High-Performance Hydraulic Motion Control in Forest Products Equipment

Hydraulics and electronic controls key to productivity gains in wood products applications

Because of the forces, loads and speeds involved in many wood products applications, hydraulics is often the power of choice. Hydraulic cylinders are ideal for moving and applying pressure on large, heavy objects such as logs, situations where electric motors may overheat and fail.

Precise control is key to getting the greatest productivity out of hydraulic systems. A common challenge is applying pressure control to logs or cants firmly without slipping or causing damage – especially under potentially powerful counteracting forces such as those provided by saws, blades or grinding wheels.

Using sophisticated electronic motion controllers, hydraulics continues to be the power of choice for many wood products machinery applications.

Pressure and position control improves quality, extends machine life

Many wood products applications involve high-speed processing of logs, which often have irregularly-shaped features. Manufacturing process steps such as debarking, end-dogging, curve sawing and veneer-stripping involve moving machine parts in reaction to the shape of the log while maintaining even pressure on the wood. Advanced electronic motion controllers transition smoothly from hydraulic control based on position inputs to hydraulic control based on pressure (or force), without stopping the motion. This precise motion supports high-speed operation for improved machine productivity and reduced waste.

In addition, smooth hydraulic operation limits hydraulic shock and contributes to longer machine life and lower life-cycle maintenance costs.

Additional electronic motion control features

Gearing and synchronizing axes

In complex wood processing applications, a single machine may need to employ multiple motion axes. Advanced electronic motion controllers can control up to eight axes simultaneously. 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.” By synchronizing the motion of multiple axes, the processing speed of a machine can change to deal with varying characteristics of the wood being processed without the need to reprogram motion algorithms or change the machine’s mechanical setup.

Tuning for optimal performance and throughput

Machine designers must be able to easily tune motion parameters in order to generate optimal motion profiles. No complicated software programming should be required to set up the PID loops to generate sophisticated motion operations.

The motion controller should also be able to execute advanced control algorithms. For example, a motion controller that supports predictive "feed forward" control elements (in addition to traditional closed-loop feedback control) provides precise, high-speed repetitive motion. In addition, motion controllers that support complex non-linear motion functions, such as the use of third-order spline function equations to interpolate smooth motion paths between target points, can be a clear advantage to developers of applications involving curving motion, such as shape saws.

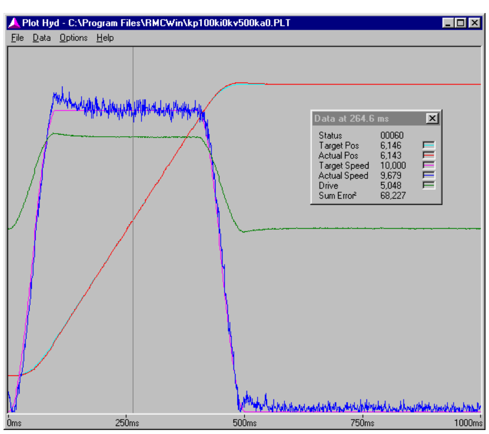

Figure 1. Sample motion plot generated by Delta Computer Systems' RMCWin software monitors how closely the actual motion profile matches the target.

Figure 1 shows how one software package can be used to provide graphical displays of actual versus target motion profiles, which can be referenced in tuning motion steps and control loop parameters.

Case study 1: End dogger requires precise position and pressure control

The following diagram shows a simplified schematic design of an "end-dogger" control system developed by Maxi Mill, Inc. (Albany, Oregon) for Boise Cascade. An end-dogger is a material transport system that carries logs through a series of chipping heads and band saws in a sawmill. "Dogs" are the stops that come into direct contact with the log on each end to grip and move the log toward the saws and chippers (see Figure 2).

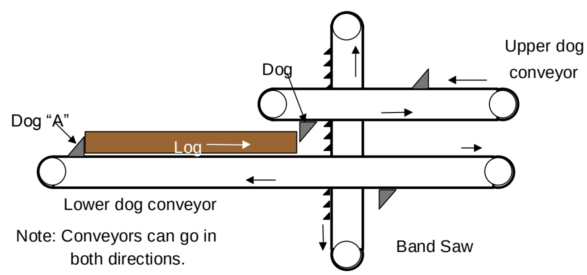

Figure 2. End-dogger's motion control system coordinates the operation of two conveyors to move the log smoothly through the saw.

Coordination between multiple motion axes keeps both ends of a log clamped as it is cut into boards, while position and pressure control ensure that the log is clamped with sufficient force to hold it without damaging it.

