Valve Selection in Severe Abrasive Service

Severe abrasive service valves have become a critical component in the design and operation of varied industrial processing plants. Whether it be catalyst, harsh polymers, chemical slurries, waste materials in mining, or the transportation of mineral slurries at low and high pressure, all such applications need cutting edge technology compared to conventional liquid and vapour services. This advanced technology would not be possible if manufacturers were not able to design and provide equipment that can operate reliably in services where abrasive fluids exist. The modern design of such valves has become more complicated due to the use of highly sophisticated process controls, varying types of process media, increased sizes, higher pressures, and in some cases elevated temperatures. These complexities and variables have specifically challenged valve designers and manufacturers, who need to work closely with the engineering design companies and end-users alike, to find viable, cost-effective and more importantly, reliable solutions. Some process requirements could not be possible if the valve designers had not innovated existing designs to accommodate highly abrasive process environments. This paper examines how the application of severe abrasive service valves has become an important component in the successful design, construction and operations of processing plants throughout the world. Supporting data is provided by the use of actual working examples from existing applications. All cases involve slurry applications; i.e. those with a liquid carrier fluid.

By Ross Waters and Malcolm Harrison – CGIS

Abrasion, is the process of scraping or wearing away of a softer material by a harder material. Abrasion is one of the three main destructive agents that challenge the operation of valves used in slurry applications. Alone, it can be a devastating effect causing valve failure, but together with erosion and corrosion, it becomes a more significant challenge in valve selection and design.

Options for High Pressure Systems

High pressure systems typically operate above ~10MPa but owner's choice may dictate the use of common valve types in all systems, within the same plant. The best choice for these systems would be ball valves with metallic seats.

Metal Seated Ball Valve Types:

- Fixed seat design, where the seat is an integral part of the body.
- Fixed seat design, where the seat is welded in-place.
- Fixed seat design, where the seat is retained by a bolted ring.
- Loose seat design, where the seat is allowed to float in either direction depending upon pressure.
- Loose seat design where the fluid pressure is allowed to force the seat against the ball surface (trunnion mounted design).

All metallic seated ball valves must have a sealing seat and ball that is protected from the erosive (and in some cases corrosive) nature of the slurry. Most common for erosion resistance is a thermal spray hard coating technologies such as High Velocity Oxygen Fuel (HVOF). This method utilizes confined combustion and an extended nozzle to heat and accelerate the powdered coating material. Typical HVOF devices operate at hypersonic gas velocities, i.e. greater than MACH 5. The extreme velocities provide kinetic energy which help produce coatings that are very dense and very well adhered in the as-sprayed condition.

Another method used when there is potential corrosion capability of the slurry is Plasma Spray. The plasma spray process uses inert gases fed past an electrode inducing the "plasma" state of the gases. When the gases exit the nozzle of the gun apparatus and return to their normal state, a tremendous amount of heat is released. A powdered coating material is injected into the plasma "flame" and propelled onto the substrate. Ceramic Coatings are most often applied using plasma spray due to their high melting temperatures (Often > 1900 C). Several types of ceramic coatings can be applied using plasma spray.

Figure 6: HVOF RiTech® Coating of Ball Component

Figure 7: Plasma Spray of Ball Component

Figure 8: Coated and Mate Lapped Loose Seat Component]

For all thermal spay coatings, the coated parts are then lapped separately before mate lapping, where the contact surface becomes so highly polished that small particles cannot pass between these parts, in a fully assembled valve.

There are also variations on the basic thermal spray coating where nano-structured coatings are used to produce a highly dense coating that is almost totally impervious to corrosion. In all cases the purpose of the coating is to protect the internal components of the valve from the process fluid. In some applications where abrasion is very high, even the bore of valve is coated for protection from erosion.

Application Examples in High Pressure

Wear and Seal - In a "Wear and Seal" (also known as martyr and master) arrangement the downstream valve is cycled first taking the wear of the flowing slurry. After the valve is closed the upstream valve is then cycled with no differential pressure ensuring secure isolation of the pipeline.

