SMART ACTUATORS

"CHEAPER, BETTER AND FASTER!" IS A COMMON DEMAND ON DEVELOPERS. BUT HOW IS THIS ACCOMPLISHED FOR PRODUCTS THAT HAVE VERY LITTLE TECHNOLOGICAL DISTINCTION, SUCH AS THE ACTUATORS FOUND ON A PAPER MACHINE HEADBOX? THE ANSWER LIES IN USING THE PRINCIPLE OF SENSOR FUSION, AND USING IT IN A CLEVER WAY.

The actuators on a paper machine headbox perform a critical function in papermaking. They are responsible for the basic forming of the paper as it is "born". As it progresses through the papermaking process, the paper's fundamental characteristics remain those given to it via the slice or dilution actuators, so modern production standards dictate that these actuators be tightly controllable. For slice applications, micron level control within a relatively small operating band (+-1mm) is desired – but this band can move ±5 mm. Sensors packages that would deliver such fine resolution across a large operating range carry a hefty price tag.

A new approach is required, and this is where sensor fusion comes in. Sensor fusion combines data from disparate sources to obtain information that is of better quality than would be the case were the sources to be used individually. For example, a slowly responding but relatively noise-free temperature sensor will deliver smooth and accurate long-term temperature data, but it will miss small and rapid variations. These would be detected by a fast sensor with low thermal inertia, but this sensor will, in turn, suffer from high frequency noise and reduced accuracy. Sensor fusion would combine the outputs of these two sensors to achieve a low-noise sensor package that has fast response and wider, more accurate operating bands than either sensor could have achieved on its own.

However, for headbox actuators, adding a second sensor would bring unacceptable cost. What other options can be considered? The answer is to create a

"virtual" second sensor and to completely rethink the control regime used to position the actuator.

Traditionally, an actuator moves until its feedback sensor matches the setpoint demanded by the controller. The resulting position is, however, entirely dependent on the characteristics of the sensor package, e.g. linearity over the operating range or sensor resolution. Of course, any inaccuracy in placement is usually relatively minor, and subsequent control scans will fine tune the setting – but this increases overall response time.

ABB's xP actuators take a different approach.

The actuators have a non-contacting absolute position sensor that measures the actuator setting. The difference between the feedback from this sensor and the target setpoint is used to compute the number of steps required to move the stepper motor straight to the desired position. As the mechanical coupling is very tight, numerical step control will place the actuator right where the process wants it to be, avoiding the iterations required by traditional techniques (fig. 1). In any case, the positioning sensor will confirm that the actuator setting is in the right vicinity. As the sensor is only required to indicate that no gross positioning errors have occurred, its accuracy and resolution specification can be substantially relaxed. The likelihood of small errors, perhaps missing just 1 or 2 steps on motor movement startup, is anyway minimized by operating well within the motor specification. Slow drift is accounted for by another element of the hardware.

The key to the success of this control regime is the "virtual" sensor. A history log records move commands and actual movements for each actuator. This data is used to create the very fine resolution virtual sensor. The controlling CPU actually requests each and every step individually from the stepper driver, ensuring very tight movement control. This means that the resolution of the virtual sensor is the same as that of the actuator's movement. In this way, the need for an expensive second physical sensor is obviated. (Figure)

The data collected also facilitates sensor and actuator health checks for proactive asset management. Over 50 parameters can be monitored via the engineering tool (fig. 2), including voltages, current consumption, temperatures, steps and lifetime movements.

