Linear measurement when and where?

How does linear measure up, and how to tell if it makes sense

by Mike Bacidore, chief editor

Several manufacturing processes can include positioning a crane, inserting a part to a defined depth or checking material thickness. These might need more than limit switches, hard stops and manual checks. How could linear measurement devices be used?

Greg Cameron, VP manufacturing quality systems, **RedViking** (www.redviking.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Linear displacement transducers can be calibrated to a known position, and any deviation from the space could be recorded to define overhead crane placement. In addition, linear-displacement devices can be used as gaging instruments to precisely measure part variation relative to the mean or master dimensions.

Sixto Moralez, regional motion engineer, **Yaskawa America** (www.yaskawa.com), Linear-measurement devices can be used within several manufacturing processes to give precise positioning at the load. A linear-measurement device offers the ability to fully close the loop on a given mechanism because it is directly laid on the mechanism itself. A fully closed loop system allows the Servopack to compensate for mechanical inaccuracies in the drive train.

Patrick Maxwell, applications engineer, **Posital Fraba** (www.fraba.com), Linear-measurement devices like draw wires can be used to provide linear distance measurements on a continuous basis or to control the length of a repeated stroke. These sensors can provide precise measurements in harsh environments, such as sluice gates for water/waste water, overhead port cranes for heavy-duty material handling, as well as for more precise tasks like the positioning or leveling of medical tables.

Jeremy Miller, product manager—linear mechanics, **Parker Hannifin** (www.parkermotion.com), The application itself is really the key determining factor for what type of linear-measurement device or positioning capability is required. As highlighted, elements like limit sensors and hard stops can be used if the application only requires positioning between two points. If, however the application demands more incremental positioning, the next question is to what accuracy and/or repeatability is required. In the example of a crane or gantry-type system, the application may only require coarse positional accuracy, in the neighborhood of tenths of a millimeter or even multiple millimeters. A good example of this might be a palletizing machine. This level of precision is typically achievable through positional control via a servo or stepper motor, and often does not require additional linear measurement devices. A rotary encoder embedded on the back of a rotary servo motor to control a belt- or screw-driven actuator often has sufficient resolution to achieve application demands, even when including the inherent inaccuracy of the drive train and mechanical linkages.

On the other hand, examples like metrology applications such as precision measurement of material thickness or optical inspection, often require much higher precision motion. In this case linear-encoder technology is often implemented in combination with linear positioning stages. By affixing the point of measurement—encoder read head—directly to the load—point of interest—we can remove effects of inaccuracies due to mechanical linkages and drive-train elements. These elements can significantly impact the system accuracy when using a rotary encoder on the motor to position, as per the example above. With the use of a linear encoder, we are now able to achieve sub-micron level repeatability specifications.

Adrian Johnson, managing director, **Contrinex USA** (www.contrinex.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Analog inductive sensors provide precise linear output signals and are ideal for applications that require precise part positioning, material differentiation and measurement of size, distance and thickness. Typically used for distances up to 40 mm, these sensors provide a high-resolution analog signal that is proportional to the distance of the metal target from the sensor face.

Kyle Horsman, sensors product specialist, **Turck** (www.turck.com), Having continuous measurement allows for a more defined, real-time execution of feedback and process control. This helps customers to have more information and make better decisions based upon precision rather than guesswork.

Andrew Skidmore, senior project engineer, **Thomson Industries** (www.thomsonlinear.com), When we talk about measurements with slides and actuators, we're usually talking about how far the component has moved, rather than a more traditional inspection type of measurement. Our actuator is usually just one link in the mechanism, and it's the total movement of the mechanism that's really important. While speed and force are also important, the accuracy and precision of the actuator are critical for achieving the required machine accuracy. So, the first thing is to correlate the actuator motion to the desired machine motion, while taking into account other lost motion in the mechanism. Calculating this stack-up will yield the required actuator precision and accuracy.

Within the actuator or slide itself there are a couple ways to measure movement. Since all of the slides and actuators convert a rotary motion to a linear movement in a fixed ratio, a reliable way of determining linear position is to track the rotary motion of the motor. This is the typical approach for slide tables and gives users access to a wide variety of signal types. In most cases slides are ready to accept a customer-supplied motor. This allows the user to install a motor with the type of feedback she or he needs to integrate into the rest of the system, such as encoders or resolvers. The linear actuators take a similar approach but measure the rotary position of the drive screw rather than the motor. This allows use of a precision multi-turn potentiometer that yields an easy to read voltage signal that is easily scaled to the stroke length of the actuator.

In either case, the accuracy of the drive screw, or lead error, and the backlash, preloaded or not, are both important. Variation in the lead of the screw degrades the accuracy of the measurement, as does backlash. Similarly belt stretch in long systems will have lower accuracy. The precision of the measurement is more a matter of the resolution of the installed encoder or the controller reading the potentiometer.

How does linear measurement compare to motion control, encoders, vision systems and laser measurement?

