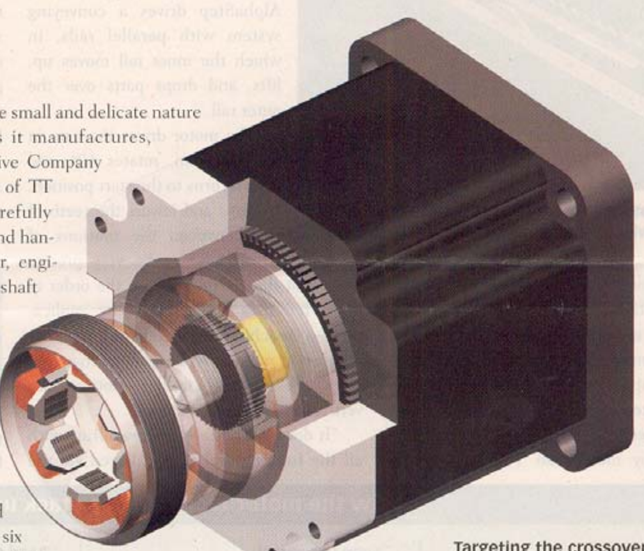
Stepper motor avoids missteps

A built-in resolver corrects motor-shaft position, keeping the motor in step at all times for precision testing application | Louise Elliott, Regional Editor

Boone, NC—Given the small and delicate nature of the components it manufactures, International Resistive Company (IRC), a subsidiary of TT Group PLC, had to think carefully about the design of its testing and handling equipment. In particular, engineers required that the motor shaft maintain position and come to a dead stop in order to meet positioning tolerances.

As an example, one test process calls for the positioning of a rotary wheel that handles round resistors. "These resistors go through short-time electrical overload two times and are exposed to six times the amount of current for which they're rated. Each part gets tested both before and after. We count on the motors to help the equipment hold tolerances within a few thousands of a inch," says Roy Keller, electronic design technician.

IRC engineers didn't even consider servo motors for this application, because of the "jitter" that servo motors sometimes exhibit

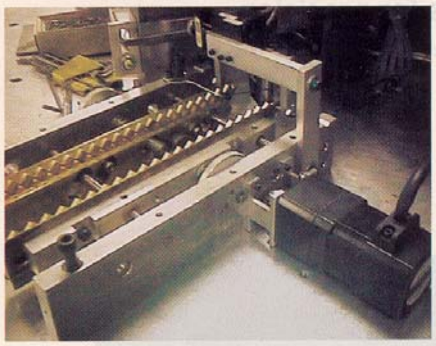


Targeting the crossover area between servo and stepper, Oriental Motor's AlphaStep Motor operates in both open and closed loop mode.

when trying to hold position. Although this movement is very small, Keller says that when bending small resistors, or testing their contacts, any movement at all can interfere with and invalidate the test results. Gain tuning or the addition of mechanical brakes to manage the problem were not options for IRC engineers.

Ordinary stepper motors, on the other hand, do not have jitter. But they can miss a step when the rotor lags behind or moves ahead of the excited winding, potentially causing an unscheduled shutdown of the production line or worse.

Seemingly having their cake and eating it too, engineers replaced the existing open-loop step motors with AlphaStep motors from Oriental Motors (Torrance, CA). The motor contains a built-in resolver that continuously monitors motor shaft position. Under normal conditions, the driver operates in open-loop mode similar to an ordinary stepper motor. But when the rotor position gets out of sync with the excited winding by more than 1.8 degrees, the motor switches to closed-loop control to maintain synchronicity.



The AlphaStep motor drives this railed conveying system, which handles small, delicate resistors.

[We count on the motors to help the equipment hold tolerances within a few thousands of a inch]

Another alternative would be to put an encoder on a conventional step motor—but cost was an issue for IRC. "An encoder for a regular step motor costs between $400 and $500. In contrast, the price tag on the small ASC66 AlphaStep is less than $650 including the resolver, and the ASC98 is under $900," Keller says. "Servo motors for these applications can cost two or three times as much."

In addition to testing equipment, IRC uses the stepper motors in materials handling applications. For example, one AlphaStep drives a conveying system with parallel rails, in which the inner rail moves up, lifts, and drops parts over the outer rail.

The motor drives the cam in one direction, rotates 60°, and then returns to the start position. It raises and lowers the teeth of the conveyor, the motions of which have to be very precise given that the resistors are on the order of just a few mils thick. In another application—a machine that bends and tests the resistor—a motor drives a gearbox that converts the motor's circular motion into vertical and horizontal motion.

"It does 1,000 steps per revolution with all the forming and testing keyed via the step count," says Keller.

In each operation, the motor stops precisely. Keller says, "The resolver counts the steps and will try to make up any missed ones. If the motor can't complete its steps, it will stop and send an alarm, instead of continuing to miss steps and possibly damage the equipment."