Choke Stations - Particularly with gravity systems and also for pumped systems, accumulated pressure must be dissipated for safe pipeline operation. Choke stations are a method and apparatus for protecting against the abrasion of pipe walls in a slurry pipeline caused by slack flow, when the pipeline is operated in the batch mode (water or various slurries are delivered through the pipeline). Pressure transducers sense the pressure at each relatively high point of the pipeline as an interface between a water batch and a following slurry batch that passes that point. When one of the sensed pressures falls below a predetermined low value of pressure, a control device actuates valves that divert the flow downstream in the pipeline through a staged choke containing flow restrictors, thus raising the fluid pressure in the water batch which then counteracts the effect of the static head of the slurry batch. The flow is redirected away from the staged choke when one of the sensed

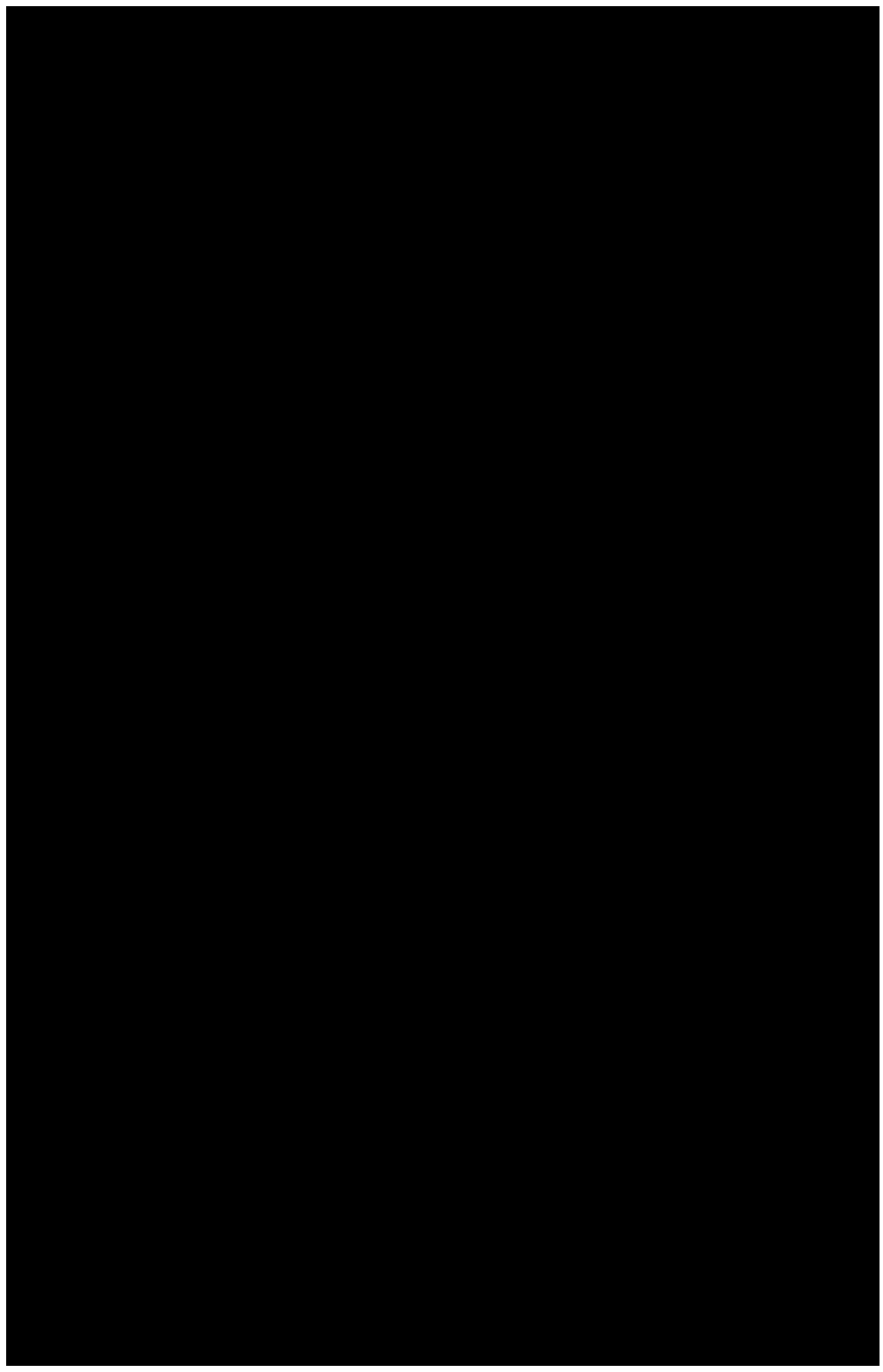

Figure 9: Internal View of Ball Valve Showing HVOF Bore Coating]

Figure 10: ValvTechnologies Pipeline Station Isolation "Wear and Seal" Arrangement

Figure 11: Typical Choke Station with Fixed and Variable Chokes]

pressures exceeds a predetermined high value of pressure, thus lowering the fluid pressure and preventing pipe wall overpressure. The choke branch isolation valves need to operate under high differential slurry flow conditions and provide zero leakage when closed.

