DRESSER Masoneilan

Special to ControlGlobal.com
March 11, 2010

Predicting Control Valve Noise in Gas and Steam Applications:
Valve Trim Exit Velocity Head vs. Valve Outlet Mach Number
By Joseph Shahda

Predicting and managing control valve noise has long been an important consideration in gas and steam applications, with the dual goals of protecting workers from potential auditory damage and preventing excessive vibration that could destroy equipment and piping, possibly leading to a catastrophic failure.

At first glance, it may seem that a logical way to achieve these goals would be to limit valve trim exit velocity head to a maximum of 480 kilopascals (kPa), and this indeed is how some have addressed the issue. In practical application, however, it is an oversimplified approach that, in many cases, will not produce the desired results. First, it typically requires the use of expensive multi-stage or multi-turn trim designs, which can cost up to 30 percent more than a simpler solution. More importantly, it also can create a false sense of safety.

This article will explain why the focus should instead be on keeping the valve outlet Mach number low. Practical examples will be used to illustrate that:

- Even if the trim exit velocity head is kept below 480 kPa, valve noise can be unacceptably high if the valve outlet Mach number is high.
- Even if the trim exit velocity number is above 480 kPa, valve noise can be kept to acceptable levels – without using costly trim designs – if the valve outlet Mach number is kept low.

Noise Prediction in Control Valves

To comply with noise standards set by the United States Department of Labor's Occupational Safety & Health Administration (OSHA) and prevent potentially dangerous vibration levels, most control system designers seek to specify valves that will keep noise levels below 90 decibels adjusted (dBA).

The IEC 60534-8-3 aerodynamic noise standard is the most widely used for noise prediction in control valves. This standard calculates the stream power and the acoustical efficiency factors at various flow regimes, identifying five flow regimes that are determined by the relationship between various pressure parameters.

This standard also provides methods for calculating the internal sound pressure, its corresponding peak frequency, the transmission loss, and the A-weighted noise level at 1 meter (3 feet) downstream of the valve and 1 meter (3 feet) away from the pipe wall.

[more]

Dresser Masoneilan / Dresser Consolidated
Dresser, Inc.
10343 Sam Houston Park Drive, Suite 210
Houston, TX 77064 U.S.A.
Office: +1 281 671 1654 Fax: +1 281 671 1735
www.dresser.com

It is important to note that IEC 60534-8-3 does not recommend limiting the trim exit velocity head to 480 kPa in order to achieve a low noise level in the valve.

Calculating Valve Trim Exit Velocity Head and Valve Outlet Mach Number

Following is an overview of the key equations that will be used in the two examples outlined in this paper.

Equation 1 – Valve Trim Exit Velocity Head

Valve trim exit velocity head is calculated using the following equation:

$$KE = \tfrac{1}{2} \cdot \rho \cdot V^2$$

Where:
- KE = Trim exit velocity head (Pascals);
- ρ = Fluid density at the trim exit in kilograms per cubic meter (kg/m^3);
- V = Fluid velocity at the trim exit in meters per second (m/s).

Equation 2 – Sonic Velocity

Sonic velocity is calculated using the following equation:

$$C = \sqrt{(\gamma \cdot R \cdot T)}$$

Where:
- C = Sonic velocity in the fluid (m/s);
- γ = Gas specific heat ratio;
- R = Universal Gas Constant; R = 8,314 / MW; MW = Gas molecular weight;
- T = Gas temperature in degrees Kelvin.

Equation 3 – Trim Exit Velocity Head (Regimes II through V)

The IEC 60534-8-3 aerodynamic standard states that "the differing flow regimes of noise generation are the result of differing sonic phenomena or reaction between molecules in the gas and the sonic shock cells." This standard defines five flow regimes, with only regime I being subsonic and regimes II thru V being sonic.