In this application, a log is loaded onto the conveyor from the side, and the lower conveyor is moved so that dog A pushes the log into contact with dog B on the upper conveyor. Once the dogs are engaged, they move the log through the chip heads and saw, then disengage and release the board. There are five distinct segments of speed control to cut each log: velocity to engage the back dog, velocity to push the log into the upper dog, velocity to enter the chip heads/saw, velocity in the saw, and exit velocity. A motion profile controls the full process.

Pressure transducers are mounted in the hydraulic lines so the system knows that the log has come into contact with dog B when dog B begins to move and pressure rises in the line between the valve for dog B and the motor.

Once the pressure measured at the hydraulic motor for the upper dog conveyor exceeds a set threshold, the pressure ramps up to the gripping setpoint value. At the same time, the control loop controlling the top conveyor motor tries to hold the position of dog B, while the lower conveyor continues to push the log to the right. This position error creates the gripping pressure. The pressure, established by an optimizing computer, holds the log steady without damaging it.

At this point, the control system changes to position control (while still monitoring and controlling the maximum gripping pressure), and the top conveyor moves in a one-to-one ratio with the bottom conveyor. With this lock-step motion in process, the upper dog conveyor is "geared" to the operation of the lower conveyor. Due to the position error created when the log first engages the top dog and the 1:1 gearing ratio, the gripping pressure is maintained even if the bottom dog stops and reverses drive direction.

The dogs carry the log through the chipping heads and band saws, maintaining constant pressure to ensure smooth motion even against the forces of the cutting heads.

Case study 2: Debarker requires position control and pressure limiting

Debarkers grind the bark off logs with a rotating grinding wheel. The key to maximizing yield is to minimize the amount of usable wood fiber that is removed from a log along with the bark. As the log rotates, the grinding head must react to the shape of the log and maintain consistent pressure on the log. If the motion of the grinding wheel is too "stiff" then the wheel might dig into the wood at undesired locations. If the motion is too soft, the wheel might bounce and result in an irregular log surface. Precise hydraulic control removes only the bark.

The challenge was mastered by lumber mill operator Mueller Brothers Timber Inc. of Old Monroe, MO. Mueller Bros. used a PLC for overall machine control functions and employed a dedicated hydraulic motion controller to operate the grinding wheel. The motion controller interfaced directly to a servo valve in order to exert proportional control of the hydraulics (avoiding the imprecise “bang bang” operation of on/off hydraulic valve control). It also interfaced directly to pressure and position transducers to allow the motion controller to interpret the difference between the pressures as the actuator applies force on the grinding wheel.

The advanced electronic motion controller allowed the system to transition smoothly from position to pressure control as the grinding wheel came into contact with the log. Position control provides coarse positioning of the grinding wheel. As the wheel touches the log, the motion controller detects an increase in hydraulic pressure and switches control algorithms to maintain a precise target force. Maintaining a constant force ensures that the grinding wheel doesn’t bounce off the log or cut too deeply.

One of the problems with many debarking machines is dealing with knots, which contribute to irregular log surfaces that can cause the log to bounce and be cut unevenly. A special operating feature called pressure-limiting mode, supported by Delta’s RMC100 motion controllers, provided a solution.

In this mode, two PID control loops run simultaneously, one loop controlling position of the actuator and one controlling hydraulic force on the log. The motion controller simultaneously reads inputs from the position sensor and the pressure transducers, attempting to hold position, but backing off the wheel when the pressure reaches a limit. The advantage is that the grinding wheel can progressively back off from the log when it hits a knot. With the pressure limiting mode enabled, the knot is ultimately ground down after multiple turns of the log, resulting in a completely smooth log surface.

The mill operator estimates that the new state-of-the-art hydraulics system increases log yields by 5% compared to previous production methods. This represents hundreds of thousands of dollars in savings on a yearly basis.

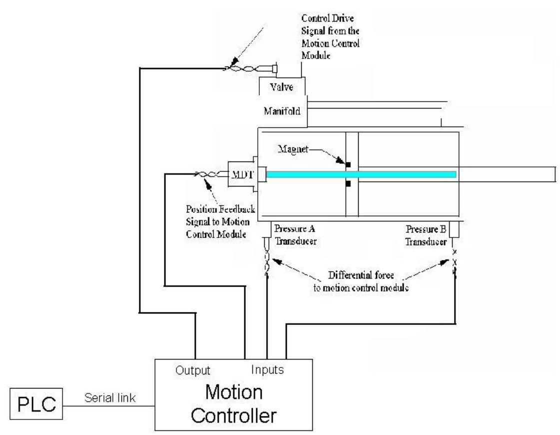

Figure 3. Pressure and position transducer inputs are monitored simultaneously to control he hydraulics in the debarker system.