Valve Station Isolation (Bidirectional) When a long distance slurry pipeline has extended portions of the line that may see pressure in either direction, valves are needed that can seal from either direction or should be installed such that when they are closed they see pressure on the preferred sealing end. These valves can see high cycling under conditions where the abrasive slurry may fall out of the preferred flow regime. Designing the valve internals for protection against erosion is critical in maintaining reliable operation.

Conclusion

By selecting the correct severe abrasive service valve, maintenance can be virtually eliminated and installed costs can be drastically reduced. True full port valves ensure an unrestricted flow path, minimize pressure drops and limit premature wear. Most valves can be manually operated but more frequently, in modern projects, are automated with pneumatic, electric, hydraulic or electro-hydraulic actuators. In higher pressure applications automated ball valves can provide cycling speeds that can match that of most operational requirements.

Now, more than 50 years after the first significant commercial slurry pipeline, valve engineers have the advantage of many innovations that came from varying resources including the NASA space exploration program. Using the correct valves for slurry applications is not only attributed to the modern advances in the application of modern elastomers and hardened materials used in knife gate valves, but also extremely hard coatings used for the surfaces of balls and seats in slurry ball valves. Credit is also given to the advances of easy access to complex finite element analysis (FEA) modeling tools, used to design the valves for such high pressures (up to 28 MPa). Without such technological advances the options available may have been too unreliable and too maintenance intensive to allow developers the capital approval for projects to proceed.

Figure 12: ValvTechnologies Pipeline Isolation Valves for Bidirectional Operation

Since the first commercial slurry pipeline was built, the effectiveness of transporting abrasive mineral slurries over long distances and at high pressure has become almost common-place. Projects transporting abrasive, erosive and corrosive slurries of iron, copper, zinc, phosphate, nickel, coal, as well as waste material (tailings) for many minerals, have been constructed and continue to operate reliably and profitably.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the following companies for the use of pictures used in this paper:

- CGIS AITF Slurry Test Loop – Canada (Figure 3)
- BHP Billiton – Australia (Figure 4)
- Fortescue Iron – Australia (Figure 5)
- ValvTechnologies, Inc – USA (Figures 6,8 & 9)
- Samarco Mineração – Brasil (Figure 10)
- Compañía Minera Antamina – Perú (Figure 11)
- OCP – Morocco (Figure 12)

REFERENCES

WASP, EDWARD J., KENNY, JOHN P., GANDHI, RAMESH L., Solid-Liquid Flow Slurry Pipeline Transportation, Trans Tech Publications, 1977

HARRISON, MALCOLM J., Severe Service Ball Valves for High Pressure Slurry Pipelines, Rio Pipeline Conference Proceedings 2009©

HARRISON, MALCOLM J., HUNT, KEVIN, Metal Seated Ball Valves for the Flow Control of Abrasive Fluids. In: Conference on Tailings and Mine Waste '98, Fort Collins, Colorado, USA: A.A. Balkema 1998.

WATERS, ROSS, Defining Severe Service Valves, Valve World, 2015

ABOUT THE AUTHORS

As the President of CGIS, Ross Waters has dedicated 35 years of his life to serving and improving the valve industry. Ross started CGIS, a valve distribution company, in 1980 in a small office in Vancouver, Canada. Thirty-five years later, the business has grown internationally and now serves clients and industries worldwide. Ross is the driving force behind increasing awareness of Severe Service Valves and is part of a MSS task force writing its definition. He has attended numerous conferences around the world presenting his paper, "Defining Severe Service Valves" and is well onto establishing himself as the leading expert in Severe Service. Ross is also an avid member of ASTM International G04 and has served as an expert witness.

Malcolm Harrison was born and educated in the UK and received a bachelor's degree in mechanical engineering. After a successful career with major EPC's working as a mechanical and piping design engineer, Malcolm relocated to the USA in 1980 to work for Bechtel in San Francisco. He eventually entered the world of valves sales in the early 1990's. First with a specialist valve sales representative company and then as mining products industry manager with Houston based, ValvTechnologies. In late 2014 he retired started his own consulting company, Fluid Equipment Consulting. Malcolm now uses his vast experience to offer subject matter expert services related to all types of valve requirements.