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Motors, Motion & Drives, Part I

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TABLE OF CONTENTS

AD INDEX

Hey robot, want to go for a stroll?

AMRs will be moving throughout the plant without the need for large engineering and infrastructure investments

By Dave Perkon, technical editor

Robots and automation may grow wheels, legs and arms. It's all part of improving manufacturing. It will be required to remain competitive in many industries. A closer look at autonomous mobile robots (AMRs) and the related standards and design decisions needed to get robots moving throughout the facility shows it may not be as hard as you'd think.

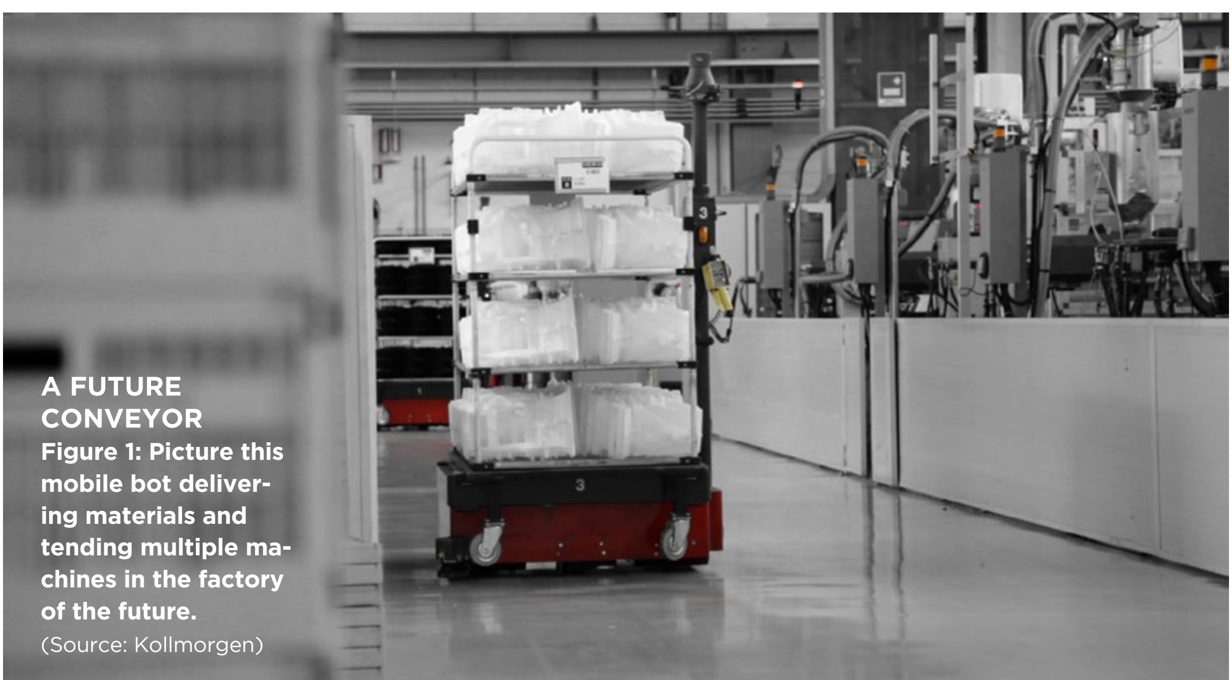
Robots will become more mobile, where needed. There will be new ways they help plant-floor workers, technicians and engineers. And there are some trends in robotics that are simplifying mobile and fixed robots applications alike.

There are a variety of ways to build and control an AMR using a SCARA or articulated-arm robot mounted on an automated guided vehicle (AGV) to improve assembly, tending, logistics, inspecting and packaging applications in manufacturing. "A robotic arm mounted on a mobile platform can have many advantages over a fixed-platform robotic solution," says Matt Wicks, chief robotics solution architect at Honeywell Intelligrated (intelligrated.com) in Mason, Ohio. "These mobile manipulation systems can enable the robot "arm" to roam over a wider area. This can effectively extend the reach of a robotic arm when used in conjunction with the AGV base. Think of the AGV as an extension of the robot arm, just like a person can reach farther when they lunge forward. Coupling these together can be an enabler for some applications such as automated truck unloading. A fixed robotic solution is not an option for unloading a 53-foot trailer, but it is possible with a mobile manipulation platform."

Control of a mobile manipulation system will depend on the actions and applications required. "In very simple applications, the AGV and manipulation system can be considered separately," says Wicks. "Just dispatch the AGV to take the articulated-arm robot to the location that it needs to perform a certain action, and, once it has arrived, turn over the control to the articulated arm. The positioning accuracy of the AGV systems vary, so it's likely that computer vision and/or other tooling and docking methods will be required to enable the robot to understand its position and environment."