Another manufacturing application at IRC consists of filling resistors—some as small as 0.250-inch long, with concrete that functions as an insulator. In this case, Keller uses a geared AlphaStep motor. "The geared version allows us to increase the number of steps, and at its coarsest setting gives 2,500 steps [as compared to 1,000 for the non-geared version] for extreme precision. That's important, because the resistor shell must be filled to a specific level. The geared motor also gives us 78 inch-lbs of torque for this application to achieve rapid fill times," he says.

"The primary advantage of the AlphaStep is that we get feedback only when we need it, at an economical price," says Keller." DN

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How the motor technologies stack up

Motor type	Type of control	Dead stop capability?	Cost
Conventional stepper	Open loop	Yes	1.0
Servo	Closed loop	Achieved through tuning, filters, or mechanical brake	1.5
AlphaStep motor with built-in resolver	Open loop during normal operation; closed loop to maintain synchronicity	Yes	1.1

Table source: Oriental Motor

Stepper Motor Closes The Loop Around Tough Moves

AlphaStep motors with planetary gearheads are available in six gear ratios from 5:1 to 50:1. An optional electromagnetic brake is activated to hold the position when power fails or is switched off.

The open-loop advantage of stepper motors combined with part-time position feedback means that this motor will never miss a step.

Craig Ludwick
Applications Engineering Manager
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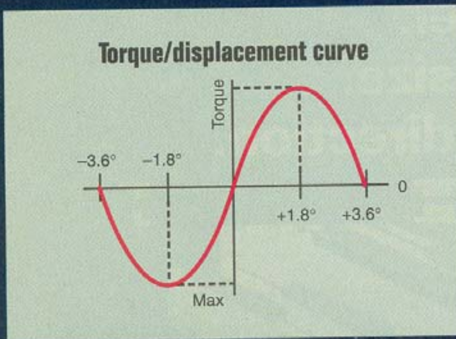
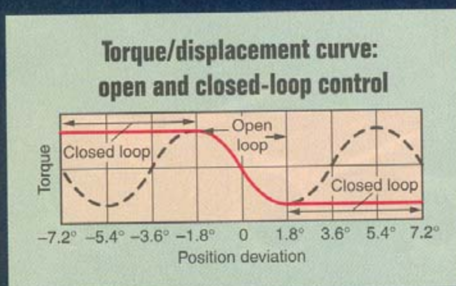
When it comes to position control, the choice is often between a stepper motor and a servomotor. Because stepper motors typically have more poles than servomotors, they produce a lot of torque for their size. They are also stable and provide quick and accurate moves. Moreover, the fact that they are open-loop devices means that they cost less than a comparable servomotor which requires an encoder or resolver for position feedback. On the downside, an excessive load or vibration can cause a stepper motor to lose synchronism with the input pulses and miss a step. And because there is no feedback loop, the motor has no way of compensating for the position inaccuracy.

Servomotors, on the other hand, avoid this problem by incorporating a feedback loop for position control. However, because servomotors are often unstable, they require gain control. A relatively high gain gives quick response to position deviations but of-



A stepper motor produces maximum torque when the rotor tooth is ±1.8° from the currently energized phase of the stator.



Under normal conditions, the motor runs in open-loop mode. However, if the position deviation is greater than ±1.8°, the motor switches to closed-loop mode. The position is corrected by exciting the motor windings to generate maximum torque based on the rotor position.

ten generates overshoot as well. Lowering the gain reduces overshoot but increases response time. Gain settings are therefore adjusted to strike a balance between response time and overshoot. Also, gain settings add a delay to the total move time.

But the AlphaStep motor/drive combination from Oriental Motor melds the best of both motor types. It combines the quick response and high torque of stepper motors with the feedback power of servomotors to compensate for missed steps. It uses a high pole-count stepper motor and incorporates a resolver for position feedback. A control algorithm makes corrections for position deviations on the fly and doesn't miss steps. Also, a smaller NdFeB magnet is used in place of AlNiCo because neodymnium has a much higher flux density while producing the same amount of torque.

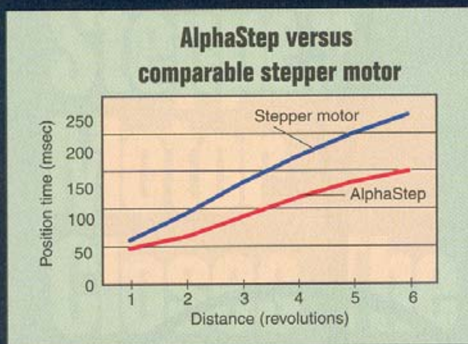
Most stepper motor rotors have 50 teeth, with an angle between each tooth of 7.2°. The stator has eight pole pieces; four set 90° apart make up one phase and the other four make up the other phase. When phases are energized, a torque vector develops and the magnetized rotor tooth moves to align with the torque vector. A pulse input to the driver energizes some phases and deenergizes others, generating another torque vector. The rotor then moves a quarter of a tooth pitch, or 1.8°, to align with this new torque vector. The process continues as each successive pulse is input to the driver. Thus, each phase is contributing a sine-shaped torque/displacement curve with a period of 7.2°. Maximum torque is produced when the rotor tooth is 1.8° to the left or right of the stable equilibrium point. This is called full stepping and it involves an eight-step electrical sequence.

