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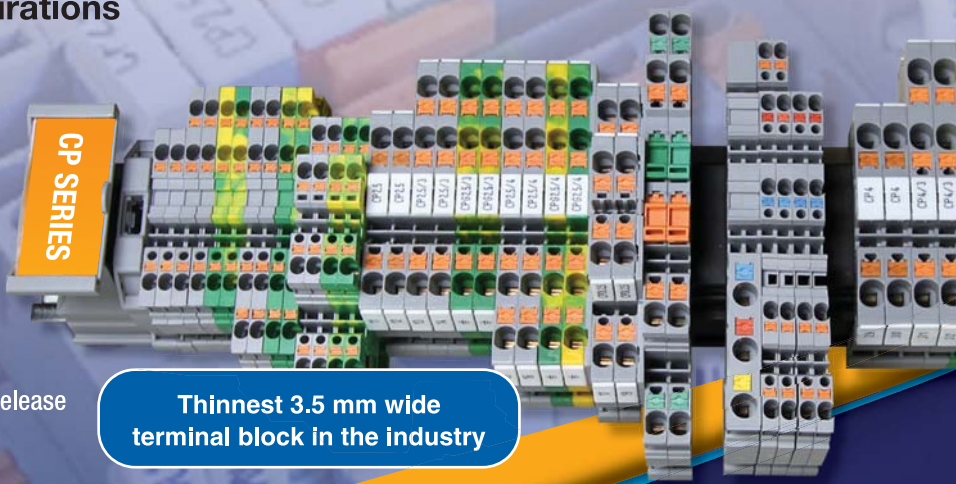

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COVER STORY: HYDROGEN ECONOMY

FEATURES

Cover Photo Credit: H2 Clipper

COLUMNS

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By **Bob Vavra**, Senior Content Director

Laid Off From Tech? Try Manufacturing

Opportunities abound for the skilled and open-minded.

NOVEMBER WAS A TOUGH MONTH for the tech industry. Amazon shed a reported 11,000 jobs, Meta dropped 13% of its workforce—or another 11,000 jobs—and Twitter's new owner is talking about a loyalty oath even as he looks to cut costs and slash a reported 75% of the existing staff.

With all of these data-centric folks hitting the unemployment lines, this is a good time for them to take a fresh look at America's new technology frontier.

Manufacturing.

The need for a larger manufacturing workforce has been well-documented—and it is documented in our new Salary Survey (see p. 14). It's an issue we've been documenting for a couple of decades now. Readers once again identify the lack of a skilled workforce as the biggest issue they face in manufacturing—ahead of the economy, the supply chain or productivity.

I hear the phrase "skills gap" in almost every discussion I have with manufacturing leaders and readers. We simply don't have enough workers to allow manufacturing to achieve its growth potential as the world spins through a post-pandemic economic recovery.

But it also is clear we don't have enough of the right kind of workers to propel manufacturing to achieve its promise. The key suppliers in this industry are touting the idea of a digital factory—an interconnected, interdependent, data-driven and optimized facility. They also are driving their product offerings to reflect that idea.

The digital factory is the wave of the future, and it is rising fast. Manufacturers of any size can benefit from this change, but they must decide to ride the wave. The alternative is to be swept aside.

To meet these goals, we need more workers who live and thrive in a digital environment. From supply chain to data management, we need an infusion of smart workers to go with a smart factory to enhance the workforce excellence we already have on our plant floors. We will not meet those goals without aggressive and compelling recruiting. We need to show the workforce of today the potential for the manufacturing of tomorrow.

So, let's start here. For all those displaced folks at Meta and Amazon and Twitter, come on over to manufacturing. It's the new home for data-driven technology, and you can be a part of making something that will last. ■

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Building the Hydrogen Highway

by **Stephen J. Mraz**, Senior Editor

The Hydrogen Economy is gaining steam as companies and countries invest billions to produce energy from renewables and use it to extract hydrogen from water. The hydrogen is then put into fuel cells to generate electricity for cars and factories and to power combustion engines.

One weak link in this plan, however, is the reliance on pipelines and ships to transport the hydrogen from the solar panels and wind turbines to where it can be used or distributed to consumers and industry.

Fortunately, Rinaldo Brutoco, a strong proponent and pioneer of green hydrogen as the fuel of the future, has worked with the engineers at H2 Clipper, the company he founded and heads, to develop a pair of hydrogen transportation technologies that could make the Hydrogen Economy an economical and environmental boon.

The H2 Clipper Dirigible

The design team at H2 Clipper have designed a 1,000-ft long dirigible, called the *H2 Clipper*, that can carry 125 to 200 tons, letting it pick up liquid hydrogen at −423.4°F from places where it can be produced cheaply with renewable electricity—from the Middle East and the Sahara to offshore wind farms in the North Sea. Next, the hydrogen is cooled down into liquid and loaded into the airship that can carry it to storage and distribution hubs in consumer markets. The airship must carry liquid hydrogen because gaseous hydrogen is not sufficiently energy-dense to be transported cost-effectively over long distances. And in addition to carrying hydrogen, it will also use the lighter-than-air gas to provide lift to the giant transport airship.

"And even though hydrogen is flammable, our design uses proper safety technologies so that the hydrogen providing lift for the H2 Clipper will not explode even in the most severe of circumstances," says Brutoco.

The *H2 Clipper* gets its thrust from four side-mounted, six-bladed propellers and an eight-bladed stern propeller. Each is powered by an electric motor with electricity coming from PEM fuel cells consuming gaseous hydrogen, solar cells mounted atop the airship, or diesel-powered generators burning biofuels. The motors put out a total of 33,200 shp.

The airship has a range of 6,000 miles and a top speed of 175 mph, thanks in part to the aircraft's pointed nose and aerodynamic shape. The shape and strength of the airframe comes courtesy of its patented triangular-patterned exoskeleton that stretches from the nose to the tail. The exoskeleton eliminates the need for a forest of internal supports, thus opening the interior for more cargo-carrying flexibility.

Images courtesy H2 Clipper

Moving liquid hydrogen is key to establishing the Hydrogen Economy. Here are two technologies developed by H2 Clipper for meeting that challenge.

A stiff outer shell covers the exoskeleton which improves the airship's aerodynamics by cutting drag, thus making the *Clipper* faster through the air. The exoskeleton also supports the electric motors turning the props.

Like all aircraft, airships are vulnerable in bad weather. But Brutoco points out that the Clipper's higher speed makes it safer than dirigibles of the past in that it lets the airship avoid thunderstorms and bad weather. Plus, the improved accuracy and availability of weather forecasts compared to what was available in the 1930s makes it safer for airships like the *Clipper*. Meteorologists using satellites data can make accurate five-day forecasts, giving airships pilots plenty of time to adjust their course.

Speed is important when the cargo is liquid hydrogen. No matter how good the insulation in the container holding the liquid hydrogen, some hydrogen will boil off. In a tanker ship traveling 15 knots for a week to get to its destination, that wasted hydrogen can add up. The *Clipper*, traveling much faster, loses less hydrogen, and the hydrogen that does boil off is recovered can be fed into the fuel cells powering the props.

Another downside of ocean-going tankers is that once they offload the hydrogen, they must travel empty to another destination to pick up more hydrogen, a money-losing voyage. The airship, on the other hand, with a cargo area of 265,000 ft^3 and payload capacity of 340,000 lb, can be loaded with cargo containers to take goods and cargo directly to a factory or distribution site, making money on both legs of the trip. Carrying cargo on both legs thus lowers the cost of hydrogen delivery and offers fast factory-to-consumer distribution.

With an average cruising speed of 175 mph, the *H2 Clipper* should operate at a cost of between $0.177 to $0.247 per ton-mile for distances of 1,000 to 6,000 miles. This makes the Clipper less expensive than rail, trucks, ships and even pipelines for moving cargo distances of 1,000 miles or more. And it is way less expensive than using airplanes.

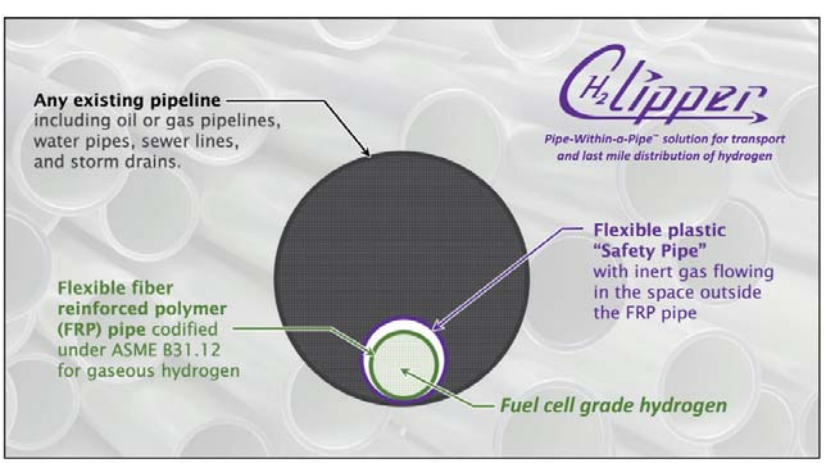
"Freight via airships will be up to 70% cheaper than cargo by plane, says Brutoco. "Even a transatlantic journey will take the Clipper less than a day. At top speed, the airship will only need twice the time of a regular aircraft."

To demonstrate the *Clipper*'s advantage, consider a tanker taking 90 tons of liquid hydrogen from Australia to Japan. The 4,000-mile voyage would take a week and only two Japanese ports will be able to handle the new hydrogen tankers. A *Clipper* airship can take 160 tons of hydrogen to Japan in one day and deliver it anywhere in Japan; airships can take off and land from almost anywhere and only

At 150 mph, a single H2 Clipper can transport over 1 million lb/day of liquified hydrogen up to 250 miles for less than $0.09/lb or deliver over 2.6 million lb/week to a destination 1,000 miles away for less than $0.30/lb. These costs are far lower than truck transport or amortizing the construction costs of a dedicated pipeline, supertanker route, or rail line and infrastructure before hydrogen can be reliably and consistently delivered.

minimal infrastructure will be needed to load and unload cargo. Replacing tankers with green airships should help the environment. It is estimated that one diesel-powered tanker pollutes as much as 50 million cars.