ROBOTS IN MOTION, A FUTURE CONVEYING METHOD

"Industrial robots with wheels will likely show up in a few years," says Samuel Alexandersson, product marketing manager at Kollmorgen AGV (www.kollmorgen.com). "We are seeing concepts and prototypes shown at tradeshows today. Companies are working through issues around safety such as when, where and how to reach for something. For example, reaching for goods presents moment loads and concerns around center of gravity and tipping. In a lights-out warehouse, only navigation and path/picking optimization were of primary concern. In a smart factory, with people roaming around, safety is the primary concern. We think the warehouse will nevertheless lead the way in this endeavor, as it has in recent mobile robot advancements



A FUTURE CONVEYOR
Figure 1: Picture this mobile bot delivering materials and tending multiple machines in the factory of the future.
(Source: Kollmorgen)

(Figure 1). Can we envision a factory of the future where a robot can tend multiple machines, even if a few meters apart? Yes. Can we envision a factory of the future with no fixed conveyors? Yes."

Connecting a robot arm to an AGV allows end customers to increase flexibility in their manufacturing processes. "The AGV can move between different work cells depending on demand," says Alexandersson. "It also allows end customers to go from isolated manufacturing process steps into an interconnected, fully automated factory of the future. Control of the robotic arm and AGV can be done by using one sophisticated controller. A more common solution is to integrate a motion controller for the robotic arm with an AGV controller, where commands and feedback are communicated via an industrial interface."

MOBILE ROBOT STANDARDS

"Autonomous mobile robots are the latest innovation that have been transforming traditional robot tasks through increased flexibility and diversified applications," says Bob Doyle, vice president, marketing, communications & advocacy,

Association for Advancing Automation (A3, www.a3automate.org) in Ann Arbor, Michigan. "AMRs are known for their unique ability to navigate in an uncontrolled environment with a higher level of understanding via sensors, blueprints, artificial intelligence and 3D or 2D vision. Their perception allows these robots to reroute automatically when something is in the way. AMRs are highly innovative compared to a traditional AGV, which is also mobile but uses wires or magnets to navigate a narrowly defined area from Point A to Point B."

The next step of the AMR is mounting an arm on a mobile base, so that it can start an operation at Point A to manipulate and actually move autonomously to Point B in an operation.

"The future of automation contains a fundamental shift: the reduction of barriers between the robot and its environment," says Doyle. "Integrators should already be cognizant of the Robotic Industries Association (RIA) R15.06 American National Standard for Industrial Robot Safety Standard, addressing hazards in an industrial environment where the robot is bolted in place with fencing around the hazard zone."

Now, the industry is full of collaborative robots working in tandem with a person while the barriers are removed, and autonomous mobile robots are adding another layer of complexity to safety considerations, continues Doyle. "The RIA is introducing a new standard to address all aspects related to the safety of people around AMRs: the R15.08 American National Standard for Industrial Mobile Robots and Robot Systems—Safety Requirements," he says.

The new standard is designed to address these considerations for manufacturers, integrators and end users. The standard describes basic hazards associated with AMRs in an industrial environment, and provides requirements to eliminate or adequately reduce the risks associated with these dangers.

CHALLENGES OF ADDED MOTION

"While simply adding a SCARA or six-axis robot on top of an AGV or AMR can be done pretty easily, many challenges exist once you do so, and there are many important considerations to not gloss over," says Scott Marsic, product manager for Epson Robots (www.epson.com). To look at a few considerations, one must start with power. "Industrial robots are typically plugged in so they can run 24/7. AMRs and AGVs are by their nature remote devices. As such, they are kind of like forklifts and need to be charged periodically or powered remotely."

Once you've solved the power issue, you face the challenge of making the remote device do the tasks you want it to do, continues Marsic. "For example, in a warehouse environment you'll need to be able to easily find your way around to find a part bin," he says. "This requires the mapping of your environment and writing some software to do this. Once I'm there, how do I find a specific part? Vision is required, and this must be integrated into the remote system. Next, how do I grab the parts? Gripper integration is critical here, but, if I am in a warehouse environment with hundreds or thousands of parts, using one generic gripper might be inadequate."

These AMRs will need to do various things. "The bottom line is AGVs and AMRs are exciting growth areas for automation, but it's important to consider in advance the full system," says Marsic. "How do all the components integrate together such that the implementation, control and management of a remote device is both possible and adaptable to environment changes?" he asks. "There will be many considerations, and this is just looking at warehouse environments."

