consumption can easily account for 20 to 30% of the cost of running in-plant machinery, and fuel is often the largest contributor to the cost of operating off-road vehicles. As a result, leading fluid-power manufacturers are taking steps to boost the efficiency of hydraulic and pneumatic equipment. Here's a look at some recent innovations.

Industrial hydraulics

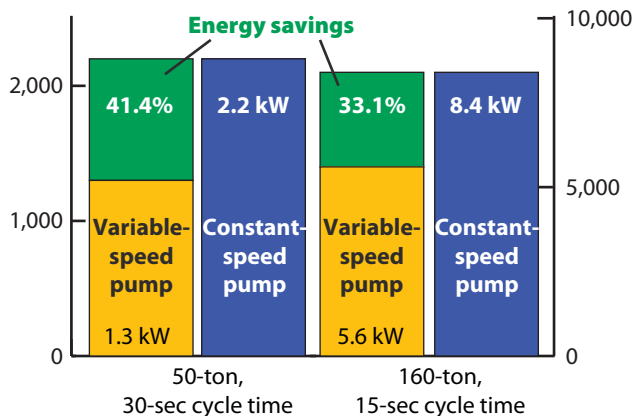
One innovation that can quickly pay for itself in energy savings is variable-speed pump technology. Traditional hydraulics run continuously at a constant speed to generate the power required to operate a machine. In these circuits, an electric motor typically runs at its rated speed, say 1,800 rpm, and drives a fixed-speed pump. The pump, in turn, rotates continuously and generates flow without regard to the actual power needed by the machine at any given moment. The varying hydraulic flow a machine demands is regulated via internal adjustment mechanisms in the pump, or by diverting excess flow back to the tank.

Advances over the years have improved the efficiency of fixed-speed pump circuits, but applying variable-speed techniques raises potential energy savings to a new level. Such systems use variable-speed electric drives to rotate pumps at their most-efficient speed — often less than 200 rpm — while supplying only the hydraulic power a process requires at any given moment. Depending on the application, this can produce energy savings between 30 and 80%, compared to fixed-speed operation, without sacrificing performance or limiting operating pressure. Pumps and motors operating at less than full speed also generate less noise and heat.

A number of fluid-power and motor manufacturers offer variable-speed pump drives with many combinations of pumps and motors. For example, the Sytronix product line from **Bosch Rexroth**, Bethlehem, Pa., has more than 140 modular, variable-speed pump/drive combinations, covering a broad spectrum of applications for demand-based control of hydraulic systems.

The basic version consists of an asynchronous standard motor and a frequency inverter driving an internal or external gear pump. This combination offers a good

Comparing energy consumption Injection-molding machines



Comparisons on plastic injection-molding machines show that replacing constant-speed, variable-displacement pumps with variable-speed pump drives cuts energy consumption more than 30%.

price/performance ratio. It's primarily used in constant-pressure systems, especially for high-power applications such as clamping and tensioning operations in machine tools. It can run at more than 3,000 rpm, but in partial-load operation it reduces speed to less than 200 rpm without affecting operating pressure.

A second version consists of an axial-piston, variable-displacement pump driven by an asynchronous standard motor and a frequency inverter. It's for high-performance, high-power applications.

Digital onboard electronics calculate the best operating speeds for the pump and motor. Destroking the variable-displacement pump lowers the flow rate and motor load,

with optimum speed for maintaining pressure generally between 300 and 400 rpm. During production breaks, the software can stop the pump without affecting operating pressure.

Finally, for high-end applications, servo-pump drives offer the greatest responsiveness and precision. The drives use an internal gear or axial-piston pump and take advantage of the high dynamic capabilities of permanently excited synchronous servomotors to boost efficiency and substantially reduce energy consumption, for example in presses and plastics-processing machines.

Variable-speed pump drives aren't warranted for every hydraulic system. But engineers should consider them whenever a machine cycle has fluctuating flows. "Intelligent" servodrives sense demand and regulate speed and power consumption of the electric motors. The more time a machine spends running under partial-load conditions, the greater the potential energy savings.

Applications where variable-speed pump drives offer substantial energy savings include: machine tools, plastics-processing machines, die casting, presses, woodworking, and papermaking. In all these applications, variable-speed pump drives maintain the reliability and power density of hydraulics, and combine it with the flexibility of electric drives.