[more]

Nearly all process applications fall into regimes II through V and, therefore, have sonic trim exit velocity. In regimes II thru V, the trim exit velocity head is calculated using the following equation:

$KE = ½ \cdot \rho \cdot C^2$

Valve Outlet Mach Number

The valve outlet Mach number is defined as the ratio of the fluid velocity at the valve outlet to the sonic velocity in the fluid at the given temperature. It is an important parameter in determining not only the noise level in the valve, but also in calculating the potential for vibration in the valve/pipe system.

Typically, a control valve body has a close resonance frequency to the pipe system. A high outlet Mach number can, therefore, generate a frequency that will match the valve/pipe system resonance frequency, causing vibration that can lead to erosion damage to the valve body.

In superheated steam and clean gas applications, it is recommended that the valve outlet Mach number be kept below 0.3 for continuous operation and below 0.5 for intermittent operation. Maintaining these low valve outlet Mach numbers helps ensure a low noise level, reducing the potential for vibration problems in the valve/pipe system.

In saturated steam applications, the maximum valve outlet velocity should be limited to Mach 0.2. Due to the thermodynamic properties of saturated steam, a very small decrease in the temperature of the fluid may lead to the formation of liquid droplets within the steam, and these droplets are extremely erosive at high velocities.

<u>Equation 4: Valve Outlet Velocity</u>

Valve outlet velocity is calculated using the following equation:

$V_{outlet} = W \cdot \rho_{outlet} / A$

Where:

- V_{outlet} = Gas velocity at the valve outlet (m/s);
- W = Mass flow rate across the valve in kilograms per second (kg/s);
- A = Valve outlet area in square meters (m^2);
- ρ_{outlet} = Gas density at the valve outlet (kg/m^3).

[more]

Equation 5 – Valve Outlet Mach Number

Valve outlet Mach number is calculated using the following equation:

$M_{outlet} = V_{outlet} / C$

Where:

- M_{outlet} = Outlet Mach number;
- V_{outlet} = Gas velocity at the valve outlet (m/s);
- C = Sonic velocity in the gas (m/s).

Practical Examples: Valve Trim Exit Velocity Head vs. Valve Outlet Mach Number

The following two examples clearly illustrate how limiting valve trim exit velocity head to a maximum of 480 kPa can give process designers a false sense of security or lead them to be overly conservative and specify unnecessary and unnecessarily costly trim designs. In the first, the trim exit velocity head is well above 480 kPa, but the low valve outlet Mach number keeps valve noise within acceptable levels. In the second, the trim exit velocity level is below the 480 kPa threshold, but the valve outlet Mach number is high, resulting in excessive valve noise.

Example 1:

Consider an application with 30,000 kg/hr of air at 100 degrees Celsius. The valve inlet pressure is 30 bar (a) and its outlet pressure is 12 bar (a). According to IEC 60534-3-8, this application is represented by flow regime IV.

A 4-inch globe style valve with a single-stage drilled hole cage is used. Using an 8-inch outlet pipe, schedule 40, valve noise is maintained at an acceptable level of approximately 85 dBA. The trim exit velocity is sonic and, using Equation 2 above, is 337 m/s. The air density at the trim outlet is 11.17 kg/m^3. Using Equation 3 above, the trim exit velocity head is 836 kPa – far above the 480 kPa threshold. The valve outlet Mach number, however, is approximately 0.24.

So, the 4-inch globe valve with a single-stage drilled hole cage achieves a low noise level, even though the trim exit velocity head is far greater than 480 kPa. It is a technically excellent solution, keeping the valve outlet Mach number below the 0.3 level specified in IEC standards, and is much more cost-effective than if a 4-inch valve with a torturous multi-stage trim was used.

[more]

Example 2:

Now consider an application with 70,000 kg/hr of natural gas at 50 degrees Celsius. The valve inlet pressure is 50 bar (g) and the outlet pressure is 5 bar (g).