Warehousing end users seemed to be the leaders in AGV type robots, whether they run on the floors or even the ceilings, says Chris Elston, chief robotics manager at YRG (www.yrginc.com) in Fort Wayne, Indiana, a master distributor of Yamaha Robots. "The concept of standard industrial robots as we know them today have been looked at numerous times to make them mobile, but the power requirements continue to challenge machine builders and system integrators," he says. "Most industrial robots require ac power to operate them at faster cycle speeds, so this limits their use on an AGV. Robots that are mounted on AGVs have to be redesigned with lower power requirements or even accept dc electrical power. These are not requests that are being overlooked, just not readily available right now with standard cataloged robots."

Mechanically and electrically, it is important to make sure that the robot arm is compatible with the mobile robot on which it is mounted, says Nicolas Lauzier, vice president of engineering at Robotiq (www.robotiq.com). “There are often combinations offered on the market which can simplify the selection,” he says (Figure 2).

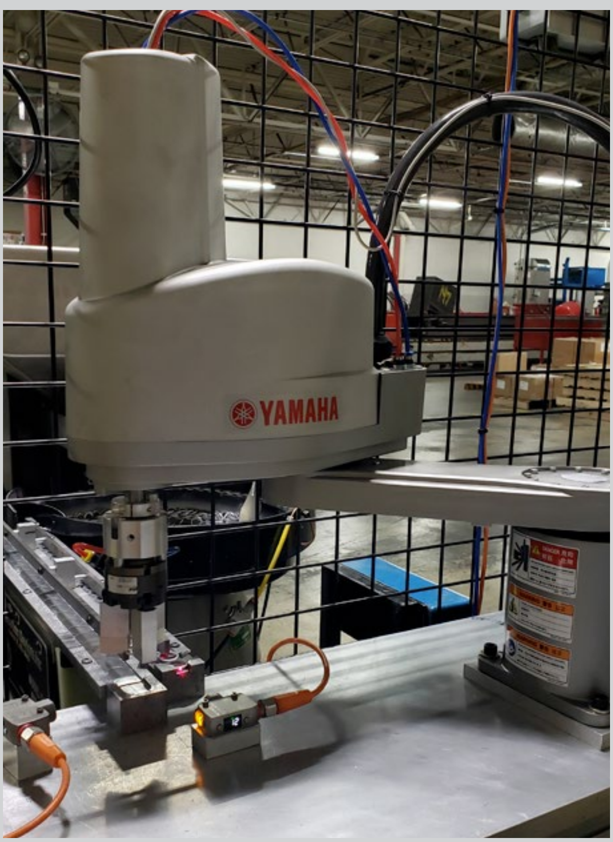
The mobile robots are usually programmed by moving them around the factory using a remote control. The onboard sensors then map the factory, and the robot is later able to orient itself autonomously. The scanned map can be adjusted on a PC in order to add restricted zones, virtual obstacles and targets for doing its tasks.

“These mobile robots are usually precise to a few centimeters, which is not enough for most applications,” says Lauzier. “One good way to cope with this missing accuracy is to use some tags mounted on the machines or stations, which can be located precisely by a camera mounted on the robot arm. With this approach, it is possible for the mobile robot to move next to the station, stop, have the camera precisely locate the tag and have the robot arm work as precisely as if it has been at this exact position when first programmed.”

TENDING AND MOBILITY
Figure 2: Add a camera and mobility to this Universal Robots’ cobot with Robotiq adaptive gripper, and this robot will be tending multiple CNC machines. (Source: Robotiq)

Welcoming robots to the plant floor

You have to crawl before you walk. "There are still a lot of end users getting their hands on a robot for the first time, and not yet ready for AGVs or robots with legs," says Chris Elston at YRG, a master distributor of Yamaha Robots. "Many older manufacturing companies in North America are re-learning automation with many companies who are reshoring production back to the United States after years of manual production overseas. Manufacturing engineers are struggling with choices of which robot to deploy, such as a cobot verses a tradition industrial robot, and in a lot of cases cobots have been misapplied. North American automation,



HOLD THE MOBILITY
Figure: Often, robot mobility is not needed as this simple Yamaha SCARA can do a lot of work simply and quickly. (Source: YRG)

CONTROL AND POSITIONING

"From my experience the controls have been discrete at this point for the fleet management of the mobility portion and the existing OEM robot control for the arm," says Micah Troxler, mobility product manager at ABB Robotics. "It is typically a PLC interface, and no single controller for both mobility and the arm have been widely established yet. Most of the mobile manipulators currently on the market follow a multi-controller strategy. The manipulator is triggered by a signal (IPC/PLC) from the AGV when the AGV confirms to have reached the designated destination to execute Task XYZ."

Because, typically, the positioning accuracy of the AGV is not sufficient enough, or is too expensive time-wise, for a manipulator to execute its tasks, an integrated vision system is needed, continues Troxler. "Combining all these different control systems, including AGV, safety, robot control, robot vision and optional additional axis and AGV guiding called simultaneous localization and mapping (SLAM), is difficult but likely to be achieved in the future."

robotics and AGV uses continue to lag, compared to Asian type companies, for example. Exceptions are tech companies or online retailers who are finding faster and better ways to use AGVs and robotics, but a bulk of manufacturing in North America is still that company in Small Town, USA, that has been in business for 50-plus years, combatting finding employees and maintaining the labor workforce."

