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AUGUST 2016

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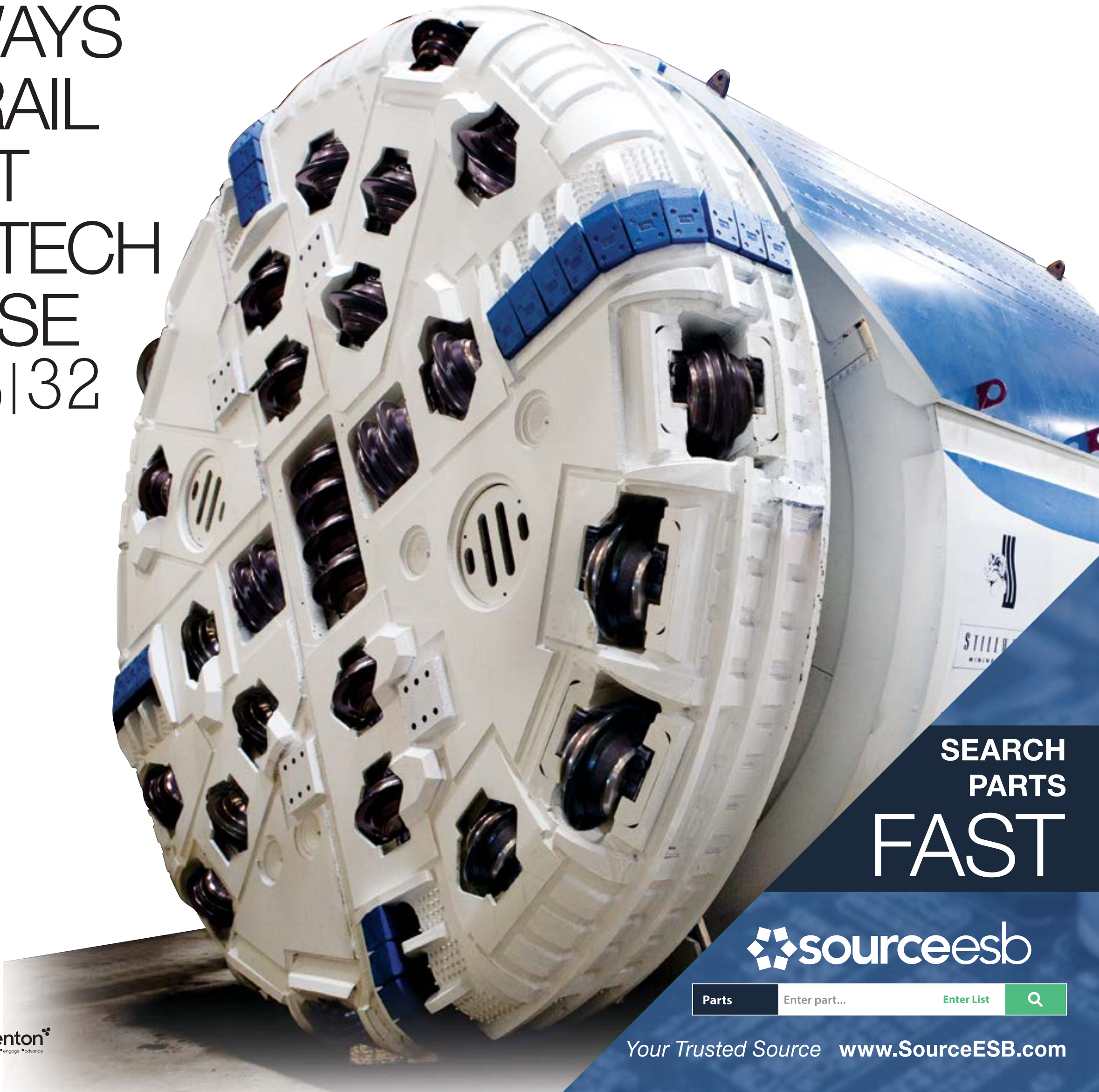
On the Right Track

SUBWAYS AND RAIL CHART HIGH-TECH COURSE

p|32



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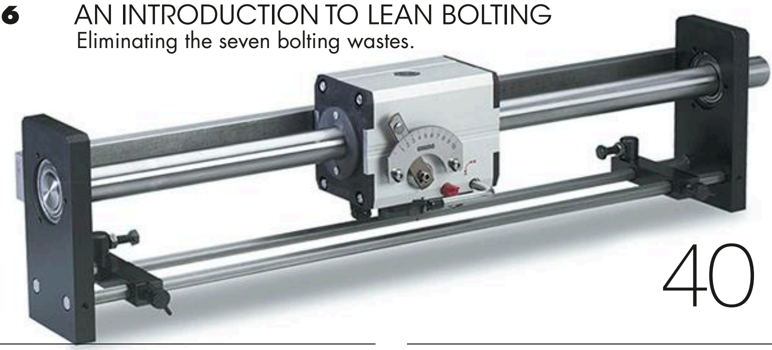

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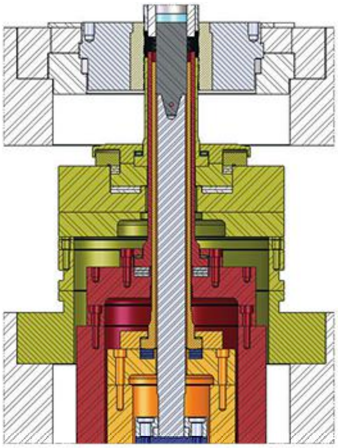

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DEPARTMENTS

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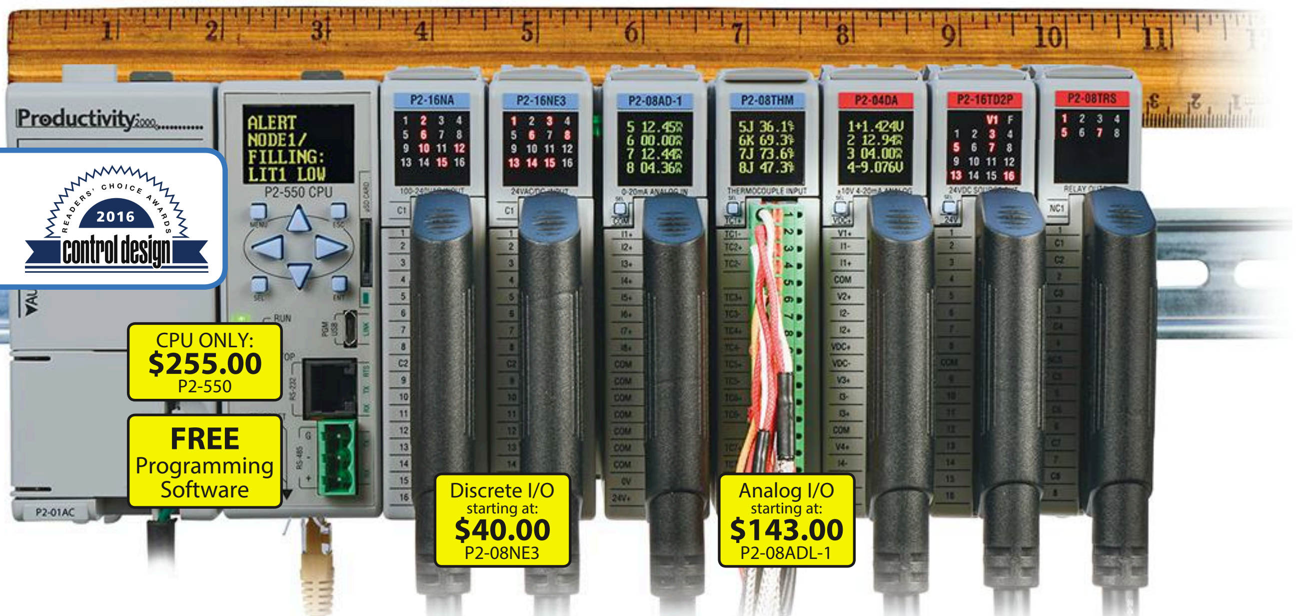

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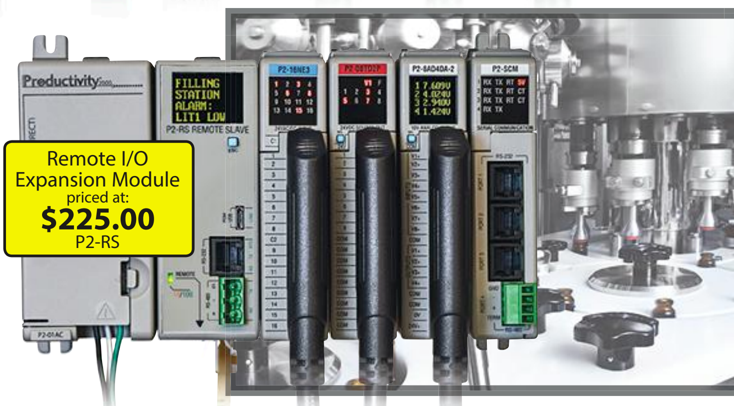

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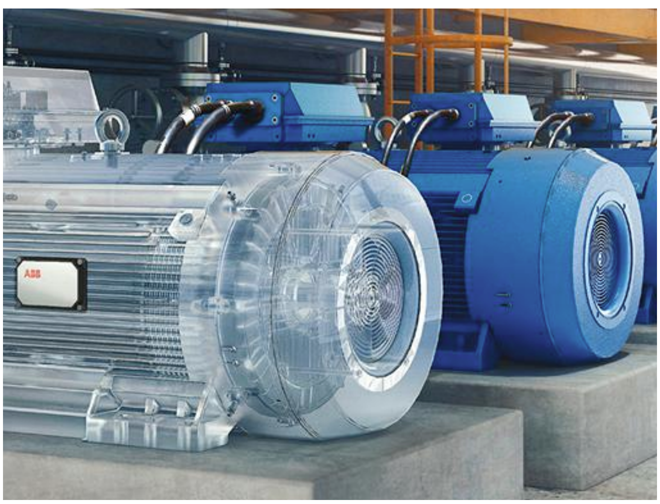
http://machinedesign.com/automotive/could-battery-swapping-ease-range-anxiety-ev-owners

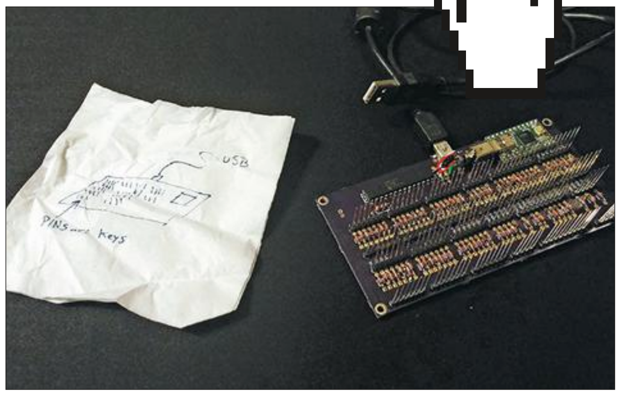
Even the fastest electrical vehicle charger may need 20 minutes or more to recharge a vehicle, leading to peak-time lines and, for long trips, range anxiety. Could battery swapping be the best alternative to electric charging?



AN INFRASTRUCTURE-FREE IIoT? MAYBE.

http://machinedesign.com/iot/can-new-technology-provide-infrastructure-free-iiot

Technology is expanding faster as connectivity offers sensing and control, preventive maintenance, supply-chain optimization, and full remote control of industrial processes.



ONE PCB DESIGN'S JOURNEY

http://machinedesign.com/controllers/napkin-final-product-one-pcb-design-s-journey-part-1

For the Maker-Pro in all of us, *Machine Design* follows a designer from doodling on a napkin to producing a final product for a new PCB.

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HAS THE PLC MET ITS MATCH?

http://machinedesign.com/controllers/has-plc-met-its-match

Decentralized technologies like PAC can work with PLCs, but by offering more features for machine vision and IIoT, they may be in a state of diminishing return.

How To Keep Your Electronics Cool

When hot weather causes the electronics inside a control cabinet to fail, there is a panic to get the machinery up and running again. There are several cooling options out there and it's important to know the facts.

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Fans

Opening the panel door and aiming a fan at the circuit boards is a bad idea.

- **It is an OSHA violation that presents a shock hazard to personnel**
- **The fan blows hot, humid, dirty air at the electronics**
- **The cooling effect is minimal**
- **It is likely to fail again since the environment is still hot**

Refrigerant Panel Air Conditioners

These coolers are prone to failure in dirty, industrial environments when dust and dirt clogs the filter.

- **It takes almost a day to install**
- **Vibration from machinery causes refrigerant leaks and component failures**
- **Compressor life expectancy is typically 2.5 years of continuous operation**
- **It requires a floor drain for the condensation**
- **Average cost to replace a bad compressor is $750**

Heat Exchangers and Heat Pipes

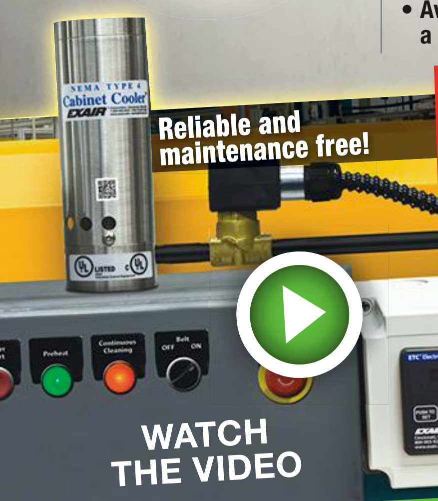
These have serious limitations. On hot summer days when the temperatures of the room and inside of the enclosure are about equal, there's not enough differencxe for exchange.

- **They fail when dust and dirt clog the filter**
- **The cooling capacity is limited due to ambient conditions**

"Plastic Box" Cooler

The "plastic box cooler" from a competitor uses an inaccurate mechanical thermostat that's designed for liquids. This thermostat has a poor ability to react quickly to changes in air temperature. **It costs up to 85% more to operate than EXAIR's ETC Cabinet Cooler® System with the same SCFM rating and Btu/hr. output.**

- **Electronics can overheat before it turns on**
- **It runs far longer than necessary before shutting off**
- **Increased cycle time wastes compressed air**



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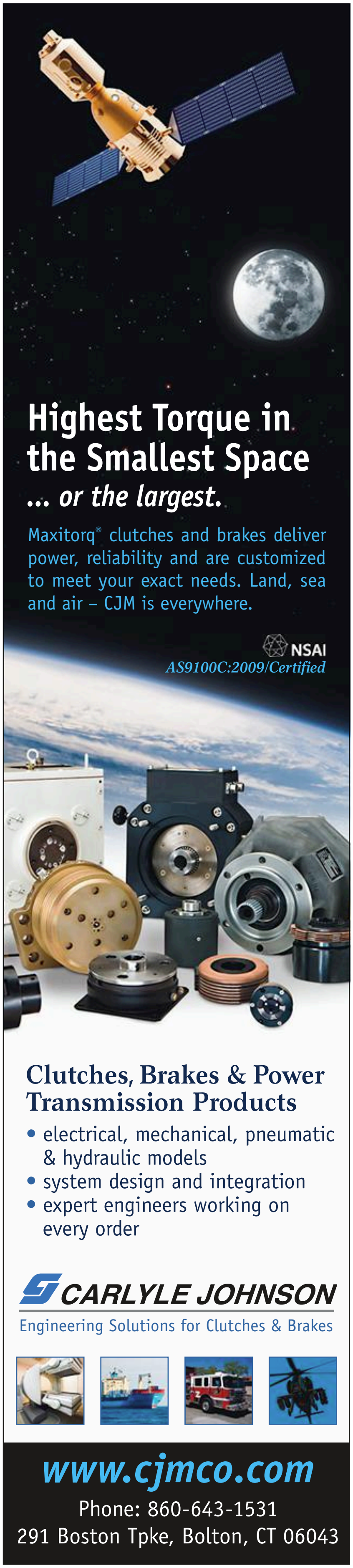

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AUGUST 2016

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Editorial

JEFF KERNS | Technology Editor
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Math for a Better Company

Hardware is advancing to be so user-friendly that I sometimes feel more like a child with an advanced Lego set than a designer. If innovation is a step forward, this feels, at best, like a shuffle in a slightly forward direction. Effective software, however, seems to be moving deeper into higher levels of math. While engineers aren't mathematicians, it is often these equations that make the world around us work. I was speaking with Stefanie Bernosky recently, a geo and data scientist, and she talked about using statistic analysis in her models. I realized that even in my engineering career, I have mainly stuck to pre-derived, or more static-like, equations. Worse yet, I simply open the Excel or MathCAD file I used previously and switch some numbers around.