Engineers at H2 Clipper have been working to reduce and simplify the needed ground infrastructure needed to load and unload liquid hydrogen and other cargo. They have already developed simplified docking and load/unload procedures which can be carried out using a single mooring mast with the Clipper free to pivot around it. It will take special equipment to work with liquid hydrogen and meet the load/unload times needed for commercial operations. Details about this are part of several patent applications and H2 Clipper considers them proprietary.



Clipper's Pipe-Within-A-Pipe technology can safely and efficiently transport hydrogen up to 1,000 miles inside virtually any existing oil and gas pipeline, water pipe, sewer line, storm drain or other pipeline. It is the safest and most cost-effective, readily deployable and scalable way to deliver fuel cell grade hydrogen to end-users.

The *Clipper* only requires a relatively small crew, but H2 is designing the airship to be pilotless and autonomous, which will definitely make it the world's largest drone.

"We initially plan for the *H2 Clipper* to have pilots onboard, but we've contemplated both modes of operation in our engineering and financial assumptions," says Brutoco. "Using experienced pilots to fly the airship and collect valuable operating data is part of our 'continuous improvement' engineering approach. Over time, we anticipate the vehicle will move towards fully autonomous operations, with a few ground-based operators overseeing several airships from a command and control center."

"With the safety pipe, sweeper gas and our proprietary continuous monitoring sensors in place, hydrogen can be run inside nearly any existing pipeline without interfering with the continued commercial use of that line."

H2 has patents covering autonomous flight operations; the optional use of artificial intelligence and remote real-time displays to assist in some maneuvers; improved means for docking in high winds; and using aerial drones to pick up, transport and deliver package goods. The firm also has patents on several pilot safety subsystems.

Pipe-Within-a-Pipe

Brutoco also has an ingenious plan for getting liquid hydrogen from storage depots to gas stations and factories: H2 Clipper's patented "Pipe-within-a-Pipe" technology (PiP). The patented covers the overall system, method, and apparatus for safely and efficiently moving hydrogen up to 1,000 miles inside virtually any oil and gas pipeline, water pipe, sewer line, storm drain or other pipeline. Using existing inside pipelines that run below ground under nearly every major city and across many countries avoids the lengthy and costly challenge of building new pipelines. PiP will give the Hydrogen Economy a leg up in terms of distribution infrastructure. It also provides the safest and most cost-effective, readily deployable and scalable way to deliver fuel cell grade hydrogen to end-users.

The PiP plan relies on flexible pipe rated for hydrogen use by the American Society of Mechanical Engineers (ASME B31.12). The pipe has a 50-year useful life at 2,500 psi. The pipe carrying hydrogen is placed inside a slightly larger diameter safety pipe. An inert gas, the "sweeper" gas, is sent between the two pipes to constantly remove any hydrogen that leaks from the inner pipe. This keeps the transported hydrogen's purity at 99.7% or higher, pure enough to use in fuel cells for electric cars, buses, trucks and locomotives. Along with sensors that monitor hydrogen levels in the safety pipe, it also prevents hydrogen from collecting to the point it becomes a fire/explosion hazard.

"With the safety pipe, sweeper gas and our proprietary continuous monitoring sensors in place, hydrogen can be run inside nearly any existing pipeline without interfering with the continued commercial use of that line," says Brutoco. "It will save companies and governments hundreds of billions of dollars and avoid delays of years in getting the Hydrogen Economy up and running by eliminat-

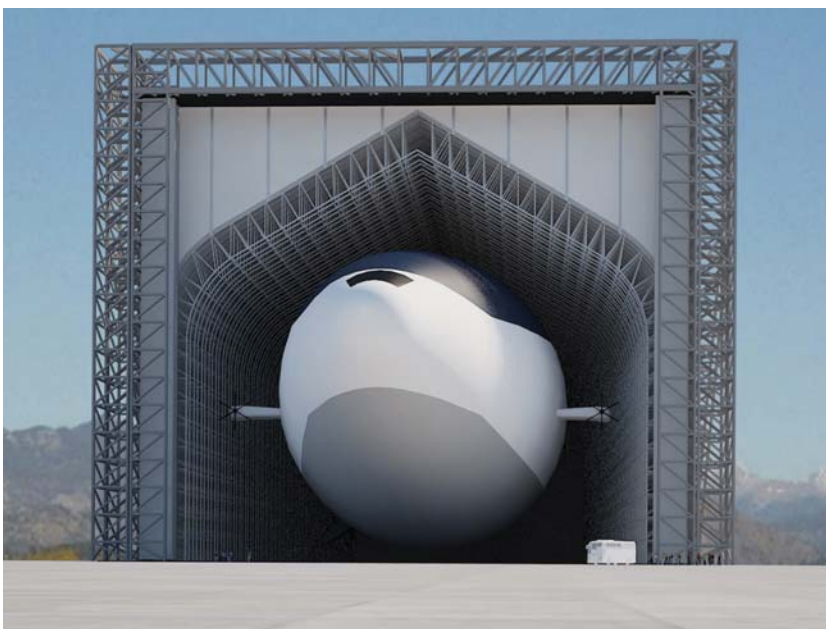
"It will save companies and governments hundreds of billions of dollars and avoid delays of years in getting the Hydrogen Economy up and running by eliminating the need to construct new hydrogen pipelines or retrofitting existing ones for hydrogen."

ing the need to construct new hydrogen pipelines or retrofitting existing ones for hydrogen.

"Taken together, these measures will dramatically accelerate the hydrogen economy, which is our mission at H2 Clipper," he adds.

H2 Clipper intends to work with existing pipeline companies, pipe manufacturers and large utility system integrators to deploy the technology as rapidly as possible.

H2 Clipper is building a prototype that it plans to flight test in 2025. The first operational airships should be delivered in 2027 and operational by 2029 if work now underway continues as planned and regulatory approval is relatively straightforward. Clipper airships are forecast to carry a $180 million sales price. ■



The Case for the Hydrogen Economy

Companies and countries are spending billions to make green energy from renewables, using it to extract hydrogen from water to generate electricity for cars and factories and to power combustion engines.

Scharfsinn86 | Dreamstime

by Stephen J. Mraz, Senior Editor

Researchers and engineers around the globe are developing and refining ways to generate, store, transport and distribute clean, fossil-free energy. One of the most promising approaches, dubbed the Hydrogen Economy, relies on hydrogen to handle these tasks.

Hydrogen's Advantage

Hydrogen is readily available and there is an inexhaustible supply of it bound up in Earth's oceans, lakes and waterways. It just takes electrolysis to separate and release the hydrogen (and oxygen) from the water. Of course, it also takes electricity which, in the Hydrogen Economy, would be generated by renewables such as solar panels and wind turbines. Using fossil-free renewables rather than coal or natural gas to supply the electricity keeps the resulting hydrogen green.

Until recently, however, the cost of hydrogen was too expensive for it to compete with gasoline and natural gas. Fortunately, technological advances have taken the cost of hydrogen from about $25/kg down to $4/kg. This alone makes hydrogen more cost-effective than gasoline. A $4 kilo of hydrogen gives an average fuel-cell equipped car an 80-mile range. It would take 2.4 gallons of gas, or $7.2 at $3/gallon, to do the same for a gas-powered car.

The cost of hydrogen should also go down if it were electrolyzed using wind or solar power where it is the least expensive. For example, a solar panel in the Sahara generates at least three times the electricity as the same panel in Northern Europe. In fact, covering just 1% of the Sahara with solar panels would create enough energy to power the whole planet. There are geographic locations

where wind and sunlight are abundant, letting clean electricity be made for $0.01 per kilowatt-hour (kWh). By comparison, the lowest cost to produce electricity by burning natural gas is roughly $0.05 per kWh.

So one of the pillars of the Hydrogen Economy is to place wind and solar farms where they are most efficient at generating electricity, then using that electricity to electrolyze water and extract hydrogen. Next, the hydrogen would be transported and distributed to distant plants and facilities, including hydrogen refueling stations for cars and other vehicles.

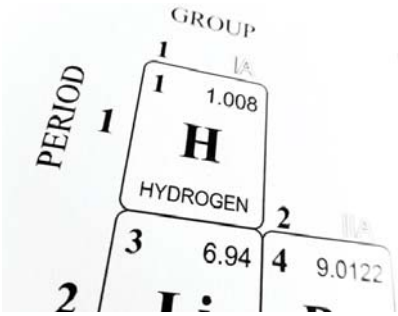
To maximize the amount of hydrogen transport vehicle or pipeline would have to move, the low-cost electricity from the solar panels or wind turbines could also be used to cryogenically cool the hydrogen until it is liquid. This would make the hydrogen more energy dense and reduce the volume needed to be transported.

"Water will be the coal of the future."
—Jules Verne

Once at its destination, hydrogen can be burned to generate enough electricity to power large-scale users such as steel plants and aircraft or put in large or small fuel cells, an invention from 1838, to create electricity. In either case, the only "waste" product is water vapor.

Batteries or Hydrogen Fuel Cells?

One of the major uses of hydrogen foreseen by those pushing the Hydrogen Economy is to power fuel cells for electric cars and trucks. Currently, most automakers seem to be opting for batteries to meet the need for electric vehicles. However, batteries have some significant issues. For example, lithium-ion batteries rely on nickel and cobalt which must be mined and refined—two environmentally risky tasks. There are also no good answers on how all those batteries will be recycled or disposed of. These problems may be sidestepped with cleaner solid-state batteries being developed, but that is a hope, not a certainty.



Lorenzot81 | Dreamstime

By contrast, fuel cells have long lives and replacing their filters lets them be reused, a sustainable proposition. Fuel cell also outdistance batteries in terms of range, and range is a major consumer concern regarding electric vehicles. A fuel cell car can also be quickly refueled in 4 min. and given a 350-mile range. A 20- to 30-minute "quick" recharge from a rapid charger only gives the car about 200 miles of travel.

