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How Additive Manufacturing Leads to Quieter Control Valves

Smart Manufacturing: 3D printing techniques enable quieter, higher performing designs for final control elements.

By Grady Emswiler, Mike Hoyme | April 29, 2023 | Smart Manufacturing (Industry 4.0)

Control valve noise is a problem in many plant environments. The sound is created by very high pressure drops across a valve, which generates high vapor velocities as the fluid moves through the narrowed passages in the valve body. Aerodynamic noise has a strong dependence on the gas velocity, so high flow and high pressure drop applications tend to reach deafening sound levels very quickly. This type of noise can damage hearing, and over time, it can destroy tubing, sensitive equipment, nearby piping connections, and valve components.

Low noise trim designs have been historically used to address this issue, but these types of solutions are usually costly and greatly reduce flow capacity. However, additive manufacturing techniques (3-D alloy printing) have introduced a whole range of new possibilities in noise reduction solutions. This article describes new designs that have been recently introduced or are slated to become available in the next few months.

A noisy problem

Plants are full of loud noise sources, including large equipment, process vents, and reciprocating pumps. Many of these sounds are point sources (Figure 1A) and the sound levels fall off as the square of the distance. Control valves are another common source of sound in industrial environments, but in this case the sound actually emanates from both the valve and the pipe, creating a linear source when the downstream pipe is long enough (Figure 1B). While a point source loses sound intensity with the square of the distance, a linear source drops intensity directly proportional to the distance, so it tends to create larger problems for plant personnel.

Common causes of control valve-generated noise include mechanical vibration of internal components, aerodynamic noise from turbulent gas flow, and hydrodynamic noise from cavitation. The sound external to the pipe poses a threat to hearing at levels above 85 dBA, and levels above 110 dBA can damage valve components and adjacent piping connections, and should thus be avoided (Figure 2).

Figure 2. Control valve noise above 110 dBA external to the pipe can fatigue bolts and ultimately crack control valve stems and shafts. For this reason, sound levels should be kept below this threshold.

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There are usually two ways to address this problem—either restricting the sound path so the sound cannot escape to the environment or eliminating the generation of the sound at the source. Sound path solutions commonly employ thick pipes, heavy insulation, and/or acoustic blankets to block the noise. These work well and are inexpensive, but these solutions have limitations.

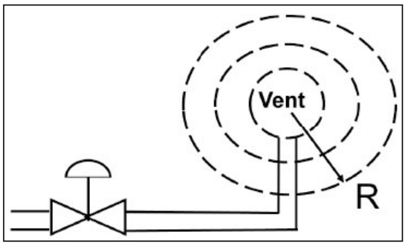


Figure 1A. Noise point sources lose sound energy quickly, falling with distance squared.

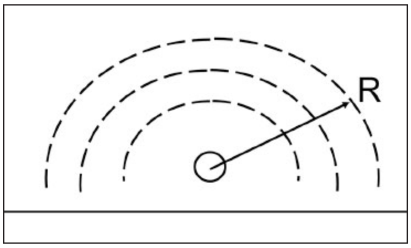


Figure 1B. Control valve noise radiates sound from the pipe itself, as depicted in this piping cross section, so the sound levels drop much more slowly with distance.

The achievable noise reduction is usually somewhat limited, and these techniques tend to become less effective over time as insulation breaks down and acoustic blankets are removed during maintenance and not reinstalled correctly. Regardless of how well they work, sound path solutions do not address the fundamental problem of sound levels greater than 110 dBA possibly damaging the equipment.

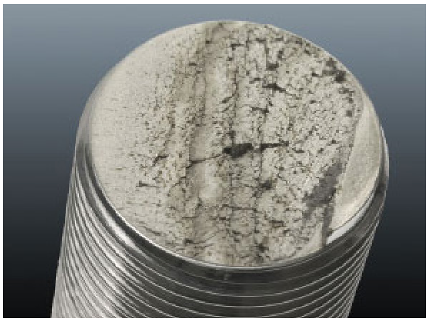
Calming the beast

The standard solution for control valve noise has been the installation of quiet valve trims to reduce the levels of noise generation at the source. These designs usually break up the flow into multiple flow paths, or they take smaller pressure drops across multiple stages, to reduce overall flow velocity and depress overall sound levels. This technology also works well, but it too has limitations:

- Low noise trims tend to restrict valve flow capacity significantly, requiring larger valve bodies to pass the same flow rate.
- Low noise trims are typically much more expensive than standard valve trims since intricate machining is required to produce these designs.
- Low noise trims often have limited applicability for rotary valves.

The landscape of control valve noise solutions has changed dramatically with the advent of additive manufacturing because it is now possible to quickly and economically create very complex trim configurations.

This recent capability has spurred new noise reduction solutions that can achieve very high levels of noise reduction while maintaining high flow capacity.



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Rotary valve low noise trims

Rotary valves tend to be much less expensive than globe valves, but they are inherently prone to higher noise levels due to their trim configuration. It is difficult to incorporate any kind of noise reduction trim into the valve since the full pressure drop is taken across the ball. For this reason, rotary valves are not usually employed in high pressure drop/high noise applications.

