Severe service - slurries

Knife gate valves applications – Part 1

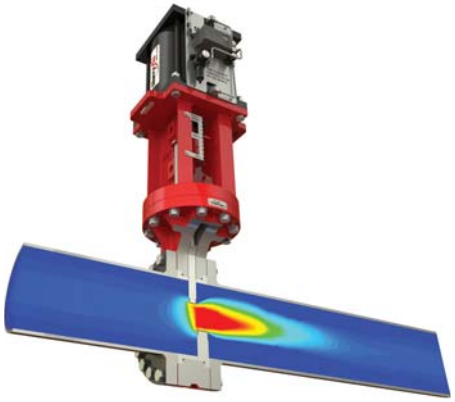
By Gobind Khiani, P.Eng.

In this article we are exploring the flow characteristics of various types of valve designs and the benefits of centering slurry in a piping system to avoid damage to valves, piping and other associated components.

This history on slurries started in pulp and paper, mining and associated industries where industry started using knife gate valves. When the slurries became abrasive and difficult, then industry had to look for severe service valves.

The commercial application of knife gate valves started in the late 1940s when a US company introduced a metal seated valve to the North American Pulp and Paper Industry. Its principal design rationale was to be able to close against a solution of water and pulp or paper fibers and be low cost to produce.

The performance required of this valve type was low, as the solution (pulp stock) would dewater and eventually provide a seal from the wood fiber itself. Once the valve was opened, the pulp stock would be flushed through the full port valve opening.



Abrasive slurry flow is centered within the pipe by a variable orifice gate style control valve.

Due to its low purchase cost, the valve became quite successful and many manufacturers began to produce copies of the original knife gate valve. Manufacturers Standardization Society of the Valve and Fittings Industry, Inc (MSS) came up with a document MSS-SP-81, which was created, and it remains today, as the basic knife gate standard encompassing 10bar rated valves from 2" through 24" entitled "Stainless steel or Stainless Steel Lined, Bonnetless, Knife Gate Valves with Flanged Ends". The Standard had, and still has, very limited testing and performance requirements.

In the 1960s a Swiss design engineer patented a new variation of knife gate that was truly a cutting or shearing valve. It was made in two body halves that allowed the gate to be housed in one of the halves so that it could be guided. Guiding allowed for the cutting action as it provided a second cutting edge on the static side of the body half, much like a pair of scissors. Even the sharpest pair of scissors won't cut paper if the two sharp blades are loose and with very tight tolerance together. Manufacturers further used this basic design and enhanced it into their current offering as a guided shear gate, control gate for applications in much higher pressure of up to 100bar/1500psig (approx) to comply with ASME B16.34 pressure classes 150, 300 and 600.

The MSS caught up to the current technology in 2014 and came up with following codes:

MSS-SP-146-High pressure, Lug and Wafer-Type, Iron and Ductile Iron Knife Gate Valves & MSS-SP-Low pressure Flanged or Lugged Carbons Steel and Iron or Ductile Iron, Cast or Fabricated, Bonnnetless, Knife Gate Valves without Liners.

Challenging scenario

While industry and technology is running at its own speed, in the world of control valves there are numerous designs that will successfully modulate the flow of clean fluids. However, if the media contains solid particulates, the scenario is more challenging. Many of these 'clean fluid' valves are not viable for slurry duty, as their angular flow paths can become eroded or plugged.

End users looking to modulate the flow of abrasive slurries must select valves with 'line-of-sight' trim geometry, (i.e. butterfly, ball, pinch or knife-gate valves). These designs provide minimal flow re-direction, as they modulate via an increase in the fluid velocity. Accelerating slurry through line-of-sight valves does come with compromises, particularly when pressure drops are elevated, making them susceptible to cavitation and increased erosion. This can result in more frequent valve replacements, potential damage to downstream piping and downtime associated to repairs.

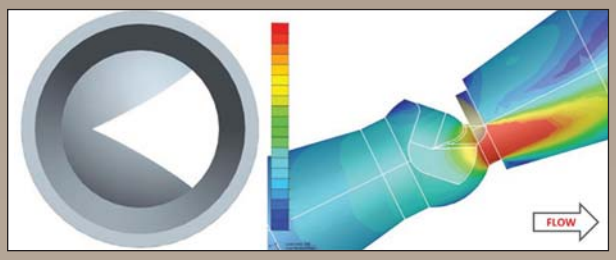
A new design

A manufacturer of control valve technology continuously engaged in research and development came up with a solution to the compromises of line-of-sight valves. In the early 2000s, an oilsands mining company was using knife-gate valves to modulate abrasive slurry. These heavy duty valves worked with some success, however their service life was short. After three weeks in service, the valves had to be replaced due to excessive wear. The continuous cycle resulted in frequent expenditures in

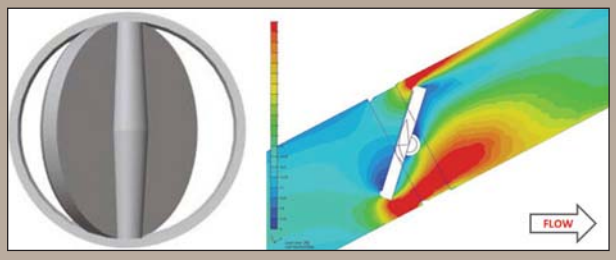
Variable orifice gate style control valves are ready for slurry service.