The price of hydrogen will likely continue falling, which will make fuel-cell cars even more attractive. But experts forecast that ultimately cars will probably have fuel cells as well as cleaner solid-state batteries, combining the best of both technologies.

Hydrogen's Dark Side

Some people might needlessly worry that large-scale electrolysis to make hydrogen would eventually lead to a shortage of water. They are unaware that currently it takes several times more water to mine, frack and refine coal, oil and gas than would be needed to electrolyze enough hydrogen to power the world. In addition, each pound of hydrogen burned or turned into electricity creates four gallons of water as a byproduct.

Another downside of hydrogen is the perception that it is inherently unsafe and a dangerous fire and explosion hazard. That perception stems largely from the Hindenburg disaster in which the airship burst into flame as it was landing in New Jersey back in 1937. The fiery crash was seen worldwide as it was filmed for newsreel distribution. And although it was a tragedy, "only" 13 of 36 passengers and 22 of 61 crewmen were killed. But until then, dirigibles using hydrogen for lift had flown safely for 27 years and the Hindenburg had safely flown millions of miles safely before its sad end.

Hydrogen can be highly flammable, but modern safety devices, protocols and technology should make hydrogen-fuel-cell powered vehicles—even dirigibles—as safe or safer than other forms of transportation.

"Since the Hindenburg crash, there have been enormous advances in materials, sensors and controls used in airships and real-time in-flight weather telemetry has significantly improved margins of safety for dirigibles," says Rinaldo Brutoco, CEO and founder of H2 Clipper, a company designing dirigibles to transport up to 200 tons of liquid hydrogen per flight.

Many engineers and scientists argue that hydrogen is a far safer fuel than oil or gas. They point out that it is light and if there is an accident or leak, the hydrogen floats up into the sky and disperses at concentrations below 4%, the concentration at which hydrogen becomes explosive. For comparison, leaked gas and stays on the ground evaporates into the air where it is flammable at concentrations of just 1.4%. And if there is a leak, hydrogen, unlike gas or oil, is non-toxic, so it will not contaminate the air, ground or water. Hydrogen flames also emit low radiant energy compared to gas or oil fires, so they are less likely to spread.

Electric cars and trucks powered by hydrogen fuel cells have been extensively tested for fire hazards. For example, tests show that a rifle fired at a tank filled with gas, diesel fuel or natural gas will make the tank explode. The same rifle shot into a hydrogen tank will put a hole in the tank and hydrogen will escape, but there won't be an explosion. Other tests reveal that if gas leaking from a car is ignited, the tank will explode and burn the entire vehicle. But igniting a leak in a hydrogen tank just ignites a faint blue flame as escaping hydrogen leaves the tank until

all the hydrogen is exhausted; it does not lead to an explosion nor does it raise the temperature inside the car by more than a couple of degrees.

In real-world testing, Honda, Toyota and Hyundai sell hydrogen fuel cell cars in California. And although ordinary drivers have refueled their hydrogen-powered cars over 60,000 times, no explosions have been reported.

Hydrogen does pose some risks, but what doesn't? The *Lancet* medical journal reported in 2007 that coal production annually kills 24 people per terawatt hour (TWh) of energy produced. For oil, the death toll per TWh is 18 and for natural gas it is 3. (The U.S consumes roughly 4,000 TWh annually). The larger threat from burning fossil fuels, however, is the air pollution it creates. In 2021, the World Health Organization said that air pollution is "the single largest environmental threat to human health and well-being." The organization estimates than 4 million people a year die prematurely due to air pollution. So a clean, green Hydrogen Economy should save lives.

The Major Move to Hydrogen

Around the world companies and government are recognizing that hydrogen is an abundant source of low-cost, clean energy. Not wanting to be left behind in the race to incorporate hydrogen into their energy strategies, over 30 countries have released plans for hydrogen and more than 200 projects backed by more than $70 billion in public funding have been announced by industry, according to McKinsey & Co.

"Hydrogen is the missing link to a climate-safe energy future."

—Francesco La Camera, Director-General of the International Renewable Energy Agency

The U.S. announced "Energy Earthshot" a program which intends to lower the cost of green hydrogen to $1 per kilogram within a decade. European governments and energy companies are working with Morocco and Algeria to build solar and windfarms to produce green hydrogen. Their next step is to transport the hydrogen to Europe with tankers and pipelines to Europe.

Saudi Arabia and the United Arab Emirates know the future of oil is limited, so they want to get on the hydrogen bandwagon as well and are investing billions in giant solar plants that will make hydrogen and ship to other countries via tankers. Saudi Arabia, for example, is investing $5 billion in a green hydrogen plant at Neom, a planned city. Australia, Korea, UAE, Chile, Morocco and Brazil, as well as multinational corporations such as Shell, BP and Toyota, are also investing in green hydrogen production. ■

Keeping Up:

Survey Hears from Engineering on Skills Competency

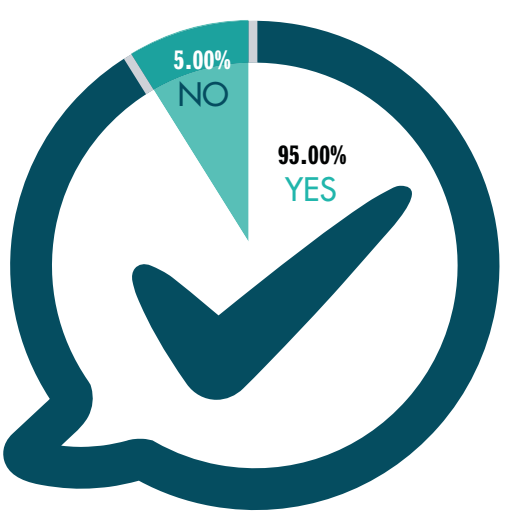
Machine Design's 2022 Salary Survey polled engineers about their preferred methods for ongoing education.

by Rehana Begg, Senior Editor

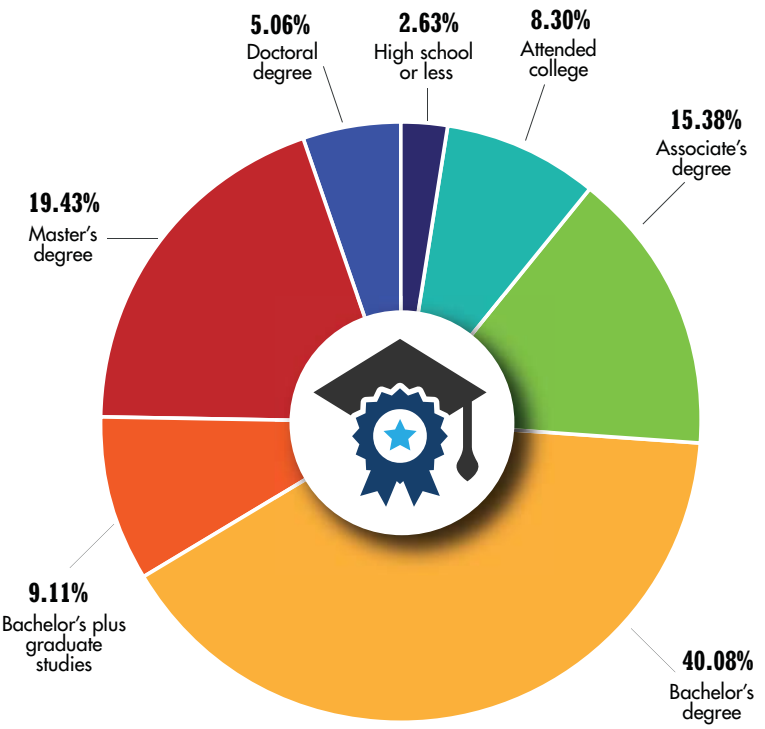
In an ever-changing field of technology, engineers expect continued learning to be part of the job. Flexibility in engineering often means improving current skill sets and cultivating new ones. And if being able to adapt to changing situations is among the most important skills an engineer can possess, what do engineers perceive as the obstacles to building those skills?

Machine Design's 2022 Salary Survey, which polled a cross-section of readers, offers a glimpse into the challenges engineers face and the opportunities employers can seize to help right-size their staffing efforts.

Would you recommend engineering as a career path to a young person looking to choose a profession?



Which one of the following best describes your highest level of education?



For a video featuring more insights from Machine Design editors, visit https://machinedesign.co/21253698.

More than 40% of all participants in this year's survey have at least a bachelor's degree or higher level of education. This foundational education is often not enough to support ongoing job requirements or competency. Typically, engineers will look to continuing education and training while performing professional duties to stay current.