Microstepping involves more torque vectors. Instead of fully energizing a phase or leaving it off, digital-to-analog converters are used so that the phases are partially on or partially off, dividing each 1.8°step into many smaller steps. Some microstepping systems are capable of a 250-step electrical sequence producing up to 125,000 steps/rev. The main advantage to microstepping is higher resolution and lower vibration.

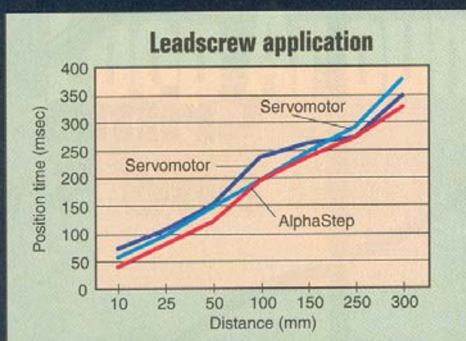
One limitation of stepper motors is that they are designed for open-loop control. The driver is given a certain number of pulses to move the motor. However, excessive load or high vibration can cause the motor to lose synchronism with the input pulses and miss steps. A stepper motor misses steps because the rotor has to move so much that the next tooth, or some other tooth, moves to align with the torque vector. When an external force or vibration is encountered, one or several rotor teeth can be skipped in either direction. Because the torque/displacement curve is 7.2°, the rotor has to be displaced a little more than 3.6° in either direction. The rotor will then move forward or backward, losing synchronism.

For position verification, encoders can be placed on the back shaft of the motor. One problem with this is that the position is often corrected at the end of a move after the encoder counter has been compared to the input pulse counter. If the motor misses steps, a correction introduces delays and additional steps.

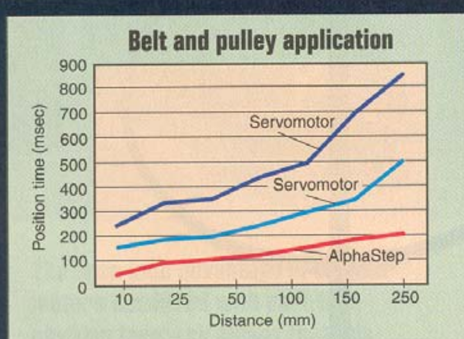
The AlphaStep incorporates a resolver for position feedback to compensate for missed steps. A resolver is used instead of a digital encoder primarily because it is a relatively simple construction with no internal circuitry or fragile glass masks. The variable reluctance resolver is a two-phase device.



For short and quick moves, the AlphaStep outperforms comparable stepper motors. Because it utilizes 100% of its torque, it moves faster than an open-loop stepper motor.



On a leadscrew application, a comparison of the AlphaStep with two servomotors shows that for short-distance moves, the AlphaStep outperforms the servomotors. However, for long moves, the low pole count of the servomotor provides quicker move times.



In belt and pulley applications, high compliance usually requires low gain settings and therefore long move times. In this case, the AlphaStep outperforms the servo for both short and long moves.

The output consists of two sine waves 90° out of phase. By sending the sine waves through a resolver-to-digital converter, the motor position is known at all times. Once the data has been digitized, the information increments or decrements a rotor position counter. Resolvers are also more suitable for hot environments and applications with vibration. Furthermore, they are less susceptible to electrical noise and require less wiring.

As the motor steps, the input pulses and resolver counts are fed into a pulse counter and a position counter, respectively. The two are constantly compared for deviations. If there are no deviations, the motor phases are normally excited. This is called the open-loop mode. However, if any deviation greater than 1.8° is detected, the unit goes into the closed-loop mode. In the closed-loop mode, the torque vector at the 1.8° displacement is energized, producing the maximum amount of torque to bring the rotor back into synchronization. If the motor has missed several steps, each successive torque vector at the 1.8° displacement is energized, until the deviation is brought to within 1.8°. At that point, the motor returns to the open-loop mode and steps normally.

After the final step, the rotor tooth returns to align with the torque vector and the accuracy becomes +5 arc min (0.083°). The only way for the motor to miss steps is to be in the closed-loop mode for more than 5 sec. In other words, if an excessive load is encountered for more than 5 sec, the driver will fault and send out an alarm signal.

The motor also incorporates a jerk-limiting filter into the driver. Jerk is the derivative of acceleration and causes vibration at velocity transitions. Limiting jerk with a filter produces smoother motion. However, adding the filter does increase move time. The ideal jerk limiting time is one cycle of the lowest resonance frequency, so it is typically around 5 to 10 msec. Therefore, the move will be that much longer, but repeatable.

The AlphaStep incorporates all of this functionality into the drive and not the pulse generator. Typical closed-loop stepper-motor systems include a complicated controller or pulse generator. The controller senses the encoder or resolver feedback and does the comparing. If the motor has missed steps, it is the function of the controller to make up the difference. It is also a function of the pulse generator to send out the pulses at a specific time to limit jerk. Because all of this is included in the AlphaStep drive, no complicated front-end system is required. Pulses can be generated by a simple pulse generator, a PLC, a computer board, or logic chips. ■