High Performance Butterfly Valves

Until the 1950s, the predominant valve types used in industrial service were long-stroke linear gate valves for on/off applications and globe valves for control. To counteract the problems inherent with linear valve designs, which included relative large size and weight, high operating force and tendency to leak, the rotary ball and butterfly valve designs were introduced. The 1960s marked the introduction of the high-performance butterfly valve.

Instead of a long stroke, the rotary valve requires just a quarter turn (90°) to cycle from the full open to full closed position. The compact design results in a smaller and lighter valve. The short travel distance and reduced surface friction means that the rotary valve can operate with a much smaller and less expensive actuator, and the complete valve package can be significantly smaller and lighter for ease of installation. Reduced moving surface contact area within the rotary valve body has made it possible to develop high-performance sealing technology that can eliminate internal leakage.

A butterfly valve is a rotary valve that uses a disc as the closure member. Butterfly valves are normally of wafer design, fitting directly between piping flanges. Butterfly valves can be either symmetric or eccentric (i.e., the stem is offset from the center of the disc).

The concept of a high-performance butterfly valve was first advanced by the U.S. space program in the 1950s. There was a need for a compact, lightweight, tight shut-off valve for the Atlas rocket fuel system. The valve used for this purpose was a single seat, unidirectional shut-off valve with a single offset disc that operated against a polymeric seat. Since the space race launched the high-performance butterfly valve, there have been many design enhancements that improve butterfly valve's performance and range of applicability.

Today, butterfly valves have proven their endurance and dependability in a wide range of industries and applications. They are available in line sizes from 2 1/2" to over 72", temperature ratings from cryogenic to 1500° F, and pressures to 1440 psi. Butterfly valves are used in isolation and control services, and with media such as slurries, steam, gases and liquids. Some of the notable applications include pulp stock, corn processing slurries, tertiary petroleum recovery, high pressure water, high cycle air separation services (both at ambient and cryogenic temperatures), LNG and commercial HVAC to name only a few.

Disc and Shaft Design

Modern, high-performance butterfly valves frequently have a double-eccentric design. First, the sealing plane of the disc is offset from the axis of rotation. This provides an uninterrupted circular sealing surface on the disc that makes it possible for a circular sealing element to be placed in the valve. It can be easily removed from the valve without disassembly of the shaft/disc closure elements.

Second, the axis of rotation of the disc is laterally displaced from the true center of the disc so that it will "cam" away from the seat to eliminate jamming or squeezing as the valve is opened and closed. This design eliminates wear points around the disc at the top and bottom of the seat. When closing, the disc cams tightly into its seat to create a bubble-tight seal with consistent torque. This eccentric rotation has a tremendous impact of extending the duration of the valve's leak-free performance.

Seat Design

Since the disc in a butterfly valve is fully supported by the shaft and its bearings, the seat is required only to perform a sealing function, not a strong supporting function, as is common with most ball valve designs. There are many seat designs.

Metal seats, which are more popular in Europe, provide consistent, long-lasting shutoff, but they are not considered bubble-tight. Services which require 100% tight shutoff must rely on soft seats.

Conventional “jam” seats are non-flexing designs that use mechanical devices, such as O-rings, braided cable reinforcements or metal springs within to deform the material into contact with the disc. These types of seats do not compensate well for wear or thermal differences within the valve. They also tend to lose their sealing performance as line pressures increase.

One-piece, flexible-lip, polymeric seats (typically PTFE) do not rely on metal back-up springs or O-rings for flexing. Therefore, they can be exposed to a wide range of temperatures and corrosive media. This design consists of a flexible lip that is pressure energized to move against the outer edge of the disc, which is a spherical segment, to create a bi-directional seal. The body and insert hold the seat in position and shield it from flow, which protects it from abrasion and erosion as well as fold-over in high velocity applications.

The key to successful PTFE seat design is to overcome the material’s tendency to cold flow and lose its shape under a compressive load. With the proper seat geometry, PTFE actually has a broad elastic range and resists cold flowing at compressive load levels up to 10 times the sealing stress required for ANSI class 150 and 300 applications. The single-piece seat geometry provides for thick cross sections throughout the seat, pre-compression of the seat for low pressure sealing and clearances surrounding the seat to allow flexibility.

For many severe process applications, butterfly valves are offered with composite polymeric/ metal seats. These designs employ the pressure-energized flexible lip seating in combination with a metal carrier that offers secondary sealing in the event of a fire, compensation for thermal cycling in cryogenic applications, or serves as a protector with media that tends to plate or cake on the seat.

Butterfly valves are frequently supplied with specially designed seats to solve problems in a wide range of industries and applications — from coal gasification where the combination of very low differential pressure, solid particles and high pressures are present, to fluid catalytic cracking (FCC) applications where solids, abrasion, fines and high temperatures are all problems, to extremely critical delayed coker switching device applications where media buildup in the valves can cause a process to shut down.

Seat Material Options

Over the years, polymeric seat materials have evolved. New materials are evaluated routinely. Today, many alternative materials are readily available to satisfy even the most demanding process requirements.

PTFE.

The basic butterfly valve seat made of virgin PTFE provides both a wide operational temperature range (-100^{o} F to 400^{o} F) and chemical compatibility to fill the widest possible range of service applications.

Filled PTFE.

The most frequently used material is a “modified” or “filled” version of PTFE. This material has less corrosion resistance than PTFE but can operate at higher temperatures and pressures. The mixture also provides better abrasion resistance. It has, therefore, become a standard against which other types of seat materials are compared. All other material alternatives are measured by their improvements - or lack thereof - over the performance of modified PTFE.