Recently, General Plug & Manufacturing from Oberlin, Ohio, looked at automating a plug process. A collaborative robot was looked at first, but the desired cycle rate of 2.5 seconds per piece was too demanding for a cobot, so a traditional SCARA was considered. Three weeks after installing its first Yamaha SCARA robot, a sustained 2.25-second cycle time with a much higher uptime and runtime has been averaging more than 1,600 pieces per hour with automation, versus 1,400 pieces per hour before automation.

"I had instructions to look into automation and was invited to a demo for a collaborative robot from a local distributor and shared findings with the owner about a guided robot vision application," says Ernie Campbell, sealant manager at General Plug & Manufacturing. "I was quite impressed with the collaborative robots but didn't see an application for it, so I got into a discussion with the same distributor, which led to Glen Morr, Yamaha application engineer, bringing a sales gurney out and showing us a Yamaha SCARA robot, and the proverbial light bulb went off. After additional research we bought two for our assembly process."

Control is only one of several aspects of mobile manipulation. "From a regulatory perspective there is nothing in place, and the industry follows the rule that an AGV must stand still while the mobile manipulator is moved, and the manipulator must be still while the AGV is moving," says Troxler. "Power demand, current peaks, especially of fast and/or heavy manipulators does not fit a classical battery performance and needs to be bypassed, as well. Robot control on a mobile base is both art and science. Before you worry about control, you have to address the power requirements and ensure the combined technologies have a reasonable operational time between charging needs."

Fortunately, much has already developed for the machine builder, integrator and end users of AMRs. "One of the biggest trends in robotics has been advances that make robots easier and less expensive to implement and maintain," says Mark Handelsman, U.S. channel sales manager at ABB Robotics. "Within the past several years collaborative robot solutions have grown from a few early adaptors to a major portion of the robot market. This includes robots designed for collaborative operations such as ABB's YuMi single- and dual-arm robots, as well as scanners and other safety devices that monitor the work area in conjunction with robot safety controls such as ABB's SafeMove2 (Figure 3). This trend both reduces the integration costs and eliminates feeders and indexers by allowing operators to safely work within the robot work envelope."

GETTING A ROBOT IN MOTION

Less is better when adding mobility to a robot. "Last year we introduced what we call our next-generation solution, which is a truly integrated machine controller versus the traditional machine/PLC controller with a separate, stand-alone robot controller," says Craig A. Souser, president/CEO of J.L. Souser & Associates (JLS, www.jlsautomation.com), in York, Pennsylvania. "An integrated machine controller, beyond elimi-

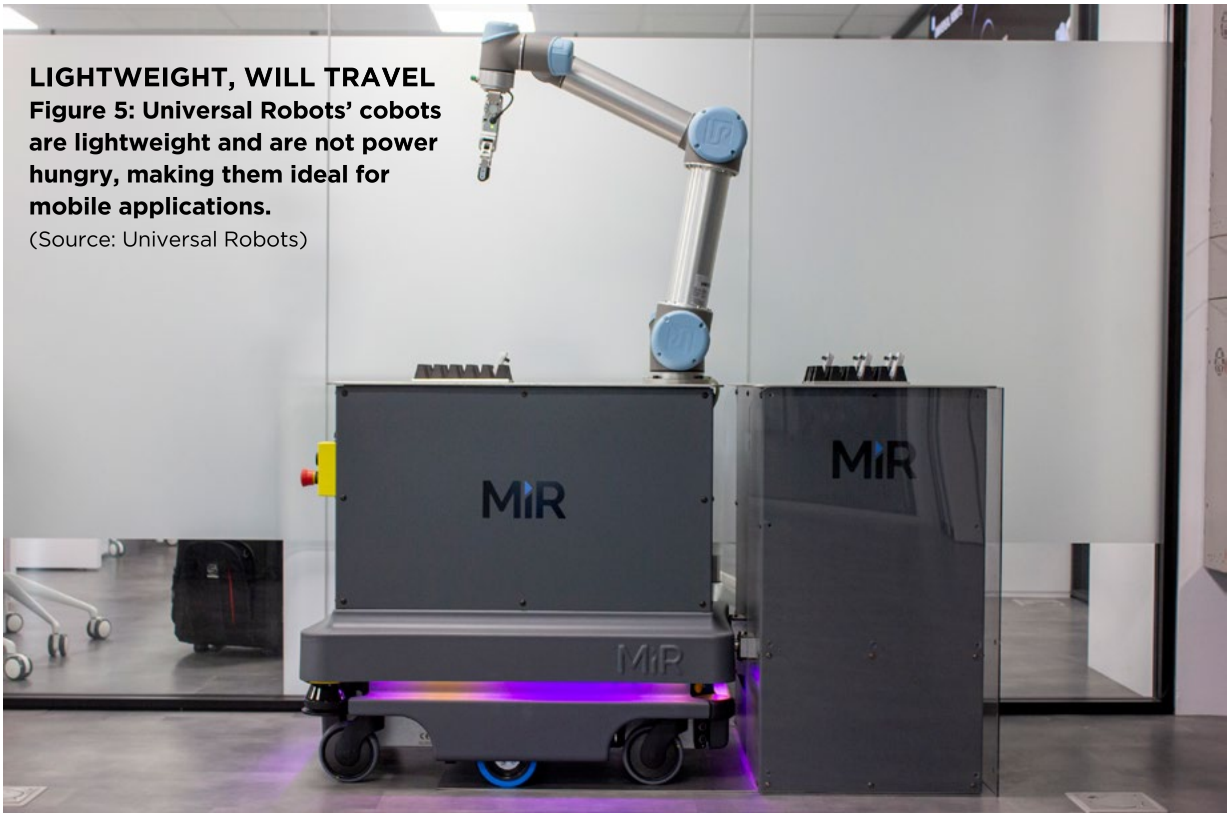
A REAL FUTURE ROBOT
Figure 3: ABB's mobile and autonomous YuMi laboratory robot concept will be designed to work alongside medical staff and lab workers. (Source: ABB)