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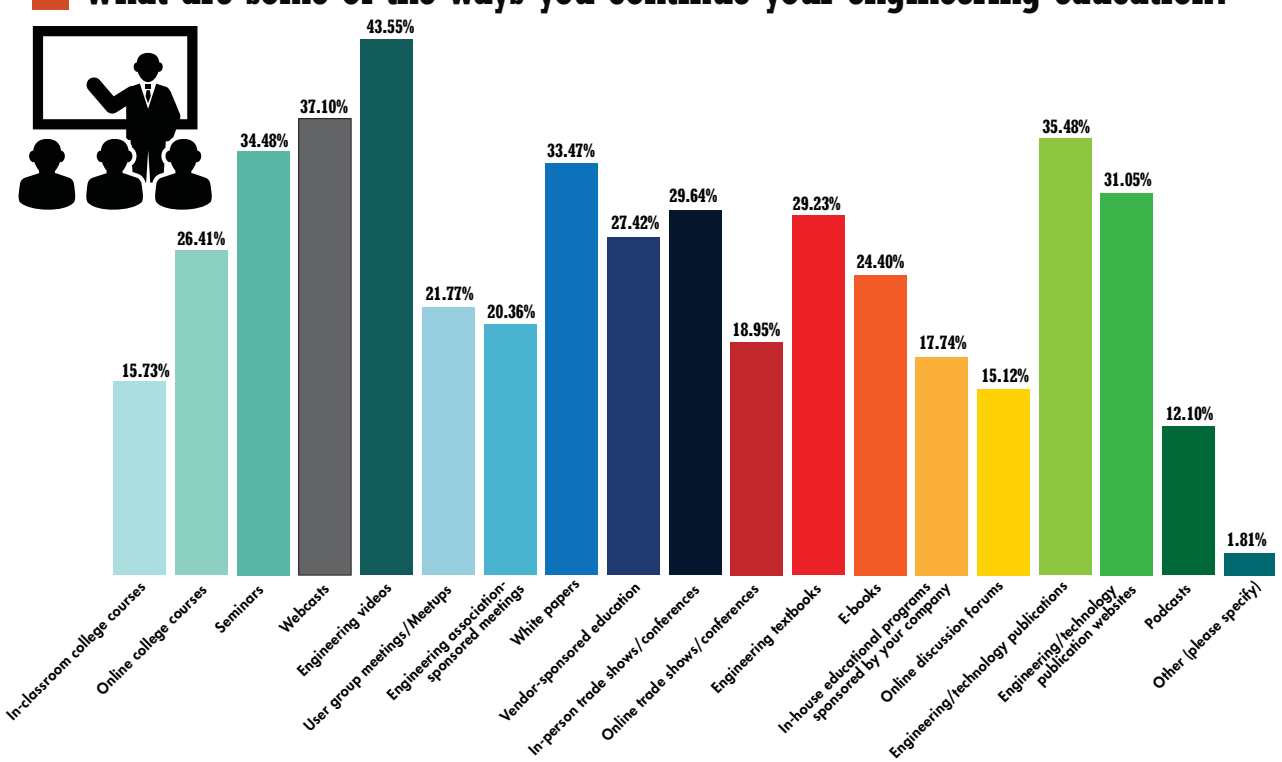
Focusing on the education-related survey questions, we highlight a few insights into ongoing education formats and the respondents' preferences.

What are some of the ways you continue your engineering education?



You Get What You Pay For

The survey asked: "What are some of the ways you continue your engineering education?"

Respondents replied: Engineering videos (43.55%), seminars (34.48%), webcasts (37.10%), engineering/technology publications (35.48%), engineering/technology publications websites (31.05%), white papers (33.47%), as well as in-person trade shows and conferences (29.64%) ranked favorably amongst respondents. Low on their list of preferences were in-classroom college and employer-sponsored courses (15.73%), online discussion forums (15.12%) and podcasts (12.10%).

Respondents were then asked to indicate which of the education forms are paid for by their employers. In line with engineers' learning preferences, the survey showed that employers were likely to pay for employees' attendance at trade shows and conferences (37.7%), as well as seminars (33.67%). Only 22.78% paid for certifications or college tuition, and 25.81% paid for engineering association dues.

Asked what the biggest challenges were in staying current with engineering information relevant to your work, the most common answer was time.

Keeping Up

Asked what the biggest challenges were in staying current with engineering information relevant to your work, the most common answer was time. But if respondents were feeling time-strapped, they were further challenged to find information applicable to their job responsibilities. Sifting through useful, relevant information from an abundance of online sources, finding summarized information on emerging technologies and finding specialized courses were just a few of the impediments noted.

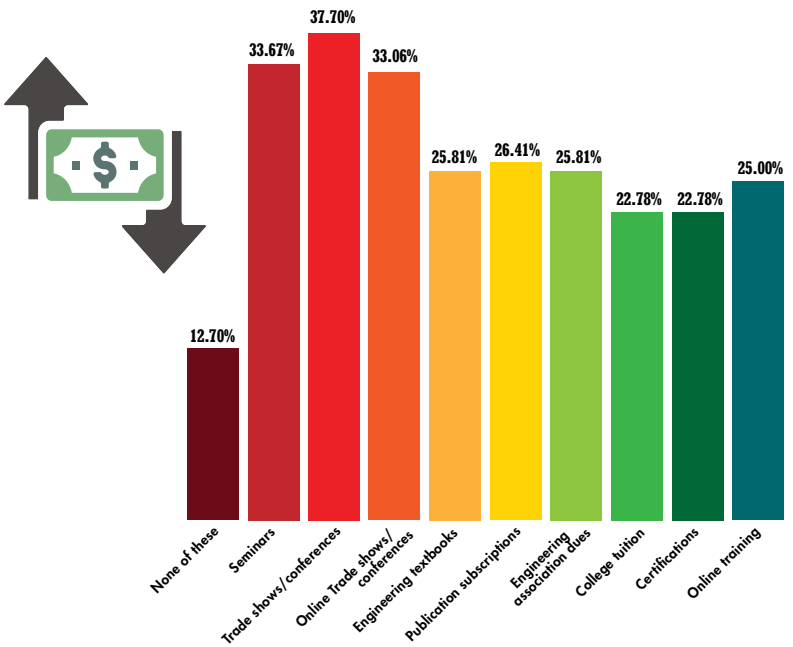
Concerns about knowing rapidly changing technology and which is most relevant to the company was a common refrain. "Parsing which technological advances are relevant to my company, and how soon they will be available or reasonably priced," noted one respondent. Another pointed to the fact that the cost of new technology "is seen by management as too high to incorporate."

At least a couple of respondents alluded to the generational divide amongst engineers and their ability to adapt technological advancements to their current work environments. "As you get older, you tend to be a little slower to learn new skills, and you need to put more effort into learning and improving," expressed one respondent. "Young talent is abundant, and they have the advantage of age," said another.

A Question of Trust and Transparency

There were other interesting comments that fed into the survey. One concern was that some publications miss the mark on serving the needs of their engineering audiences, and took umbrage with "dishonest technical publications that try to steer industry toward certain trends."

For which of these forms of education does your company reimburse costs to engineers?

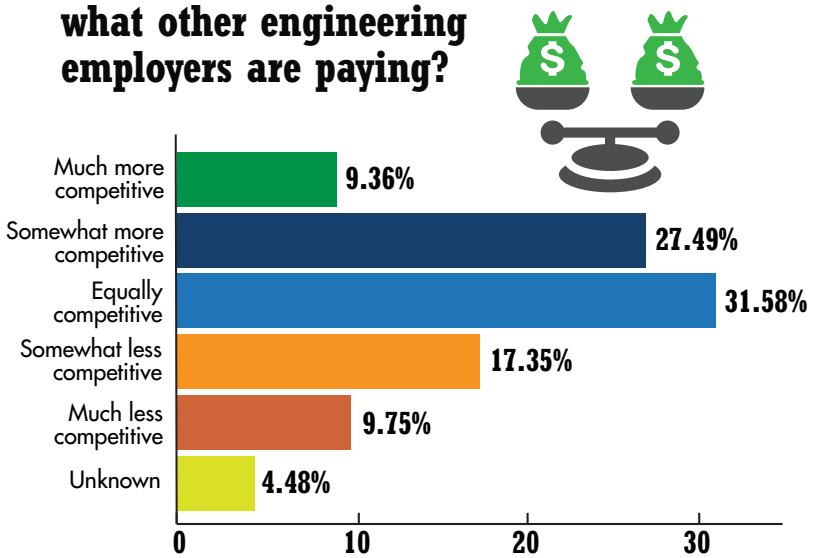


"As you get older, you tend to be a little slower to learn new skills, and you need to put more effort into learning and improving."

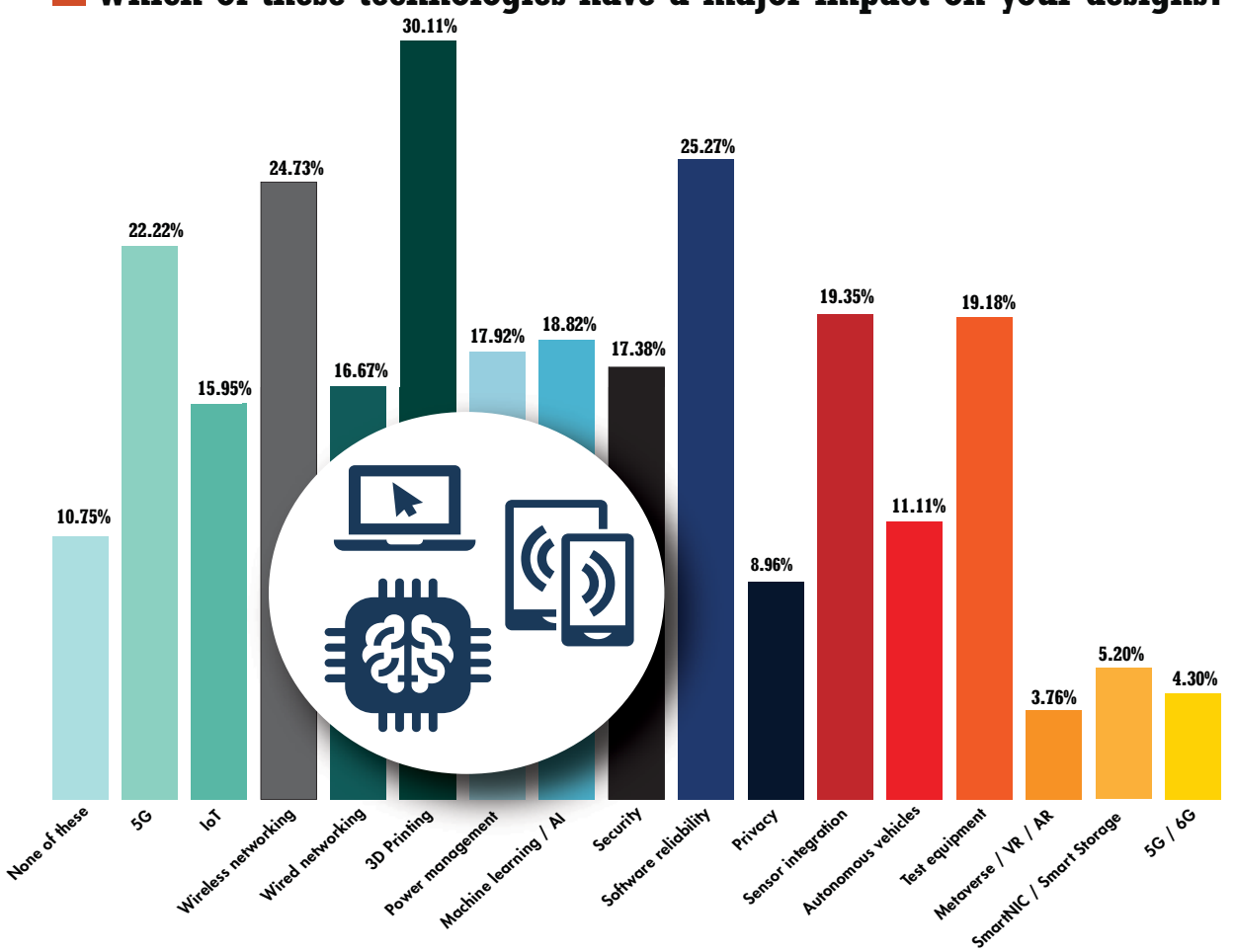
Several others said the tasks of "finding accurate information and reviews along with adequate customer specifications" were arduous. "Finding accurate information and reviews along with adequate customer specifications," was another sentiment echoed on this theme.