It seems as though after being largely a mainstay, math is now being removed or minimized in many career paths. But it should be remembered that math is a way to understand patterns in nature. In the digital age in which we live, it seems we are not only ready, but that it is necessary, to go to the next level—finding patterns or structure in our math. When dealing with statistical learning, data structure, and FEA-type applications, classical calculus can seem limiting at times. Some professors in Europe are moving toward encouraging matrix theory and linear algebra along with calculus. When working in simulations or numerical analysis, having a range of mathematics can offer dynamic and perhaps more accurate models.

If engineering is reduced to just learning software and engineers don't understand the theory behind it, we can't be sure of the risk we are putting in our models. If we have some experience, we can say it passes the "smell test"—it seems right—but the software could have compounded uncertainties that make it more guesswork than engineering. Experience is good, but not if it doesn't make you question what's behind the button because that's the way the company has always done it. Or maybe you think you will make a profit, so it's good enough. If the United States continues down such a path while Europe advances its math program, we might be left wondering why we can't seem to reduce cost or be as accurate as other countries.

Personally, I'm still 100% pro-hands-on. However, I feel I must say that there is a time to tinker and a time to hone. Tinkering can get you started, but to have staying power in the market, you need those math skills. In addition, when your new algorithm creates a model that allows your startup to outperform the competition, go to a local school and tell the students that you don't have to know this math stuff to exist. But if you want to thrive, you should pay attention. md

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How does it work?

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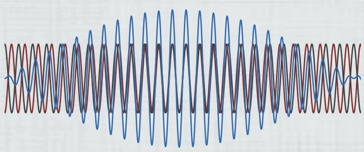

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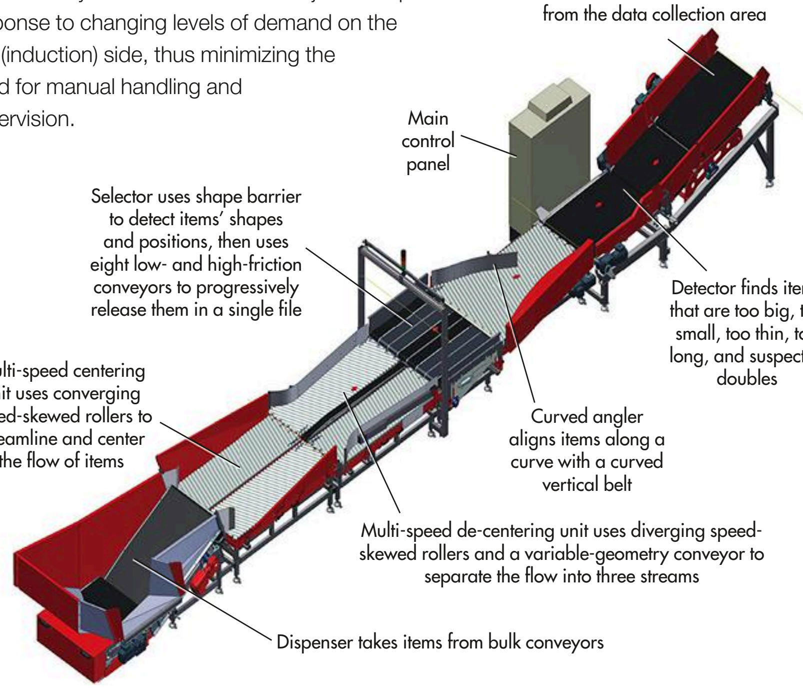
Singulator Gets Parcels and Packages Organized

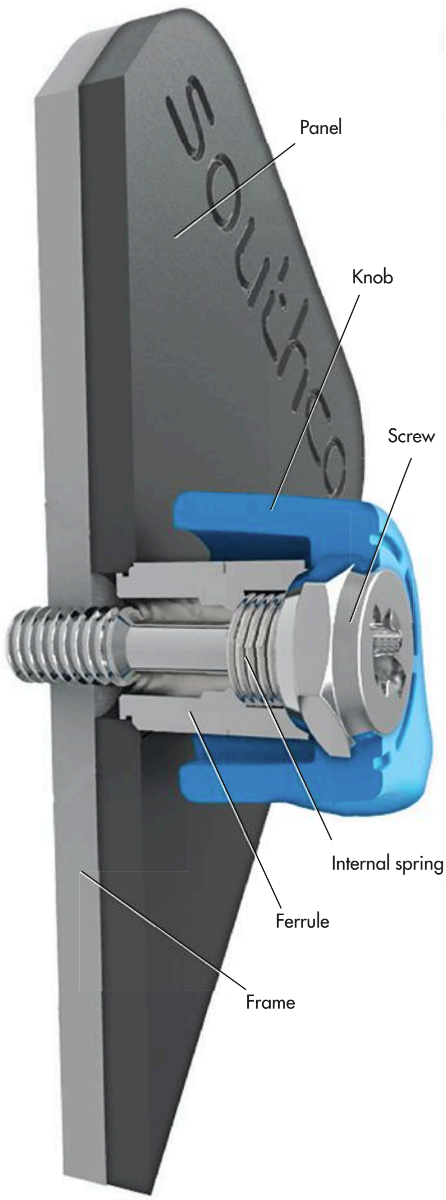
THE INCREASING AMOUNT of goods being sent by online retailers—not to mention the Post Office—is putting a premium on fast, accurate sorting of boxes, parcel, flats, totes, and sealed bags. To keep the packages flowing between unloading and sorting, engineers at Mechanica Sistema developed the Automatic Parcel Singulator, which is available through the Beumer Group (www.beumergroup.com). The Singulator can separate, space, and align up to 4,500 items per hour, depending on parcel size. It handles packages ranging in weight from 0.1 to 35 kg and in size from 100 × 100 × 10 mm to 1,200 × 700 × 700 mm. The fully automated machine adjusts its speed in response to changing levels of demand on the pull (induction) side, thus minimizing the need for manual handling and supervision.



The machine uses a minimum of moving parts, so there is less wear and tear. Power-saving features, such as variable-speed drives and a sleep mode, save energy. The entire unit is controlled by PLCs. Frequency inverters let the machine recapture kinetic energy and convert it to electricity, minimizing its energy consumption.

Items can be fed into the singulator from fully automatic container tippers, boom conveyors, or loading conveyors. They then get aligned, spaced, and released in a single flow. The items go through a detector section that checks the dimensions. Those that are out of gauge are removed and diverted to another handling machine. Data from the detector can also be used to split the packages into two different lines, delivering them to another conveyor, sorter, or handling station. Parts on the Singulator can be changed or swapped out without using screws, which simplifies maintenance. md

Knob-Style Captive Fastener Provides Tool-Free Access



THE NEW 4C Wing Knob captive screws from Southco (www.southco.com), Concordville, Pa., can be quickly installed or removed by hand. Their over-molded, distinctively contoured wing-style head design can be used to designate access points through color. The screws make it simple to position sliding components.

They come with optional press-in, flare-in, and surface-mount technology for versatility in fastening and unfastening—either by hand or tool—when mounting doors, panels, and other hardware components in applications where space is limited.

The fastener features high-strength screws, hardened carbon steel, zinc-plating, and includes a strong, 300-series stainless-steel passivated internal spring. A high-heat-resistant plastic knob withstands SMT installation to printed circuit boards during the reflow process. md

News

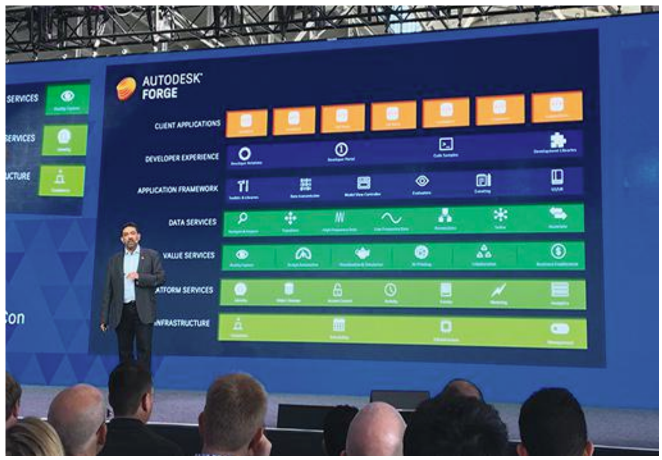
CONNECTING THE DIGITAL WORLD with Manufacturing

What does it take to make something? What tools do you need to take an original idea from the design board to actual physical production? These are the questions Autodesk wanted to answer when it launched its first-ever Forge Development Conference. *Machine Design* attended the recent event to see what the latest releases had in store.

The Forge Platform is a set of cloud services and resources for developers to quickly create data-centric apps, experiences, and services. Forge gives users direct access to their application program interfaces (APIs). They provide users direct access to their code so they can create programs and interfaces for their designs.

The Forge Dev Con featured a full slate of Internet of Things (IoT) panels and conferences. IoT in its basic definition is the connection of sensors and machines with useful information and data to the end user.

Jim Quanci, senior director of Autodesk Forge Partner Development, told us that hardware startups are up 76%, sensors are more affordable than ever, and there is plenty of cheap and accessible bandwidth for connected devices. The Forge platform wants to be the service to analyze and provide access to the data collected off of IoT devices. Helping its customers analyze the data is one part of the IoT puzzle that Autodesk looks to fill. In speaking with several of the Autodesk speakers, they are upfront and honest when they say that they only help solve one part of the IoT puzzle. The warning they give attendees is that if anyone approaches you with an entire IoT



This year marks the first-ever Forge DevCon for Autodesk. The Forge Platform provides Autodesk users with a selection of application program interfaces (APIs) to help program their own applications. The image above highlights all the available application interfaces available for users.

solution, they are lying. Autodesk pairs up with Verizon for the connectivity and a variety of boutique system integrators for sensor implementation.

Some of the best examples here for IoT data collection were presented by 3D Robotics. Chris Anderson, CEO of 3D Robotics and founder of DIY Drones, started his work in drones as an exploration into Lego drone construction and his company has now become a leader in aerial data collection. Their drones can fly over an area and collect geographical information that will later be analyzed using the Autodesk Forge platform. The data becomes elevation plans, heat mapping, and clearance areas, to name just a few.

Robert Bodor, vice president and general manager of Proto Labs, demonstrated how his company is using the Forge APIs to provide customers with a submittal process for their designs. They can upload their models and obtain a quote for parts to be made.

Lastly, Mark Stocks, director of information architecture from JE Dunn Construction, demonstrated how the Forge Cloud Services provide up-to-date access for construction plans. The interconnected devices from the design office to the construction site through the Forge cloud allow for last-minute design changes and constant monitoring of the construction progress.

3D Robotics highlights how drones can be used for geographical surveying purposes in conjunction with Autodesk program interfaces.

The same Forge platform introduces online collaboration through Autodesk 360, which has been mentioned before in our magazine *(see "Learn to Stop Worrying and Love the Cloud" on www.machinedesign.com)*. Autodesk 360 provides collaboration access with end users to work on similar files, provide layout updates for building construction, and last-minute design changes. The Autodesk PLM 360 platform offers security by providing login IP addresses and the location of those logins. The Autodesk ID works with existing browsers, and the Cloud App Security can log the rate of active users and rules can setup to control access. ■

SOLAR IMPULSE MAKES
Record Round-the-World Journey

ON JUNE 7, 2016, the Solar Impulse 2 team, scheduled to land in JFK, delayed its arrival. When flying a prototype plane around the world without any fuel, there are bound to be a few less-than-ideal weather conditions. But that wasn't a setback for veteran pilots Bertrand Piccard and Andre Borschberg. They understand that changing the world takes patience. The Solar Impulse 2 has been an idea for over 13 years, and in development for over three. As of June 11, Solar Impulse 2 had set eight world records, visited seven countries, flown over 19,000 miles, and after the weather cleared, landed safely around 4 a.m. at New York's JFK.


Solar Impulse does a flyover of Manhattan by night.

The Solar Impulse 2 team says that it does not carry passengers, but ideas. While much of the philosophy and spirit is to inspire change in the way everyone—businesses and governments included—thinks about green technology, this article will focus only on an overview of the disruptive ideas carried out by this groundbreaking plane. (More about the team's spirit can be found in an online blog at www.machinedesign.com.)

According to Swiss pilot and adventurer Piccard, "The idea is to show that you can change the way we do business to be efficient, environmental, and economical." The team of companies (Solvay, OMEGA, Schindler, ABB, and More) that sat on the stage in Hangar 19 at JFK all have similar beliefs—that an evolution of technology, both environmental and profitable, is imperative to survival. The only way to prove this, as far as the Solar Impulse team was concerned, was through action.

Richard Northcote, chief sustainability officer for Covestro, said his company's investment into R&D for this project allowed it to generate polyurethane, and discover the right air fill that provides better insulation properties. Through the challenge of trying to build this aircraft, the company found a way to save up to 20% on yearly energy bills compared to standard home insulation. This positive discovery could have a great impact on developing countries with food shortages and limited or no refrigeration.

The urethane that protects the pilots and batteries from extreme conditions without a heating system was able to reduce its volume while providing better insulation and rigidity. The insulation contains 40% smaller pores while still being lightweight. This is only one of the innovations Solar Impulse has on-board. "This product was generated and used for the first time on Solar Impulse," Northcote says. "Everyone said insulation has reached its [peak] level and it could not get any better. Well, our foam is 10% better than this un-improvable limit … We also have a goal to cut our carbon emissions in half by 2025. One of the ways to do this is to use alternative energy, but this doesn't do anything to reduce your energy consumption. So our goal for 2030 is to cut our energy consumption in half while continuing to produce the same volumes we are producing today. We have been told that this is not possible, but we have also been told that insulation couldn't get any better."

"We produced the garments the pilots wear under the flight suits and about 50% of the composite materials that form the skeleton of the plane," says Solvay's communication director David Klucsik. "This technology was not created for Solar Impulse. It existed, and has existed in some cases for a number of years, but the mindset changed. We were able to find ways to apply our technology in ways we thought were impossible ... Solar Impulse is inspiring innovation that is producing better energy efficiencies and lightweighting, and those two themes carry forward into virtually every aspect of our lives."

From left, Solar Impulse pilots and co-founders Bertrand Piccard and Andre Borschberg.

Reducing energy and CO_2 emissions is not just about saving the planet, but also operating businesses effectively to produce a product that is more effective and costs less because of the efficiency in producing it. This isn't just a dream. "We have the technology today to cut our CO_2 emissions in half," says Piccard.

With all of this innovation and the brilliant minds supporting Solar Impulse 2, it was ready to fly. However, other challenges were just beginning, among them making sure that international governments would allow the team to fly an experimental plane over densely population areas and cross borders to land at international airports. Fortunately, the experience of everyone involved ensured all certifications were received and the global community welcomed the flight.

This represents an example of what you can accomplish with the right engineers who have the desire to challenge what is possible. Even Abu Dhabi, the capital of the United Arab Emirates, expressed that they wanted to host at the start and finish of the adventure, showing a surprising turn toward more sustainable practices. ■

WILL ALKALINE BATTERIES Replace Lithium-Ion Batteries?