And keep in mind that variable-speed pump drives can be integrated into existing equipment without major redesigns. This lets users quickly reduce energy consumption without investing in new equipment. Simulation programs are available that evaluate a machine's hydraulic circuits and estimate savings, before investing in hardware. And because existing hydraulic circuits often remain unchanged, the switch can be made with surprisingly little effort.

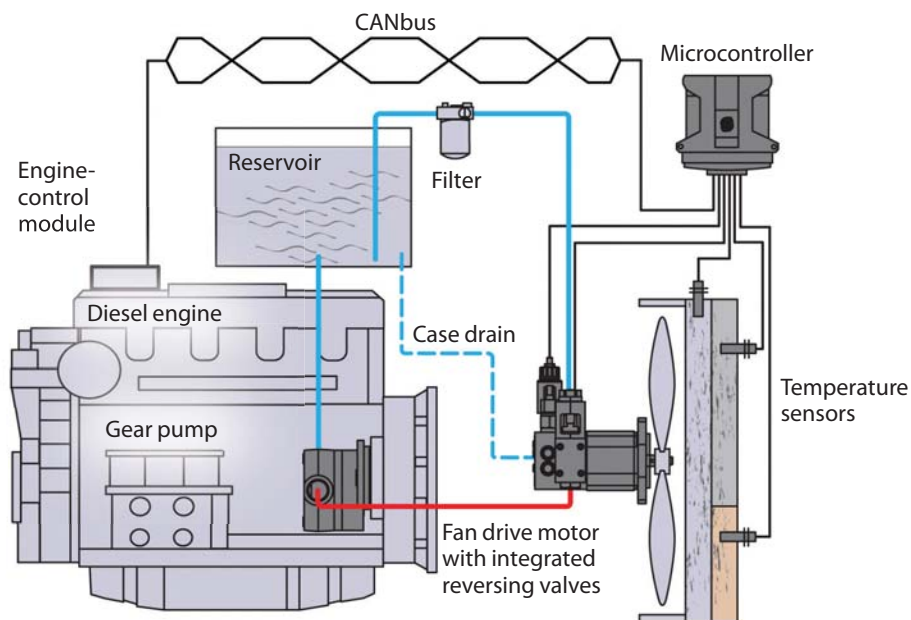
Mobile hydraulics

Belt-driven fans have been the most common method of cooling vehicle engines for more than 100 years because they are simple, durable, economical, and efficient. However, as emission standards become more demanding, vehicle designers need to develop more-efficient cooling systems. That's because reducing the power required for cooling also reduces the engine's fuel consumption and makes more power available to do work. Also, diesel-engine temperature affects both fuel consumption and emissions. So maintaining engine



Hydraulic fan drives consume less power than belt drives, improving vehicle fuel economy.

Hydraulic fan drive



A basic hydraulic fan drive uses a gear pump to supply high-pressure fluid to a hydraulic gearmotor which, in turn, drives the fan. The ECU monitors coolant temperature and communicates with the engine controls to operate the drive at peak efficiency.

sible with a belt drive.

This is especially important because a diesel engine's power-to-fuel-consumption ratio peaks within a relatively narrow range of temperatures. Second, emissions are lowest within another narrow range of temperatures. These two operating regions overlap within an even tighter band, so keeping

temperature within a narrow range has become a priority.

Belt-driven fans use a substantial amount of power whether the engine is idling or running at full speed. The problem is, belt drives operate at a fixed speed ratio to the engine speed. So belt-driven fans pull air through the radiator all the time, regardless of how much or how little cooling the engine needs. Whenever the engine is running, so is the fan. This is inefficient because the belt drive consumes engine power whether cooling is needed or not.

Hydraulic fan drives are more effective because cooling demand, not engine speed, determines fan speed. The hydraulic system drives the fan at the precise speed required to provide only the amount of airflow needed. This means the fan is not wasting energy rotating faster than necessary, just because the engine is running at high speed.

A basic drive has a hydraulic gear pump transmitting power (flow and pressure) to a hydraulic gearmotor, which drives the fan. An electronic-control unit (ECU) monitors operating conditions and commands an electrohydraulic pressure-control valve that regulates hydraulic motor speed.

A hydraulic drive does not waste power turning the fan when cooling is not needed, so the engine burns less fuel and releases fewer emissions. For example, when a vehicle's engine first starts, the fan is typically not needed. This lets the engine reach operating temperature faster than if the fan was pulling cold air through the radiator, which is normally the case with belt-driven fans.

