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OIL&GAS ENGINEERING®
March 2021
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End rotary valve cavitation

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Next-gen trim cuts rotary valve cavitation

Enabled by additive manufacturing; proved in river water trial

Brandon Bell, Emerson

Rotary-style control valves are commonly used in the upstream, midstream, and downstream oil & gas industries. They are relatively inexpensive for a given line size and have high flow capacities, making them an excellent choice for many applications. Unfortunately, the low recovery factor of these designs makes them more prone to cavitation.

Cavitation poses serious problems for control valves, especially in high-flow and high-pressure-drop applications. As a liquid passes through the control valve restriction, increased velocity creates a low-pressure zone downstream of the valve that effectively boils the liquid and creates vapor bubbles in the flow stream.

As the fluid passes beyond the trim and velocity slows, the pressure returns and the vapor bubbles collapse. The implosion of the bubbles creates localized micro jets and shockwaves that can severely damage valve components and piping, especially if the bubble happens to be near a metal surface (Figure 1).

Equipment damage is amplified if the process fluid contains erosive particles or corrosive chemicals. Under these conditions, the rate of damage can accelerate considerably, as with the application described below.

Perfect storm

A Louisiana refinery recently encountered a situation that constituted a worst-case combination of cavitation and erosion.

Figure 1: Samples of cavitation damage. Cavitation often destroys plugs, seats, and the walls of control valves and downstream piping. Image courtesy Emerson

The application involved a control valve passing large quantities of river water laden with fine silt. The flow rates and line size demanded a rotary valve, and the pressure drop across the valve was high. Personnel noted cavitation with high noise and vibration levels.

In addition, the high-velocity river silt had an erosive effect that exacerbated the equipment damage. The cavitating liquid exiting the 10" rotary globe valve was impinging on the wall of the downstream piping. The combination of cavitation and river silt erosion began wearing through the pipe wall and eventually breached it (Figure 2).

Due to pressure boundary loss from cavitation and erosion damage, the control valve was replaced every 24 months, and the downstream piping was replaced every six to twelve months. A surprise breach leading to unexpected downtime is costly. Providing a safer situation for plant personnel was a high priority for the refinery.

Historically, anti-cavitation trim options for rotary valves have been limited, with most rotary valve manufacturers only offering some type of attenuator integrated into the ball of the valve (Figure 3).

As the valve opens, the flow is directed through channels to create backpressure and dissipate the fluid energy. These devices have limited pressure drop capability. They do reduce cavitation damage, but they have varying effectiveness at differing degrees of ball rotation. They also can divert the process fluid toward the valve body walls and downstream piping, causing concentrated damage in those areas. For this reason, rotary valves are usually not specified for high cavitation conditions.

Additive manufacturing options

Fortunately, recent advances in additive manufacturing have changed the landscape for anti-cavitation trim designs. Additive manufacturing uses precision-guided lasers and high-hardness alloys to build up valve components in a 3D printing arrangement. This manufacturing technique enables specialized trim designs that

Figure 2: Downstream piping fails due to extreme cavitation and the erosive effects of river silt striking the pipe wall. Note the river water spraying out of the pipe at the bottom left of the photo. Image courtesy Emerson

would have been impossible or prohibitively expensive to fabricate just a few years ago. The required parts are created from a variety of high-grade, high-strength alloys. One of these new designs is the Cavitrol Hex anti-cavitation trim offered for the Fisher Vee-ball rotary control valve (Figure 4).

Unlike previous designs, this rotary valve anti-cavitation trim is inserted into the valve from the downstream side and is not connected to the rotating ball in any way, allowing the trim to perform as desired to reduce cavitation regardless of the degree of valve opening. It also can be retrofitted and installed into any existing Fisher Vee-ball valve.

The specialized flow channels reduce cavitation within the valve and direct the process fluid straight downstream. Since liquid flow no longer impinges on the pipe walls, downstream pipe damage is reduced, while the trim protects the valve from cavitation damage.

> **"A refinery in Louisiana was replacing a 10" control valve** every 24 months and sections of downstream piping every six to 12 months due to river water cavitation and erosion."

