



Richard Tan and Ricardo Castaneda, Baker Hughes, a GE company (BHGE), outline the benefits of a control valve health-monitoring system.

CUT DOWNTIME, ENHANCE OPTIMISATION

When it comes to asset management at refineries or petrochemical complexes, control valves do not often get the same attention as large capital equipment like turbomachinery, heat recovery steam generators (HRSGs) or distillation columns. As an integral part of plant

instrumentation, control valves are critical to ensure proper, continuous and efficient plant operations. Since control valve selection is driven by process data and to a certain extent its intended functionality, the chosen solution determines the ramp up rate and performance of the plant.



Figure 1. Masoneilan control valve with digital valve positioner.



Figure 2. Emergency shutdown digital valve positioner.

Control valves are responsible for maintaining adequate flow and pressure to keep the controlled variables close to their setpoint. Deficiencies, therefore, can introduce undesired process variability due to changes in the response time, linearity, overshoot and undershoot, among other factors.

Typical issues in downstream processing

As global demand for products such as kerosene and diesel continues to rise, higher conversion of feedstock to transportation fuel is becoming commercially important, to maximise yield from each barrel. This trend is supported by the increase in installations of

higher efficiency refineries and upgrades to existing plants. In these facilities, heavy residue goes through various stages of catalytic high temperature, high pressure (HTHP) hydrocarbon processing to yield valuable end products.

In heavy residue refining/upgrading, the hydrocarbon liquid typically consists of large amounts of solids. The hydrocarbon fluid is intentionally subjected to a high pressure drop (ΔP) to allow separation of lighter hydrocarbons from the heavier ones. The side effects of this rapid, high pressure reduction include not only cavitation, but also a significant amount of energy delivered to the valve which, in turn, may cause vibration in the surrounding piping system. In addition, the high operating temperatures in this application cause rapid outgassing at the onset of the ΔP , resulting in high velocity, three-phase flow at the outlet. Together with the entrenched solids, the high velocity streams could cause severe erosion to the surrounding system.

Considering the situation of severe cavitation in high pressure letdown residue, conventional single and multi-stage anti-cavitation trim designs may be insufficient for this service. This is because the combination of solids and gas stream flowing at high velocity can erode or plug small area holes in multi-stage designs that are meant for anti-cavitation purposes. In general, any material will be damaged by cavitation regardless of its hardness as harder material lasts longer, but it is still a matter of time before the selected material starts to fail under cavitation. Alongside the adoption of hardened materials, other defensive strategies, such as special geometry to minimise pressure recovery and cavitation damage, are key to improving the longevity of valves.

A non-clogging trim design is ideal in the presence of solids to prevent potential clogging, which would lead to unexpected capacity reduction. It is also necessary to protect small gaps, such as those around seals, from direct exposure to solids. Otherwise, captured slurry and powdery fines at the trim area will cause the valve to stick and eliminate the ability to throttle smoothly. This phenomenon translates into delayed response to control signal, and inability to reach setpoint.

It is common for hydrocarbon vapour streams to carry powdery fines. Since the particle size is significantly smaller than the size of drilled holes in the valve trim, they will accumulate and build up inside the valve over time in continuous service. Therefore, trim clogging is commonly found in drilled hole trim valves. A micron filter may seem to be the solution, but once fouled, it introduces unwanted ΔP so high that it is unacceptable to the process design. Non-clogging noise attenuation technology is a better choice to both reduce noise and to prevent clogging.

Valves consist of hundreds of parts made of hardened and unhardened materials. Special design considerations are essential to enable proper valve operation at elevated temperature applications. Parts of different material and geometry do not share the same thermal properties. This means that thermal expansion

of every part is not necessarily uniform in all directions. One of the main challenges is to manage the thermal expansion of parts in such a way that proper valve throttling is not affected. In addition, prolonged exposure to high temperature will subject the valve to thermal degradation, which will weaken the component's ability to withstand cavitation and erosion mentioned earlier.

In regards to flow capacity, it is critical to define the 'operating boundary' of the valve according to its service. In addition to the normal and maximum cases, valve selection should consider abnormalities and emergencies that are likely to be encountered by the valve. There is often a minimum flow case, wherein differential pressure across the valve is highest, resulting in higher energy dissipation across the valve. Consequently, this operating case has higher potential for the fluid to cavitate, and eventually cause more internal damage to the valve. Therefore, valve design should consider the energy being transferred to the valve in all operating scenarios.

Modern digital tools for preventive and predictive diagnostics

Replacing failed parts that are critical to control valves is expensive. However, the cost of parts replacement is significantly small compared to the total cost of lost production encountered during this downtime. Mechanical failure in control valves is likely after continuous periods of operation, particularly in adverse environments of residue hydrocarbon applications. All of the risk-prevention valve technologies discussed above intend to enable the control valve to last longer. Therefore, it is of utmost interest to leverage the investment to protect expensive capital equipment and eventually minimise unexpected downtime.

Having knowledge of the control valves' wellbeing in real time along with the ability to predict impending failure is important. The greatest advantage of this capability is to make it possible to preemptively address primary unexpected emergency downtime that could cause catastrophic accidents.