All told, perceptions matter. Engineers, like most employees, want to be heard. They want to contribute and want to be part of something meaningful. It all speaks to the appreciation they have for the efforts their employers make to their livelihood and the measure of effort they are willing to invest in their professional growth. ■

Generally speaking, how do you think your compensation package compares with what other engineering employers are paying?



Which of these technologies have a major impact on your designs?



GFCI-Protected Circuits: Don't Get Tripped Up by VFDs

The growth of single-phase applications create new opportunities and challenges for OEMs.

by Ian Miller, National Services Business Development Manager, Motion Canada

The proliferation of affordable and readily available semiconductors in the industrial space has enabled many innovations, making things easier for manufacturers overall. This is particularly true with the introduction of variable frequency drives (VFDs). Historically, you were stuck with a fixed speed on a prime mover or limited to using non-efficient, cost-prohibitive devices. The advent of VFDs has allowed for an easy, efficient, low-maintenance and cost-effective means for controlling that speed. This added level of control of the prime mover has made equipment operation more efficient and improved automation.

VFD use continues to grow in the OEM space for small and mobile equipment, which needs to be plugged into a single-phase outlet or in a commercial setting where three-phase power is less accessible. Examples include mobile pumping units, hose crimpers, lifts, actuator-driven devices, fans/blowers or any application where a motor is the prime mover and varying that motor's speed would improve that equipment's operation. Aside from the benefits of variable speed control, this increased use is driven by VFDs' ability to use a single-phase power source while outputting a three-phase, current-controlled supply to the motor.

This mobile filter cart uses a VFD to allow for a larger motor and variable flow, which is important for water removal. *Courtesy Motion*

These may seem like small features at face value, but they hold much value, particularly for small-batch production. Outputting three-phase power means that standard three-phase induction motors can be used. These motors are both cost-effective and widely available. Control of the current can allow for many features that aid in the controllability of the motor, but it also allows you to avoid the inrush current that typically comes when starting an induction motor.

In context, when sourcing from a standard duplex 120V 15A receptacle, you would typically cap the motor size at ¾-hp to avoid nuisance tripping. When using a VFD, a 1.5-hp motor can be used in the exact application sourcing from the same plug. Doubling the available power of your prime mover in a situation like this can have obvious benefits for the functionality or capacity of a piece of equipment.

Together, these benefits make VFDs an ideal way to control motors on small OEM equipment. This has also been recognized by VFD manufacturers, who have started adding features such as expanded IO (additional/configurable inputs and outputs) and basic logic control. Some go as far as integrating CODESYS-based and motion control programming platforms directly into the VFD. These additions mean that many VFDs are an ideal platform for controlling the motor speed and operating the equipment, eliminating the need for an additional onboard microcontroller.

Understand the Limitations

Despite the many benefits, there are also a few limitations to using a VFD in such an application. One of the most common problems OEMs face is using such equipment on a ground fault circuit interrupter (GFCI) breaker or receptacle. A GFCI is a device that prevents users from being electrocuted. It works by monitoring current flowing through the ground conductor.

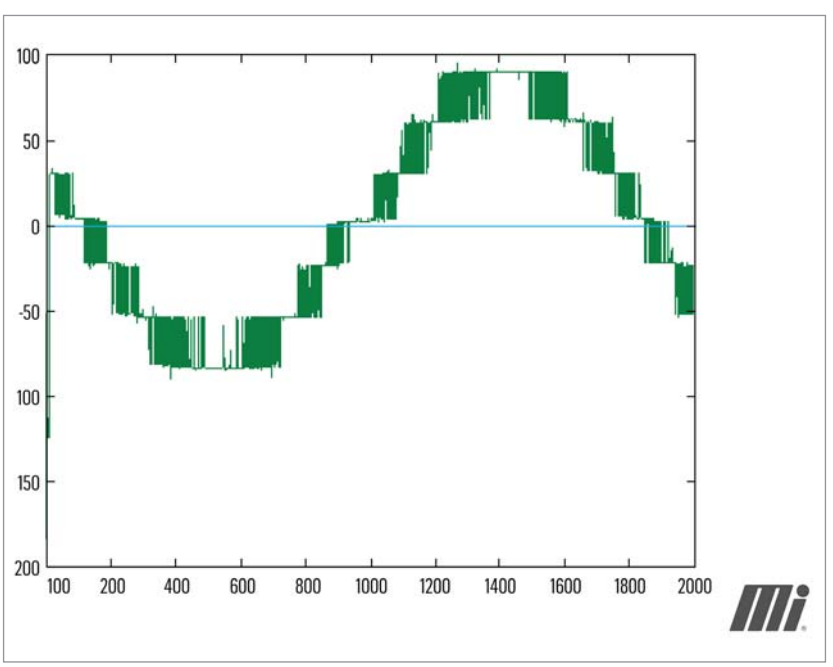
When a critical threshold is identified, the device assumes that an operator is possibly being shocked, and the circuit is interrupted to protect the potential victim. Because they are so commonly used in the market and VFDs are known to trip GFCIs, this can be a large issue for OEMs.

One of the most common problems OEMs face is using such equipment on a ground fault circuit interrupter (GFCI) breaker or receptacle. A GFCI is a device that prevents users from being electrocuted. It works by monitoring current flowing through the ground conductor.

The reason why VFDs commonly trip GFCIs has to do with VFD construction and how it mimics an AC wave. A VFD can best be thought of in three parts. The first is the front end, which consists of a rectifier circuit. This takes incoming power and rectifies it from AC to DC. After the rectifier comes the DC bus, which feeds the final stage of a VFD: the inverter. This last part uses power from the DC bus to emulate a three-phase AC waveform that will power the motor. The issue that leads to VFDs tripping GFCIs is most closely associated with this inverter stage. This is because of the high-frequency harmonics caused by the solid-state switches that can lead to ground currents, also known as "common-mode noise."

To understand common-mode noise, you need insight into how VFDs imitate a three-phase AC waveform. First, the frequency of the mimicked waveform is not what develops the noise. Rather, the problem is the switching frequency (also known as the carrier frequency) used to develop the waveform.

In a typical (grid-supplied) three-phase sine wave, you will always have a zero-sum after adding up all three potentials at any given point along all three waveforms. This is because each wave is 120 deg. out of sync. The concept can best be pictured as a circle divided into three equal sections (like a pie with three large slices) with a mark placed at the circumference where each region interfaces. If you centered that circle on a set of Cartesian



Unfiltered output from seven-level sine wave inverter (single phase). *Courtesy Motion*

coordinates with the center set at zero, the top of the circle at 1 and the bottom at −1, the same would be true.

As you spin that circle, you will find that the sum of all three points will always equal zero at any time. This is analogous to what you would see when charting three-phase power; likewise, this happens as you turn a three-phase generator in real time. The common-mode noise issue comes into effect as the waveforms generated by an inverter do not sum to zero in this same manner.

These waveforms do not sum to zero because most inverters use a multilevel chopper circuit to mimic or approximate the waveform. Because of this rough method, the difference between the actual waveforms as charted in real-time will not sum to zero. This leads to a difference of potential at any given instance and will lead to capacitive induced currents. These currents will seek a path to ground, which can trip a GFCI device.

Minimize the Impact

There are several ways to minimize the impact of common-mode noise. The first is to lower the carrier frequency. These frequencies typically range from 1 to 13 kHz and are programmable through the VFD's parameter set. The lower the frequency, the smaller currents will be.

Next, you should keep the cable run from the motor to the VFD as short as possible and, if needed, use shielded cable. Long leads introduce more capacitance into the circuit, making things worse. You can also consult with your VFD manufacturer; some are introducing output chokes and low-leakage filters, which will make for superior VFDs in this application.

If the VFD is equipped with a standard filter (not the low-leakage type), consider removing it. Most VFDs will have a switch or screw that can be moved or removed to isolate the filter from the circuit, which can also help. Finally, evaluate your control mode. Most drives have an option to perform an auto-tune on startup or measure the stator resistance. These activities can lead to a trip, so select an option that avoids adding such complications. An option such as "fixed boost" will often help prevent these issues.

Understanding the factors that lead to GFCI nuisance tripping will help you avoid the problem. It is often not a matter of following just one of the above recommendations; sometimes you need to find the right combination for your application and the specific VFD used. ■

BASED OUT OF CALGARY, Ian Miller, P.Eng. is a national services business development manager for Motion. He has over a decade of hydraulic and electrical experience in the field, including system design, troubleshooting and technical training/support. Discover more VFD solutions at http://Motionind.biz/3SNfJ4e.

by **Rehana Begg,** Senior Editor

Q&A WITH THE

ROBOT GUY:

David Sandiland Discusses Robotics Cable Management

David Sandiland, robotics product & sales manager, igus, shares insights into the design and guiding principles behind selecting the best cable management systems for six access robots.

As a high-performance plastics manufacturer, igus is known for its plastic plain bearings, flexible cables and connectors, as well as its cable management products and robotic components.

