Quantum PLC-based motion control enhances machining accuracy

The existing situation
After 100 years of producing cam-actuated screw machines, Davenport Machine, Rochester, N.Y., the world’s leading manufacturer of screw machines, is betting on electronics to provide motion control for the next 100 years. Davenport shipped the world’s first computer-controlled, fully servo-driven, multiple-spindle screw machine. Because the new machine can handle approximately 80% of screw machine parts made in the world today, its combination of aggressive price, fast changeover, high output, and high accuracy make it a very high volume seller for Davenport.

Objective
Motion-controlled screw machines are essential in today’s market to produce smaller lot sizes to meet just-in-time parts purchasing goals. A typical changeover with the new machine takes just 45 minutes making short runs profitable for end users. A mechanical cam machine changeover takes considerably longer.
The development goal for the new machine was to duplicate the functions and capabilities of mechanical cams and gears with electronic cams and speed control, resulting in a more flexible machine that can hold much tighter tolerances and provide faster cycle times and higher spindle speeds than an all-mechanical unit.
Solution
Application engineering assistance and software development was provided by the Industrial Applications Group of Schneider Automation. Square D supplied much of the control equipment. The new five-spindle unit supplements the company's traditional five-spindle cam actuated machine and is the first computer-controlled screw machine of any size to forego a conventional CNC system in favor of a PLC-based motion control accessed by a PC-based MMI. Linear and rotational servo motors power all of the machine's 14 axes — main spindle, stock feed, indexing, tapping, the five end axes, and the five cross slide axes. The unique control and drive technology enhances machining accuracy and provides greater flexibility in machine functions. It also saves approximately $25,000 per machine in manufacturing cost compared to an equivalent machine having CNC control.

The heart of the new control system is a Modicon TSX Quantum Automation Series PLC having a Modicon 16-axis digital SERCOS motion controller located on its backplane. Cutting profiles, feeds, speeds, and positions are stored in software and introduced through servo motion. Only quick-change tool holders must be taken on and off the machine. Advanced electronic control also provides other advantages — positioning accuracy of ±3 sec. of arc, and a traverse rate of 480 IPM. The PLC communicates with the MMI and performs the screw machine's routine sequencing, interlocking, power distribution, air, lubrication, counter, timer, and mode selection functions.

The motion controller communicates with 14 intelligent servo drives and tightly coordinates the machine's servo drives over a standard SERCOS 4M baud fiber optic network. The SERCOS standard, which is very popular in Europe, is becoming widely accepted in North America. The 486 microprocessor-based motion module is the first ever to permit real-time synchronization between sequential logic and motion logic in a multi-axis control system. Logic and I/O processing are coupled with the MMI and motion controller through a real-time register database maintained by the communications task portion of the motion application. Because the motion module multitasks, the axes operate simultaneously but independently.

The motion module is programmed in a C/C++ environment and utilizes the Modicon motion library to perform motion tasks. The motion is generated via conversational programming, where the operator essentially enters the desired parameters. The data is then compiled and a motion profile is generated. No knowledge of CNC M-codes or G-codes is required to generate motion profiles. Programming motion in C/C++ allows considerable design flexibility in creating the profiles. Eleven Modicon Monoblock SERCOS 10 amp servo drives power the machine's five end-working linear servo motors, its five cross-slide linear servo motors, and one stock-feed linear servo motor. The newly introduced drives combine transformer, power supply, and amplifier into a single, compact unit not requiring cold plate mounting. Monoblock drives consume only about half the cabinet space of conventional drives of equivalent ratings.

Rounding out the drive count are a conventional Modicon Cyberline 60 amp drive for the main spindle servo motor plus two Cyberline 30 amp drives for the indexing and threading spindle servo motors. A servo motor rather than a variable frequency drive was selected for the main spindle to eliminate the need for a mechanical orienting device when positioning for cross drilling and tapping. All 14 drives are mounted within one 4x6-foot air-conditioned cabinet. The Modicon Cyberline AC permanent magnet brushless servo motors incorporate built-in resolvers.

Each screw machine is supplied with a machine setup/part program configuration (or part summary) software package developed by Davenport Machine. The conversational, fill-in-the-blanks application is intended for off-line use on a PC and loading into the MMI's hard disk. The configuration form lists data fields that are filled in by the customer engineer or machine operator to generate the motion profile for each part to be made.

Customer benefits
- The unique control and drive technology enhances machining accuracy and provides greater flexibility in machine functions, i.e. positioning accuracy of ±3 sec. of arc, and a traverse rate of 480 IPM.
- The new technology saves approximately $25,000 per machine in manufacturing cost compared to an equivalent machine having CNC control.
- Programming motion in C/C++ allowed considerable design flexibility in creating the profiles, saving programming and start-up time.
- Monoblock drives require about half the cabinet space of conventional drives of equivalent ratings; smaller overall machine size equals space-savings for end customer.