MULTIPLE AMRS IN USE
Figure 4: Bosch-Rexroth combines known technology from its articulated arm APAS robots with an AGV and uses it in its manufacturing facilities. (Source: Bosch-Rexroth)

nating a number of pieces of hardware by combining the machine and robot controller into a single controller, eliminates some critical communication requirements as everything is now in one machine, and the system overall is much simpler. The electrical footprint reduction is dramatic. This is a pretty common approach for companies in Europe, but JLS is one of the few to offer this in the United States. We selected B&R as our platform."

Others are combining the mobility and robot control, as well. "By taking a holistic approach on the assembly process, we are able to combine these technologies using known technology from the SCARA/articulated arm with the ever-improving guidance of AGV location," says Chris Lupfer, sales manager assembly technology at Bosch Rexroth (www.boschrexroth-us.com). "The result is the ability to provide a complete system that customers can easily build themselves and then use in their assembly operations. At Rexroth, we have done this with our APAS robot mounted on an AGV, and we are using it in Bosch manufacturing facilities (Figure 4)."

Mounting a collaborative robot on an autonomous guided robot (AGR) or AMR platform is straightforward, according to Joe Campbell, senior manager of applications development, Universal Robots (www.universal-robots.com). "Universal Robots' cobots are lightweight and are not



LIGHTWEIGHT, WILL TRAVEL
Figure 5: Universal Robots' cobots are lightweight and are not power hungry, making them ideal for mobile applications.
(Source: Universal Robots)

power hungry, making them ideal for mobile applications," he says. "New controller configurations allow mounting within the AMR platform, and the collaborative technology ensures safe operation in multiple locations (Figure 5)."

Unlike traditional robots, collaborative are a perfect match for AGV or AMR mounting, continues Campbell. "Control is simple, as robot motions and AMR motions would not overlap, and simple communications between the two devices can be established in multiple protocols," he says. "It is also worth noting that this is an extension of a very simple concept that is gaining favor throughout low-volume/high-mix manufacturing: cobot-as-a-tool. Collaborative robots mounted to manually powered carts allow the cobot to be moved from machine to machine, station to station, depending on the production mix for the day."

ROBOTS PLAYING TOGETHER

"Integrators should know the AMR's easy programming and implementation make them even more attractive to end users, and most AMRs are at peak production when combined with another traditional robot system," says Bob Doyle at A3. "Something to keep in mind, however, is understanding AMR companies can go straight to market without an integrator. Providing solutions for using AMRs with traditional systems will give integrators the competitive edge."

Two examples of AMRs in action include the Honeywell General Merchandise Truck Unloader and the Mobile Industrial Robots MiR1000. The Truck Unloader is a flexible piece of machinery that can unload a variety of shapes, sizes or multi-weighted products from a truck container using machine vision and sensors to decide how to best complete the task. The MiR1000 replaces the forklift, designed to withstand a payload of 1,000 kg and equipped with six laser scanners, 3D cameras and an artificial intelligence camera.