A 6-inch globe style valve with a 28-stage torturous path trim, capacity (Cv) 110, is used for this application. With a 10-inch outlet pipe, schedule 40, the valve noise level is an unacceptably high 102 dBA. The trim exit velocity head is 300 kPa – well below 480 kPa. The valve outlet Mach number is 0.53. Despite the low trim exit velocity head, the high valve outlet Mach number causes an unacceptably high valve noise level.

If, however, the same trim is installed in an 8-inch globe style valve, the valve outlet Mach number drops to 0.3 and the valve noise level falls to an acceptable level of approximately 82 dBA.

An equally effective, and more cost-efficient, option in this situation would be to use an 8-inch globe style valve with two drilled hole low-noise cages. The noise level would be only slightly higher at 84 dBA, the valve outlet Mach number would remain unchanged at 0.3, and the valve solution would cost significantly less than either of the solutions outlined above.

This example clearly demonstrates that a low trim exit velocity head does not necessarily result in a low noise level in the valve unless the valve outlet Mach number also is low.

Practical Tips for Sizing Control Valves in Gas and Steam Applications

By following two simple steps when sizing control valves for gas and steam applications, specifiers can help ensure that noise levels are kept in check.

Step 1: Be sure that the valve outlet Mach number is less than or equal to 0.3. Choosing the right valve size is key; it is the most important contributor to the valve outlet Mach number.

Step 2: Select the type of trim that will deliver the desired noise level according to the specification. The trim exit velocity head should not be a factor in the selection of control valve trim for gas and steam applications.

[more]

Conclusion

Limiting the trim exit velocity head to a maximum of 480 kPa as a means of managing control valve noise is not practical in many steam and gas applications. More importantly, as demonstrated in the examples given here, this approach can be extremely expensive while being overly conservative in many instances and insufficient to ensure a low valve noise level in other applications.

By focusing instead on finding the valve solution that will provide a low valve outlet Mach number – 0.3 or lower – system designers can help ensure they will achieve the desired low noise levels as cost effectively as possible.

Valve Outlet Mach Number vs. Trim Exit Velocity Head in Gas and Steam Applications	Yes	No
Trim Exit Velocity Head <= 480 kPa Leads to Low Noise Level		X
Trim Exit Velocity Head <= 480 kPa Prevents Valve Vibration and Valve Failure		X
Trim Exit Velocity Head > 480 kPa Leads to High Noise Level		X
Trim Exit Velocity Head > 480 kPa Leads to Valve Vibration and Valve Failure		X
Low Valve Outlet Mach Number is a "Must" to Achieve Low Noise Level	X	
Low Valve Outlet Mach Number is a "Must" to Prevent Valve Vibration and Valve Failure	X	
High Valve Outlet Mach Number Leads to High Noise Level	X	
High Valve Outlet Mach Number Leads to Valve Vibration and Valve Failure	X	
Trim Exit Velocity Head <= 480 kPa is a "Must" to Achieve Low Noise Level and Prevent Valve Failure		X
Low Valve Outlet Mach Number is a "Must" to Achieve Low Noise Level and Prevent Valve Failure	X	

Fig. 1: This checklist summarizes the effects of trim exit velocity head and valve outlet Mach number on control valve noise, vibration and performance.

[more]

About the Author

Joseph Shahda is a senior principal engineer with Dresser Masoneilan®, the leading global partner in process control valves and solutions for more than 125 years (www.dresser.com). A 13-year veteran of the control valve industry, his focus is application engineering, including delivering application solutions for end users worldwide and providing technical training for colleagues around the globe. He has a master's degree in mechanical engineering from Northeastern University in Boston and a Bachelor of Science degree in physics from The American University of Beirut in Beirut, Lebanon. Mr. Shahda can be reached at +1 508 941-5459 or joseph.shahda@dresser.com.

# # #

MEDIA CONTACT:
Piotr Pojedynek
Global Marketing Communication Manager
Dresser Inc., Flow Technologies
+1 281 671 1653
piotr.pojedynek@dresser.com