Composite Metal/Polymer-Fire-Tite®.

316 Stainless, Alloy 20 or Monel / PTFE or other polymer composite seats are used for fire safe or applications where coking or abrasive media is present. The Fire-Tite design provides sealing during and after a fire and meets API and BS standards. Monel and Alloy 20 are particularly used for corrosion resistance in many petroleum process applications.

UHMW Polyethylene.

Used for higher radioactive applications where PTFE is not acceptable. This material also meets the requirements of the tobacco industry where PTFE is not acceptable and is especially well suited for handling highly abrasive media.

KEL-F®.

This material, PCTFE, is used extensively in cryogenic services handling industrial gases and liquefied propane(LPG) and natural gas (LNG).

Flow Characteristic.

The flow characteristic is a curve that compares the percentage of flow to the percentage of valve travel (i.e., butterfly disc rotation or linear movement of a globe valve). Inherent flow characteristic applies to situations when constant pressure drop is maintained across the valve. Installed flow characteristic takes into account the variations in the pressure drop caused by conditions in the system where the valve is installed.

Common inherent flow characteristic for various valve types include quick-opening, linear and equal percentage. With the quick opening flow characteristic, the valve achieves most of its flow before the valve has been opened more than 50%. The inherent flow characteristic is said to be linear when the amount of valve opening is proportional to the rate of flow. With an equal percentage flow characteristic, the amount of valve opening and the amount of flow increases by a fixed percentage.

The quick opening flow characteristic, common to globe valves, inhibits precise control of media particularly at low flow rates. For most applications, high-performance butterfly valves make good control valves because of their modified equal percentage flow characteristic. This curve approximates the linear flow for greater throttling precision and control stability, resulting in decreased process variability.

Butterfly Advantages

Butterfly valves are the fastest growing segment of the total valve market today because of their numerous advantages, which include:

Tight Shutoff.

Offset shaft and eccentric disc arrangements combined with modern single piece, flexible-lip, polymeric seats provide bubble-tight shutoff over a wide range of operating conditions.

Reduced Torque Requirements.

The rotary design of butterfly valves and minimal wear surfaces dramatically reduces torque requirements. Therefore, they can be operated with smaller, less expensive actuators.

Lightweight/Compact.

Because the butterfly valve has a significantly narrower face-to-face dimension and a shorter centerline to the top of the valve profile, it uses less metal than a gate valve. The result is significant weight and size reduction for the same or higher rating. These factors also have a positive impact on piping and plant design.

Significantly lower weight, particularly in the larger sizes, means lower piping stress and reduces the number and/or size of the pipe supports. It also results in less load transmitted to the structural steel. Finally, smaller size and lower weight can translate into significantly fewer man-hours to install valves, especially for larger sizes.

Extended Cycle Life.

The double eccentric disc and shaft, in combination with polymeric seats, reduces seat wear and dramatically increases leak-free life cycles.

Ease of Automation.

Butterfly valves are easily automated. Every valve is drilled and tapped to accept linkage for a broad range of actuators. Unlike the gate valve, there is no need to purchase a special yoke or other device to modify the gate valve body to accept actuation. And because butterfly valves are quarter-turn, the actuated valve profile is much smaller than linear valves.

Wide Temperature Range.

High-performance, flexible-lip seals extend the operating temperature range of butterfly valves.

Ease of Maintenance.

Compared to many valve types, butterfly valves are easy to maintain. In one design, the insert can be removed with a screw driver and the self-aligning seat replaced. All this can be done on site and the valve can be put back into the line immediately. No machining is required as with gate valves.

Reduced Emissions.

Stem leakage is a routine maintenance problem with most linear valves. A leak path is easily generated from the vertical and/or long multi-turn strike of the stem through the packing. The packing gland must be frequently tightened, and in some cases grease injection is performed, but this rarely results in completely eliminating stem leakage. This is a major concern today as clean air emission requirements must be met worldwide. In contrast, the butterfly valve shaft rotates only 90^0 within the stem packing. This minimizes the potential for leakage. Should leakage occur, it can be eliminated by simply tightening the packing gland. The gland compresses the V-Ring packing, spreading the "wings" of the rings and creating a tighter seal. Because the packing is not jammed, the torque remains constant. For applications where more stringent emissions control is required, butterfly valves can be equipped with a spring-loaded packing arrangement.

Lower Costs.

Butterfly valves are less expensive than most other valve types. With actuation, the total cost ratio of the valve package is reduced even further, especially in larger sizes. Ease of maintenance, actuation and installation can also dramatically reduce total life cycle costs.

Disadvantages

The primary drawback of a butterfly valve is that the disc and shaft are situated in the waterway. Therefore, butterfly valves are inappropriate designs when full flow is required, or when a device (i.e., a pig) will be periodically used to clean the lines.

Highly abrasive media also present a problem for butterfly valves because they erode the disc. The operation and closure of the disc in a butterfly valve may also be impeded in very thick media such as slurries. In these instances, a ball or knife gate valve may provide more cost-effective performance.

For control applications, butterfly valves may not always provide an appropriate flow characterization for the control scheme. In these instances, other types of valves, although more expensive, may be used for improved control repeatability.

Continued Growth

With few exceptions, high-performance butterfly valves provide tight shutoff, a long life cycle, and life cycle costs that are lower than any other alternative. Large numbers of butterfly valves are being used today to replace both globe and gate valves, which were first specified decades before the development of the high-performance butterfly valve. Butterfly valves also may be a more cost-effective replacement for ball valves. The total presence of butterfly valves will continue to grow in comparison to other valve types as they make their way into more industrial shut-off and control applications.

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