"Incorporating cutting-edge technology, AMRs like these can allow companies to reduce the work in manufacturing and make more on-time deliveries," says Doyle. "Hybrid solutions incorporating traditional systems and AMRs working together are optimal. The truck-unloading AMR interfaces with a traditional fixed automated palletizer or conveyance system, leading the product further on its journey with complete automation. The robots enhance each other and increase efficiency and can even maximize floor space, allowing for system integrators to work more machines into solutions; all of this can move product through processing at a faster pace."

It's no longer enough to transport material from Point A to Point B; the most valuable AMRs incorporate a data-driven strategy," continues Doyle. "Traditional fulfillment centers use a person to pull inventory and bring it to a pick-and-pack station, which is done off-line with no understanding of flow-path optimization. Today's AMRs are creating a digital understanding of end-to-end movement. AMRs are building aggregate data across the entire organization to create a common data architecture that understands the movement pattern of materials, how to improve and how to reconfigure and simulate optimizations."

So far, system integrators can look for AMR incorporation in unloading trailers, fleet management in warehouses, conveyor systems, manufacturing work cells, hospitals, aerospace, semiconductors, automotive and logistics.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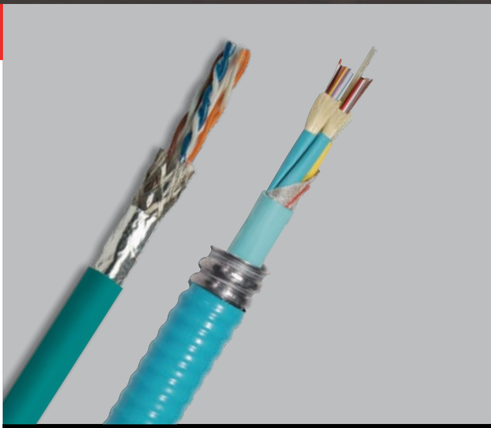

How to be gentle and accurate with linear motion

Displacement in a given direction, at a velocity and acceleration and after a period of time must all come to an end

By Dave Perkon, technical editor

When discussing the physics of linear motion, rotary and oscillating motion often surface, as well. Linear motion is more than just displacement; it has a start and a stop point, and compressed air and rotary motion often drive the physics of the move and the resulting cycle time.

Fortunately, calculus is not needed to calculate linear motion as it is simplified by assuming a constant acceleration. The equations for linear motion and the related variables including constant acceleration, displacement, velocity and time are easily accessible.

Linear-motion automation components, such as pneumatic actuators and motor-driven actuators, all operate within the defined physics equations. All motion starts and stops, but some are easy to create multiples of such. Most provide the ability to adjust positions of the start and stop points, but accuracy and repeatability vary, and some are programmable.

Linear motion, moving the part or tooling, is initiated and stopped in many ways. Compressed air and rotary motion are two of the most common methods used on automated equipment, and each method controls the motion in different ways.

The compressed air controlled through air-preparation units, solenoids, tubes and flow controls actuates cylinders and pneumatic actuators. This pneumatic actuated linear motion usually only has two positions, such as advanced/ returned, extended/ retracted, raised/ lowered or open/ closed. The advanced and returned displacement—the start and stop position—can be adjusted, and the speed of the move can be varied.

Simple pneumatic linear motion literally runs into hard stops at each end of travel; the travel is often fixed. These hard stops can be built internally to the cylinder or actuator or mounted externally either to the device itself or surrounding support structure. In any case, it's good practice to decelerate and even stop the cylinder piston before impacting the end cap. The stops are more like cushions as metal-to-metal stops are loud and abrupt. As the speed of the motion increases, external shock absorbers or soft-bump stops are often used to control the stopping of the actuator at the end of travel.

System air pressure, solenoid valve and hose size, and the air volume through a flow control all combine to determine pneumatic-actuator velocity and acceleration. These actuators often accelerate the whole motion before hitting the hard stop. Obviously, machine cycle time drives the actuator speed requirements, but the cylinder speed should only be set as fast as needed. If the cylinder extends and waits or the cycle time is faster than needed, adjusting the flow control to reduce the speed can greatly soften the abrupt stops at the end of travel.

The repeatability of the hard-stop positioning is well under 0.01 inch, but adjusting it to an accurate position can be difficult. Moving the advanced or retracted position of an end-of-travel stop by loosening a nut, turning a bolt and retightening the nut may require several tries to get within a few thousandths of an inch of the desired position.

Better control of the linear motion speed, acceleration and starting and stopping positions is possible by adding rotary motion to an appropriate linear motion actuator instead of compressed air. Improved precision and gentler operation can be had using rotary motion via a variable-frequency dive (VFD) and motor, stepper motor and servo motor. And there are other differences.

To start, these motor-driven linear actuators are not supposed to run into hard stops. That would be a crash condition, and certainly not a gentle-stop method. It may even damage the actuator or the carriage and bearings in the device. The controlling drives and automation controllers are programmed to move the carriage between the hard stops in this case, without contacting them.

