Process Flow Optimization with Absolute Encoders in Valve Control

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Abstract

In process flow control, there are many factors affecting variability but the greatest contributor is the control valve's performance. Issues associated with control valves, such as dead band, actuator/positioner's design, response time, valve type and sizing, all have huge impacts on process flow. Extensive studies on control loops have indicated as high as 80% of all control loops did not perform adequately in reducing process variability, apparently due to various issues with the control valve.

In order to implement tighter control loops, the key is to focus on improving performances of these control valves' components. This paper will focus on the methods used to improve accuracy and resolution of control valves.

Introduction

Consumer requirements in today's world dictate the need for manufacturers to rigorously improve product features while lowering price, to keep pace with the competition. This leads to improved efficiency by minimizing process variability. Industries such as paper fabrication, bottlers, and even hydroelectric power plants require very precise process flow control to maintain high levels of efficiency in their operations. To achieve this, the process flow control systems must be capable of instantaneous and precise responses, via control valves.

The application of Avago's AEAS-7000 encoder enhances valve precision by increasing the step size resolution. AEAS-7000 offers 16-bits single turn resolution with additional 14-bits for multi turn (total of 30-bits). In other words, within one full turn of the stem (360°), there are 16-bits or 65,536 steps. This translates into the resolution of each step size to be 0.005°. Combined with high sensitivity flow rate sensors, fine resolution motors and fast controllers, the performance of the total system solution is phenomenal.

Conventional Control Valve Mechanism

There are various types of valves currently available, such as gate, globe, pinch, diaphragm, needle, plug, ball and butterfly valves. Gate, plug and ball valves are used primarily for turning on and off liquid or gas flows, although in certain applications, these valves may be used for throttling.

Most single seated valves use cage or retainer style construction. These valves can be easily modified to provide reduced capacity flow, noise attenuation or for elimination of cavitations.

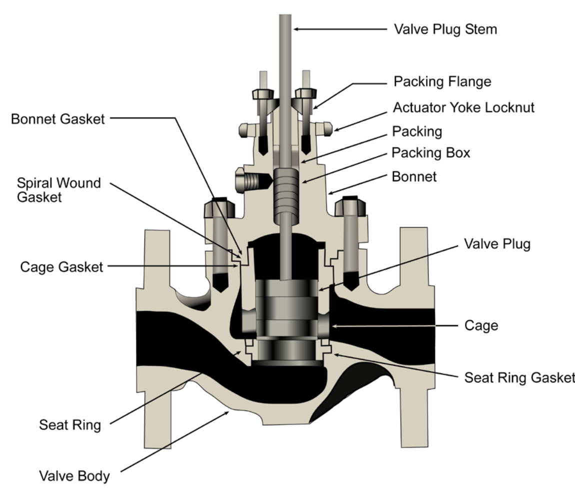

Figure 1. Cross section view of a sliding stem control valve.

The design of the control valve needs to satisfy a series of conditions such as limiting flow rate, allowable sizing pressure drop, effects of fittings, etc. This topic will focus purely on the effect of control valves on flow rate and pressure drop (See Figure 1).

The valve coefficient, C_v, is determined by flow rate, q, and allowable sizing pressure drop, $P_1 - P_2$, as shown below. N_1 is a constant, F_P is the piping geometry factor and G_f is liquid specific gravity.

$$C_v = \frac{q}{N_1 F_p \sqrt{\frac{P_1 - P_2}{G_f}}}$$

In a flow control system, flow rate sensors detect variations in flow rate; typically fluctuations of less than 1% or 2%. If the fluctuations are due to changes in the settings, then these rates of change can be monitored and controlled to follow either linear, equal percentage or quick opening (assuming usage of cages for globe style valve bodies)(Figure 2).

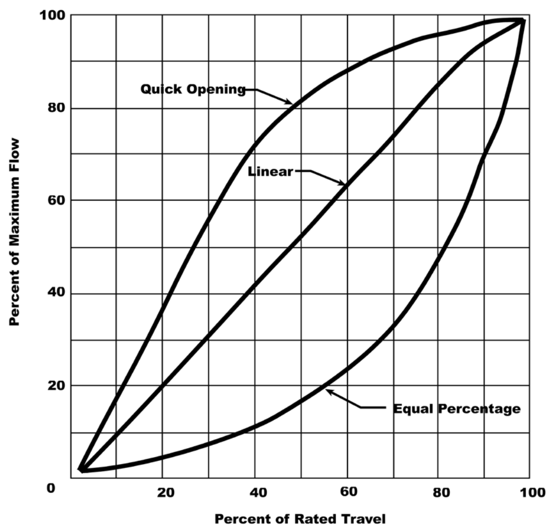

Figure 2. Inherent flow characteristics curve.

If the fluctuations were not due to an intentional process flow change, then the system needs to regain equilibrium by compensating for the undesired deviation. The ability to fine tune and maintain equilibrium is very dependent on detection of small perturbations and fast system response. Correction of flow dynamics is implemented via a closed loop system involving a flow sensor, microcontroller or microprocessors and control valves.

Enhancement of Control Valve Solution with Avago Optical Encoder

Avago enhances control valves by promoting faster valve response time and smaller step size resolution.

For **butterfly valves**, the positions of fully open or closed involve a complete movement of 90°. Throttling is controlled by pneumatic actuators. The precise flow control is very much dependent on detection of the flow rate and how accurately the system can move the pneumatic actuators.