And because the ECU adjusts fan speed based on coolant temperature and other key parameters, the end result is more-precise control of engine temperature than is pos-

ing the engine within this narrow temperature range provides the best fuel economy and lowest emissions.

Because hydraulic fan drives consume less power than belt-driven versions and control engine-operating temperature for the best fuel economy, they can pay for themselves in fuel savings. How quickly depends on the application, but the return on investment is often measured in months, not years.

For example, in recent tests by **Turola OpenCircuit-Gear**, Ames, Iowa, comparing belt and hydraulic fan drives on a 50-ton mine truck with a 725-hp engine under near-identical conditions, the latter cut fuel consumption by 14%. Even with a conservative price of \$3.00/gallon, this potentially cuts annual fuel cost by nearly \$20,000/vehicle. Total installation cost to retrofit the hydraulic fan drive is less than \$6,000/vehicle, offering a return on investment in about four months.

Hydraulic fan drives also offer other advantages. Reversing flow in the hydraulic circuit lets the fan blow dirt and debris out through the front of the radiator that would otherwise reduce cooling efficiency. Because the hydraulic fan motor connects to a pair of hoses rather than a belt attached to the engine, the radiator and fan can mount anywhere on the vehicle — offering design flexibility.

And hydraulic fan drives can increase power to the engine for short periods. When the machine needs quicker acceleration or more muscle for work, the ECU commands the pump and motor to shift to a neutral position, so the drive consumes no power. This may let equipment designers use a smaller engine.

Hydraulic fan drives may not be a viable alternative

An ultrasonic leak detector is fairly inexpensive and capable of pinpointing most leaks, even in noisy production environments.

in every case. OEMs simply looking for the lowest initial cost will still prefer belt drives. But in most cases, hydraulic fan drives offer higher productivity, better fuel economy, and lower emissions — as well as significant savings over the life of a vehicle.

Pneumatics

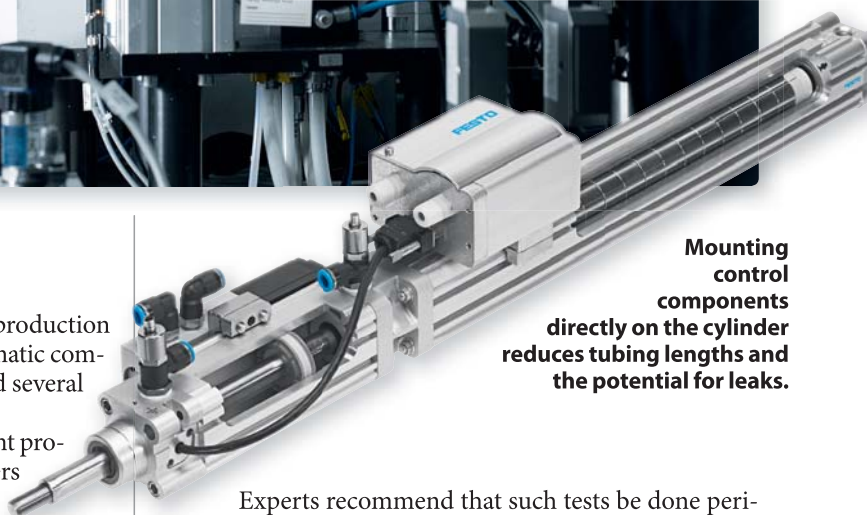
Last but not least, industrial machines and production systems often rely on simple and durable pneumatic components and systems. Here, experts recommend several ways to approach energy savings.

Leak detection. A good leakage-management program is essential for any plant. It radically lowers compressed-air consumption and the associated costs as leaks are a waste of compressed air, which translates into lost energy and money. In addition, leaks create pressure losses that can significantly slow production processes and prevent machines from running at peak capacity.

Manufacturers can substantially reduce operating costs by simply implementing a solid leak-detection program. The objective should be to completely check the pneumatic system from the compressor to each machine and device. A simple ultrasonic leak detector can help manually identify individual leaks on machines. From there, technicians can categorize the leaks by size and importance, record their locations, and fix them when normal machine downtime is scheduled.

An ultrasonic leak detector is fairly cheap, typically in the \$500 to \$3,000 range for a device that is suitable for most locations and can detect most leaks.