Another difference is that end-of-travel switches on motor-driven linear actuators are not meant to be actuated during normal operation such as advanced and returned sensors are on pneumatic actuators. Activating end-of-travel switches on a motor-driven actuator will usually cause the motor drive to perform an immediate stop before the physical end of travel is reached.

In more precise applications, such as moving between two or more programmable points, a home switch is part of the precise and gentle stopping performance of these motor-driven linear actuators. Open-loop control, such as step and direction signals to a stepper motor drive or closed-loop control such as encoder feedback to the servo motor drive, allow programming of target positions that are then reached via a discrete signal, analog voltage or controller instruction block.

The linear motion is stopped differently in pneumatic actuators and motor-driven actuators. Both have methods to ensure gentle stops. Cushions and shocks used in pneumatic applications quickly and smoothly stop the load. With motor-driven actuators, the controller and related program provide smooth stopping at many locations, precisely. All linear motion eventually comes to a stop.

A clean adjustable speed drive installation

Follow some basic rules when selecting, designing and installing a VFD for cost effective and efficient control of 3-phase AC motors

By Dave Perkon, technical editor

There are many options to vary the speed of motors in automated machines. Depending on the application, servo-motor drive and dc drive can be used, but the star of the show is the variable frequency drive (VFD). When the cost, reliability and ease of operation and use are considered, it's hard to beat the VFD when there is a need to vary the speed of motors controlling conveyors, belts, pumps, blowers and fans.

Sometimes constant speed just isn't enough. Many of you mechanical types are happy to change the diameter of the pulley or sprockets driving the rotating motion, but electronics is much more flexible for adjustable motor speed control. There are some basics to keep in mind when specifying, designing a control circuit and integrating a VFD.

To start, if there are requirements to control the speed of a three-phase ac motor, there are many options available. Gather your requirements and talk to your favorite industrial parts supplier or manufacturer and consider using the popular VFD.

While VFD input voltage can be as low as 115 Vac single phase, 208/230/460 Vac single- or three-phase supply is more common. This supply voltage is connected to the VFD through a short circuit, branch circuit protective device such as a fuse or circuit breaker. The drive's output and the motor it's controlling is always three-phase.

For the most part, a VFD can handle electromagnetic interference (EMI) noise often found in industrial facility's supply voltage, but it never hurts to install some type of line-side filter upstream of the VFD, or at least include spare back panel space to add a drive isolation transformer, filters or reactors in the future. Plan ahead.

On the load side, the inductive motors and the VFD controlling it can create EMI noise and adversely affect nearby sensitive equipment. Just like it's best-practice design to add surge and lighting protection at the main disconnect of most control panels, it's at least good practice to add drive load side reactors or isolation transformers to protect against harmonics, reflected waves and electrical disturbances. Carefully understand installation requirements and talk with the manufacturer, as random "noise" problems can be difficult to find—don't add to the possible problems.

Worth noting is the reflected wave disturbance's effect on the cable connecting the drive to the motor. These waves can double the voltage at the motor, so limit cable length and be sure to specify inverter-duty motors which have higher insulation ratings, especially on 460 Vac and higher-supply voltage applications. If the cable distance is much more than 100 feet, consider installing the drive closer to the motor.

Once the proper supply voltage and related hardware are connected, it's time to get down to what the VFD's purpose is—adjusting the speed of a three-phase ac inductive motor. But it does more than that. It also provides overload protection required by the National Electric Code so an overload relay on the load side is typically not required.

The drive also starts, stops and controls the direction, and acceleration and deceleration of the motor. In the past, start and stop signals were commonly discrete inputs, often in the form of relay contact closures. Other control modes include keypad control, as well as two- and three-wire control. A speed reference signal is also adjustable via a keypad or internal drive parameter. Analog speed references are also available via 4–20 mA and 0-10 V signals. A more modern approach is to use network communications for drive control and speed reference signals.

There are many communication options for drives, such as RS-232/485 Modbus and industrial Ethernet protocols such as EtherNet/IP, to perform the starting, stopping and speed-changing functions. This communication also returns a variety of drive status information, such as running, and alarm codes, such as overvoltage and overcurrent faults, among many others.

With all the access to the data and parameters that digital drive communication provides, all but the simplest PLC drive control applications should include it as opposed to simple discrete signals. Ladder diagram, add-on instructions or similar in the PLC provides significant VFD control and data capabilities compared to what were available in the past.

The ability to change speed to optimize the process or reduce the speed of variable torque loads such as pump, fan and blower applications can greatly improve efficiency. Check out the Affinity Laws. Even constant torque loads such as conveyors, compressors and mixers may benefit from motor speed changes and reduced acceleration when starting and stopping can reduce overloads, wear and forces on the equipment.

