SOCIETY OF PLASTICS ENGINEERS
Plastics Engineering
April 2007

NORTH AMERICA

Direct-Drive Motor and Nonlinear Actuator Boost Productivity of Electric Injection Unit

By Patrick A. Toensmeier

The Industrial Group of Moog Inc. has developed an injection system for all-electric molding machines. The system is made up of a specially designed drive, actuator, and process control that reportedly make it faster, more powerful, and more accurate than conventional injection systems.

Key components of the "High Power, High Speed Injection System" are a high-torque, direct-drive servomotor on the injection axis, a nonlinear, direct-drive actuator connected to the plasticizing unit, and a software-based process control that's embedded in the drive for fast, accurate adjustments to injection pressure and actuator velocity.

The result, says Burkhard Erne, business manager at Moog ProControl and developer of the system, is an extremely precise, energy-efficient unit that is equally effective at molding thinwall and thickwall parts, and can be scaled up for use on an injection machine of any size.

ProControl, a Swiss company acquired by Moog in 2005, specializes in motion-control technology for plastics-processing machines. ProControl's achievements include the first European all-electric injection machine (1992), the first all-electric blow-molding machine (1996), and the first all-electric optical-disc-molding machine (2002).

Direct-drive electric motors are not unique to Moog. What Moog claims is different about its motor is that it's been designed for plastics processing. "We've added more specific performance features for plastics," says Sunil Murthy, Americas marketing manager at Moog.

Leveraging the Levers

The system's performance stems in part from the nonlinear, direct-drive actuator, which is powered by a second high-torque servomotor. The actuator is a crank mechanism that resembles a hydraulic toggle system laid on its side. Connected to a planetary gearbox, the actuator utilizes two levers: a main lever that is set at an angle and attached to a secondary lever that drives the injection screw. When the motor pushes the actuator forward, the eccentric angle of the main lever changes, exerting a high degree of pressure on the secondary lever, which extends the injection screw.

Because the direct-drive design of the system eliminates the need for intermediate couplings, speed reducers, and other secondary devices that drain power, the nonlinear actuator achieves a power-transfer level of 95%, says Murthy. Linear actuators that are connected to ball screws, by contrast, are 75% efficient in power transfer, he notes. As a result, the crank mechanism permits the injection system to maintain a comparatively high holding pressure of 80% for as long as necessary to pack a part. In conventional electric machines, maintaining high holding pressure usually requires a power surge that drives up current levels and equipment costs.

"The nonlinear actuator mechanism and direct-drive motor reduce that [type of power] requirement," says Murthy. "It's a big advantage in that it takes the cost and complexity out of using the motor and drive."

The high-torque motor and actuator increase the injection system's power and energy efficiency by substantially reducing inertia. Since the high-power-density motor achieves high torque at low speed, it's capable of rapid acceleration with every injection cycle. As a result, extremely fast fill times are possible.

"Inertia is the biggest load on acceleration," says Erne. "The higher you have to spin up your motor, the longer it takes to accelerate. If you have a high-torque motor running at low speed, you don't have to spin your motor inertia up to the high speed."

Zero to 600

As an example of how powerful the system is, Erne says that in tests the motor accelerated from zero to 600 mm/sec in as little as 35 milliseconds, and took about that much time to decelerate. "So if you have a very short stroke, you are probably looking at a fill time of less than 100 milliseconds" for small parts like thinwall packaging.

Moreover, the 600-mm/sec shot speed was achieved with a relatively large 56-mm-diameter screw at a pressure of 2000 bar, which is "quite amazing," Erne says. "[Japanese OEMs] might have similar speeds on 50- to 80-ton [electric] injection presses with smaller screw diameters. The Japanese quote 400 mm/sec as a high speed. We go with a much larger screw diameter and reach 600 mm/sec. You could use this [size screw] on a 200- to 250-ton injection machine," he says.

"You can run a larger screw on a bigger machine at the quoted speed, but only if it makes sense," Erne adds. "PET preforms, for example, could be made on a 500-ton machine, but you would have to scale up the structure and go for the next larger motor. To achieve the same capabilities and performance in a linear system, the motor and drive would have to be almost twice as big."

The motor and actuator are scalable and can be designed in larger versions to meet the process needs of higher-tonnage injection machines. The injection system can theoretically be engineered for machines ranging from 50 to 4000 tons. The only limitation, notes Erne, is the amount of power needed for a motor and drive on very large machines. "At some stage you will have to put on a second or third motor and a drive for each to get the power you need. It's technically feasible to build [such a system], but because nobody is using that [much electrical] power, it would be more economical to use two drives and two motors."

Integrated Software

Another key component of the High Power, High Speed Injection System is the software. Erne notes that although the algorithm isn't too different from that of other programs, by integrating the entire control into the drive, feedback signals don't have to be transmitted to an external unit by a field box or in analog form, which would reduce their resolution and accuracy. "The total process control may therefore be able to close the loop at a much higher bandwidth than with a traditional system," he says. Erne believes it's unusual to have this much integration of a closed-loop control in a drive. Moog ProControl has patented the software.

An important feature of the software is its ability to control the pressure and angle of the crank mechanism in the actuator, notes Mauro Gnecco, Americas business development manager at Moog. This is difficult because of the nonlinear motion of the actuator. Gnecco says that the software constantly monitors and controls the angular velocity of the crank mechanism and, importantly, the pressure it generates, this last by means of a load cell. The ability to consistently maintain injection pressure means that extremely tight tolerances can be achieved with shot weights, a benefit that reduces material costs.

Since the injection system has fewer components than a conventional unit and greater power, it's more compact and easier to install, says Murthy. And the elimination of ball screws in the motor contributes to reduced maintenance. The nonlinear actuator uses roller bearings and ball bearings for low-friction operation, and is designed to run for 30,000 hours before it needs maintenance.

The system is relatively new for injection molding, though some OEMs have specified it for their machines. Netstal uses a similar approach on the 500-kN (56-ton) "e-jet" optical-disc-molding machines. Jinhwa Glotech Co. Ltd. of South Korea recently announced plans to use the system for machines that mold thinwall parts for markets as diverse as telecommunications and automotive. Erne says the unit will soon appear on a line of all-electric machines manufactured in the People's Republic of China. Electric injection machines are relatively unusual in China, he notes, and production, at least initially, will be for domestic use within China.

Combining a direct-drive servomotor with a nonlinear actuator has also found an application in blow molding. Austrian packaging processor Alpla (U.S. office is in Lima, Ohio), which commissions its own process equipment from Soplar SA of Switzerland, has for a decade been using the system in shuttle blow-molding machines, according to Erne, who says it's used to transport molds from one station to another.

Moog is based in East Aurora, New York, USA.

Contact @ +1 716 652-2000 or www.moog.com/industrial