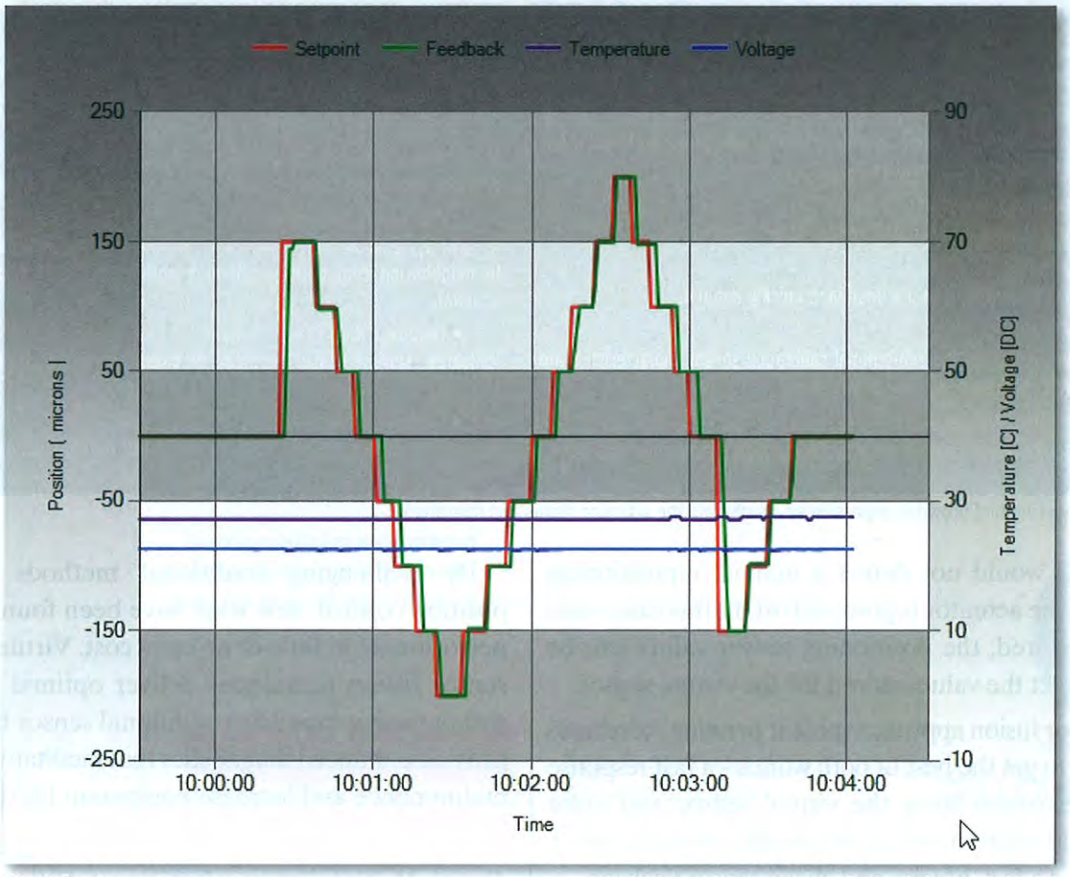

Fig. 1. Performance moves.

> ENGINEERING TOOL

Actuator diagnostic examples

Red & green circles actuator alarms

- **Soft Bend Alert**
  Indicates that an actuator is nearing the specified hard bend limits for this system
- **DC Power Error**
  Actuator has detected abnormal power conditions.
- **Locked**
  Due to alarm conditions, this actuator is prevented from making further moves, until operator intervention.
- **Insufficient Movement**
  Actuator was unable to reach its intended target position.
- **Oscillating**
  Actuator is not settling within a deadband quickly enough.
- **Calibration**
  Actuator has indicated that sub-optimal calibration/sensor characteristics are in place. Will continue to operate in limp mode.
- **Over-temperature**
  Actuator temperature sensors are indicating a high temperature condition.
- **Unexpected Move**
  System detected an actuator move when none was requested by the Embedded System Controller (ESC).
- **Removed from service**
  Indicates that the system has been placed into maintenance mode. No automated moves will be issued to the actuators from the ESC.
- **Communication Error/Not Programmed**
  No response within a normal timeframe has been received. For instance, actuator unplugged, incorrectly addressed, or some other gross fault.
- **Adjacent Actuator Alert**
  In slice systems we may temporarily disable an actuator from moves due to neighboring conditions – although nothing explicitly wrong with this actuator.
- **Feedback High/Low Limit Error**
  Indicates serious sensor problem, or data transmission from actuator to ESC.
- **First/Second Order Limits**
  Indicates breaches of bend limits (soft or hard) during slice operations.

Fig. 2: The engineering tool provides unparalleled insight into the actuator status and operation.

The CPU would not detect a manual repositioning made when the actuator is powered off. In this case, once power is restored, the positioning sensor values can be used to correct the values stored for the virtual sensor.

This sensor fusion approach (patent pending) combines two sensors to get the best of both worlds - a fast response and fine resolution from the virtual sensor and error bounding and position indication from the physical sensor. This provides a fast, precise and cheap sensor package.

By challenging traditional methods of actuator position control, new ways have been found to improve performance at little or no extra cost. Virtual sensors and sensor fusion techniques deliver optimal performance without using expensive additional sensor hardware and provide enhanced diagnostics that facilitate preventative maintenance and increase equipment lifetime.

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