Case study 3: Smooth motion is key to optimizing log yields by new shape saw

The name of the game in forest products machinery design is getting the highest yields from today’s timber. USNR of Woodland, WA is one of the companies leading the way. One area where big benefits can be obtained is in the ability to cut shaped cants along curved profiles that maximize usable, recoverable board feet from each cant.

Automated shape sawing involves two key elements: 1) Using a high-speed scan and solutions system to plan the cuts and 2) controlling the angle and position of the saw blades (and other motion axes) to follow the profiles quickly and precisely. The elements of the system are shown in Figure 4.

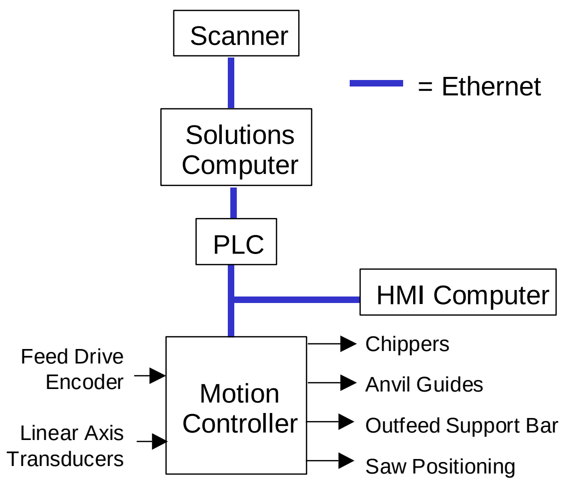

Figure 4. Interconnection of system control blocks.

USNR selected the Delta Computer Systems RMC100 motion controller for two main reasons: The RMC100 is feature rich and extremely easy to program. The PLC can talk to the RMC directly with no interfacing modules required. To a PLC, the Delta RMC looks like just another PLC, using the same data table structure as many popular PLCs, which makes message passing very easy to program from the PLC standpoint. The PLC can download motion instructions in the form of high-level commands that are stored in a table in the motion controller.

Spline functions are an integral part of the instruction set native to the RMC and they are particularly useful in the USNR application. Using spline functions, the motion controller calculates the acceleration and velocity needed to get from the current point to the next point in a motion profile. The calculations provide a continually varying velocity to smoothly connect the target points. Multiple spline points are stored in a table in the RMC, allowing the RMC to operate independently once given the “go” command by the PLC. This is a major improvement over motion control that is implemented as a sequence of discrete motion steps.

Though the minimum number of points for a curve is three, the PLC in this application sends up to 90 points following the shape of a 16-foot long cant. The motion controller then connects those points into a smooth cubic spline. Smoothly varying acceleration of the hydraulic axes ensures that the saws move smoothly. The quality of the cuts remain high, even with curved logs, and machine maintenance costs are kept down because smooth motion avoids hydraulic shock, which can shorten the operating life of machine components.

With a 1 or 2 millisecond scan and update rate, the Delta RMC performs calculations and control actions much faster than if control were done by the PLC alone, resulting in better cutting accuracy. The motion controller’s internal sequencing table can be written to at any time, even while motion is active, allowing for “on-the-fly" changes to setpoints, speeds, and actions.

Tuning of motion control loops

The plotting and tuning features that are supported by Delta Computer Systems' RMCWin development software are very easy to use and helpful in obtaining the control accuracy needed. For example, RMCWin supports an automatic Feed Forward adjustment function that monitors a given move, then adjusts the Feed Forward term in the control equation based on the results of the move. Each move can also be plotted, showing all the variables of position, command, drive, etc., in one plot with time increments and status bit information at each point along the way. Figure 4 shows the plot of a spline move provided by RMCWin.

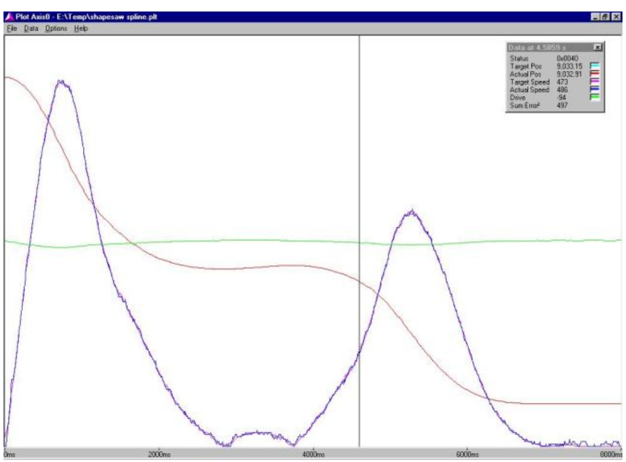

Figure 5. Motion plot generated by RMCWin software.

"We've used other motion controllers before, but the Delta RMC is the easiest to use and has generated the best results," said USNR Control and Optimization Engineering Manager Wade Hendrix.