Five years ago, as involvement in the robotic industry grew, the company decided to create a product and sales role that focused on cable management for robotics. David Sandiland was fortunate enough to be awarded the role, and has since traveled across North America—Mexico, the United States and Canada alike—to work with large automotive manufacturers, mom-and-pop robotics integrators and everything in between to help clients better understand the benefits and pitfalls of robotic cable management.

"There's a lot of different ways to manage cables on robots," Sandiland said. "I've seen anything from duct tape to zip ties to corrugated hose to our product. Some of them are better than others."

Customers are generally interested in learning how to improve their existing processes. That interest, according to Sandiland, stems from both the MRO end, "where robots that have gone out into the world from an integrator or an OEM and just aren't functioning properly because of a lack of cable management or poor cable management," as well as from the OEMs and integrators, "who are trying to

do it right the first time, rather than cobble something together and send it out into the world and hope everything works."

Sandiland said that igus brings about 100 products to market every year. The implication is that he will routinely need to educate clients about new technologies, as well as broach topics such as cable management mistakes and retraction best practices.

Machine Design: **What role does cable management play in the design and reliability of a robot?**

David Sandiland: Robots can do a lot of things, but at the end of the day, they are of no use to anyone without a tool at the end of it—be that a gripper or a welding gun…All of those tools need some form of cables and hoses to go from Point A to Point B to get power for that tool. That robot is useless with that tool. That tool can work properly only if the cables are functioning properly, and that's why the cable management portion is so important to cycle time or uptime. Downtime is a killer, especially in the larger industries like automotive. Every minute that they are down they're losing productivity and money. Spending that money upfront for a good cable management system makes all the difference in the end.

MD: **Bring us into the design space. Can you walk us through some of the relevant cable system types and how one can make specific choices, such as the right material for the application, and how this can be designed into a selection process?**

DS: The cable management, as part of an overall solution, is oftentimes overlooked or left till the end. And so, we're really encouraging designers to include it in their upfront design because it makes a big difference when they can understand the limitations of a cable product. I always tell designers that they have to understand the limitations before you're trying to make [the application] do something that it can't. We're working with engineers and coming up with products that engineers tell us they want. We have a robot configurator, where the engineer can find the products based on what robot they have, and get a real sense of what it's going to cost and look like before they get too deep into this.

igus has added the TRX range to the triflex R series of chain products. The TRX now makes the chain telescopic. *Images courtesy Machine Design*

The robot cable that we manufacture is a circular cable carrier called triflex R. It is a three-dimensional cable carrier. It's different from everything else in the market. The standard in the market right now is what's called a corrugated hose. It's just a solid tube, where the cables go into it. The tube has no real three-dimensionality to it, so it resists torsion and resists bending. It doesn't like moving with the robot. Whereas, the product that we offer…it does torsion with the robot; it does bend and twist and turn with the robot; it has a lot of freedom to it. So, it relieves a lot of stress on robots.

Getting into the cable portion, robots are significantly different than standard applications. In standard applications,

"Robots can do a lot of things, but at the end of the day, they are of no use to anyone without a tool at the end of it—be that a gripper or a welding gun...All of those tools need some form of cables and hoses to go from Point A to Point B to get power for that tool."

typically, the cables are moving in one direction—whether it be vertical or horizontal. Those are called high flex, or continuous flex cables, and their construction is significantly different from a robot or torsion-running cable.

It's really important for designers to understand the difference, because adding a continuous flex or high flex cable into a robot dress pack, regardless of the key management you choose, can really lead to some issues. We've seen this particularly with cables that are communication cables, sensor cables, bus cables… anything with fine copper and braided shields.

Having the proper torsion is important, but also having a product that will relieve as much mechanical stress as humanly possible on the cable from the robot motion is important. triflex R has that built into it, with the bend radius and the torsion ability of it. And that really makes a big difference when it comes to cable life versus, say, zip ties and corrugated tube.

MD: **Tell us a bit more about the product's stress release function. Describe the difference between the snap/lock mechanism versus a closed tube design. Why would you select one or the other in a particular application?**

DS: [We have a product] called TRE. There's a slit on each side, and it is available in nine sizes. Different applications call for different sizes, different robots, different cable packages. The benefit of this product is the fact that you have an opening on each side, and you can add and remove cables easily.

Additionally, it doesn't matter what the size of your connector is. In many applications, the connectors are very large on the end of these cables, and if you have just a corrugated tube, you're trying to fish that through the tube. It's very difficult to do, if not impossible. And what ends up happening a lot of times is customers cut the connector off to feed the cable through and reattach the connector. This can lead to a host of other issues. Field wiring a lot of times will end up with premature failures. Probably 80% of our businesses comes from this application because of the ease of installation.

But to your point, there are applications where there's going to be some particulate in the air, and they don't really want to have the opening. We have another product called TRCF cable, which is fully closed. It is designed with openable wings for the flatheaded screwdriver, and there are three internal sections. You can open the wings, and open up a bunch of sections and layer cables in before closing it.

The other place that we use this product a lot is in laser welding. We're seeing this applied more and more in the automotive industry. In the past welding had been a very messy, dirty application with spot welding, or MIG/TIG or wire welding. Laser welding is a new application where they use fiber optics, and they send energy to a tool and the tool laser welds.

The problem with that fiber optic cable is a very, very large bend radius. And we've seen a lot of customers with failures. A lot of large automotive and aerospace companies are investing a lot of money in laser welding because it's a more efficient welding option. But it's a very difficult cable management option. igus is the only company that has an integrated bend radius solution for laser welding. We have two sizes for that.

The closed version is probably going to be used in 20% of the time, depending on the application. We default to the open style because it gives the customer a lot more flexibility for removing cables and repairs.

MD: **Take us to your robotics customer. What are some of the typical cable management mistakes that you see, or that the industry encounters?**

DS: The No. 1 thing that we see is no retraction. Retraction is built-in slack. Basically, a robot does a lot of different motions, and a lot of times customers will find a reason to not implement retraction. What they end up doing is leave a loop of their cable management from the top of the arm to the end of the arm. And, yes, this will give you enough slack to make those movements. But the problems become major when that slack catches on a tool or catches on a fixture or the arm or anything like that.

Our retraction system guides give you slack on demand rather than pre-building it, and guessing and saying, "Oh, we should have six feet of length, or whatever, hanging there." This retraction system will give you that slack, but at the same time we get the slack out of the way. So, you're getting the required amount of conduit that you need, but not doing it artificially by adding slack to it.

We do a lot of retrofitting in MRO applications where they receive something from an OEM integrator, and the integrator did not implement retraction. The rule of thumb that we use at igus is that if you've got more than 180 deg. of rotation at the end of arm, between the three joints—the end of arm joints four, five and six—you really need to have retraction because there's just no way to reliably manage that type of rotation with slack.

This system is going to give you predictability. A system that just implements slack is going to give you unpredictable things and a lot of damage. And then, on top of that you get a lot of momentum, a lot of swing.

Another big one that we see is poor bracket location at the end of arm. In a

Not unlike other igus triflex R e-chains, TRX is flexible and features torsion resistance. It can be lengthened and shortened and it is also capable of 3D movement.

typical industrial six-axis robot, the customer will install the bracket in a perpendicular position to the bracket space. We would prefer for it to be in the same plane, pointing down, just like the robot is. This is a major issue for a lot of different reasons. One of the first things that we do when we see customers is talk about proper end-of-arm bracket location. This is the business end where all the action happens, and if you don't have this in the right location, you're never going to be successful.

MD: **David, what's new on the market?**

DS: We've just released a new product called triflex R TRX. Our engineers put their heads together and said, "Why can't we put the retraction right in the conduit, rather than having it separate?" So now we have a product that works not too dissimilar from our triflex R TRE. The only difference is, there's a band down the center that is going to create some form of resistance. So, it will stretch apart and retract with its own retraction system.

"We've just released a new product called triflex R TRX. Our engineers put their heads together and said, "Why can't we put the retraction right in the conduit, rather than having it separate?" So now we have a product that works not too dissimilar from our triflex R TRE. The only difference is, there's a band down the center that is going to create some form of resistance."

We just showed it at IMTS in Chicago, and the feedback from it was great. At this point, it is going to be based on material handling applications, medium- to large-size robots—the ones that don't have the payload capacity to implement a larger retraction system, or for a customer who wants to save a little bit of money but doesn't want to have a loop. The TRX is revolutionary and we feel really excited about it. I think the market is going to gravitate towards the simplicity.

We are in the very final stages now and I expect to have pricing available for customers by the end of October, and hopefully shipping by the end of the year. ■

MachineDesign

FAQ

Modular DIN enclosure systems for innovative designs

DIN enclosure systems are widely used in industrial applications but have been limited in their versions. Modular DIN enclosures are providing systems design engineers more options to work with.

Q1: What do I look for in a DIN enclosure if my applications are varied and often complex?

Depending on the type of applications you are involved with, whether for industrial machines and equipment or electronic control applications, a modular enclosure that can handle a variety of connection types might be ideal. While some applications require fixed push-in terminals others might be more geared toward pluggable push-in terminals of various types. Adaptation becomes key particularly with innovative designs. Be sure to look for terminals that are compact, offering high signal density to the user.

Q2: How would such an enclosure work?

Modular DIN enclosures are flexible and easy to install through a quick snap-together design. Integrated terminals are provided to connect wires from outside of the enclosure to PC boards inside of the enclosure. Common bus concepts can be integrated into the bottom assembly. Such enclosures should offer integrated test points for quick on-site access. The mounting position of a circuit board that is perpendicular to the top rail, as is how the Altech KV 4600 DIN enclosure is designed, makes it possible to integrate up to two circuit boards. An optional snap-in rail bus mounting system (In-Rail-Bus) allows for device communication for power, signal, and data transfer. Contact spring blocks with gilded double-spring contacts provide high contact reliability.

Q3: Would a modular DIN enclosure allow me to have front-facing terminals for easy diagnostics?

