Needs of Plastics Molding Machine Market Drive Selection of New Motion Controllers

The need for machine builders and owners to be competitive in the plastics industry is driving some key requirements on machine designers and system integrators. The first is the need for achieving higher productivity and higher quality output, while keeping manufacturing costs down. This is accomplished in part by making control systems "smarter," capable of supporting smoother, more precise machine operation.

The second key requirement on machine designers is the need for new machines to be designed and constructed using modular design techniques. Modular design decreases the cost of machine maintenance and installation, and promotes the use of "best-of-class" components in constructing them.

Both of these requirements are causing builders of new machines to take a new look at how they select and use technology, and one of the most critical choices involves selecting the best motion control technology. For owners of existing machines, many of which use older, "open loop" control systems, adding a new electronic motion controller can improve productivity and decrease lifecycle costs.

Smooth motion improves production quality, extends machine life

In the case of machines like those used in plastics molding, high quality output stems from smoothly controlled operations. The molding cycle typically involves a motion step (mold closing, then filling) followed by a pressure step (as the desired shape and density of the manufactured part are attained). Control system designers would like to use a motion controller that has the ability to transition from control based on position inputs to control based on pressure (or force), without stopping the motion. In hydraulic systems, smooth motion also requires smooth valve control, and the motion controller should provide control signals to drive a proportional valve, adding or subtracting hydraulic pressure in minute amounts. Because of the system's smooth operation, hydraulic pressure transients and pressure overshoot are reduced, eliminating flash and the potential for hydraulic leaks, thereby extending the life of the machine and lowering life-cycle maintenance costs. Smooth injection also results in even density within the molded parts, which contributes to their strength. Some older-generation hydraulic control systems control via cylinder position sensing only, and use valves with only "open" and "closed" positions (sometimes called "bang bang" valving), which can result in imprecise controls and lower quality output as well as the need for more frequent system maintenance.

Modular Systems Simplify Design

Modular design of control systems is not a new concept, but the construction of modular systems using components (e.g., PLCs, I/O interfaces, displays and key switches) from different vendors has been difficult. Control elements from one vendor didn't communicate easily with elements from another vendor. The result was the need to invest extra time and money in getting different controllers to work together and to play with specialized I/O. Often, the better alternative was to use single-vendor solutions which may prove sub-optimal for the control task. The advent of standard industry buses has changed this. Designers can now use control system elements from different vendors with standardized interfaces to a "fieldbus" that forms the backbone of the control system architecture (see Figure 1.)

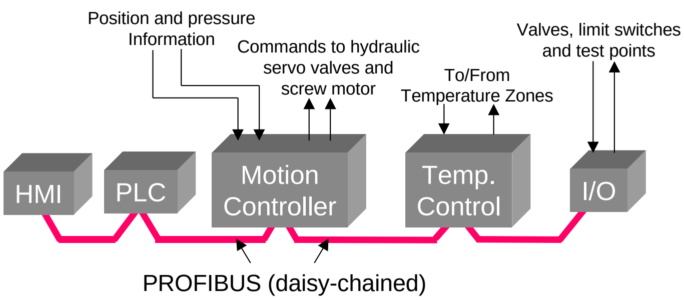

Figure 1. PROFIBUS-based injection molding machine block diagram

The diagram above shows a new injection molding machine control system based on PROFIBUS, an internationally accepted standard that is supported with over 1700 different system building blocks from more than 800 manufacturers. Using PROFIBUS (a high performance, 12 Mbit/sec. RS485 serial link), components can be added and subtracted by plugging them into the bus and programming their interfaces using standardized data communications structures. The standard "pluggable" PROFIBUS interface also lessens the time to manufacture new machines by reducing wiring time.

Key control system components in the typical system (ref. Figure 1.) include the programmable logic controller (PLC), which typically acts like a functional supervisor for the machine, issuing motion commands and communicating with the operator interface (often called HMI for human machine interface). The HMI is used by the machine operator to set up the machine's operation and view diagnostic messages.

A distributed I/O system such as that shown in the diagram above may consist of one PROFIBUS node for all the I/Os within the cabinet (e.g., valves and limit switches that are used to activate mechanical mechanisms associated with the machine, and inputs that provide diagnostic information). The temperature control system consists of discrete closed-loop controllers with PROFIBUS slave interfaces. Each controller may control many temperature zones.