While there are many other things to consider when integrating a VFD into an automated system, configuring a drive properly is a must. While minimal drive configuration is necessary—even though there may be more than 50 parameters—some is almost always required. Carefully record the motor nameplate data. Use that data to program the drive parameters such as rated voltage, full load current and speed—at a minimum. Spend the time to review the user's manual to get it right.

What you need to know about motor selection

Answer some questions about the application before specifying a motor

By Dave Perkon, technical editor

When it comes to motors in your automation, what do you specify? For a custom machine builder or OEM, it is usually a good practice to consider the cost; however, the application, operation and environment are the big players in motor selection. It's not just about voltage, torque and rpm. The application places specific requirements on motor performance beyond these basic specifications.

So, what type of motor is appropriate for an application? The first thought may be to contact a local electrical distributor or automation vendor. While these distributors, vendors and industrial manufacturers are happy to help with knowledgeable sales personnel and detailed websites, they are going to ask some questions, which will be about the application requirements.

The motor suppliers and manufacturers will have much to say about the type of motor, as well as the innovation and performance of their products, whether they are ac or dc, synchronous or inductive, servo or stepper motors. Yet, resist the urge to select a type of motor until each application's load, speed and operating characteristics are defined.

Obviously, a motor is selected to meet the demands of the application, so the demands should be defined. A big part of these demands are based on the type of load the motor output drives. What is the motor moving? The motor load includes a variable or constant torque and a variable or constant horsepower. The motor may also require positional control or torque control.

Some loads are constant torque—the load doesn't change. For example, the lever arm or roll diameter remains constant. In some constant-torque applications, the horsepower may vary—more work needs to be done or more force is needed to do the work. Basic examples of these constant-torque and variable-horsepower applications include compressors, cranes, conveyors and some pumps—gear-type or positive displacement. Compressing at a higher air pressure, lifting different weight loads with the crane or adding a loaded pallet to the conveyor varies the motor horsepower needed to move the load. Define the work. A wide variety of ac and dc motors work well in these applications.

There are also constant-horsepower and variable-torque applications. A simple example of this is an unwind or rewind application. The material speed remains constant while the roll diameter decreases or increases. The constant material speed ensures a constant horsepower while the roll diameter—lever arm—changes, varying the torque. This application commonly used dc motors many decades ago. More recently, servo motors or ac motors with closed-loop control are popular choices. With these heavy loads, don't forget about regenerative braking as a means to control the regenerative power when stopping.

There are also variable horsepower and torque applications such as mixers/agitators, fans and centrifugal pumps. These are the type of applications where energy efficiency is often discussed. Small changes in the speed of these motors results in large reductions in energy usage. Motor speed plays a large role in these applications. Can you run the mixer, fan or pump slower at times? When the motor speed increase, the load increases, which requires more horsepower and more torque.

The speed of a motor is always part of the motor selection discussion, as is an application's need for frequent or fast starts and stops. Will the motor need to start and stop or reverse direction often? Does it need to do so quickly? Will the motor run at constant speed, or does it need to be variable? The answers, in addition to determining the type of motor needed, such as an inverter-duty ac motor, helps to determine if across-the-line starters or variable frequency drives (VFDs) are needed.

More advanced motor applications require accurate and repeatable positional control, torque control and speed control. These applications include single- and multiple-axis gantries, pick-and-places and web-handling machines. While a stepper motor running

Resist the urge to select a type of motor until each application's load, speed and operating characteristics are defined.

open loop may satisfy the requirements of these applications, closed-loop control using servo motors is often required.

Do you really need a servo motor? An ac or dc motor with encoder feedback can also be used in many high-performance applications, providing good speed regulation and reasonable positioning capability. For example, an ac motor specifically designed for inverter or vector duty works well in variable-speed applications and can provide constant-torque capability to zero speed.

In what environment will the motor be installed? The motor selected for industrial applications must be robust and capable of handling the environmental conditions. Don't make the mistake of specifying a single-phase ac induction motor, often used on a small appliance such as a washer or dryer, to control small loads on a machine. There are significant differences between a continuously running industrial machine and a washing machine cleaning six or eight loads of laundry a week. The appliance motor may work great, but there is more than just dust present in industrial applications. Motors need to survive extreme environmental conditions, including high and low temperatures, varying electrical demands and contaminants. A properly selected motor will provide optimal performance and a long service life in harsh environments. Washdown-duty, stainless-steel and severe-duty are just a few requirements to consider depending on the industrial environment.

With the motor application understood and well defined, it's likely the solutions available are many. Although a machine with five different motor applications may require five different types of motors, keep the overall system in mind; using like or similar motors can reduce design complexity, startup time and spare-part needs.