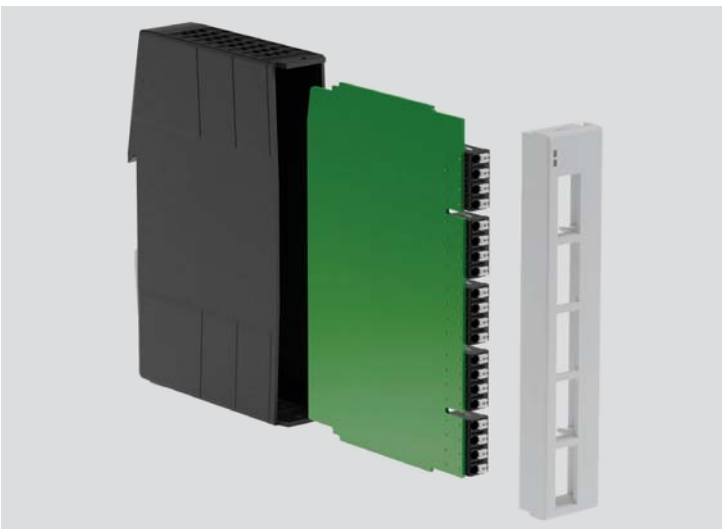
Where most DIN enclosure provide side-facing terminal blocks, the right modular system would allow for front accessibility. A large front area would allow for full functionality as well as the flexible arrangement of terminals. Be sure the layout provides easy integration of common communication interfaces, including RJ45, D-Sub, USB, light conductors, radio, and NFC.

Q4: Would such a design allow for greater printed circuit board surface availability?

Absolutely. The PCB surface can be fully used for the layout since it is not blocked by the terminals. An open layout configuration increases board real estate so that designs can provide additional features not available from other enclosure systems. With the inclusion of lateral ventilation slots, optimum heat dissipation is available through free convection, allowing for applications that exhibit high thermal stress. The ability to pack more features into the board design, means that costs can remain lower than normal as well.

Q5: What aspects of the modular DIN enclosure would provide ease-of-use?

Consider solutions that offer fixed integrated and pluggable connection technologies. For example, pluggable terminal blocks could be arranged in line to allow for the use of prewired leads. This approach would save time and improve the handling of connections during installation, maintenance, and repair operations. Tool-free installation of conductors by pluggable push-in terminal technology provides for a modular terminal technology that makes wiring quicker, easier, and more reliable. Finally, a system such as Altech's KV 4600 offers an integrated plug removal aid to allow for the convenient unlocking of terminal blocks on an individual basis as needed. This is great for applications where high connection density is necessary under limited spatial conditions.



Q6: Are such enclosures applicable for use in high shock and vibration situations?

The right modular DIN enclosure offers high mechanical stability and vibration resistance. This includes vibration-resistant connection of the conductors as well. When considering your environment, including shock and vibration, be sure to focus on each component and not just some of the components. Often designs may include vibration resistant mounts to the printed circuit board and forget to provide the same protection in their fixed or pluggable interconnections.

Q7: Are there versions meant for industrial IoT applications?

Modular DIN enclosures allow for common bus concepts to be integrated into the bottom assembly. For example, the I/O electronics enclosure (a variant of the KV 4600 series) offers a super compact module width of only 12.5mm with a depth of 66mm. The I/O enclosure was designed for modern control systems and industrial IoT applications such as in process engineering, discrete manufacturing, and other applications where space is limited. They feature convenient front connection technology for the transfer of signals, data, and power. Device systems are often contacted and managed decentrally via bus systems. For this purpose, the I/O electronic enclosure offers connecting elements that are separately available and make it possible to link the individual modules.

Q8: Is marking available so that it is easy for maintenance and repair operations?

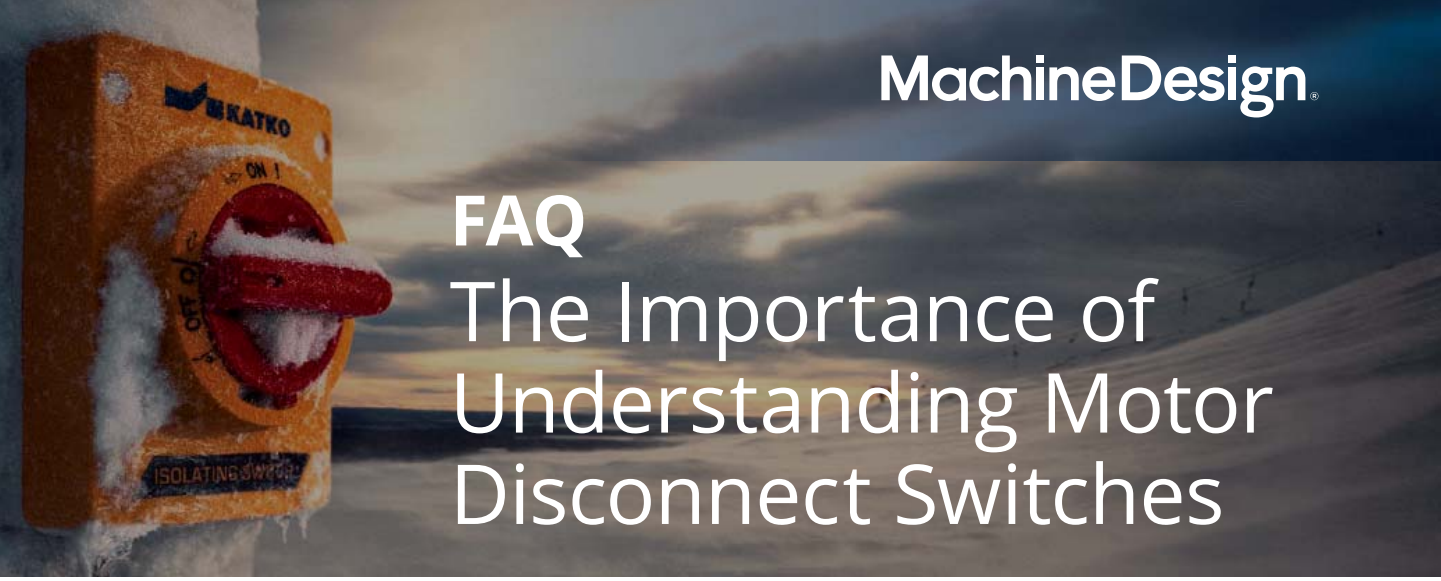
Because these modular DIN enclosures offer a large surface, they provide space for individual and abrasion-resistant laser markings and pad or digital printing processes depending on user requirements. There are also various methods used to code the individual terminal blocks to eliminate wiring errors as well.

Q9. Are other customizations possible?

Yes, modular DIN enclosures should offer an array of customization possibilities. Manufacturers can mill or mold in custom openings for different types of connectors or ports for all sorts of communication interfaces. These can be integrated into the front face or the side of the enclosure. Other options may be available as well, such as light conductors for status indication, grounding springs, and tilt-able front covers for manipulation protection. You should look for a supplier that offers many standard designs to choose from which can then be customized to meet your application requirements.

Q10: Are modular DIN enclosures available for a wide variety of applications?

The flexibility of modular DIN enclosures creates the broadest capabilities available in the market. DIN enclosure applications are literally limitless and are available to work with all manner of electromechanical devices including relays, sensing and monitoring devices, transducer, and printed circuit boards. Once you've decided the parameters of your system, it is easy to configure the right modular DIN enclosure for your needs.



MachineDesign

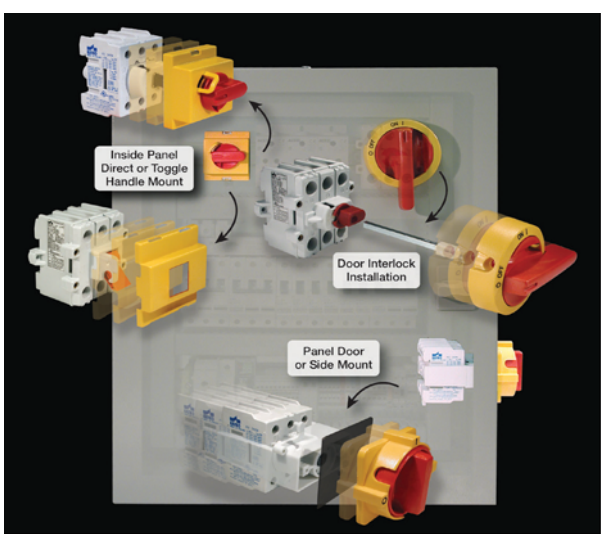
FAQ
The Importance of Understanding Motor Disconnect Switches

Q: What is the major purpose for using motor disconnect switches?

A: Motor disconnect switches are an important part of a system's safety protocol for electrical equipment that needs robust protection for both the equipment and personnel. These devices are used to make it easy for manufacturers to disconnect and reconnect power so that operators are able to work safely downstream of the switch—with absolutely no concern about coming in contact with live voltage or power. Besides being used to open and close the motor circuits when repair or maintenance is needed, disconnect switches can be used for lockout/tagout purposes to keep equipment shut down and isolated until proper restart sequences are completed. Disconnect switches also allow operators to access a control panel without being exposed to the line-side voltage. In fact, with today's safety regulations, manufacturers are required to include a local—and visible—disconnect switch for motors and equipment.

Q: What components make up a disconnect switch?

A: Disconnect switches are made of wired contacts connected to an actuator of some type, whether a handle or toggle. An enclosure protects the contacts from environmental hazards anywhere from dust and dirt to water and moisture. The handle or toggle allows users to engage and disengage the electrical contacts without opening the distribution enclosure or motor controller. Locking the switch in the disconnect position is often required so that power cannot be turned on accidentally.



Be sure to work with a company that offers multiple options for mounting your disconnect switch so that you can adapt quickly and easily to any application.

Q: What options are available for mounting in different applications?

A: Mounting is an important part of selecting the right disconnect switch because some applications have limited space to work with. Options to consider include a door interlock installation where the switch is placed on the back panel and the shaft is inserted into the disconnect switch and stays with the switch, with the panel door open and the door interlock handle on the outside of the panel door. For a panel door mount or side mount application, the switch itself is located on the inside of the door bracket while the handle is on the outside of

the door or side panel. Then, there is a standard inside panel application with direct handle or toggle operated switch. Note which of these mounting methods are ones you might wish to have a locking capability for in order to best protect personnel and equipment.