"The context-sensitive help information contained in RMCWin is one of the best I've seen," said USNR Control Engineer Eric Matschke. "The entire manual is accessible from the help option at the top of the screen. In addition, the majority of editable parameters have direct connections to complete 'functional descriptions' located in the on-line manual. Just a right mouse click allows you to access help on a currently highlighted parameter. There are also many hyperlinks to other help topics."

The proper motion controller, supported by user-friendly design tools, gives forest products equipment manufacturers like USNR the "edge" in building machines that improve yields and accommodate the timber that is available today.

Case study 4: Paper Pulp Refiner Upgrade

The Norske Canada pulp refiner at Powell River, British Columbia has a thermo-mechanical pulp (TMP) refining process that presses wood chips between rotating grooved metal plates in a succession of machines to produce individual fibers as an early step in the paper making process.

The positioning of the refining plates was initially controlled by a proprietary "black box" controller, and the mill personnel found it difficult to tune and troubleshoot the old rotary dial plate positioning controls. Damage to the plates can occur if they are allowed to collide, yet viewing the actual gap measurement was difficult for mill personnel.

A Delta Computer Systems RMC100 motion controller was installed to perform closed-loop control, monitoring the data from the MDTs up to 100 times per second and then operating the proportional hydraulic valve to move the plate positioning piston to make the actual position match the target position. Figure 6 shows how the motion controller connects to the hydraulics. A servo-quality proportional valve was used so that small changes in valve position can be made to affect very precise hydraulic motion.

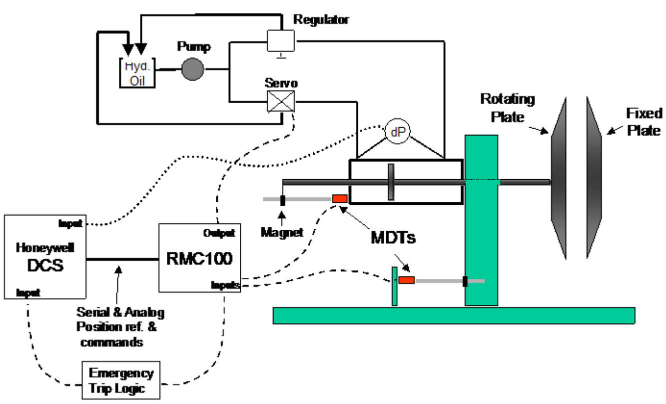

Figure 6. System schematic

The Delta controller has the capability of managing pressure and position control simultaneously, and the mill is adding pressure control to further improve system performance.

The RMC100 is interfaced to the mill's main Honeywell distributed control system (DCS) via serial and analog connections (see figure 5). The analog link provides the grinding plate position setpoint from the DCS (which obtains the setpoint information from the machine operator via an HMI with CRT screen.) The serial link carries status info from the RMC back to the DCS that can be used for tuning the process.

The RMC100 is programmed by writing high-level motion commands in a function table inside the controller, using Delta's RMCWin software. Up to 255 commands can be loaded in a single operation and held in the RMC's internal memory, allowing an entire motion sequence to be initiated by setpoint information from the Honeywell DCS. The Honeywell system is free to handle other control functions while the motion controller manages the hydraulics.

A key to meeting the performance requirements of applications like the refiner upgrade is Delta controllers' suite of graphical tuning tools. Without special tools it is almost impossible to tune fast-moving processes – there is no way to see what is happening in real-time simply by observing the machinery as it moves. Delta's RMCWin software package solves this problem by allowing users to plot actual versus target values of key motion parameters over time, making it easy to see where even small positioning errors occur in order to guide the optimization process. Though they had no previous experience with the RMC100, the mill personnel found the new Delta controllers easy to program and tune. Once through the initial learning curve, they were able to tune the system themselves.

With the control system upgrade, the mill has gained three main benefits:

1. Fast and stable response from the machine. For example, electrical power usage by the machine (measured in megaWatts) used to exhibit transients as the older control system moved the plate to compensate for the changing wood chip load. By providing quicker response to changing conditions and more accurate plate loading, the power consumption by the machine has smoothed out.
2. Increased operator confidence in the refining process. The old control system was hard to calibrate and operators had to frequently visit the machine, paying close attention to insure correct operation. With the new system, the DCS controller monitors the process closely and operators seldom need to go out to the refiner. And the new control system is enabling the collection of process data that was previously not tracked closely. For example, the mill has been exhibiting an availability of 97% for the past eight months. Before the upgrade, this parameter wasn't tracked closely.
3. By selecting vendors of state-of-the-art gear for the control system retrofit, the mill engineers also gained better availability of replacement modules, easier programming capability, and better access to all the parameters for tuning and optimizing.

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