Fortunately, additive manufacturing has enabled entirely new trim configurations that can reduce sound levels significantly (Figure 3). For example, in-ball attenuators produced using additive manufacturing can provide up to 18 dB of sound level reduction for next generation rotary trims. These noise reduction levels are achieved while largely maintaining the high flow capacities common with rotary valves. This can save significant costs over globe valve alternatives in a typical application.

Advanced globe valve trim designs

A wide selection of low noise trims is available in globe valves, each using a progressively more complicated trim configuration to produce higher levels of noise reduction. Usually, the more complex the trim style, the higher the noise reduction and cost, and the lower the flow capacity. Very high noise reduction levels have historically only been achieved at very high cost and by grossly restricting flow capacity through the valve. If high flow capacities are required, a much larger valve body has been necessary when using standard low dB trim designs.

A new generation of trim styles is entering the market to address the flow capacity problem (Figure 4). These new styles employ very complex flow passages and have only recently been made possible through additive manufacturing.

These innovative designs achieve very high levels of control valve noise reduction by creating numerous flow passages and more efficient pressure drop stages, reducing overall noise generation and shifting much of the sound to higher, less destructive frequencies. Despite the very high sound level reduction, the designs maintain high flow capacity through the valve. This allows smaller, less costly valve sizes to be used for a given application.

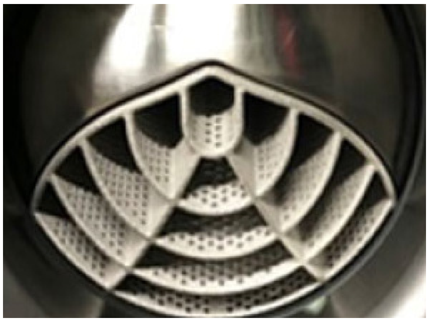

Figure 3. Innovative additive manufactured rotary valve solutions can reduce sound levels up to 80 percent over traditional manufactured designs.

The same additive manufacturing technology can also be used to create trim designs that achieve the very highest levels of sound reduction (Figure 5). These trims do sacrifice flow capacity, but they can be employed in very difficult applications where traditional noise reduction solutions are inadequate. These low noise trim designs round out a suite of existing low dB solutions that can be used to address a broad spectrum of noise reduction, valve capacity, and installed cost requirements.

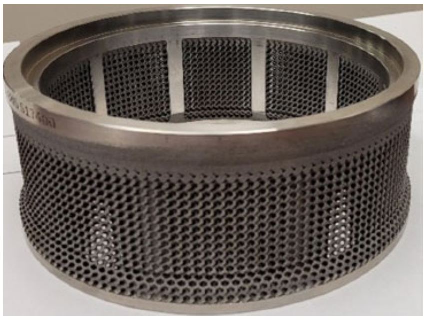

Figure 4. Innovative additive manufactured globe valve solution that meets or exceeds traditional manufactured noise reduction with 20 percent higher flow capacity.

Modal attenuator

An option already on the market uses an entirely different means of reducing control valve noise. It is a passive device that employs similar concepts as car mufflers, using destructive sound resonance to offset and cancel noise (Figure 6). First conceived in the 1980s as a college research project, the technology was shelved for decades until recently when additive manufacturing made it economically possible to develop a pattern to produce the component as a cast assembly.

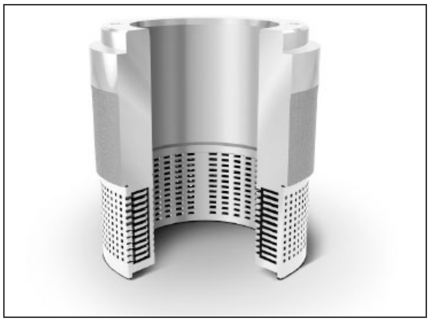

Figure 5. When extreme noise reduction is required, solutions are available that can be used to achieve noise reduction levels as high as 40 dB.

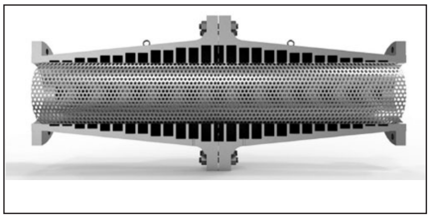

Figure 6. This modal suppressor employs a series of varying sized chambers to generate destructive interference over a range of frequencies, with virtually no pressure drop.

The modal attenuator consists of a series of carefully engineered resonant cavities to provide sound reduction across a wide spectrum of frequencies. The full-bore design allows unrestricted flow, and internal drain channels drain off condensate that could build up in the device and reduce performance. Installed just downstream of the valve, the modal attenuator achieves an overall sound reduction of up to 15 dBA while creating no restriction in flow capacity whatsoever. The device can be used on existing valves or paired with a low noise control valve to achieve even higher levels of noise reduction. Unlike diffusers or silencers, the modal attenuator works consistently across a wide range of flow rates.

Evaluate the options

When faced with a control valve noise problem, it is worth taking the time to investigate the many new options that have recently become available or are being introduced. Additive manufacturing has greatly broadened the landscape of what is possible, and many solutions are now offered that address the most demanding control valve noise attenuation applications.