WHILE INVESTIGATING A design for a rechargeable zinc-manganese dioxide battery, a team from the Pacific Northwest National Laboratory (PNNL) decided to bring out the "big guns": advanced spectroscopy techniques that would enable them to observe the chemical reactions within the battery. This led to the discovery of why their manganese cathode could not repair itself during recharge—and a solution that could become an inexpensive and safer alternative to lithium-ion batteries. The results were published in a paper in the journal *Nature*.

Rechargeable zinc-manganese-dioxide ($Zn\text{-}MnO_2$) alkaline batteries are already on the market, but they can only be used for a few charge cycles. Due to an effect called electrode "sluff-off," significant quantities of manganese ions do not make it back to the anode during recharging. Since these ions are necessary for oxidation of the anode during discharge, energy density decreases with every charge cycle. This same outcome was recorded when testing the design at PNNL, which consisted of a Zn cathode and MnO_2 anode separated by an aqueous electrolyte.

To determine the root of the electrode sluff-off problem, the scientists performed transmission electron microscopy, nuclear magnetic resonance, and x-ray diffraction as the battery was in operation. The advanced tests showed an unexpected internal reaction in the $Zn\text{-}MnO_2$ battery that further explained why portions of the manganese ions were not reuniting with the anode.

COMPARING $Zn\text{-}MnO_2$ TO LITHIUM-ION BATTERIES WAS ERRONEOUS

Before discovering the reversible reaction that was taking place between the manganese and the protons in the electrolyte, rechargeable $Zn\text{-}MnO_2$ batteries were assumed to operate like lithium-ion batteries in a process called intercalation.

When looking at Li-ion batteries during discharge, lithium cations are formed as the lithium-graphite anode oxidizes to supply a flow of electrons to the load. The lithium ions are pulled from the anode and travel through the electrolyte. They pass a selectively permeable barrier and then, in a reversible intercalation process, they insert themselves between the molecules of the cathode. Meanwhile, the current flows through the circuit and back into the positive terminal of the battery, enabling the intercalated lithium ions to become neutralized via reduction of the cathode.

Similarly during charging, a load pulls electrons (current) from the cathode so that the lithium metal oxidizes again. The lithium ions transfer through the electrolyte back to the anode and reunite with electrons as they flow to the negative terminal. In the end, the lithium-ion battery is back to its original state for another cycle of usage.

The results of the spectrometry and microscopy for the $Zn\text{-}MnO_2$ battery, on the

other hand, showed a process that is much different than the reversible intercalation that occurs in Li-ion batteries. Instead of simply inserting themselves between molecules in the cathode, the tests showed that manganese ions were reacting with the protons in the electrolyte. They would then react with the zinc in the cathode to create zinc hydroxyl sulfate. This reaction at the cathode is irreversible, which means the next charge cycle would be significantly less effective.

To remedy this, the scientists simply added manganese ions to the electrolyte, keeping the reaction at equilibrium. Thus, a virtually equal quantity of manganese ions would reunite with the cathode. In their next round of testing, the battery with the manganese-enriched electrolyte performed over 5,000 cycles while retaining 92% of its initial storage capacity of 285 mAh. ■

LAB DEVELOPS VISCOSITY PROFILES for Carbon-Binding Materials

WITH THE AID of computer modeling, a team from the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) is investigating the behavior of CO2BOLs when binding to CO_2 emissions. CO2BOLs, the acronym for carbon-dioxide binding organic liquids, are used to bind emissions and exhaust so that they may be scrubbed. The residual CO_2 then can be used for fuel or in other processes.

But as CO2BOLs bind to more and more carbon, viscosity increases to levels whereby they become hard to process and can be harmful to machinery and piping. Thus, PNNL scientists were tasked with finding out which form of CO2BOLs would bind the most carbon dioxide while maintaining a low viscosity.

The research, led by chemist Roger Rousseau and his colleague Vassiliki-Alexandra "Vanda" Glezakou, began with investigating a simple CO2BOL called IPADM. Capable of keeping track of the position and movement of thousands of atoms, the computer program enabled the scientists to observe interaction between IPADM with CO_2.

The simulations showed that when neutral CO_2 bound to IPADM, it generated a IPADM-CO_2 molecule with a positive and negative charge on different parts of the molecule. This ion is called a "zwitterion," which is German for hybrid-ion, because it is a hybrid of a cation and anion. In this particular CO2BOL, the zwitterion IPADM-CO_2 is most easily and most abundantly formed.

When binding CO_2 to IPADM in a real-life scenario, the scientists realized that the generated zwitterion is the most likely culprit for driving up the viscosity during carbon-dioxide binding. They rationalized this thought by saying that the opposite charges caused interlocking between individual IPADM-CO_2 molecules and reduced their ability to move freely.

As a result, the scientists began to simulate carbon-dioxide binding to two other CO2BOLs to see if more quantities of neutral acids would be generated, rather than zwitterions. In one of the CO2BOLs, called EODM, the simulation showed that binding CO_2 generated 50% neutral acid and 50% zwitterions. They tested the viscosity of EODM-CO_2 in real life and found that it had 50% lower viscosity than IPADM when bound to the same amount of carbon dioxide.

Testing on more CO2BOLs is currently underway, to observe their abilities to generate more neutral acids rather than dipolar zwitterions during carbon binding. By leveraging the simulation software, they hope to develop higher-capacity CO2BOLs that can bind to more CO_2 with lower rises in viscosity. ■

Designing Apps for Smart Products

Machine Design had a chance to speak with Bryan Kester, director of IoT at Autodesk, about how to help engineers design applications for smart products.

Interview by CARLOS GONZALEZ

Please tell me a little about yourself and your background.

I was the chief executive officer of SeeControl, which was acquired by Autodesk in October of 2015. SeeControl was established in 2010 and was a one-stop shop in the cloud for building Internet of Things (IoT) applications. It did data collection and analytics (real time or historical), but more importantly was that people could build IoT applications without being a software developer. It was geared toward business analysts and engineers, whether they were mechanical, civil, or electrical—groups that are not experts in three-tier web applications that millions of devices need to use and interface with.

Prior to that, I was a venture capitalist and operating executive focusing in on startups around the Silicon Valley area. The common thread is that I have always had this fascination with IoT going back to the early RFID days in the early 2000s. I worked with a company that did healthcare RFID, which was acquired by Cardinal Health. I have always been fascinated with being able to control things over the Internet, which led to me teaming up with our CTO to create the platform we have today.

We agreed to be acquired by Autodesk because they have a fantastic vision toward the cloud. This vision addresses the current movement of people designing electronics and sensors in to everything because it has become cost-effective. This technology is not necessarily new, but it is now cheaper and achievable.

How does SeeControl fit into the Autodesk platform?

There are two different things happening. SeeControl is now called Fusion Connect. It is part of our already successful design product Fusion 360, which is one of two cloud-based CAD/CAM systems in the market. I am part of a large team that does product lifecycle management (PLM), which handles product-management automation after the CAD/CAM piece.

PLM and IoT are inextricably linked in that the lifecycle of a product does not stop when it is sold; it goes out into the field and sends data back. The idea is that if you instrument, from within your Fusion 360 CAD tool, the sensors, the microcontrollers, the circuit boards, and computers that go into the product all the way to our Fusion Connect IoT tool—which allows you to build customer-facing applications for our smart products—you have a lifecycle where IoT is touching every aspect.

The entire product lifecycle is changed when IoT is considered at the design phase. The user is designing based on the performance history of the sensors and circuits boards, including things such as how much power they may draw, and the form factor to be used. Then the user launches the prototype into the world and receives feedback from the sensors.

They indicate what improvements can be achieved or which components should be changed due to the product's performance. This will inform the PLM to obtain compo-

> I have been talking to more IoT people than ever before in my career, and they are educating and urging their higher management to start working on IoT solutions.
>
> —Bryan Kester, Director of IoT, Autodesk

nents from different suppliers, which will increase performance. Once the user is ready to sell the product, you can then offer advanced services from your product, such as preventive or predictive maintenance.

Ultimately, what a lot of our customers are starting to do is turn their product into an actual service. For example, a company that makes hydraulic pumps will also sell you a long-term subscription on operating or output data—i.e., the amount of fluid that it pumps. So part of the impact of IoT from the design phase to lifelong field service, which can span decades, is transforming the whole cycle of design, make, and use. It also transforms the relationship between manufacturer and customers, where manufacturers start becoming service companies for their products.

If the manufacturer is providing analytic service, where is the data stored and who controls the data?

If you enter a factory setting, certain shop-floor systems have been in place for decades. They collect data that is sitting on a server in the facility. It is not stored online or on the internet; it is not centrally viewable; and operation management personnel typically only look at the data or mine it after something has gone wrong. Anything above and beyond normal preventive maintenance is not widely viewable or consumable by most of the organization.

The efficiency of the plant is usually provided by the plant manager, and it typically involves just a number or a top-level overview in a PowerPoint file or Excel report shared with the corporate organization. Many organizations simply do not have the ability to view the data across their operations. This creates an opportunity for manufacturers to come in "over the top" with preconnected products with either cellular connectivity or an external connection to collect data for IoT purposes. For business managers of these plants, this provides a service in which they do not have to approach IT or invest extra time and money.

I have been doing software as a service (SaaS) for 20 years, and operations professionals are always reluctant to approach IT for solutions, so buying an "IT" based service from their trusted industrial equipment vendor is easy. That being said, I have been talking to more IT people than ever before in my career, and they are educating and urging their higher management to start working on IoT solutions.

What is the range of people involved in IoT projects today?

It is still a mixed bag. I worked in the "dot.com" era, trying to convince people the internet was important and would end up changing the work environment. Today, I am seeing the same phenomenon—people are struggling with "what is IoT?," what it means for them, and how do they do this.

In terms of people or personnel, there is an increase in product managers as well as some increases in marketing and sales. But more importantly, we are seeing the creation of new job titles. For example, new positions being created include titles like director of IoT platforms, vice president of connectivity, or vice president of remote monitoring. You see these titles emerging at forward-thinking companies that know they cannot fill those roles with an incumbent because it crosses several different business units. They are hiring people that can cross into all of these different work areas.

What products and services does Autodesk offer in its IoT solution?

Autodesk is just part of the IoT solution—the central cloud analytics and web application piece. Companies claiming "end-to-end" solutions are being dishonest. One of my customers in a recent interview stated that in his 35 years as a product manager, he never had been involved in a more complicated project than IoT. He originally had 21 different suppliers, and not a single person or company can own the whole project; it is just too complicated. With us, he is down to one vendor for the cloud piece and a handful of others for devices and connectivity.

By default you have to work with partners. For example, Verizon is a big partner of Autodesk and are helping customers with industrial remote monitoring. We sell through wireless carriers, data-connection-device companies, or embedded systems companies, and—most importantly—system integrators (SIs).

IoT projects need a well-educated SI to configure and deploy solutions on these platforms for you. These SIs typically come from small boutique companies that know how to pull together virtually all of the components into a cohesive solution. The components are an embedded system, with device software similar to a smartphone app, a connectivity layer for the network, and large software in the backend and visualization layer, such as Fusion Connect, to provide the cloud service.

Do you feel that Autodesk is approached first in the planning or later on by other companies?

Today we mainly are receiving business through the partner ecosystem we brought in to Autodesk. That will change as we increase the awareness level of Fusion Connect among Autodesk customers—we have tens of thousands of customers in our manufacturing vertical alone.

We are planning for the market approach to change, where many of our users will approach us directly for IoT services and procure the service online to try it out and see if IoT is a fit for their company. We try to classify our customers into two groups: those who are just learning about IoT and the cloud, and those fully transforming companies embracing IoT systems. The advantage of our platform is that if you have an idea, you can execute it with minimal effort, and a product manager can show it to your customers for instant feedback and quick market launch. md

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What are the Differences Between Various Nickel-Based Metals and Alloys?

NICKEL IS A versatile metal element that alloys with most other metals. It gives alloys great corrosion resistance and the ability to withstand high temperatures and pressures. Here's a quick look at five of the more common nickel alloys.

Extra-high nickel alloys (Duranickel): These all have more than 94% nickel content. Extra-high nickel alloys that have 4.75% manganese resist sulfidation at high temperatures. Duranickel 301 becomes much stronger if thermally treated, which causes precipitation of submicroscopic particles of Ni3Al and Ti throughout its matrix, a process called "precipitation hardening." Duranickel retains excellent spring properties up to 600°F. The corrosion resistance of these alloys is similar to that of commercially pure wrought nickel.

Nickel alloys resist high pressures and temperatures, making them well suited for high-performance applications such as jet-engine blades. They also resist corrosion. That's why Monel is used in deep-seal mining where seawater poses a constant threat of corrosion.

Nickel-molybdenum (Ni-Mo), nickel-molybdenum-chromium (Ni-Mo-Cr) alloys (Hastelloys): Alloys in this category are used for their high strength despite high temperatures and corrosive surroundings. Hastelloy B is known for its resistance to HCl (hydrogen chloride) and for its creep and rupture strength at temperatures around 1,400°F.

Hastelloy C resists active oxidizing agents such as wet CL2 (chlorine), hypochlorite bleach, FeCl3 (iron chloride), and HNO3 (nitric acid). Hastelloy C also resists oxidizing and reducing atmospheres at temperatures up to 2,000°F, and can still carry loads at temperatures to 1,600°F.

Hastelloy C-276 resists pitting, stress corrosion, cracking, and reducing atmospheres as hot at 1,900°F. It also resists formation of grain-boundary precipitates in heat-affected weld zones, so it is suitable for most chemical-process applications in the as-welded condition.

Hastelloy X resists oxidizing at temperatures up to 2,200°F, and retains useful creep and ruptures properties at 1,800°F.

Nickel-molybdenum-chromium-copper (Ni-Mo-Cr-

CU) alloys (Illium): Engineers often turn to these alloys, which are mostly cast, for their corrosion resistance. Wrought Illium, for example, is highly resistant to sea water, H2SO4 (sulfuric acid), HNO3 (nitric acid), and H3PO4, (phosphoric acid), as well as many fluorides. Wrought Illium's cast counterpart is Illium G.

28 58.6934
2914 1.8
1453
Ni
[AR]$3d^8 4s^2$
8.9 2,3

Illium B, a cast alloy, is especially resistant to sulfuric acid. It can also have its hardness increased by heat treatment at temperatures from 1,100°F to 1,400°F.

Illium 98 is a casting alloy with much better corrosion resistance than Illium G. Several of these Illium alloys also highly resist wear and abrasion in corrosive environments.

Illium G, a weldable wrought alloy, resists hot sulfuric acid and phosphoric acid.

Nickel-copper alloys (Monel): The most common of these alloys are Monel 400, Monel R-405 (a free-machining alloy), and Monel K-500. The K-500 version can be precipitate-hardened to high levels of strength much like Duranickel.

These Monel alloys combine ready formability, a wide range of mechanical properties, and high corrosion resistance. They are strong and tough at sub-zero temperatures and are generally free from stress-corrosion cracking. K-500, however, shows a tendency to stress-corrosion cracking when it is precipitation-hardened.

Cast nickel-copper alloys containing 3 to 4% silicon have excellent nongalling and anti-seizing characteristics.

Nickel-chromium (Ni-Cr) and nickel-chromium-iron (Ni-Cr-Fe) superalloys: These alloys, which include Inconel 600 and Inconel 800, are noted for their strength and corrosion resistance at high temperatures. Some of these alloys are derived from the Ni-Cr group by adding aluminum and/or titanium for precipitation hardening. Controlled precipitation hardening of Ni-Cr and Ni-Cr-Fe alloys lets metallurgists increase strength and hardness temperatures to about 1,300°F. Included in this list of precipitation-hardened alloys are 713 C, IN-100, IN-733, MAR-M200, MAM-241, Mar-M432, and wrought alloys Inconel X-750, Rene 41, Rene 95, Waspaloy, Udimet 700, Astroloy, and Udimet 520.