Air management. In addition to leakage management, there needs to be a strong air-consumption management program. Knowing the standard consumption of each machine during different batch processes is a vital prerequisite for properly sizing the compressed-air supply and distribution lines and for determining leakage losses.



Mounting control components directly on the cylinder reduces tubing lengths and the potential for leaks.

Experts recommend that such tests be done periodically, both during machine operation and downtime. Characteristics that could provide more insight include consumption per machine cycle, average consumption per minute, average pressure, and minimum and maximum flow rates.

Engineering design. Even systems with no leaks waste energy if they're poorly designed. Engineers can significantly boost efficiency by using the principles of good pneumatic-system design as building blocks to construct a machine.

For example, replacing double-acting cylinders in a machine with single-acting cylinders eliminates air-powered retract strokes over the life of the machine, generating substantial air savings. Single-acting cylinders also have one less port per cylinder and use less tubing. Fitting ports that interface with the tubing are notorious for springing leaks. A simple change like this can cut compressed-air consumption in half and greatly reduce potential leak points.

Today, it is easy to source pneumatic actuators with integrated accessories such as valves and flow controls. With these devices, the hardware for control and actuation of the cylinder rests directly on its own body, therefore eliminating expansive runs of tubing from the controller to the

actuator. This, in turn, reduces the probability of leaks and unnecessary pressure drops that degrade machine performance.

Also, when specifying individual valves, engineers must optimize the flow rates of the valve without under or oversizing. Undersized valves can “choke” flow and limit performance. Oversized valves, on the other hand, not only increase air and energy consumption, they unnecessarily add to cost, size, and weight and can slow actuation time.

In vacuum applications (one of the biggest sources of energy loss of any pneumatic application), always consider using inexpensive vacuum switches that cut off the air supply when the desired vacuum level is reached.

And as with other components, make sure filters are properly sized and that they are replaced periodically, as a clogged filter can create a big drop in supply pressure. Modern filters incorporate digital indicators which signal when the filter is clogged beyond acceptable limits. These signals can be tied into the process PLC and trigger a message to the operator that a maintenance check is needed.

One highly recommended way to select pneumatic components is to use interactive software, which is available from several major manufacturers. Online sizing tools from **Festo**, Hauppauge, N. Y., for example, include selectors and calculators for products such as pneumatic drives and compressed-air-preparation units.

Such software helps engineers size components and run simulations to test operating parameters for them. Simulation lets designers interactively experiment with components without the cost, complexity, and time required for physical testing. For instance, they can find products that produce the most throughput or force for the desired stroke, that consume the least amount of air, or the ones that balance these factors for the highest productivity and profit.

Advanced diagnostics. The advanced machine-diagnostics concept is a relatively new idea in the pneumatic field. It promotes dedicated and permanent condition monitoring of machines to help detect changes in critical process parameters early enough to prevent downtime and, more critically, avoid catastrophic failures. If downtime still occurs, advanced diagnostics can quickly analyze the cause of failure.

Condition-monitoring systems can provide information as basic as simply indicating something is wrong or as complex as pinpointing the exact component on a subsystem level that is exhibiting a failure pattern. It can also home in on the root cause of failure, the failure type, and detailed steps to fix the problem. Today's condition-monitoring systems can collect data from multiple pressure and flow sensors embedded over distant machine locations via industrial Ethernet, display data in real time, create baseline thresholds, and churn out diagnostic information, all from one intelligent device and display.

On critical subsystems, diagnostics can involve installing an inexpensive flow sensor at the component's air inlet. Nowadays, flowmeters double as air-consumption meters that deliver a pulse every time a preset air-consumption level is reached. Pulses are counted in the master controller to check if consumption in critical components is within preset limits.

Similarly, on complete machines, dedicated hardware can monitor parameters such as pressure, flow, air consumption, actuator stroke times, valve cycle times, and vacuum suction and evacuation times. This information can then be used to create baselines for each parameter which can be monitored on a permanent basis.

The real advantage of such systems is the guidance they give to maintenance personnel. For example, they can generate alarms that tell repair technicians the type of problem, where it is, and how to fix it.

Automated monitoring systems help keep equipment and plants running in an energy-efficient mode while delivering peak performance. They also give manufacturers the ability to evaluate the residual life span of equipment. **MD**

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