PROFIBUS is just one of the many fieldbuses that the designer has to choose from. Different buses provide different features and advantages. One of the newest system communications buses is EtherNet/IP, which has its origin in the high-bandwidth Ethernet protocol, but adds an element of time determinism to make sure that time-critical control functions are handled correctly.

Select a motion controller that's well-connected

Modular "open systems" design calls for components that are well-connected. In such systems, the motion controller must be capable of not only connecting to the bus, but it must also use the bus' communications capability to the fullest.

In a motion controller, high performance is often expressed in terms of support for higher "scan rates," the rates at which the controller tests its inputs, makes decisions and generates controlling outputs. Designers should look for an advanced motion controller that is capable of "closing the control loop" one thousand times per second. This is up to four times the rate of some control systems used in older machines. Faster scans and closed loop motion control mean faster machine operation and higher productivity for the machine owner.

Motion control performance is also enhanced if the motion controller incorporates a direct interface to the system's transducers, the devices that directly measure the parameters being controlled (e.g., position and pressure). Applications requiring precision and robustness have long favored the use of magnetostrictive linear displacement transducers (MDTs), and motion controllers should provide a direct interface to popular MDT devices. Motion controllers should also connect directly to analog and quadrature feedback devices.

System costs can be kept down if the motion controller is capable of managing many axes. For example, a single multi-axis controller can control the plasticizer screw, the shot injector, the mold clamp, and the part ejector in an injection molding machine. One axis can be precisely synchronized with another, or multiple slave axes can be synchronized to a single master in a process known as "gearing".

Another way to keep system hardware costs down is by selecting a motion controller that can control each hydraulic cylinder with a single valve even in position/pressure applications (many older hydraulic motion control systems require two valves.)

Tuning for optimal performance/throughput

Another requirement of machine designers is the ability to optimize their use of motion controls. In the typical machine operation, the controlling PLC programs the motion controller by writing sequences of motion commands called "steps" into the controller. No complicated software programming should be required to generate sophisticated motion profiles and PID loops. As some motion controllers can be very difficult to program, the designer should inquire about a comtroller's programmability and the vendor's level of software support before making a controller selection for his/her next project.

The technology for tuning and optimizing designs is advancing rapidly. A new tool that is now becoming available is the Tuning Wizard, software that automates the tuning process by building a set of mathematical system models and determining which model best fits the real system being optimized. The Tuning Wizard next prompts the user to set the desired system response between "conservative and aggressive" using a computer mouse and slider bar and computes the optimum PID and feed forward gains.

The fieldbus interface also enables motion controllers to allow other computers or controllers to monitor its operation. Using this facility, the HMI computer can generate system diagnostic information, such as graphical displays of actual versus target motion profiles and logs of motion commands, which can decrease service times and allows for the machine to be serviced by less experienced maintenance people. Designers should look for motion controllers that are supported with development tools that make the most use of the controller/HMI connection. The following computer screen plot (Figure 2) is typical of the information that Delta-based system designers have to work with. As the plot shows, designers are able to monitor how closely the actual motion profile matches the target.

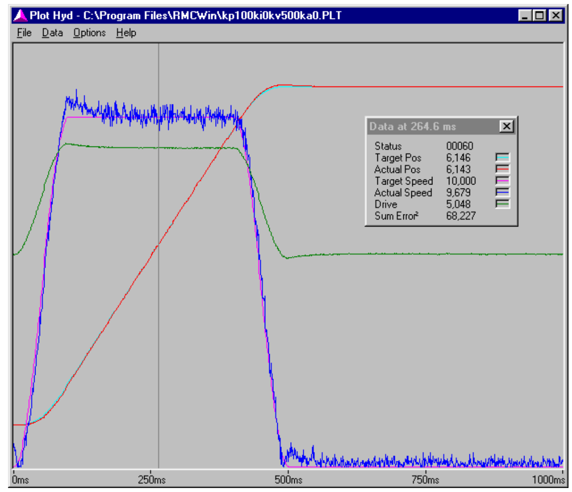

Figure 2. Delta Computer Systems' RMCWin Plot showing well-tuned system.

Tuning the system to match the optimal motion profile is also made easier if the motion controller is capable of executing advanced control algorithms. For example, if precise, high-speed repetitive motion is required, a motion controller that supports predictive "feed forward" control elements (in addition to traditional closed-loop feedback control) is desirable.