Several of these types of alloys (Inconel 625, IN-102, Udimet620, and RA 383) can be strengthened by adding refractory metals such as molybdenum, tungsten, and columbium. The resulting alloys have good oxidation resistance and strength at high temperatures. They cannot be precipitation- hardened, but they can withstand thousands of hours at temperatures to 1,200°F. Alloys HW and HX (Alloy Casting Institute designations) are typical casting alloys that survive temperatures to 2,000°F. md

VICTORIA FRAZA KICKHAM | Distribution Editor

CHANGING AUTO LANDSCAPE

Creates Challenges, Opportunities

More electronic content, new competitors, and a deeper level of integration in today's cars add up to continued prosperity in automotive markets.

The auto industry's recovery from the 2008-2009 recession continues to be good news to the electronics supply channel, especially as automakers embrace the changing ecosystem of the car to develop more advanced infotainment, safety, and security features. The change is altering the competitive landscape across the supply channel—think of Apple, Samsung, Google, and others that are developing automotive applications and systems—while opening the door for distributors to supply a wider range of components and services.

"You have a lot of different technologies designed for the [automobile] or taken from other verticals and being applied toward autos," says Mark Boyadjis, principal analyst and manager, automotive user experience, for industry researcher IHS Automotive. "It's changing the total makeup of the vehicle."

Apple Carplay is one example of how the inside of the car is changing. An app that replicates the iPhone interface inside the car, Carplay is available in more than 100 models and as an aftermarket service. The key feature is Siri, as the system is controlled largely by voice commands and is in response to consumers' desire for greater safety in today's connected vehicles. Android offers a similar application with its Android Auto app. Samsung is also try-

ing to capture a piece of the automotive market, focusing on supplying components for autonomous driving and infotainment systems—a market the company had not previously invested in.

All of these point to the changing automotive ecosystem, growing need for deeper integration of electronic content, and the changing competitive landscape.

"Samsung hadn't really done anything in the vehicle, but in the last 12 to 18 months [has been] investing in this market," says Boyadjis. "They're going after parts of the business that the tier one supply chain currently owns."

SENSOR FUSION, AI HOLD PROMISE

A recent report from IHS Automotive points to sensor-fusion engine-control units (ECUs) as a key growth driver in the automotive industry, further emphasizing the advancing automobile. Safety-critical applications surrounding collision and speed, for instance, are prime areas for this technology, which pulls together different types of sensors in a customer-facing feature. In 2015, just 4% of new vehicle platforms included sensor-fusion ECUs for surround-view park assistance and safety-critical functions, for instance, but by 2025 that is expected to rise to 21%, according to IHS data. This represents one of the highest growth rates for components used in the automotive industry.

"Using a combination of these sensors will help car OEMs achieve robust sensing schemes and promote redundancy," according to IHS' most recent Automotive Electronics Roadmap. "Sensor fusion ECUs combine information from different sensors to implement algorithms for achieving the highest level of functional safety."

Artificial Intelligence (AI) is another growth opportunity, albeit one that remains a bit more futuristic. IHS points to the potential use of AI in autonomous driving, citing increasing demand for hardware and software solutions that support AI, which uses electronics and software to emulate the functions of the human brain. Unit shipments of AI systems used in infotainment and advanced driver assistance systems (ADAS) are expected to rise from 7 million in 2015 to 122 million by 2025, the researcher says.

The majority of AI systems today focus on speech recognition, but the potential exists for more advanced applications. And although AI systems are relatively rare in the automotive market today, they are expected to become standard in new vehicles over the next five years, IHS says, especially in infotainment human-machine interfaces. Such systems are expected to move beyond speech recognition to include gesture recognition, eye tracking and driver monitoring, virtual assistance, and natural language interfaces. ADAS and autonomous vehicles are another big potential area, where camera-based machine vision systems, radar-based detection units, driver condition evaluation, and sensor fusion ECUs will be in high demand.

Such advances are no surprise to industry watchers such as Boyadjis.

"In developed markets, it's no longer surprising to find a fully vetted car ecosystem in any car," he explains. "The reality is that a lot of the global auto makers are already pivoting into connected car 2.0—a fully vetted, developed … car ecosystem."

THE PATH FORWARD

Despite slower growth in the automotive industry last year, the automotive semiconductor market grew 0.2% year-over-year to reach $29 billion in 2015, according to IHS. And although the automotive market remains a small portion of overall global electronic system sales, many suppliers remain focused on investing in this business. Leading distributors such as Avnet have pointed to strength in the automotive sector, along with long-term opportunities to go beyond supplying electronic content to providing services that support data, security, and business analytics aspects of the content in the car.

The bottom line is that the connected car is here, and most automakers are focused on what's next—that is, what is the next level of advancement they can offer consumers? Developing deeper integration that links to the connected home is one example. This comes at a time when the transportation industry is set for dramatic change, with the advent of self-driving cars, advances in electric vehicles, and the growth of ride-sharing services.

"It's a model that's going to change pretty drastically for [auto makers] in the next 10 to 15 years," Boyadjis says, pointing to a not-so-far-fetched scenario in which consumers subscribe to mobility services instead of purchasing new cars.

Though such a situation is certainly not right around the corner, automotive industry advances in the last few years point to a swiftly changing industry hinged on electronics.

"Many, many automakers and the rest of the supply chain see the change and are starting to drive the change due to customer preferences," Boyadjis adds. ■

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All Aboard!

THE FUTURE OF RAILROADS, SUBWAYS, AND SMART CITIES

The rise of the Internet of Things and smart cities will increase our reliance on the rail system and how modern rails and subways are being constructed.

Smart cities are an inevitable result of the Internet of Things (IoT) being inserted into every aspect of our lives. As we increase the number of smart cities, we will see an uptick in population as well. A report from the engineering firm Arup highlights the need for future cities to design new rail lines or modernize our existing rail systems. By 2050, seven out of every 10 people will live in an urban area, and rail will be the most used method of transportation. We will incorporate many of the advances of IoT into our rail systems, which will not only help us track and monitor daily ridership but also help maintain our infrastructure. In this feature, we highlight and review the future of cities and rail as well place a spotlight on the newest subway line in New York City, the Second Avenue expansion line.

THE FUTURE OF CITIES AND RAIL

POPULATION

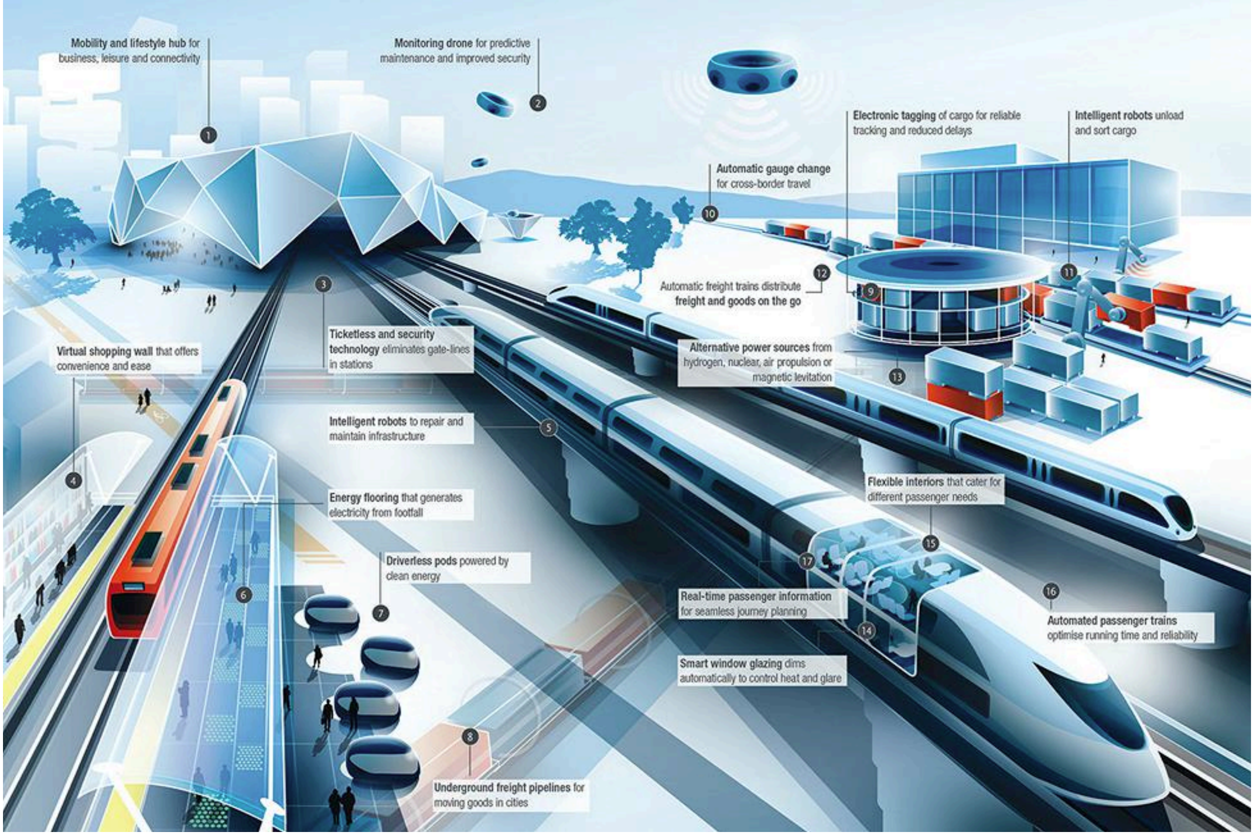
There are several factors impacting the future of cities. More than ever before, major cities across the United States and the world are seeing large population growth. According to the 2013 May issue of Siemens' *como* publication, by 2050, 75% of the world's population will live in cities. This will lead to the evolution of megacities, cities that are home to more than 10 million people. A megacity can be a single metropolitan area or two or more metropolitan areas that unite to create a large mega-region, which reach numbers of 100 million people or more.

An example would be New York City, which is comprised of five boroughs (Manhattan, Brooklyn, the Bronx, Queens, and Staten Island) and will develop into a megacity. At the same time, the cities of Washington, D.C., New York City, and Boston can develop into a mega-region. Another example would be the cities of Hong Kong-Shenhzen-Guangzhou in China. It is expected that by 2050, 50% of the world's population will have moved into the middle class, according to the United Nations' *World Population Prospects: The 2010 Revision*. Paired with the previous projection that most people will live in or around urban areas, you can expect a large impact to the methods of travel in and out of cities.

CLIMATE CHANGE AND ENERGY

Climate change is greatly impacting our cities. With the rise of global temperatures in recent years, there has been an associated increase in the frequency and intensity of extreme weathers. These changes in temperature, storm activity, and sea level will impact the transportation infrastructure, its design, operation, and maintenance, leading to disruptions, damages, and failures in older transportation systems. The National Research Council reported that damages from flooding will force rail and subway lines to be either rebuilt or raised in future expansion projects. Many of our current rail or subway lines are either near shore or below sea level. Future rail systems will have to be built keeping the rising sea levels and climate changes in mind.

Energy and climate change tend to go hand-in-hand as we try to reduce our use of oil-based fuel and increase our use of alternative and renewable energy sources. To prevent the average global temperature from increasing beyond a delta of 2°C, greenhouse gas emissions need to be reduced by 50% by the year 2050. As a result, the method of powering our rail systems must change. According to Railway-Technology.com, two alternate modes of energy can find their way into rail systems by 2050. The first is liquefied natural gas (LNG) and



Arup, the engineering firm designing the Second Avenue Subway Project, published *The Future of Rail 2050*, which highlighted the social and technology trends that will factor into rail transportation of smart cities. *(Photo Credit: Arup | The Future of Rail 2050)*

the second is hydrogen-based fuel or hydrail. LNG, which is natural gas that has been converted to liquid form for ease of storage and transport, could reduce carbon emissions by 30%. Hydrail could replace diesel engines and generators, which are used in today's modern diesel-electric trains. The energy would be generated by hydrogen fuel cells and the electricity stored in batteries from regenerative braking. The hydrogen itself could be mass produced by either nuclear, wind, solar, or hydroelectric energy production.

SMART TECHNOLOGY AND IOT

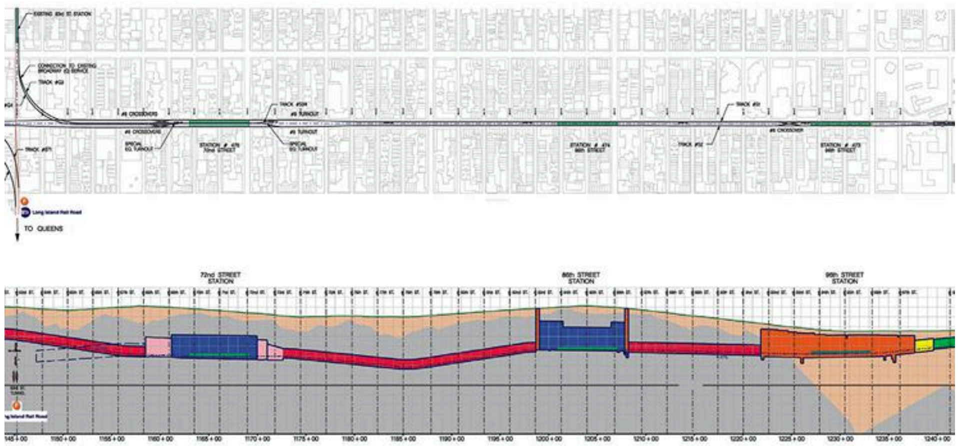
With the development and increase of IoT, smart solutions are necessary to modernize transportation systems and methods. The International Transport Forum reported that, by 2050, the mobility of the common passenger will increase by 200% to 300%. As the amount of ridership increases, transportation systems will have to track how many riders a day are on the system, what are the high occupancy times, and what deficiencies reduce the overall quality of the system. This is where the world of smart sensors and analytics can help. Machine-to-machine technology will increase efficiency by embedding sensors in objects and systems to automate tasks and capture real-time information for predictive maintenance. Developments in smart robots will be a crucial part to inspect tunnels and bridges in an aging infrastructure. Robots are already being used to repair water pipes and to test load-bearing cables and tethers of bridges and elevators.

HISTORY OF THE SECOND AVENUE SUBWAY PROJECT

If the future of cities depends greatly on modernizing transportation like new and efficient rails systems, our methods of construction must improve to accelerate the construction process. The Second Avenue Subway Project is an example of how modern engineering in a busy urban environment is handling that task. In New York City, the Second Avenue Subway has been under construction for the last year nine years. The ceremonial groundbreaking took place in April 2007. The Second Avenue Subway is being designed by the engineering firm Arup and once Phase 1 is completed (extension of the Q line from 57th Street and 7th Avenue to 96th Street and 2nd Avenue) it will serve approximately 200,000 daily riders, decrease crowding on the Lexington Avenue Line by as much as 13% on weekdays, which is an average 23,500 fewer riders, and reduce travel time to the Upper East Side by 10 minutes or more.

However, the project has been on the books since 1919 when it was first proposed. It has been a long process to develop the new subway system, especially when you consider the speed with which the initial subway was built. The initial plans for the subway system were approved in 1894 and construction began in 1900. In just four years, workers had laid out over nine miles of track across and the first underground line of the subway was opened in 1904. Within the first 30 years of service, the system we know today was established. So why has it taken so long for the Second Avenue Subway to get underway?

There are several factors that play into the delay of the construction. The first major aspect is a constant changing economic landscape. In 1929, the stock market crashed, resulting



The map highlights the construction techniques used on the project. The red tunnels and pink caverns are created via the Tunnel Boring Machine while the blue stations are done via mining. The 96 St. Station in orange was completed via the cut-and-cover method.
(Photo Credit: Metropolitan Transportation Authority)

in the Great Depression. A new plan was developed but was then placed on hold as the United States entered World War II. Between 1972 and 1975, federal funding was granted and construction started in 1972, but the fiscal crisis of 1975 delayed the project even more. It was not until 2004 that the MTA proposed to reopen the Second Avenue Subway project, creating a new underground line from 125th Street to Lower Manhattan.

The delay due to finances introduced other problems that were not around during the initial construction. Safety regulations and construction standards have improved the workplace environment. The workforce that was used during the original construction, which included underage workers, could not be used today. The average number of workers was 4,661 per day and the single-day high was 12,000.