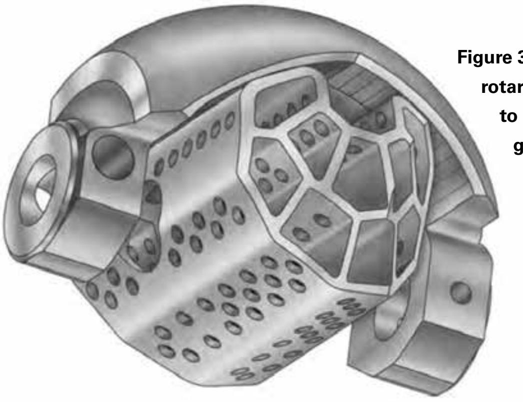

Figure 3: Anti-cavitation options for rotary valves are usually limited to some type of attenuator integrated into the control ball to dissipate energy and protect the valve trim. Image courtesy Emerson

Successful river trial

At the previously mentioned Louisiana refinery, an existing 10" rotary valve in river water service was replaced with a 10" Fisher 300# Vee-Ball valve with a Cavitrol Hex anti-cavitation trim. Cavitation noise and vibration abatement were immediately apparent. After a year in service, the valve was pulled and inspected (Figure 5).

No damage to the downstream piping was apparent. Damage to the valve was limited to erosion of the lower section of the anti-cavitation trim face. The refinery staff was pleased with the result since damage to the pressure retaining components appeared to be stopped, noise and vibration was significantly reduced and erosion effects from entrained particulate in the process fluid was limited to the replaceable Cavitrol Hex trim only.

After inspecting the valve, Emerson and Impact Partner John H. Carter Co. offered an upgraded trim composed of R31233 alloy rather than the original S31603 material. This higher hardness cobalt alloy was better suited to handle the erosive nature of the river silt. New trim was installed, and the valve returned to service. After another year of punishing conditions, the valve was again pulled for inspection.

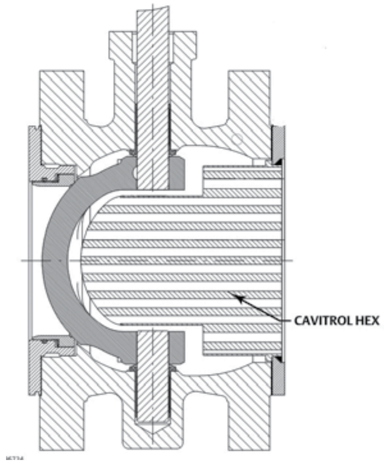

Figure 4: Anti-cavitation trim embodies a design enabled by additive manufacturing. The trim can be retrofitted to existing valves and works well at any throttling position. Flow enters the above diagram from the left. Image courtesy Emerson

Figure 5: After a year in service there was no sign of downstream piping damage and damage was limited to relatively minor erosion on the face of the trim. The valve body suffered no damage at all. Image courtesy Emerson

Figure 6: The anti-cavitation trim was replaced with a higher hardness R31233 alloy and returned to service for another year. The inspection team found a few small rocks stuck in the trim, but no damage to downstream piping, no damage to the valve body and reduced erosion damage of the Hex trim. Image courtesy Emerson

Other than finding some small rocks trapped in the trim that had slipped through an upstream filter, the inspection team found no damage to the downstream piping and valve body, and significantly reduced erosion damage to the Cavitrol Hex trim (Figure 6).

The valve remains in service to this day and the refinery is pleased with the valve's dramatically improved performance.

Final words

Certain applications require the high flow capability of rotary valves, but these types of valves can be prone to cavitation, and anti-cavitation trims for this valve type are limited and only moderately effective. Additive manufacturing techniques have revolutionized the industry and enabled designs not economically feasible just a few years ago.

If an operating unit has applications where rotary valves face cavitation conditions, it is likely worth the time to research the latest anti-cavitation trim offerings and see what options are available. Significantly improved designs enabled by additive manufacturing techniques may solve issues that could not be addressed before.

In this particular application, the Cavitrol Hex trim generated significant savings for the operating unit. The refinery was replacing a 10" control valve every 24 months and replacing the downstream piping every 6 to 12 months due to pressure boundary loss from cavitation and erosion damage. After installation of the new anti-cavitation trim design, plant personnel have not replaced either the valve or downstream piping for years and plant safety was significantly improved. Equipment and maintenance cost savings quickly offset the cost of the valve, while also reducing downtime significantly, providing a quick return on investment. OG

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