Plastics machine builders can now select "best of class" system components from multiple vendors. The products of this assemblage of leading edge technologies are machines that offer high levels of maintainability and reliability, while at the same time being easy to design and optimize for maximum precision and productivity.

Case Study: Plastics Injection Molding Machine Upgrade

Engineers at DeKalb Molded Plastics Inc. of Butler, IN identified a problem with one of their existing injection molding machines. Due to the fact that the molding process was running "open loop" (i.e., there was no precise regulation of the delivery rate of foam during the injection cycle), the molding cycle times varied greatly from cycle to cycle. As a result, the quality of the molded parts wasn't as uniform as the company wanted. Some molded parts needed to be scrapped, and machine down-time resulted as process technicians dealt with the problems.

The company solved the problems by adding a closed-loop hydraulic motion controller to control the hydraulic cylinders that inject the foam. (see before/after system diagrams in Figure 3 below) Due to time constraints, retraining issues and cost, the customer did not wish to completely replace the existing machine control system.

The new controller, an RMC100 by Delta Computer Systems, gets its inject cycle command information from the molding machine's existing Barber Colman MACO 8000 controller (which previously drove the hydraulic valve directly). The RMC100 controls the velocity of the injector cylinders by driving a proportional valve using position feedback from magnetostrictive displacement transducers (MDTs) mounted on the cylinders. This add-on method permits the inject cycle step programming to remain in the familiar Barber-Colman controller, eliminating the need for technician re-training.

In addition, the Barber Colman controller monitors pressure transducers in the hydraulic cylinders as a safety measure to insure that pressures don't exceed preset limits.

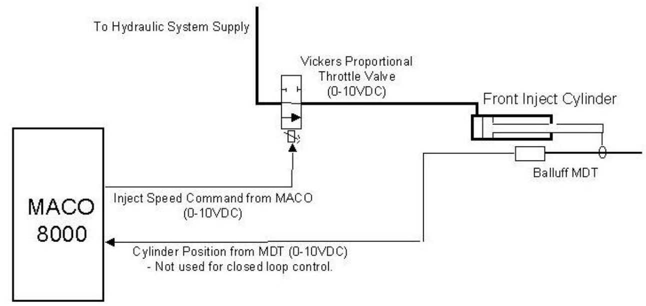

Figure 3a. DeKalb system block diagram before upgrade

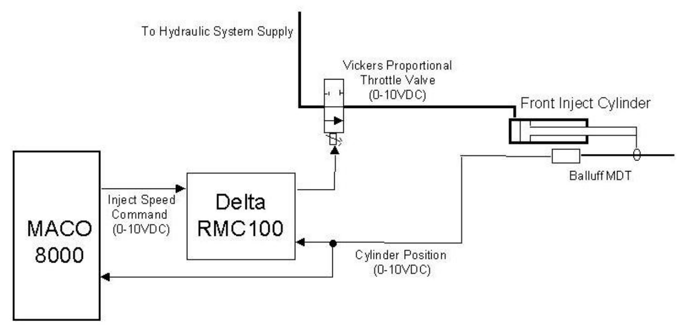

Figure 3b. DeKalb System block diagram after upgrade

The RMC100 motion controller was programmed using Delta's RMCWin configuration software package. In addition to providing direct interfaces for all of the transducers and the proportional valve, the Delta controller was interfaced to a graphical user interface (GUI) software package that can display the actual versus target injection position, speed profiles, and valve drive command as a X-Y graph plot. It also provides for the creating and editing of "recipes" containing process control loop parameters, such as proportional and integral loop gains (P and I), and other set-point values, and storage by name for future retrieval in a Microsoft Access database. A new panel-mounted Windows-based PC with touch screen human-machine interface (HMI) gives machine operators a real-time "window" into the molding process. In addition to facilitating the tuning of the motion controller for optimal performance, the graphical screens help the machine operators monitor and diagnose performance issues with the hydraulic components, such as insufficient oil pre-charge in the system's hydraulic fluid accumulator.

By adding closed-loop control of the injection process, DeKalb was able to reduce what was originally up to a 7-second difference between one molding cycle and another to under 50 msec (0.050 sec). In addition, they were able to improve the quality of their molded output by more than 10%, and reduce machine downtime due to quality problems from 10% of production time to under 1%. The company expects that the payback period for the cost of the entire upgrade project to be under 6 months.

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