The methods of construction today are also stricter. The most popular method of construction was the cut-and-cover method. Here, workers would dig giant trenches through existing streets to lay down tracks. The soil is supported by vertical walls and a frame is built to support concrete or the metal street decking. The decking allows for part of the street to stay open while construction continues underground. Once the underground rail and station was complete, the workers cover the trench back up. While cut-and-cover is still used to a certain degree, one could not use it for the whole line with the amount of traffic, vehicles, and people that occurs on Second Avenue. Engineers have turned to modern methods of construction beneath the surface that do not interrupt the traffic and pedestrians above.

MODERN CONSTRUCTION METHODS

The Second Avenue Subway Project consists of four phases. Phase 1 is scheduled to be completed by the end of 2016. Phases 2, 3, and 4 will see extensions north to 125th Street, south to 63rd Street, and finally south to Hanover Square respectively. The cut-and-cover method will be used for many of the stations. For Phase 1, these stations include 72nd Street, 86th Street, and 96th Street. Modern cut-and-cover methods take into consideration the building types, where a mix of high-rise buildings on plies and low-rise masonry buildings on shallow foundations exist. Limitations on building movement, groundwater drawdown, vibration, noise, and underground utilities lead to the support-wall types to rigid designs: slurry walls, secant pile walls, or contiguous pile walls. These walls can be permanent or temporary once they are combined with a secondary cast-in-place concrete wall. Slurry walls are when a soft mud or cement-like fluid mixture is poured into an open trench. They are mainly used on areas of soft earth close to open water. Secant pile walls are formed by constructing intersecting reinforced concrete piles with either steel rebar or steel beams. The centers of the piles are spaced out, but no less than two diameters apart. Contiguous pile walls are piles of concrete that virtually touch each other and the gaps can be grouted to form a watertight retaining wall.

However, the tunnels connecting these stations will be reached by the modern method via a tunnel-boring machine (TBM). The TBM will tunnel from the existing 63rd Street tunnel, which was started back in 1972, and connect the stations together up to 96th Street. A TBM is comprised by the following parts:

Cutters: Cutting tools, made out of alloy steel, are installed on a large circular steel structure known as the cutterhead.

Buckets: Peripheral scoops are designed into the body of the cutterhead.

Main bearing: The cutterhead is connected to a large and high-capacity slewing, which is installed into the bearing housing known as the cutterhead support.

This is the tunnel-boring machine (TBM) from The Robbins Company. The TBM is 485 tons, 450 feet long, and uses a 22-foot diameter cutterhead to mine 7,789 linear feet in two tunnels. *(Photo Credit: The Robbins Company)*

Gripper system: The TBM anchoring system is located approximately 12-15 meters (40-50 feet) behind the front end. The front end is comprised of the cutterhead plus the cutterhead support/main bearing assembly.

Main beam: A long, hollow steel structure which slides through the gripper systems and bridges the distance between the front end and the gripper carrier.

Conveyor: A belt material handling system installed inside the main beam with its tail pulley inside the cutterhead and the head pulley protruding from the back end of the main beam discharging onto a transfer conveyor.

Propel cylinders: The front end is also connected to the gripper system by a set of large hydraulic cylinders.

Rear support legs: The aft end of the main beam is connected to a set of hydraulic legs to support the TBM during the reset cycles.

The TBM operates by the cutterhead rotating via several large variable electrical drive systems all connected to a common ring gear. The gripper system is engaged and the rear support legs are retracted. The rotating cutterhead is pushed into the rock face by the propel cylinders. The propel force is reacted by the gripper system, which is firmly planted into the tunnel side walls by the large gripper cylinder about 12-15 meters behind the tunnel face. The broken rock or muck chips fall to the tunnel floor in front of the cutterhead. The buckets scoop the fallen muck and elevate it to the top where it falls on the conveyor inside the cutterhead through chutes. The TBM conveyor transports the muck through the main beam and discharges into a muck transfer conveyor to be taken out of the tunnel.

When the propel cylinders reach the end of their stroke, approximately 1.8-2 meters (6-6.56 feet), the TBM is reset. The propel push and the cutterhead rotation are stopped. The rear

support legs are extended. The gripper system is disengaged from the tunnel wall. The propel cylinders are retracted to reset the gripper system. The gripper system is re-engaged with the tunnel wall. The rear section legs are retracted. The TBM is ready for the next boring cycle.

The TBM has modern advancements like a Human Machine Interface, which includes digital monitors, displays, and controls. This allows for adjustments during the drilling process.

After the completed supporting structure for the station has been installed, the first work train rides over new tracks from the 63rd Street Station.

(Photo Credit: MTA Capital Construction/Rehema Trimiew)

It uses lasers and feedback sensors for adjustment. Main-beam type TBMs have the best performance in hard competent rock. They have bored in massive rock formations as strong as 350 MPa (50,000 psi) unconfined compressive strength, which are just as hard as good-grade structural steels.

The third method of construction will be mining. This will be reserved for tight spaces that cannot be accessed by the TBM. Under controlled and monitored conditions, explosives will be inserted into small holes that have been drilled out. They will then be detonated sequentially for short intervals, breaking the rock and soil, which will be excavated and removed by backhoes, bulldozers, and a crane suspended clamshell shovel.

RAIL CONSTRUCTION WORLDWIDE

Arup is not only the designing the Second Avenue Subway Project, but has several train designs around the world. The High Speed 1 rail, which runs in London; the G:Link or the Gold Coast Light Rail in Queensland, Australia; and the future High Speed 2 rail, which will connect London to the West Midlands are examples of future rails opening cities to their surrounding areas and becoming larger. In the case of the Gold Coast especially, the region is one of the fastest-growing in Australia, with an annual population growth of 2% to 3%. As we extend ourselves into megacities and mega-regions, more efficient rail transportations using the latest network connected technology will be needed. md

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Keeping It Simple with Rolling-Ring Drives

Engineers can keep packaging equipment simple and cost-effective with rolling-ring drives.

One of the most indispensable features common to most packaging machines are components that provide linear motion. These components are critical for sealing, conveying, inserting, ejecting, scoring, folding, and carrying out other critical packaging tasks. Most of these linear-motion devices require some way to generate reciprocating motion or index a linear-drive device to fully carry out their packaging tasks.

Even so, in many cases, the packaging application does not warrant complicated designs and interacting subsystems. In fact, when a packaging machine's linear-motion requirements do not include sensor-dependent indexing or highly accurate slicing or cutting, engineers can often use a simple device called a rolling-ring drive. These less sophisticated, more affordable mechanical devices simplify designs and reduce operating and maintenance costs. This helps manage budgets and assures end users that machines will be relatively easy to operate and maintain.

ROLLING-RING BASICS

Rolling-ring drives convert rotary motion into basic, back-and-forth linear movement. Thus, the drives become viable alternatives to electronic controls, as they eliminate the need for many additional components such as clutches, cams, and gears.

Additionally, rolling-ring drives run on smooth, case-hardened shafts. There are no threads to trap debris or grease. This eliminates the risk of clogs and jams that can cause screw-driven nuts to churn until the screw is ruined. This translates into reduced downtime and savings for rolling-ring drives, since there is no need to interrupt production and stop the system to clean or repair the shaft.

Rolling-ring drives also eliminate backlash from linear drives in packaging machinery. Mechanical power-transmission

The rolling ring-drive housed in the drive head converts rotary motion of the shaft to linear motion for the drive head. In a packaging device, the head might hold a blade for cutting boxes or an adhesive applicator for laying down a bead of glue.

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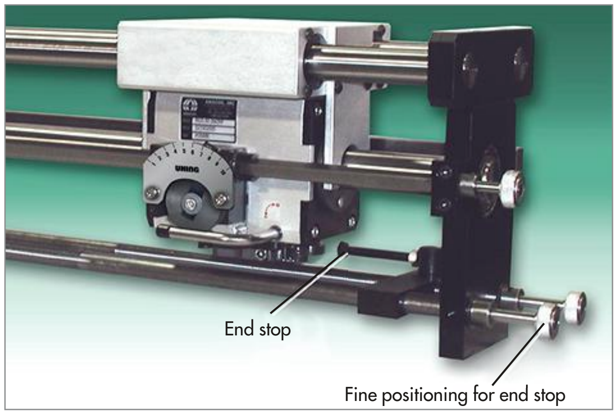
devices (e.g., leadscrews, gear assemblies, couplings) usually involve joined or mated parts such as meshing teeth in opposing gears. Joined parts always have a little space between them. This space lets lubricants make their way between the parts and reduce wear that would otherwise result if the surfaces were in constant contact. Reducing wear improves longevity.

While the drive is moving, the spaces between parts do not cause any problems. When travel direction is reversed, however, the mated parts must separate and travel in the opposite direction until they mate with the opposing joined part. The distance traveled, no matter how minute, causes backlash in linear motion. The greater the backlash, the more the drive's accuracy and repeatability are compromised.

There are a variety of mechanical and electronic anti-backlash solutions. For example, preloaded nuts or active cam mechanisms can reduce or eliminate backlash. Other remedies include flexing gears, shims, and mechanisms designed to preload the gear train. Electronic backlash correction methods include various types of encoders and feedback devices.



The drive head's travel speed and direction are mechanically controlled with hardware fittings (end stops) that pivot the rolling-ring bearing assembly inside of the head.

A rolling-ring drive transmits mechanical power, but uses a different approach to overcoming backlash. The technique is cost-effective because it does not require an investment in

THE NEED FOR COMPLEXITY IN PACKAGING EQUIPMENT

THANKS TO ADVANCES in sensors, motors, and machine technology in general, packaging designers have more speed, accuracy, and automation options at their disposal than ever before. This has helped designers meet demands for increasingly more complex packaging applications, especially when it comes to linear motion.

Numerous reliable, time-proven machines are available to meet practically every linear-motion need, including ball screws, pneumatics, hydraulics, and timing belts, to name a few. After choosing one of these methods, engineers then must choose from an even larger selection of support components—sensors, motors, switches, and so forth—to control the linear motion.

High-end packaging machines incorporate the electronics and controls necessary to provide the linear motion that's required. This means the investment in linear motion for packaging equipment can be significant. For many operations, however, the investment is justified and necessary. Irregularly shaped boxes, for example, have become commonplace. Flap detection utilized when gluing a container together requires the integration of sensors and robotics. Batch-control processes, precision labeling, and other high-accuracy packaging procedures also rely on components capable of fine resolution and precise repeatability.

Similarly, selecting a precision ball screw to move a perforating tool across a sheet of printed corrugate might be appropriate if the perforating tool needs to be indexed along the line of travel as opposed to making one continuous cut. Using a precision ball screw means the designer needs to include clutches and gears to stop and reverse the tool, and a bidirectional motor. If the corrugate being cut is fibrous and produces a lot of debris, a shaft bellows or other device needs to be added to protect the screw threads and prevent clogs and jams.

For linear movement of plastic bags under a sealing tool, perhaps a simple conveyor is adequate. However, what if the linear movement needs to stop-and-start or reverse or speed up? If so, a timing belt drive might be more suitable for moving the conveyor.

To tell the timing belt drive how fast to go, which way to go, when to stop, and when to go backward or forward, the control system may require servo/stepping motors, switches, encoders, sensors, or PLCs. Likewise, hydraulic drives also usually require complicated mechanics and electronics as well as multi-speed, direct braked reversible motors, pumps, and solenoids.

How an engineer solves an application's linear-motion challenge dictates cost and complexity at the design stage, and determines the investments needed in operating, training, and maintenance for the end user. The necessity of complex controls is normal and generally an accepted part of the design. And the rapid rate of new product development has helped keep the costs of linear-motion components in a competitive, relatively affordable range.

Still, when designing machines to perform complex packaging applications, costs can quickly add up and necessitate that end-user budgets accommodate training operators and maintenance personnel. That's the overriding reason engineers should use their ingenuity to use lower-cost, simpler devices, such as rolling-ring drives, to solve some of their linear-motion problems in packaging.

preloads, programming, encoders, and other devices similar to those described earlier.

In a rolling-ring linear drive, the bearing assembly is fixed within the housing (nut). Each bearing in the assembly is held at a specific angle relative to the shaft. The key to a rolling-ring drive's zero backlash is the design of rolling-ring bearings. The bearings are machined so that a central ridge runs around the surface of the inner race. When the rolling-ring drive is placed on a smooth shaft, the ridge of each bearing establishes a point of continuous contact with it. When the shaft rotates, the rotary motion is immediately converted into linear output. No free movement or play occurs between shaft and bearing, even during reversals.

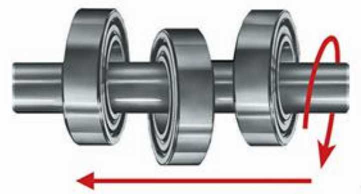
ROLLING RINGS IN PACKAGING

Let's say an engineer needs linear motion for a tool head—a simple, repeating reciprocating motion over a fixed distance—to apply glue prior to assembling a corrugated carton. High-end design isn't needed or justified.

Electronics and controls are fine for precision trimming of Mylar-brand label sheets. But the simple reciprocating motion needed for some processes, such as scoring boards and running a glue gun back and forth, does not need high-end design and the accompanying complex electronic controls and programming.

ANATOMY OF A ROLLING-RING DRIVE

The angled position of the three rings relative to the shaft determines the drive's pitch (lateral movement per revolution of the shaft) and thrust (force exerted by the shaft).



The drive shaft is case smooth and case hardened. There are no threads, so there's no need for protective devices to keep dirt and debris from clogging the threads.

Each rolling-ring bearing's inner race has a contoured ridge. When the shaft turns, it bears against this ridge and creates compression and friction.

IN THE 1940s, German engineer Joachim Uhing invented the rolling-ring drive. Soon after, he founded the Uhing Co. to manufacture and market the devices. After the patents expired, other companies jumped into the market, including Amacoil/Uhing, Cemanco/KMK, and Marldon. There are also numerous Asian imitators.

Rolling-ring drives can convert rotational motion into precise linear motion. They also work with clockwise and counter-clockwise motion

Instead, a rolling-ring drive uses the dynamic bearing/shaft setup described earlier to convert the smooth, threadless shaft's rotary-motion input into linear motion. Linear speed and travel direction of the nut are then controlled by pivoting the bearings on the shaft.

This system becomes a variable-speed linear drive free from programming and electronic controls. Travel speed and direction are mechanically controlled with hardware fittings (end stops) that pivot the bearing assembly in a controlled manner. The shaft does not need to be reversed.

The linear speed of the drive head can be adjusted using a lever. It pivots the rolling-ring bearings inside the head to increase or decrease the pitch and, therefore, the drive's linear speed.

Instead of going with a variable-speed, reversible motor such as a servo or stepper motor, a less-costly unidirectional motor may be employed. The drive does not need to be slowed down or stopped when reversing travel direction. That, too, is controlled mechanically without having to adjust motors or controls. Machinery operating time is thereby increased while reducing unnecessary slowdowns and interruptions in production.

Additionally, in many cases, a drive like this may be powered by a comparatively inexpensive single-speed motor. The linear speed of the drive is mechanically adjustable using a lever control on the drive. Turning the lever pivots the bearings on the shaft, which effectively increases or decreases the linear speed of the drive.

Rolling-ring drives are a simple, elegant way to generate linear motion in packaging machines. Their simplicity—linear output from a rotating shaft without electronics—gives the technology a certain allure from a design standpoint. However, rolling-ring linear motion provides the most noticeable advantage, in terms of efficiency and cost-effectiveness, when used to produce continuous reciprocating motion of the drive head. Using rolling-ring drives for indexing, however, is not always practical.

For example, a picking or grasping tool may need to be positioned over a series of bottles, lowered to grab and lift the bottles, and then moved to where it can lower the bottles into a shipping container. Packaging machinery such as this requires custom linear motion of the tool head. Furthermore, linear speed may have to be ramped up or down, and the tool must be indexed—driven backward and forward based on sensor feedback.

