Anti-Backlash Systems

This Application Note describes a general block diagram, theory of operation and some basic guidelines for applying these systems. For specific systems, consult the applicable installation manuals and brochures.

General Background

Danaher Motion's anti-backlash systems have model numbers prefixed with RDP (for Rack Drive Panel). There may be other numbers affixed, depending on the type of system (i.e., SCR, PWM, or brushless drive).

RPD systems find application on machines with rack and pinions (where travel may be too long for a ballscrew), on pinion and bullgear axes, or any situation where it is desirable to engage gearing and eliminate backlash.

RDP systems consist of two motors, two (or dual-axis) amplifiers, and an RDP control card (may be configured either as a stand-alone module or incorporated into a rack with the amplifiers). Each motor shaft has a pinion that engages the main drive gear or rack.

Some History

Several different electric servo anti-backlash systems have been marketed since the early 1960's. Early systems utilized SCR drives by simply applying opposite polarity pulses to the opposing motors. This system had many drawbacks, but was very simple and used only one amplifier. Other systems incorporated torque motors to take up the backlash. These systems were only good for unidirectional applications. Of course, many mechanical variations have been used.

Early systems used conventional master/slave arrangements with tachometers in series and various tach feedback schemes to provide "tracking," "stability," and other terms to indicate an attempt to provide the desired control capabilities. None of these attemps provided the dynamic response of which the drives are capable.

By the late 1960's, Danaher Motion perfected the technique it uses for anti-backlash control. An approach was developed that allows the two servos to be used as fully-integrating, full backwidth capability drives. The unique part of the RDP system is its "equalizer," that monitors the velocity loop outputs of the two amplifiers and provides corrective signals to cause these outputs to "track" within pre-determined limits. Thus, the "servo fight" phenomenon (always the reason why two full-featured servo loops could not previously be connected together) is controlled.

Theory of Operation

As with many great ideas, once conceived and developed, the concept is really quite simple. Great care has been taken to ensure grounding, noise control, and flexibility for having motors mounted with the shaft parallel or anti-parallel for operation with the driven gear in tension or compression.

In essence, the "equalizer" circuit monitors the velocity error signals of both drives and, while heavily damped to allow for transient variations, forces the two drives to operate together with no "servo fighting." The backlash current circuit injects offsets into the current loop to provide the desired "windup" of the gearing to eliminate the backlash. Refer to the system manual for exact schematic showing all adjustments, jumper selections, etc.

In operation, both amplifiers receive the same signals from the Computer Numerical Control (CNC) for acceleration, deceleration, running, torque, etc. The "equalizer" circuit corrects for offsets, drifts, etc., in the loops and maintains complete control over the speed with which either drive can "cross the backlash" to help with accelerations, decelerations, and torque loads due to cutting or other forces. The backlash current circuit provides control over the anti-backlash torque.

When the CNC command (machine requirement for torque) is zero, the motors have their respective anti-backlash currents in them and are maintaining the desired windup in the driven gear. At any other CNC command, the motors share the load. At comman "a" (or "-a"), one of the motors is no longer in contact with a gear face and, with any increasing command, "crosses the backlash" (under control of the "equalizer" circuit) and aids the other motor.

A major advantage of the anti-backlash approach is in system response to transient disturbance. This system readily responds to transient cutter reaction forces that will likely be imposed on only one of the motors. Even at high speeds, variations in the driven gear is easily dealt with as each drive is controlled by its own tachometer (with no bandwidth-robbing feedback from schemes such as two tachs in series). "Overspeed" and "current limiting" is automatic to protect each individual motor. No compromise is made in the system's small signal resolution capability (as can happen when tachs are operated either in parallel or series). The individual drives are standard units (not modified) that are interconnected through the I/Os of the RDP module.

Applications

Because the motors can share torque loads, each motor may be sized at less than the continuous requirement (unless they are required to be in control of the backlash at the load). The following formula is used to calculate motor sizing:

$$\text{Minimum motor sizing} = \frac{\text{Continuous torque}}{2} + \text{Anti-backlash torque}$$

Motors are generally identical, with identical gearing to the load.

Experience has shown that several factors may indicate that a larges motor than what was calculated using the previous formula makes sense. In actual use, customers often decide that a given machine is operated better with significantly higher anti-backlash settings than originally predicted. Friction levels in these machines may be higher than predicted. Single motor operation is often desirable during setup, checkout, or field service troubleshooting.

As a result, Danaher Motion generally recommends sizing each motor to be large enough to handle the total load. Systems sized accordingly often have slightly higher initial costs with adequate safety margins for better reliability, and flexibility to machine changes.