Michael Miller, regional motion engineer, **Yaskawa America** (www.yaskawa.com), Linear measurement complements motion control by giving feedback of the actual load to position precisely. Linear measurement is another avenue from the traditional rotary encoder but gives the same type of feedback. Vision systems give coordinates of a snapshot or area where objects are located given a workspace. Lastly, laser measurement is used to give depth measurement where a physical linear device cannot be installed. Typically, this is for carton depths or object detection.

Greg Cameron, VP manufacturing quality systems, **RedViking** (www.redviking.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Linear-measurement devices are typically more accurate and repeatable compared to motion control, encoders, vision systems and laser measurement. Linear displacement provides specified, precise axis-point measurements whereas vision and laser measurements allow you to see a contour of a part or a wider view with multiple measurement output.

The most beneficial methods include various measurement types because environmental conditions, product type, sampling rates and many other factors may vary the method you choose. Measurement throughput, repeatability, accuracy, cost, process control, part quality and ease of documentation are all at stake and must be considered. With vision systems, environments should be completely free of debris, so when measuring in a manufacturing environment, vision may not be your best choice. If you're measuring very small parts, with many features and high sampling rates, vision or laser measurement would be your best choice.

Patrick Maxwell, applications engineer, **Posital Fraba** (www.fraba.com), Draw wires are a versatile and cost-effective way of measuring linear displacements for motion control. They consist of a rotary encoder coupled to a robust draw-wire mechanism, or spool. As the wire extends or retracts, the rotation of the wire spool is measured by the encoder and reported to the control system. This simple mechanism has proven to be reliable in challenging indoor or outdoor environments and is not affected by the moisture or dust that can fog lenses in optical or laser-based measurement systems. The linear range is up to 15 meters, or 49 ft.

Like the encoders that they are based on, linear sensors are available with a variety of interfaces, from analog to Ethernet. This makes them readily adaptable to a wide range or linear motion control applications.

Adrian Johnson, managing director, **Contrinex USA** (www.contrinex.com), Control System Integrators Association (CSIA, www.controlsys.org) member, The popularity of inductive linear sensors has to do with their robust design for harsh environments, insensitivity to dirt/dust/heat, accuracy on reflective metals, simple setup to PLC and hence cost-effectiveness.

Kyle Horsman, sensors product specialist, **Turck** (www.turck.com), Choosing the best measurement solution is about fitting the product to the application. Comparing linear and rotary devices is a good example. The same theory applies to a linear device as with something that is rotary. There is a defined measuring range and a corresponding output type, which can then be interpreted by the control system, and further processes are defined based upon application requirements. When dealing with linear motion, rotary products can be used but there are typically additional computations that need to occur to get a corresponding output.

Andrew Skidmore, senior project engineer, **Thomson Industries** (www.thomsonlinear.com), Linear measurement within slides is just part of motion control. Encoders, resolvers, potentiometers and similar direct measurement devices will monitor the position of the slide or actuator so the user can calculate the motion of the machine. Other systems such as vision or laser systems are often useful for verifying or fine-tuning the final position of the machine.

Can you offer any linear-measurement application examples or best practices that demonstrate how best to utilize it?

Greg Cameron, VP manufacturing quality systems, **RedViking** (www.redviking.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Linear-measurement devices are used in gaging applications to locate a pallet or a tooling position within an assembly process. When it comes to deciding whether to use linear measurement devices or vision/laser measurement devices, weigh the cost of quality to the product. Does the additional information rendered by measuring multiple data points through laser or vision systems provide a higher quality product or do I only need two or three data points to get the same result? In this case, linear measurements may be best.

Karl Knutson, senior applications engineer, **Curtiss-Wright** (www.curtisswright.com), They are effective in applications requiring extremely high accuracy. Instead of using the encoder on the motor for position measurement, the linear feedback device attached to the load takes the actuator out of the equation. Actuators are not perfectly rigid, and temperature fluctuations change the length of the components in the actuator. Both of those would influence accuracy when using the feedback device on the motor and would be eliminated using a linear device at the load.

Kyle Horsman, sensors product specialist, **Turck** (www.turck.com), The number of real applications is endless. Turck sees a number of opportunities with part position and vertical/horizontal equipment location. Speed control is another example. Speed control works by using a distance vs. time relationship. When placing a part, a carriage rides in a linear motion along the face of the sensor. The output corresponds to that linear position and the next step in the process can occur. The output continuously adjusts as the position moves and then a simple calculation can occur within the controller to determine the speed at which the equipment is travelling.

Sixto Moralez, regional motion engineer, **Yaskawa America** (www.yaskawa.com), A typical example would include a ball-screw application but could include a belt drive or rack-and-pinion system. The ball screw is coupled to a servo motor that has an encoder embedded within the servo-motor housing. This servo motor is then connected to a Servopack for control. The Servopack has the ability to send pulses to the servo motor to control the load by using the encoder feedback device to position the load. However, this isn't a fully closed option because it does not account for any mechanical compliance in the system. Thus, the use of a linear-measurement device would give another layer of feedback to the Servopack to know exactly where the load is in relation to the servo motor and correct for any position error. cd