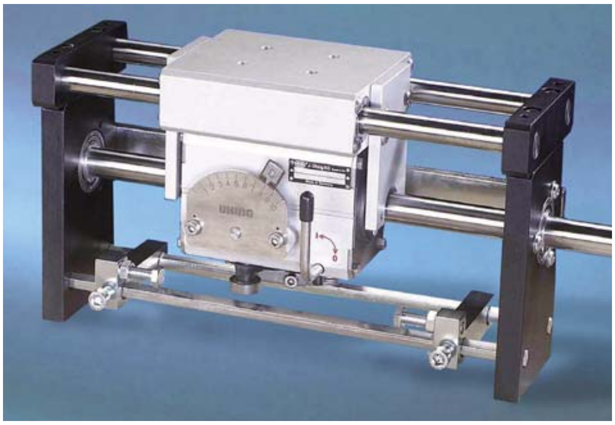
Attaching sensors and encoders to a rolling-ring drive lets it handle indexing and other specialized linear-motion requirements.

Typically, it takes programming, variable-speed motors, and motion-control units to ramp down the drive head before reversal. While a rolling-ring drive can be made to ramp up and down using only hardware fittings through purely mechanical means, it is often not practical given the operating speed and precision of many packaging machines. In these types of cases, rolling-ring drives are unable to compete with electronics and programming in terms of speed and accuracy.

A rolling-ring drive could be fitted with a sensor and linear encoder to monitor positioning data. Then a process controller would signal and control the stepper or servo motor and other components. This is essentially the same sort of control that would be needed with most other linear-motion technologies. Other than the smooth shaft, there is no compelling reason—no significant savings of time or money—to use rolling-ring motion in this situation.

In addition to speed and accuracy, packaging engineers planning on using a rolling-ring drive must also consider how the payload will attach to the drive head. That's because

A process controller could use position data to signal and control the stepper or servomotor that rotates the rolling-ring drive's shaft, thus controlling closing the feedback loop for motion control.



A linear-bearing slide load carrier keeps weight and overturning moments off the rolling-ring bearings in this rolling-ring drive application. The drive pushes on the yokes attached to the load platform to move the load carrier above it. All of the weight and forces are absorbed by the linear-bearing slide, which keeps additional pressures off the rolling-ring bearings.

the bearings inside the nut are installed under factory-specified pressure.

Placing a significant load (weight or overturning moments of force) directly on the nut increases pressure on the bearings. This increase in pressure must be relieved or the specially machined inner races of the bearings will flatten over time, causing the drive unit to lose thrust.

Using a load carrier such as a linear bearing slide removes all forces from the rolling-ring drive. The drive simply pushes against the yokes to slide the load. All weight and forces generated by the load are absorbed by the linear bearing slide. The rolling-ring drive is thus free to do what it was designed to do—push.

When the application permits, engineers can develop simpler, less-costly designs that are based on rolling-ring linear motion. As mechanical power-transmission devices, rolling-ring drives are able to provide viable alternatives to screw-based machines and other types of linear-motion setups. For repetitive, back-and-forth motion, rolling-ring drives with variable pitch can save both time and money by eliminating the need for clutches, cams, gears, and other external controls.

Depending on the size of the drive, rolling-ring drives can deliver up to 800 lb. of axial thrust. The only maintenance a rolling-ring drive needs is lubrication of the drive shaft once a month—bi-monthly if use is heavy.

Armed with specific application data, companies supplying rolling-ring drives can determine if a rolling ring device will improve a packaging machine design. Additionally, suppliers can properly size rolling-ring drives and recommend numerous options to meet a customer's unique linear-motion needs. md

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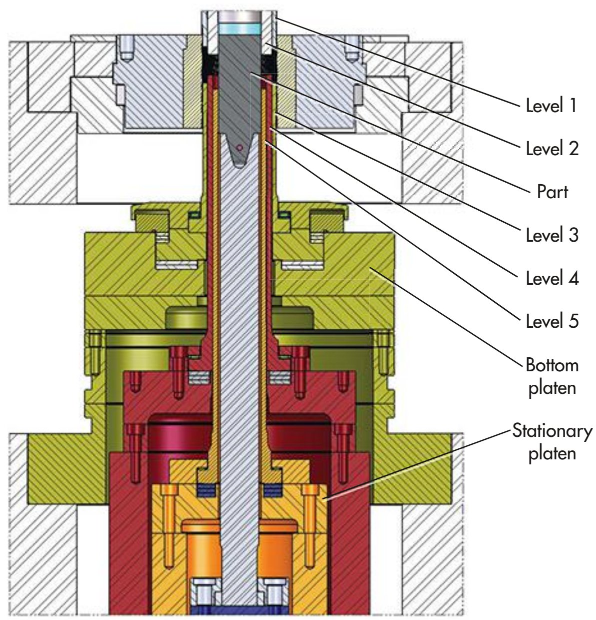
Reap the Benefits of Modern-Day Powder Metallurgy

Advances in PM over the years have steadily expanded its market, and now the technology is poised to start taking over other parts-manufacturing processes.

Given the many materials and processes available today, finding the best combination for an application can significantly affect the cost, time of production, and performance of the product. For example, some powder-metallurgy (PM) processes have been viewed as a solution for simple, high-volume, non-critical applications. But PM is now being considered for new applications, as post-processes have increased surface and overall part density. In doing so, they have improved both wear and strength of PM parts. In addition, modern powders are produced in more sophisticated processes that have enhanced finished part density, strength, and other properties.

Over the years, powder-metallurgy companies have received many awards for complex designs in mass-produced parts in the aerospace, power, medical, and automotive industries to prove the validity of the PM process. This article will take a look at powder processes and how powder metallurgy works, and offers up considerations to mull when selecting PM for your part.



Compacting in stages allows for more uniform density in complex shapes. In addition it can ensure the entire mold is filled and compacted. (Courtesy of Capstan Atlantic)

THE PROOF IS IN THE POWDER

Though powdered-metal processes have been around at least since 3000 B.C. for iron objects, this article will focus on post-industrial revolutions in powdered metallurgy. By 1922, cemented carbides and impregnated lubricants in ball bearings started changing the machine industry. To produce the quality parts made possible with PM today required improvements in fine uniform particles and metallurgical purity.

Powders as far back as the 1970s may have been as basic as grinding scrap metals into a powder. This produced a powder with varying particle size. Low powder quality often led to parts that were not fully dense. This meant higher porosity, which accelerates wear or causes surface fatigue failure. Engineers continued to use PM despite the problems because it could make shapes that would be difficult or impossible with other processes, and it saved costs due to its minimal waste process. In particular, when it comes to metals that are hard to form and/or mill, or are expensive, PM becomes a viable solution to expand an engineer’s toolbox to new metallurgy and shapes.

Generally, PM is competitive with casting, machining, and forging, and often associated with the aerospace, power, and medical industries. While these industries might be low volume in nature, PM parts have experienced significant growth thanks to the automotive industry, specifically in terms of pro-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ducing gears and other parts for mass production that began ramping up as early as the 1980s.

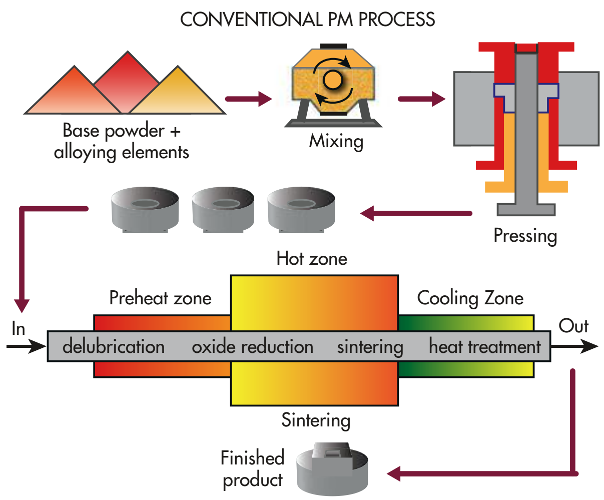
Educating engineers to what is possible with PM plays a big role in the market's growth. Richard Slattery, vice president, engineering at Capstan Atlantic, says, "In school, you might have part of one class on PM. It seems like a side-thought in the engineering toolbox, but with the advances in powders, design, and binders, engineers need more than just part of one class to see the solutions that PM can provide."

"Today, metal-powder mixtures and alloys are engineered to optimize the process," says Jim Adams, vice president of technical services for Metal Powder Industries Federation. "Parts manufactured from sinter-hardening alloys, for example, are furnace-atmosphere-quenched, eliminating the need for post-processing heat treatment and warpage that occurs during conventional oil-quenching. Other materials permit soft-magnetic properties due to specific alloying of iron/nickel, iron/silicon, or iron/phosphorus. Powders can be tailor-made to meet the most important property requirements."

Cloyes Gear & Products Inc., a Division of HHI/MPG, Subiaco, Ark., won an award of distinction in the 2016 Metal Powder Industries Federation Design Excellence Awards for three sprockets. A crankshaft rubberized sprocket and two rubberized oil-pump sprockets go into a General Motors Generation II High-Feature V-6 engine used in the Cadillac CT6, ATS, GMC Acadia, and Chevrolet Camaro.

Atomization is one way to make higher-quality powders. By feeding a liquid metal through an opening where it is struck by a liquid or gas—often water—small particles can be formed with minimal impurities. The feedstock will play a large role in the impurities, but according to Copper Development Association Inc., copper and copper alloys are generally over 99% pure. The size of the particle is important, as smaller particles affect compaction and the porosity of finished parts.

Post-processing, such as annealing, can improve powder properties. Normally done in a long continuous furnace, annealing may cause powder to clump together. A simple solution is to mechanically separate or break up the powders; then using different screens, the powder is separated by particle size. For example, Sandvik Materials Technology offers many types of pow-



Most powder-metallurgy parts weigh less than 5 lb. (2.27 kg), although parts weighing as much as 35 lb. (15.89 kg) can be fabricated in conventional PM equipment. While many of the early PM parts, such as bushings and bearings, were very simple shapes, today's sophisticated PM process produces components with complex contours and multiple levels, and does so quite economically.

dered metals with ranges in size from 250 to 38 microns.

Metals and alloys are easy to mix as powders. "This makes it possible to customize powders for a customer's needs," says Slattery. "When engineers need to hone properties, we can not only produce a wide variety of properties, we offer over 40, but we can customize a powder much more cost-effectively than a smelter."

With traditional metal production, a 150- to 200-ton batch might be normal. A customer would need a lot of product to ask for a customized batch. The automotive industry can justify large batches, but more regulations on carbon emissions are pushing for lightweighting. Advanced high-strength steels (AHHS) and new alloys offer many options, but often require costly changes to the production line. For example, U.S. Steel invested $500 million to upgrade production to make different types of AHSS. Powders might not be able to handle as much force as some of the AHSS, but the process allows for porosity and complex shapes that can reduce cost, material, and weight.

For the automotive industry, GKN Hoeganaes Corp.'s Ancorsteel 4300 offers a chromium bearing material that improves strength levels compared to traditional steels. Alloys such as this can improve a part's density to around 7.0 g/cm^3 (medium- to high-density applications may have part densities of 6.7 to 7.6 g/cm^3). However, it is possible to obtain higher densities of 7.4 g/cm^3 and greater with processes like double pressing/double sintering, also called re-pressing.

Re-pressing may not be an economic solution, though. The additional processing and energy might reduce the cost benefits of using a PM part. One-way single press and single sintering is improving with selectively densifying areas of critical importance and leaving the core—or non-critical areas—at a lower density. For gears, the critical area is tooth density.

The porosity-induced lack of density kept PM gears from being adopted for high-strength applications until about 15 years ago. By using multiple post-process techniques that have brought densities close to wrought metals, PM is finding its way into some high-cycle, high-strength applications.

Roll densification uses a pressing force and a secondary compaction tool called the master gear, which is rolled into the sintered part. "Capstan was the first company to experiment with roll densification," says Slattery. "Rolling densification is used specifically to improve the tooth density on a PM gear. Other processes like heat treatments and double compacting/double sintering can improve overall part density. PM gears see such high cycles that increasing the tooth's surface density will greatly enhance wear resistance. Some high-cycle applications make coatings and plating ineffective. But single-press, high-density, roll-densification-processed gears are able to compete with properties of 8620 wrought carbon steel."

Indo-US MIM Tec Pvt. Ltd., Bangalore, India, won an award of distinction in the 2016 Metal Powder Industries Federation Design Excellence Awards for this diesel leak-off union. Consisting of stainless steel, it was made with the MIM process. The material and process change improved performance from its previous plastic part that suffered due to the tough working environment. In addition, the new part reduced cost associated with the plastic part by 10%.

ADVANTAGES OF PM

"Thousands of reliable PM designs now serve industries in a wide range of applications," says Metal Power Industries' Adams. "These designs include complex or unique shapes that would be impractical with other metalworking processes. Many designs eliminate or minimize machining and scrap, providing high material-yield ratios, suitable for moderate-to-high-volume production requirements. Dimensional tolerances are maintained closely with excellent part-to-part reproducibility. Precise alloying results in excellent performance and reliability in critical applications."

The porosity of the PM parts allows for alloying, which can increase machinability, improve part density, and present the option of impregnating the materials with lubricants.

In addition, PM has been a lightweighting technology since its inception. For press-and-sinter parts, designers have utilized through-holes, produced with core rods during compaction, to reduce part mass and cross-sectional area. This resulted in smaller presses being able to compact larger parts.

DISADVANTAGES OF PM

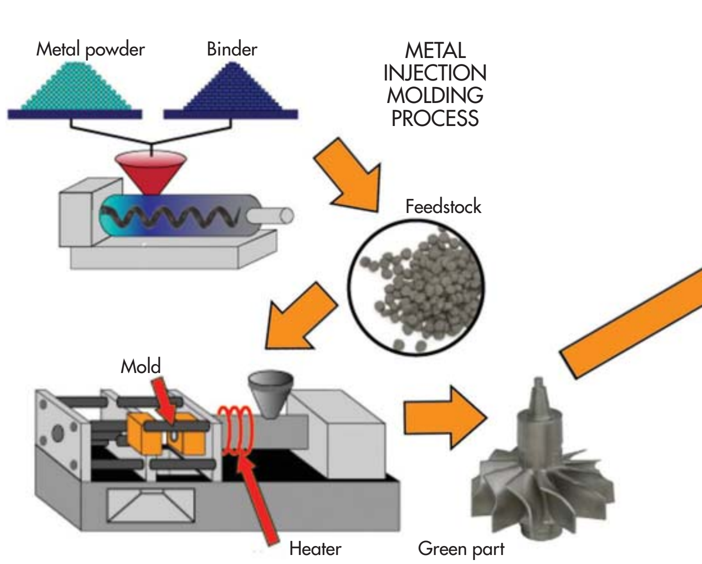
Additional processes and tooling for secondary compaction tools can offset the cost advantage of designing for a PM parts. These processes, while adding energy and cost, are there so that PM can compete with other processes. Another limitation is part size.

"Typical PM parts require 30-45 tsi (tons per square inch) to compact the powder," says Adams. "This limits the size of a part to about 35-55 in^2. The majority of presses typically compact gear faces up to 3 inches. Many sprockets and sensor rings are being produced over 8 inches in diameter. The sintered part properties can be improved by high-temperature sintering, but this again increases cost."

DESIGNING FOR POWDER

Particle size and compaction of the powder into the mold are important to the finished part's density. Complex shapes may have small features or cantilevered areas that would be difficult to eject during compaction. However, dry lubricants are added to the powder to increase the part's ability to be ejected without fracturing. Lubricants also ensure complex shapes fill with powder when compacted.

Design engineers generally need not worry about lubricants. A powder producer will work with a company to make or select specific powders and process information based on a part's needs. If an engineer already using a PM process wants to change the material or provider, he or she should talk to the producer first to ensure the new powder and lubricant will satisfy



the application. PM parts generally have a waxy lube—about 0.5 to 1.5% by weight—and if needed, a multiple-stage compaction process to ensure the finished part meets its proper dimensions.