Q: What specifications can be considered for general use of a disconnect switch?

A: Applications vary quite a bit, but you'll find that 16A to 150A/600V should take care of most of your needs. You will have to consider the size of the manufacturer's solution since many pieces of equipment built today have less real estate available for such devices. This is why companies like Altech have focused on compact designs, such as their UL 508, which is one of the smallest 80A disconnect switches on the market.

Q: What else might I consider when looking for the right disconnect switch?

A: We suggest that you look for a switch mechanism that is digitally controlled—that is, the switch mechanism speed is independent from the operator speed. For example, Altech's UL 98 disconnect switches operate regardless of how slow the handle moves. At a certain point the switch goes from off to on or vice versa. Also, when considering a disconnect switch, look for a manufacturer who uses the same design for either direct or extended handle units. Be sure that the manufacturer you choose also has a comprehensive range of accessories including a variety of door mounting kits and fuse holders. Another consideration, depending on your application would be the materials the disconnect switch is made out of. Look for a company that offers different enclosures such as aluminum, sheet metal, stainless steel and polycarbonate enclosed disconnect switches.

Q: What certifications will I need to consider when selecting a disconnect switch?

A: The National Electrical Code (NEC) says that a disconnect switch must be located in sight from all motors or manufacturing equipment, not more than 50 feet from the equipment it controls. UL listings are also required for the electrical mechanisms of disconnect switches. Altech disconnect switches have been designed and manufactured in accordance with EN 60947-l, EN 60947-3, IEC 60947-1, IEC 60947-3, Low Voltage Directive 2006/95/EY, and UL60947-4-1 (formerly UL508).

Safety Air Gun Provides Power and Control

The TurboBlast Safety Air Gun is capable of producing up to 23 lb of force with a simple press of a button trigger. It is a solution for blowoff applications requiring maximum force such as removing stubborn or heavy debris like slag and flash, part drying or cooling from a distance, as well as heavy duty cleanup in busy facilities. The TurboBlast features a cast aluminum handle with a rugged elastomer grip that's not only comfortable but UV resistant, chemical resistant, and insulated from heat or cold. The light touch activation trigger creates a powerful blast of air and also includes a "Dead Man's" grip that turns air off if the air gun is dropped. All models include an integrated nozzle guard for safety. Models are available with an adjustable gate valve to control blowing force on the fly, or without the gate valve.

EXAIR

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DeltaV Update Helps Improve Operator Performance

A new version of the DeltaV distributed control system (DCS) helps plants digitally transform operations through improved production optimization and enhanced operator performance. New software designed to reduce the burden of IT support and modernization spend coupled with expanded analytics will help increase flexibility and speed to market and drive operational improvements. Users can increase their speed to market through the DeltaV Spectral Process Analytics Technology (PAT). The DeltaV Spectral PAT integrates two analytics solutions with the DeltaV DCS for real-time closed-loop control. This tighter control helps reduce human error and increase speed to market of quality therapies by moving plants closer to continuous manufacturing of drugs..

EMERSON

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Digital Wrench Can be Connected With Wi-Fi

The OPEXplus digital torque wrench can measure both the torque and the angle of rotation. It covers a range of torques from 3 to 800 Nm, and it transfers the tightening results to any IT system without the need for additional control. OPEXplus torque tools are recognized in networks via the embedded Wi-Fi module. When a tool in an assembly line is changed, the module can simply be plugged into the new screwdriver. The supplied software allows parameterization via a hotspot, the customer network or a serial interface. The intelligent OPEXplus transmits the tightening results with a tightening curve, as well as maximum torque and angle of rotation, directly to any of the user's IT systems without the need for additional control.

BOSCH REXROTH

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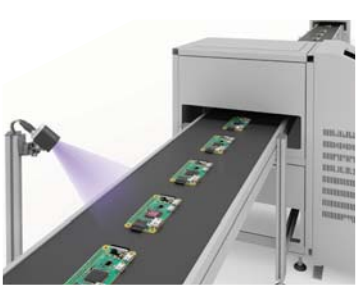
AI Vision System Learns as it Scans



The VISOR Object AI independently learns distinguishing characteristic features based on a few images of the object to be detected. Even strong process and product variations such as fluctuations between batches, contamination, reflections, changing shapes or varying 3D orientation can be taught with just a few mouse clicks. It then is able to reliably recognize the objects appearing in front of the lens and assign them to different classes. Once a classification has been taught, it works reliably and robustly, without the user having to worry about suitable detection rules and parameters, as is the case with classic, rule-based image processing (e.g., using pattern comparison, contour or contrast recognition). Because the VISOR Object AI is capable of learning, it typically only needs around five sample images per object class to sufficiently achieve a stable detection process. The AI algorithm is implemented in the sensor itself and therefore does not require any network or cloud connections.

SENSOPART

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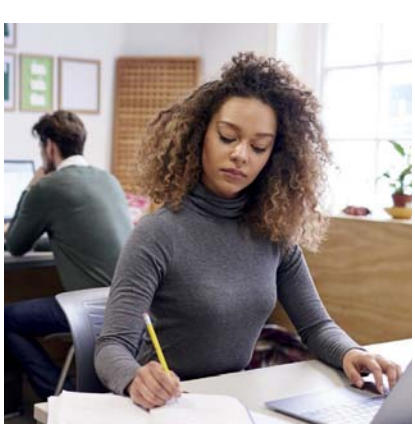
Mechanical Powder Metal Engineer, Weaverville, NC: develop, evaluate, design, and improve manufacturing methods, materials, and tooling for powder metal processes. Implement knowledge of mechanical compacting presses, sintering furnaces, and secondary operations; tool design for multi-platen presses and maintenance of press tooling; adapt existing part designs; quality control and test methods. MUST: minimum of BS degree (or foreign equiv) in Mechanical Engineering + 2 years experience in powder metallurgy and tooling, and proficient in Auto-Cad and Solid-Works. US work authorized. FAX resume to Engineering Manager, Dodge Industrial, 828-645-5211.

Ad Index



ENDEAVOR BUSINESS MEDIA

Dexterous Robotic Finger Prototype Withstands Physical Impacts

Researchers are developing a sturdy, dexterous robotic hand that can withstand physical impacts.

by MD Staff

When robots work in unstructured environments, the physical impact of bumps and collisions can be inevitable. The impact can damage the robots' hardware systems. This is often the case for rigid multi-fingered robotic hands.

A team of researchers who recognized the need for dexterous robotic hands that can withstand physical impacts in environments, have designed a robotic finger than can absorb physical impacts in their working environments,

The research team from Harbin Institute of Technology (China) have created a solution that mimics the human finger in dexterity and its ability to contend with physical impacts during their interactions with humans and objects.

"This will enable the dexterous hand to have better mechanical robustness, thus solving the problem that the rigid driven dexterous hand is easily damaged by physical collisions in unstructured environments," said Yiwei Liu, a professor at Harbin.

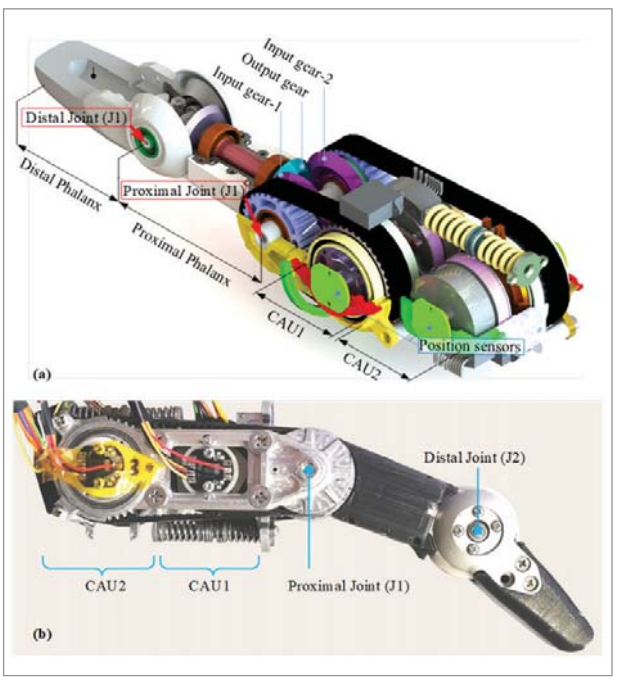
The Problem with Robotic Hand Design

Currently, variable stiffness actuator systems are go-to technology in robotic hand design. Likened to a human body, they provide dexterity and flexibility or stiffness, depending on the task performed.

The researchers explained that variable stiffness actuators are driven by two actuators, which also necessitates the use of two sets of decelerators, actuation devices and sensors. The additional components in the current cable-driven design increase the weight and volume.

Variable Stiffness Actuator Principle

The research team have instead developed an "antagonistic variable stiffness finger mechanism" that is based on achieving mechanical passive compliance against physical impacts. In this solution, the robot finger is based on gear transmission. "The mechanically robust finger is based on the concept of mechanical passive compliance, where the contact forces between a robotic manipulator and a stiff environment are controlled," noted the researchers.



A sectional view of the CAD model of the finger (top) and the prototype antagonistic variable stiffness finger mechanism (bottom). *Higher Education Press Limited Company*

The researchers tout several advantages for new robotic finger design in this experimental study: The mechanical fingers are more reliable and easer to manufacture than current designs. The fingers absorb physical impacts while adjusting their stiffness based on the requirements of the task. In addition, the finger mechanism is compact and does not have the weight and complexity of additional actuators.

Getting a Grip

The finger prototype weighs 480 grams and was fabricated with alloy material and 3D-printed material. The finger is described as robust in withstanding physical impacts and performs well for power, grasping and manipulation, according to the paper published in the journal *Frontiers of Mechanical Engineering.*

Next steps are to improve the finger's stiffness adjustment range and make it more compact in size and weight. But the ultimate goal, the authors noted, is the design and fabrication of a complete dexterous hand.

"This research is of great importance to improving the manipulation level of dexterous hands in unstructured environments or physical interacting tasks," said Liu. ■

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