This control valve diagnostic information is highly valuable as it enables the user to optimise scheduled shutdown for equipment repair and reconstruction. Since the shutdown is preplanned, overall loss can be minimised. From a financial perspective, this allows adequate time for accurate budget planning and prioritisation of spare parts pre-purchase according to the criticality of control valves. This information also provides a picture of the running condition of the current plant/process. Based on this information, users will be able to decide if modification and improvement of the current plant/process is necessary. Since failure can now be predicted from trends in diagnostics, the operator is able to plan systematic equipment outages for changeout at different stages. This improves the efficiency of repair and rejuvenation operations during planned shutdowns.

Control valve deficiencies may evolve silently or abruptly, the most challenging being the former as they create a false sense of stability. By incorporating microprocessors in industrial instrumentation, equipment providers have simplified the troubleshooting process significantly in recent years. With a new generation of diagnostic capability, instruments can identify internal malfunctions and failures, ranging from simple low power warnings to more sophisticated alerts. These alerts can flag impending performance issues that are not necessarily considered device failure, but still prevent the instrument from performing its function. An example is a pressure transmitter able to detect blockages in its impulse line or a valve positioner able to detect low air supply pressure.

How can a new generation of engineers and technicians improve process efficiency and reduce downtime while adopting predictive diagnostics and speeding up their learning curve? As more devices come online with health diagnostics, software tools such as plant asset manager (PAM) become necessary to manage the resulting alarms. With hundreds or even thousands of devices in a plant, the challenge is differentiating a notification from a true alarm requiring attention.

While technicians can troubleshoot and fix failed valves more quickly with modern technology, they often cannot detect the probability of valve failure in advance. A smart valve positioner can anticipate a failure, so that the maintenance team can be ready with tools and parts. Predictive diagnostics are now available but require a new set of skills and tools to access performance information that is not generally tracked by technicians or traditional PAM programs.

To predict valve failure, there are key practices and observations to discuss, including periodic and automatic monitoring at current operating conditions and the notion of 'occurring vs occurred.' Control valves are part of a closed control loop that is tuned according to process dynamics and response time. Valve performance deterioration symptoms often yield to a later failure and the process itself will be impacted gradually and quietly.

Contemporary process variability is now observed closely and problem solving related to the reduction of process variability is a full-time job with advanced instrumentation required to complete the effort. Here is where all the control loop elements' response times play an important role. When a control loop is tuned, process and instrument response times are considered to find the best proportional, integral, and derivative (PID) tuning parameters, but if a control loop element's response time starts to slow down, the current tuning parameters eventually will not be enough, thereby causing the process to move away from the desired setpoint.

Control valves have the slowest response among the control loop elements, and the PID controller needs to compensate for that. As the friction increases in the valve, the valve moves more slowly, which in some cases causes the valve to get stuck momentarily and suddenly

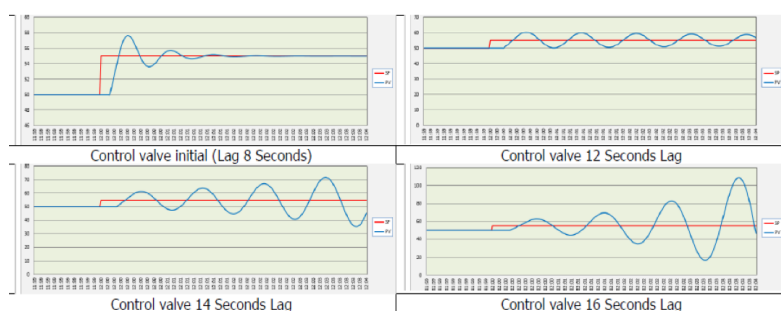


Figure 3. Representation of control loop oscillation due to increased lag time at the control valve.

jump into another position (this is called stick and slip), thereby causing undesired process oscillations. However, if the friction or lag is observed periodically over time, a trend can be generated. Assuming that after servicing the valve friction is 10 psi, and lag is 2 sec., after six months in operation the data shows that friction increased to 15 psi and lag value is now 8 sec. (+6 sec. shift) (Figure 3). A linear approximation will show that friction is increasing an average of 0.83 psi/month and lag is increasing 1 sec./month (assuming the friction did not increase due to an operator packing adjustment). If no action is taken after six months, valve friction might be at 20 psi and 16 sec. lag. The setpoint vs position trend shows no evidence of

stick and slip. This observation suggests that actuator and valve are still healthy and able to move the valve to the desired position, but that it takes longer to match the desired position set by the controller.

From the maintenance perspective, there are no red flags, but from the process operator's perspective the story might be different. If the process shows some signs of small oscillation, the chances are that no action will be taken. Oscillation may increase over time, yielding to higher process variability. Since the valve has not failed yet, traditional diagnostics is not

able to pick any warning or alert. The process oscillation will be captured by the operator who would try to adjust the control loop to bring it back to steady state. But things start to get worse over time, until traditional diagnostics detect a valve failure and an alert is triggered calling for immediate corrective action.

Conclusion

While the best fit control valve design solution is vital to allow successful unit operation, a prognostic control valve health-monitoring system will allow preemptive actions, preventing major mishaps. A combination of both will significantly improve efficiency in hydrocarbon processing plants. 