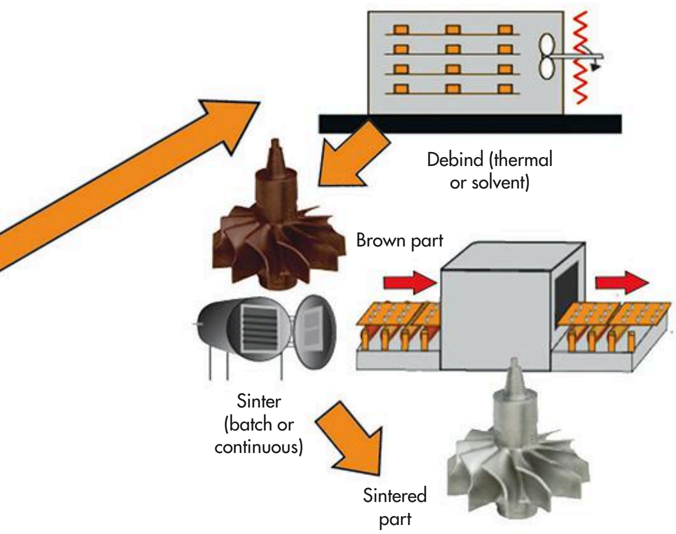
The advantage of PM's near-net dimensions has led to growing demands for precision machining of PM parts. Keeping parts as near-net-shape as possible reduces scrap, energy costs, and lead times. If your part needs to enter into a post process, ask a metal-powder supplier about introducing high-performance additives to improve processes such as machining.

"The aluminum PM parts market is undergoing a new surge as automotive designers seek lighter-weight parts for new applications," says Adams. "The use of higher-strength aluminum alloys with metal matrix composites (MMCs) is showing renewed interest to reduce mass and provide improved properties. This focus is currently, a project within the Lightweight Innovations for Tomorrow (LIFT) consortium. This industry-led, government-funded consortium is investigating the development of a cost-effective process for submicron reinforced-aluminum MMCs."

Most properties of PM parts relate closely to the part's final density, or amount of porosity. Higher density equates to lower porosity.

"Generally, as density increases, so does yield strength, ultimate tensile strength, Young's modulus, impact strength, and elongation. Design engineers should understand the part's environment and property requirements when specifying a material," says Adams. "In some applications, lower density or higher porosity is preferred, such as for filters or self-lubricating bearings. The interconnected porosity of a self-lubricating bearing acts as oil reservoirs within the bearing, releasing oil while in use as the oil viscosity changes due to heat from friction. As the bearing cools, the oil returns to the reservoirs through capillary action."

There might be a case in which a part made from brittle material, or is heat-treated, will generate a high concentration

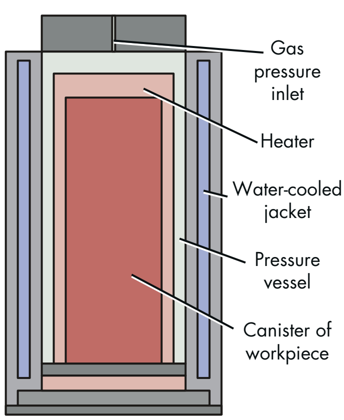


of martensite. Increasing the density of a part with high concentrations of martensite would also increase the brittleness, which in turn decreases the impact strength and ductility. The pores, however, are able to act as stress raisers. Consequently, reducing porosity will produce higher-strength properties in general.

Researchers are continuously developing higher-compactability powders through alloying. Controlling part density during sintering with time and temperature can expedite sintering while increasing density. Hot isostatic pressing (HIP) can be used to compact metal powders or PM, and metal-injection-molding (MIM) can collapse the internal pores to increase density and properties.

Small intricate parts, typically under 225 grams (0.5 lb.) with less than 1 cm (0.5 in.) cross-sectional area, work well in the MIM process. Also, it is the preferred solution for moderate- to high-volume, small intricate parts.

HOT ISOSTATIC PRESSING



"The medical, electronics, communications, jewelry, and firearms industries have embraced this technology, with many companies serving this sector operating in-house MIM departments," says Adams. "Properties are excellent, as its density is typically 97% or higher to theoretical density, and can easily be HIP processed to 100% of theoretical density. As the parts chemistry can be slightly altered through alloying, in many cases, properties exceed its wrought material competitors." md

CHRISTOPHER BUNAI | Chief Engineer
Stress Indicators Inc., Gaithersburg, MD; www.smartbolts.com

An Introduction to LEAN BOLTING

Learn how to eliminate bolting wastes with this useful checklist.

From the buildings we work in, the data centers we depend on, and especially in the machines we design, we inevitably rely on bolted joint connections. Unfortunately, due to the perceived simplicity of bolted joints, they can be a commonly undervalued subsystem. The irony is that problematic bolted joints can and do break down, even in the most finely designed machines.

All too often, machine designers fail to consider some fundamental aspects of bolted joints, creating a variety of issues that plague equipment. Making matters worse, suggested solutions to correct the joint don't always address the root cause. These misguided corrections add a level of complexity that often obscure the original cause. In all the confusion, these extra and unnecessary steps have inadvertently introduced some fat into a process that would be better off "lean."

THE 7 BOLTING WASTES

Over-Processing
Activities related to bolted joint installation and maintenance that are unnecessary, inefficient, or do not add value.

Improper Preload
A bolt having too much or too little tension. Or having too much or too little clamp load in a bolted joint.

Defects & Rework
Bolted joints that do not meet design specifications. If this goes unnoticed, it is a defect. If it is noticed, it creates rework.

Delays
Time lost doing non-value adding activities, such as waiting for machine repairs or breakdowns or searching for a tool.

Unnecessary Maintenance
Performing maintenance on a bolted joint that is properly secured, providing reliable service, and satisfying its design requirements.

Inadequate Design Optimization
Insufficiently considering the relative factors contributing to bolted-joint security, such as preload, quality of bolted joint members, corrosion resistance, in-service loading, vibration, relaxation, and hydrogen embrittlement.

Difficult Installation Conditions
Environmental factors contributing to the challenging nature, inconvenience, and potential dangers of installing the bolt.

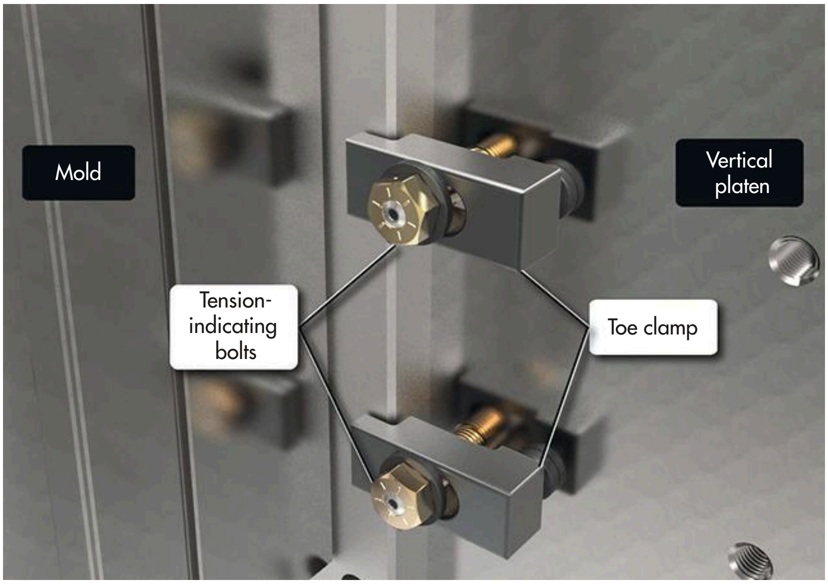
THE ADAPTATION TO LEAN

In the pursuit of world-class bolting, businesses can learn from world-class manufacturing. Just as there are the Seven Manufacturing Wastes within Lean Manufacturing, there are Seven Bolting Wastes within Lean Bolting. The seven bolting wastes undermine value in the design, use, and maintenance of bolted joints. The analysis, identification, and elimination of these wastes increase the likelihood of economically meeting a project's design goals.

The seven bolting wastes can exist at any point during the lifecycle of a fastener, and it is important to evaluate new perspectives with an open mind when searching for bolting wastes. During such an examination, it is best to not get caught in the "we've always done it that way" trap. One lean technique that can help here is called the 5 Why's. The purpose of this technique is to determine root causes.

The concept is simple; when a problem arises, define it. Once defined, ask "Why" the problem occurred. Then, once you've figured that out, ask "Why" again. Repeat this process at least five times, or as many times as it takes, to get to the root cause. If you correctly identify an issue's root cause, reliability and quality can be more easily improved.

Here is a deeper look at each bolting waste:



Toe clamps fastened to a vertical platen with tension-indicating SmartBolts hold the mold tightly in place. The bolts let operators know the joint is good and will hold the mold safely in place.

Over-processing. When evaluating a bolted joint for over-processing, list all of the steps used to install and maintain it. Common steps could include cleaning the joint, applying a thread lubricant, calibrating the torque wrench, torque striping, and conducting maintenance. The next step would be to ask "Why are we doing each of these steps? Is each one absolutely necessary or could it be waste?" If waste is identified, strive to eliminate it by breaking down the design, installation, and maintenance process into the least amount of steps necessary without compromising quality. Successfully executing this activity will bring significant efficiency and valuable improvements.

Improper preload. The primary means by which bolted joints provide security is through proper preload. This makes improper preload an important waste to manage. Improper preload does not just mean not enough tension; it can also mean too much tension. Excessive preload can lead to stripped threads, bolts yielding and fracturing, or crushed joint components. In contrast, insufficient preload causes self-loosening, fatigue failure, and loss of dimensional consistency in the form of separation or slipping.

Regardless of prevalent industry confusion, improper preload does not mean improper torque. Torque is, unfortunately, a common misnomer for bolt tightness. Torque is a rotational force (not compressive) that does not provide joint security. In fact, over-reliance on the predictability of the torque-tension relationship is one of the most common causes of improper preload.

Defects and rework. When combating defects and rework, it is necessary to have a method of identifying defective assemblies. Although it is ideal to eliminate both defects and rework, it is better to have rework than defects; rework provides an opportunity to correct the issue, rather than have it cost more time and money in the future. In this context, defects can be considered as any bolted joints that go into service without meeting design specifications. It is good practice to use robust design techniques so that it becomes easier to

LEAN MANUFACTURING

LEAN MANUFACTURING is an outgrowth of the Toyota Production System developed in Japan throughout the 20th Century. Toyota proposed that the best way to enhance the value of its products was to methodically minimize or eliminate waste from the value stream. The value stream is the series of processes (supply chain) that connect raw materials to the products shipped to customers. Toyota determined that the customers would be unwilling to pay for non-value-adding activities within the value stream. Toyota's goal then became to provide customers with the highest-quality products at the lowest possible cost.

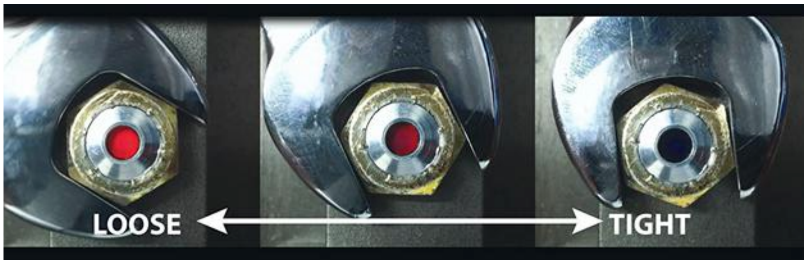
meet critical-to-quality metrics. Choosing to "build in" quality significantly reduces operation and maintenance costs associated with the joint in-service. A poka-yoke strategy (Japanese for "error-proofing") can be a great way to prevent defects and minimize rework.

Delays. Delays—on the scale of minutes, days, or even months—can be quite common if you're not careful. The longer the delay, the more expensive it becomes. Major equipment failures can wreak havoc on operations that can rarely afford lost time. Nevertheless, minor delays hurt profitability as well, especially when they get a chance to accumulate through repetitive processes. Having to double-check or rework a joint installation can push schedules back, making it worthwhile to get the assembly right the first time. Properly securing bolted joints at initial installation and efficiently monitoring their security in-service significantly minimizes delays due to malfunctions.

Unnecessary maintenance. This waste is not always easy to identify, so it is good to start thinking about maintenance during joint design. The key here is distinguishing between necessary and unnecessary maintenance. Companies want to focus on joints that need maintenance, not those that don't. The most common need for joint maintenance is to ensure that there is sufficient residual preload. Labor-intensive techniques such as "torque-checking" have become commonplace, but can provide inaccurate results.

"Torque check" maintenance is a good example of waste because significant time and effort must be spent checking every bolt—even ones already properly secured. Ultimately, reducing this waste comes down to having in-service monitoring of bolted-joint clamp force, and only a handful of technologies can do this. One of the best is to use tension-indicating fasteners. These fasteners indicate the tensile force developed during installation, as well as the residual load on the joint while in-service. Some tension-indicating fasteners (such as DTI SmartBolts from Stress Indicators) offer a visual indicator that allows for rapid inspection and identification of bolted

The SmartBolt built-in visual tension indicator turns from red to black when proper tension has been reached, and the indicator is completely reversible for the life of the fastener.



joints that require maintenance, letting companies minimize unnecessary maintenance.

Inadequate design optimization. This is the broadest of the wastes. Bolted joints are exposed to a wide spectrum of environments. From extreme temperatures, heavy vibrations, and seawater to mud and grime, high vacuum, and acidic exposure, the joint must be designed to withstand all relevant factors. As many design factors as possible should be identified and combatted through smart design choices. For instance, the pairing of tension-indicating fasteners and wedge lock washers are a powerful combination for developing, maintaining, and monitoring preload in high vibration environments. It is also important to select quality components evaluated for compatibility with one another.

A common mistake is to use low-strength steel washers with high-strength nuts and bolts. This can cause significant relaxation of joints as the washer yields under the increased clamp loads. Another simple example would be selecting a bolt that is too small and lacking the needed strength. However, selecting bolts that are too large can also significantly increase costs as tool size and installation times rise. An often-overlooked aspect is a bolt's length-to-diameter ratio. Strength requirements aside, the higher the ratio, the more elongation stored during loading. This reduced "stiffness" becomes important when trying to maintain preload in softer joints. Selecting the largest practical length-to-diameter ratio helps preserve bolt preload and fatigue resistance.

Difficult installation conditions. Troublesome installation conditions are some of the most challenging wastes to control. Installation conditions can be as controlled as an air-conditioned lab with excellent lighting or as difficult as subsea maintenance requiring scuba divers. Regardless of how difficult installation might be, standard operating procedures should be evaluated in terms of feasibility, practicality, and, most importantly, safety of installation. Although many costs associated with installing bolts under challenging conditions are unavoidable and do add some form of value, it is necessary to weigh how better tools and methods might improve operations.

LEAN BOLTING IN PRACTICE

In application, systematically eliminating wastes from bolting processes leads to improvements. Let's take an example from industry: A Tier 1 injection-molding company struggled to consistently secure large molds in their presses. The company wanted a better way to protect machine operators and equipment.

One major concern was determining how many toe clamps were needed to properly secure the molds, according to the tooling manager. The number of clamps used depended on recommendations from the engineering department, which were based on the mold's weight and access points available on the mold. If a mold couldn't be clamped in an ideal place, additional toe clamps were used to compensate. Also, stripping out the threads of the unhardened platen was frequent because high-strength bolts were used without adequate thread engagement. Fluctuations in mold thickness, clamp type, and bolt lengths made it difficult to control engagement. Furthermore, impact guns and torque wrenches were used interchangeably to tighten bolts. The factory operated 24 hours a day and the company wanted more efficient operator rotations. On top of this, molds still slipped out of proper position.