Modulating the flow of abrasive slurry is challenging. When the fluid passes through a control valve, the restricted openings cause the media to accelerate. This high velocity slurry is directed into the valve's body and downstream pipe wall. The continuous erosion often results is frequent valve replacements, damaged piping and downtime.

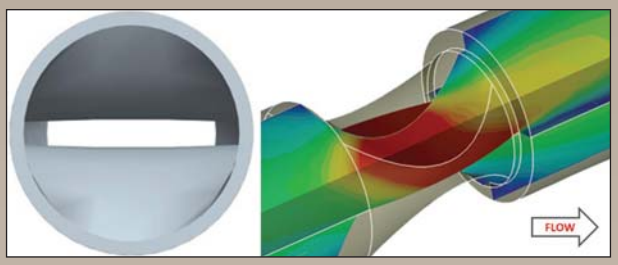
Ball valve: A ball valve directs abrasive flow to one side of the valve and piping, damaging both.



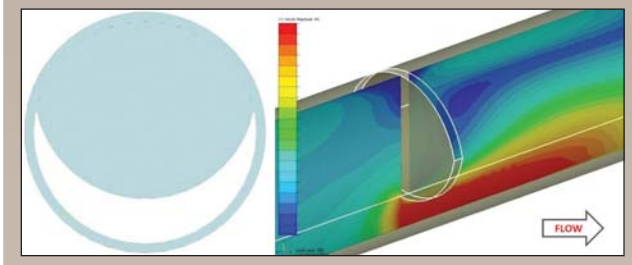
Butterfly valve: The disc accelerates abrasive media onto both sides of the valve body and pipe walls.



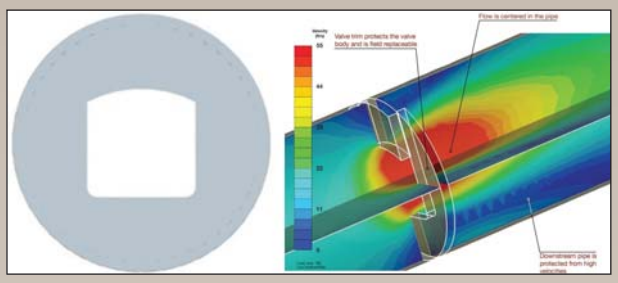
Pinch valve: High velocity flow wears both sides of the valve's sleeve and downstream pipe.



Knife gate valve: These make terrible control valves, as the bottom of the valve and pipe erode quickly.



Variable orifice gate style control valve: A trim design which acts as a variable orifice, centering the flow within the pipe. This protects the pressure containing valve body and the integrity of the downstream piping.



labor and product, yet the most significant issue was decreased oil production. Pipe line shutdowns were costing the company millions in lost annual revenue.

Engineers reviewed the process data, the current valves in service and the client's requirements. The replacement design had to fit within the same face-to-face dimensions, therefore maintaining the basic knife-gate valve layout was critical.

The final prototype introduced a design that was a radical departure from all other line-of-sight valves.

The traditional 'convex' gate shape was inverted to be 'concave', with a much narrower profile. The gate works in concert with a second flow restriction element, called the seat plate. The plate is a fixed restriction that sits in the flow path (at the 3, 6 and 9 o'clock positions), directing flow towards the middle of the pipe. The concave gate located at the 12 o'clock position completes the circle, resulting in a centered orifice with variable control. The design protects the pressure containing valve body and the integrity of the downstream piping.

The resulting service life for this application increased from three weeks to two years.

Such research and development of technology in the valve industry led to a patented valve for abrasive applications.

Example 1: a client was utilizing 6 x 20" ANSI 300 titanium butterfly valves for abrasive slurry control. After 28 days, the valves were pulled from line and replaced, resulting in over 70 valve replacements per year. The titanium control valves now in service do not require maintenance for 12 months.

Example 2: An Australian mine had several modulating ANSI 150 6" pinch valves, each with rubber sleeves being replaced on a weekly basis. With control valves installed, the site can operate for several months without stopping to service valves.

Example 3: In northern British Columbia, a producer of natural gas switched their ANSI 600 ball valves in favor of control valve technology. Despite the combination of high pressure and severely abrasive slurry, they observed a quantum leap in service life and significant reduction in valve replacements. Due to their initial success, the natural gas producer recently standardized on this type of 'knife gate style' control valve technology for several new gas plants.

Gobind Khiani, P.Eng., is a Lead Discipline Engineer at Fluor Corporation, Canada and writes regularly for Valve World.