With 16-bits accuracy lending each step size 0.005° resolution, slight fluctuations or perturbation in flow can be easily compensated by a slight rotation of the actuator. Figure 3 depicts a simple butterfly valve mounted with Avago's AEAS-7000 encoder.

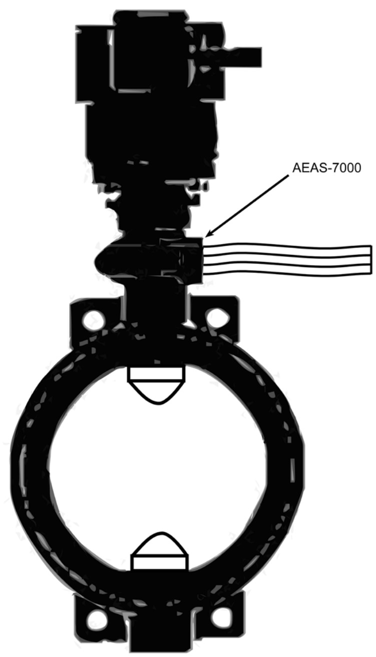

Figure 3. Diagram displaying mounting of Avago's absolute encoder on a butterfly valve.

For example, assume use of a highly sensitive flow rate sensor or pressure sensor. A small fluctuation of 0.1% was detected by the sensor. If the system was designed to respond and correct for 0.1% fluctuation, then the change in flow, based on the valve equation for Q, would be:

$$Q = N.\ \pi r^2 \sqrt{\frac{2g.\,(P1 - P2)}{\rho}}$$

thus, $$\frac{\delta Q}{Q} = \frac{\delta P}{2P}$$

The system will require a change of 0.05% in flow rate. This translates to a change of cross sectional area of the valve by:

$$\delta A = \pi r^2 (1 - \sin\theta)$$

with a minimum angular resolution of 0.005° (Note: $\theta = 0°$ for fully closed and $\theta = 90°$ for fully open).

Avago's absolute encoder is capable of providing 16-bits resolution (0.005°), which exceeds expectation and minimum requirements.

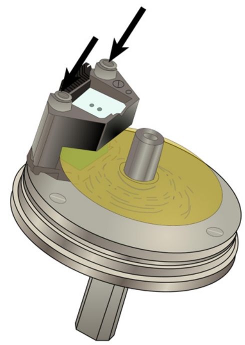

Figure 4. Zoom-in diagram of the mounted absolute encoder with code wheel.

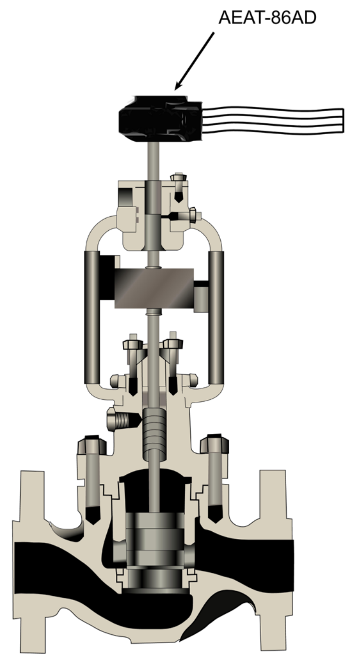

Figure 5. Cross section area of the sliding stem valve with Avago AEAT-86AD mounted on the stem.

For **sliding stem valves** and **gate valves**, the movement involves multiple rotations. Each rotation brings the wedge closer to the seat, finally sealing the opening. Gate valves are typically not used for throttling due to high erosion of the gate. For certain applications, where the design of the gate valve allows such controlled action, the usage of Avago's AEAT-86AD enhances the control of these gates.

Figure 5 shows how Avago absolute encoders can work in tandem with these valves, by monitoring multiple rotational movements (14-bits) as well as controlling precise rotational position within each single turn (16-bits).

Advantages of AEAS-7000 and AEAT-86AD Encoder for Control Valves

- Accurate movement of 0.005° step size within each rotation
- Capable of tracking multiple turns (16,384 turns)
- Provides additional information such as speed and direction for precise control
- Small module size
- Consumes minimum amount of power
- High reliability allows AEAS-7000 and AEAT-86AD to be almost maintenance free
- The entire modules of AEAS-7000 and AEAT-86AD do not generate noise or vibration
- AEAS-7000, with optical technology, is a state-of-the-art solution capable of enhancing process flow rate control

Conclusion

Process flow control is vital in industries such as the food industry (bottled drinks, can drinks, breweries, etc.), petroleum, chemical, sewage industries and even hydroelectric power plants. The key factor affecting process flow control is the control valve. The need for the control valves to respond instantaneously and precisely is even more prevalent when companies push for higher throughput and efficiency. Any process variations must be instantly compensated to reduce losses in throughput and efficiency.

With the introduction of high accuracy encoders into control valves, the entire control system can be optimized, which translates into higher productivity and lower yield loss.

References

1) Figure 1, 2, 3, 5: "Control Valve Handbook", Fisher Controls International reference guide.
2) "Statistical process control in Continuous Flow Process", John R English and Kenneth E Case.
3) "Process Dynamics and Control", Dale E. Seborg, Thomas F. Edgar, and Duncan A. Mellichamp.

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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