After observing the mold changeover operations, it became apparent there were a number of steps to examine:

- A gantry crane lifting heavy molds in and out
- The injection press temporarily clamping the mold during installation
- Setting up and adjusting mold-toe clamps and bolts
- Connecting cooling lines
- Releasing the press' clamp after toe clamps are fastened

After going through that procedure, the company utilized the seven bolting wastes to evaluate as well as troubleshoot the connection.

Over-processing. Due to concern for mold slipping, technicians would use more clamps than specified to ensure security of the mold. Although this sounds reasonable, it nevertheless represents a waste because of the additional time and tooling needed.

Improper preload. Bolts were suffering from both insufficient and excessive preloads. It was convention to specify a torque value based on the bolt diameter, but with only torque control available, improper preload was widespread. Also contributing to improper preload was use of an impact gun in the absence of a torque wrench. Impact guns struggle to provide both adequate tension control and torque control.

Ordinary bolts can be retrofit to become a SmartBolt.

Defects and rework. Before technicians would strip the platen, the machine would have to be stopped. The stripped hole was then drilled out and retapped, and a helical threaded insert used. The changeover process then had to start over. The inability to properly set up and secure the mold the first time created rework.

> "The seven bolting wastes undermine value in the design, use, and maintenance of bolted joints. The analysis, identification, and elimination of these wastes increase the likelihood of economically meeting a project's design goals."

Delays. The time needed to repair the platen created significant delays in getting the machine operational. In addition, time was often wasted searching for properly sized torque wrenches.

Unnecessary maintenance. During changeovers, new operators were commonly expected to recheck the mold bolts by tightening them a second time. This was likely waste as secure bolts were double checked. Also, in the serious but rarer event of a mold slipping, it could be damaged and require unscheduled maintenance. If the mold had never slipped, the maintenance would not have been needed, making it preventable and thus unnecessary.

Inadequate design optimization. An opportunity for optimization was in the mold clamp hardware. For example, several types of toe clamps were in use, and technicians would browse through a mix of bolts of different lengths and a variety of different-sized washers to select what they thought were best. In some cases, they found out the hard way that the bolts they chose were simply not long enough to ensure enough engagement and they stripped the threads. Furthermore, improperly sized washers caused the bolt head to gouge the washer face, which further distorted the torque tension relationship.

Difficult installation conditions. The hazardous environment of working between movable platens and a 20,000-lb. mold led technicians to minimize the time that was spent inside the machine. The tight workspace was often coated in oil and heavy molds were frequently lifted overhead.

As a result of the bolting wastes evaluation, the company determined that tension-indicating fasteners would be a lean solution. DTI SmartBolts let the tooling manager set a specific tension value suitable to the application. The SmartBolts would signal a "tight" black color when proper preload was achieved. If preload was lost, the indicator displayed a bright red "loose" signal.

Once in use, technicians could now be confident the right amount of clamp load was being applied, so extra fasteners were unnecessary. This directly solved the second bolting waste of improper preload. Because SmartBolt accuracy does not depend on torque, they can be installed with a breaker bar, torque wrench, or impact gun. In fact, impact guns can be adjusted to the right pressure based on the bolt's visual indicator. Correcting defects and rework required a discussion on thread engagement. The company adopted the rule of thumb that at least one diameter of thread engagement is needed for steel and 1.5 diameters of engagement for aluminum. Improving standardization among clamps, washers, and bolt lengths was also recommended through a "5S" program. (5S is a workstation organization method consisting of Sort, Set in Order, Shine, Standardize, and Sustain activities.)

Now, with proper thread engagement and preload control, thread stripping and bolt breakage were dramatically reduced. The delays experienced were also reduced by eliminating the risk of thread stripping and the need for torque wrenches at final installation. Operator changeover time was reduced by using SmartBolts' visual indicators. The visual indicators acted similar to an Andon, a system used in Lean Manufacturing to alert maintenance staff of problems on the line. Finally, rapid inspection of bolts by new shift operators minimized time spent between platens, helping to provide a safer and more efficient work environment for all employees. md

Motion Modules Support CanOPEN Communications

THE LEXIUM Motion Module (LMM) is a compact programmable motion controller that is now offered with CANopen supporting CiA DS301: CANopen Application Layer/Communication Profile and DSP402: Device Profile for Drives/Motion Control. It is offered with a one-axis Development Board, which includes isolated I/O, CAN communications transceivers, and locking pluggable connectors, or as a part of a complete starter kit with the development board, a NEMA 17 frame motor and encoder, a USB-to-CAN communications converter, and a power supply. The module measures 2.7 x 1.4 x 0.16 in. (68 x 35 x 4 mm). In addition, a selection of motors is available to complement the 1.5 Amp LMM including rotary stepper motors in NEMA sizes 8 (20mm), 11 (28mm), 14 (36mm), and 17 (42mm). Custom motor sizes and styles are also available, as are LMM with alternate power levels and communication platforms.

SCHNEIDER ELECTRIC Motion USA, *www.motion.schneider-electric.com*, (877) 342-5173

Fiber Optic Cables Eliminate Signal Jitter

THE PFO-100-TR fiber-optic transmitter and receiver is capable of transmitting data at distances up to 40 kilometer, or 80 kilometer upon request. Single mode fiber-optic cables are available, along with multi-mode fiber-optic cables for shorter distances. Signal-jitter elimination circuitry ensures high-quality transmission over long distances and qualifies them for cross-town fiber links, cross-campus productions, remote camera links, pre-installed fiber venues, and other applications. The combined PFO-100 transmitter and receiver are a matched pair for specific wavelengths, which may be either the standard 1310 nm or any requested wavelength between 1270-1610 nm.

LINK ELECTRONICS, *www.LinkElectronics.com*, (800) 776-4411

Laser Processing System Comprises Two Workstations

THE LASERDYNE 606D multi-axis laser processing system features two independent workstations in a single unitized structure. The two workstations are fast and accurate with an X-Y-Z speed of 2000 in./min., 2-g acceleration, and bi-directional accuracy of 0.0008 in. (20 µm). It consists of two six-axis motion systems, a Class 1 enclosure with dual-automated doors, two S94P laser-process controls for motion and laser coordination, and two fiber lasers, which can be the same type or different. Graphite fiber composite structures for the linear axes contribute to the system's high dynamic accuracy, and linear motors on the X and Y axes improve throughput.

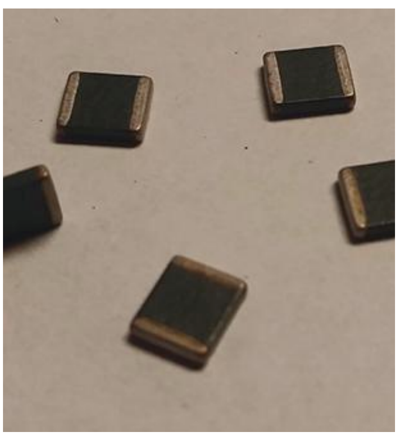
PRIMA POWER, *www.primapower.com*, (763) 433-3700

Arc Motors Enable Various Degrees of Rotary Motion

THE INFINITY Series of arc-shaped motors enables OEMs to move light payloads in smooth and accurate arc-shaped and full 360-degree rotary motion profiles. Ultra-thin arc-shaped motor segments can be used individually or be interconnected to create exact partial arc segment motion or full 360-deg. rotary motion. Modular construction allows for virtually unlimited diameter and through holes, levels of flexibility that are not possible with conventional motor designs. **APPLIMOTION,** *www.electromate.com/applimotion.html*, (877) 737-8698

Surface-Mount Varistors Offer Operating Temperatures Up To 150°C

THE AVY Series automotive surface-mount varistor operates at temperatures as high as 150°C. It is rated for up to 2000 amps of current and 25J load dump energy. Available in six



sizes, they may be used in 12-V, 24-V, and 42-V electrical systems. They target applications like anti-lock brakes, direct ignition, airbag control, and wiper motors, offering protection from destructive voltage transients. They do not have a plastic coating for a better flammability rating. **STACKPOLE ELECTRONICS** Inc., *www.seielect.com* (919) 850-9500

Limit Switches Easily Interface with BUS Box

THE MP700 series of sealed limit switches are now available with an M12 connector integrated directly into the housing for easy and flexible interfacing with a bus interconnect box. A simple and detachable cable-connection alternative to the common potted cable solution, this option is implemented for 30-mm and 35-mm housing sizes. Metal and plastic IP67 housings are offered for rugged outdoor applications and indoor use. A five-pin version is used in the MP740/60 metallic cases and a four-pin for the MP730/750 plastic cases.

The electrical rating is adapted to the power specification of M12 connectors for 4 A up to 120 Vac and 3 A for 240 Vac.

A wide selection of actuator types includes pin and roller plungers and roller levers. The electrical-switching module is a positive opening circuit with either slow-action or snap-action movements for a broad range of industrial applications. The products fulfil the EN 60947-5-1 standards and are UL approved.

WILBRECHT LEDCO, a Microprecision company, *www.wilbrechtledco.com,* (888) 323-8751

Customizable Housing Broadens Controller Options

THE ME-IO housing enables design engineers to create and build their own custom controllers. A variety of widths, heights, and configurations are offered. Models can accommodate up to 60 connection points in an 18-mm wide package, but larger widths of 37.6 mm and 75.2 mm are also available. The housing has two types of plugs for fast and easy field termination, and features built-in backplane communication for scalable design, without taking up valuable connection points for communication. A variety of accessories are also available, including different cover sizes, pre-drilled covers for LEDs, and a rotatable marking cover.

Power Supplies Offers Advanced Convection Cooling

THE CUS200M series of medically and Information Technology Equipment (ITE)-certified power supplies feature efficiency levels of up to 94%, and reduced internal heating to extend electrolytic capacitor life. When convection cooled, the CUS200M can deliver 200 W; with 1.5 m/s airflow, it offers up to 250 W. Packaged in the industry 3 x 5-in. standard footprint, it targets applications including hospital, dental, broadcast, and test and measurement equipment, and is particularly useful where audible fan noise is undesirable. It operates from a universal input of 85-265 Vac, and is available with nominal outputs of 12, 18, 24, and 48 Vdc, which can be adjusted with a potentiometer. All models deliver full power with ambient temperatures of -20 to +50oC and 50% power at +70oC. Standard on all models is an open collector DC good signal, remote on/off, and a 5-V standby output (0.6A convection, 1A forced air). Off-load power draw is less than 0.5 W when in standby mode.

TDK LAMBDA, *www.tdk-lambda.com,* (800) LAMBDA-4

PHOENIX HOUSING, (800) 888-7388, *www.phoenixcontact.com*

DC Contactors Target Heavy-Duty Electronic Apps

THE JENNINGS JEV250 (shown), JEV400, and JEVB500 Series DC contactors are designed for extended mechanical and electrical life, offering a mechanical life of up to 2 million cycles. JEVB500 and JEV400 Series DC contactors feature charging and discharging protection for electrical circuits, and a 450 V voltage rating makes them suited to heavy-duty applications like the electric grid, heavy-duty electrical vehicles of the future, and power-station communications, as well as solar and wind-power applications. They achieve 10-20% energy savings by controlling the inrush current with a constant current inside the magnet coil, even when the supply voltage changes. They lower noise emissions to a maximum of 60 decibels, which is the level of office conversation and the quietest available in the industry. To learn more, go to the company website and find Jennings under the "Brands" tab.
THOMAS & Betts Corp., *www.tnb.com,* (800) 238-5000

HMI Indicators Are Easy to Install

SERIES 45 indicators for human-machine interfaces feature a broad range of machine operating functions, and are available with full-face or front illumination. Complete with 29.45 mm or 38 mm bezels, they can provide all-around visibility. The indicators can be custom labeled using direct marking techniques including engraving and pad printing or complementary legend plates. They may be constructed out of premium metal or plastic in a broad spectrum of colors. An anti-rotation device and snap-on design facilitate assembly without the need for special tools.

Helical Gears Resistant to Preload and Gear Meshing

PLANETARY HPG-R gearheads feature helical gearing for noise reduction and higher torque capacity, along with low-speed reduction ratios ranging from 3:1 to 10:1. The internal gear design allows a preload on the order of microns, enabling slight elastic deformation to maintain low backlash and compensate for interference between meshing parts and thus prolonging the life of the gearhead. The HPG helical gears also feature Quick Connect coupling for easy mounting to any servo motor. They are available with flange output, shaft output without key, and shaft output with key and center-tapped hole.

HARMONIC DRIVE, *www.harmonic-drive.net,* (800) 921-3332

Piston Inserter Automatically Aligns, Eliminates Trapped Air

TRIDAK MODEL 3200 Piston Inserter facilitates piston insertion into cartridges and syringe barrels, achieving consistent piston-insertion depth and alignment, and exact ratios when the product is dispensed. Unlike manual piston insertion, the Model 3200 automatically eliminates trapped air; it easily adjusts to accommodate single and dual cartridges and syringes. In addition, the dual-hand actuation trigger improves operator safety. Universally sized for compatibility with cartridges and syringe barrels up to 500 mL, it has a short cycle time of 1-3 seconds to help manufacturers achieve savings in time and labor.

DYMAX CORP., *www.dymax.com, (860) 482-1010*

They work over a voltage range of 6 to 230 Vac.

EAO CORP., *www.eao.com,* (203) 951-4600

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Measuring Product Development Productivity

Measuring the productivity of product development is a complex and multifaceted task—one that is significantly different from manufacturing operations. Output from manufacturing is increasingly automated and can be summarized as emanating from "equipment assisted by people." Output from engineering and the cross-functions that work with engineering to bring about a product that can be repeatedly made is usefully summarized as emanating from "people assisted by equipment." The people in R&D and product development turn out the designs, not the equipment. Therefore, measuring the productivity of people is highly important.

Departments. People, for the most part, are organized into departments according to the roles they perform for the company. Those functional departments supply expertise to company activities and projects. Since the 1930s, organization science has shown that people are affected by the dynamics of the departments they work in—both positively and negatively. Note that we're not calling them teams. But, in truth, departments are also a type of team.

Measuring the output and productivity of departments is risky because managers then try to optimize their department's output. This, in turn, lowers projects' outputs (whose resultant IP and products are the actual generators of revenues and profits). By consequence, this also reduces the effectiveness of the organization as a whole.

Measuring departments is important, but beware of measuring output. The focus should be on the competencies, hiring/firing/turnover, capacity, innovativeness, and other areas relating to the department's capabilities and service levels to meet its demand.

Projects. The second key measurement area is projects. Why? Because this is where management authorizes investments in order to earn revenues and profits. Each investment is a wager that risks money. Some wagers have high risk and some have low risk, but each is a bet. Those bets are expected to be the future of the company (if not individually, then certainly collectively). It is absolutely critical to measure the ability to consistently and systematically execute projects. It's also critical to have company-wide metrics that show averages, medians, modes, totals, and other cross-project measures across the types and sizes of projects undertaken.

Measuring projects should not be confused with measuring the product specs and values that are the purpose of those projects. Every project has to have product measures. But the values of product measures within each project are unique to that product, and cannot be used on products in other projects. Generically, they can (and are), but that type of measurement—such average reliability and average defects per unit—resides in other departments. Those types of metrics are handled elsewhere and fed back. In summary, common "standardized" measures should reside across all projects, and should not be confused with unique product measures in each project.

Improvement efforts. The third key measurement area is improvement efforts. Most improvement activities are limited in duration: They come and go and rarely return. They last a few months to a few years—e.g., putting in new software or training in a new skill set. Each effort needs its own unique metrics, analogous to unique product metrics within a project described above. However, the result of improvements is best measured by monitoring aggregate increases in output, productivity, or quality.

CXO-level performance. The fourth and final area is to measure the collective results of everything. These are the measures that interest the CEO and investor community. Given all the money invested (the input), what is the value of the revenues/profits and intellectual property generated (the output)? Measuring product development productivity is defined as its output divided by its input.

In short, measuring productivity is essential, and must be done to some extent at all levels in the organization. If the measured optimization of a system is targeted to the lower levels of the system, then the system as a whole is generally not optimized. Measuring productivity and output in aggregate at the top is the place to do it. md