A Literature Review of Butterfly Valves

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ABSTRACT: A butterfly valve is a type of flow control system which is commonly used to control a fluid that flows through a pipe segment. Analysis and optimisation are actually of particular importance in the design and use of butterfly valves. Finite element method (FEM) is often used for the analysis to predict valve disk protection, and computational fluid dynamics (CFD) is widely used to analyse valve flow characteristics. However, due to the high non-linarites, reliable results are difficult to obtain for optimizing butterfly valve. This reason there is widespread use of met models or replacement model methods. This paper combines the met model with the FEM and CFD research to optimize a conventional butterfly valve, where the design goal is the weight of the valve disk, and the strength of the disk and the pressure loss coefficient of the valve are constraints. Ball and butterfly valves are quarter-turn style valves which are commonly used in the oil and gas industry to stop and start (isolate and open) the fluid flow. Ball valves have a very robust nature and for aggressive process services involving flammable and potentially dangerous fluids such as hydrocarbons they are a very common option. Butterfly valves in process facilities are not as robust as ball valves, and thus require higher maintenance costs.

KEYWORDS: Ball Valve, Butterfly Valves, Fluid Analysis, Globe Valve, Pressure Loss Coefficient.

INTRODUCTION

A butterfly valve is a type of flow-control system, typically used as a control valve in applications where the valve has relatively low pressure drop requirement. Typical uses may include equipment insulation, fill or drain systems, bypass systems and other applications where the only flow / pressure management requirement is whether they should be on or off. The ball valve having disk is still present inside the flow; the pressure drop is therefore still caused in the flow irrespective of the location of the valve. In a piping system, valves are mechanical devices that are used to steer, stop, start, mix, and control process fluid flow, pressure, or temperature. Straight globe valves commonly used in the oil and gas industry permit regulation or control of the flow [1]. The working principle of straight pattern globe valves is that flow reaches the centre of the valve where the seat and plug are located. The flow makes a 90-degree turn toward the seat, followed by a further 90-degree turn to the outlet port as shown in Figure 1.

Since the butterfly valve has a significant effect on the fluid that flows through it, several researchers have done a lot of work to study the fluid characteristics of the butterfly valve. The ball valve having disk is still present inside the flow; the pressure drop is therefore still caused in the flow irrespective of the location of the valve. Since the butterfly valve has a significant effect on the fluid that flows through it, several researchers have done a lot of work to study the fluid characteristics of the butterfly valve. In the middle of the valve there is a small region vena contracta, where the pressure is at a minimum point and the velocity is at a maximum. The pressure at the narrow area below the plug can drop below the vapour pressure of the liquid in many globe valves in liquid services. Flashing will occur as the gas bubbles from the liquid are vaporised. The bubbles absorb the energy and collapse, producing waves of heat. As a result, the pressure waves will damage the globe valve seat, plug, and body. Cavitation in the trim seat and plug body, and downstream piping may create irregular pits and erosion [2].

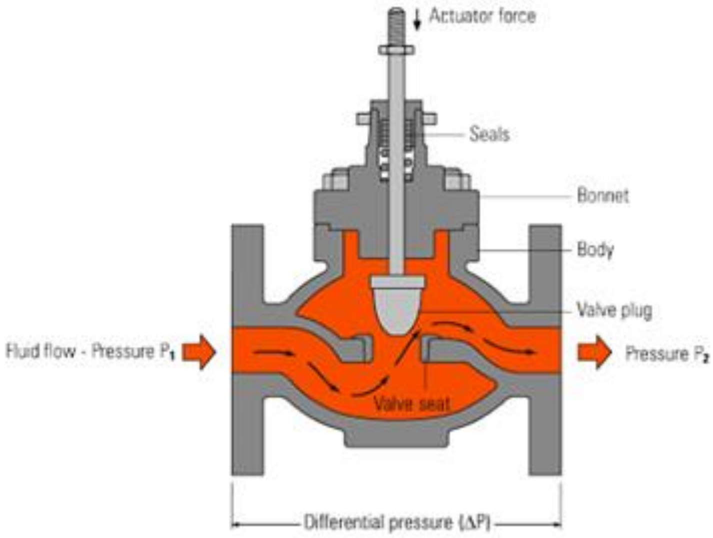

Figure 1: Flow Path in a T-Pattern Globe Valve

Figure 2 demonstrates damage to cavitation in the form of tiny pits very close to damage to corrosion in the globe valve plugs. Cavitation which intensifies the corrosion effect is called corrosion in the cavitation [3].

Figure 2: Cavitation Corrosion in Plugs of the Globe Valves

PRESSURE LOSS COEFFICIENT

For a given valve-opening angle, the pressure loss equation is used to compare the pressure loss of a valve to the valve-dump. K1 is the most commonly used feature nowadays for valve size and pipe network. For most applications, a correct valve size can be reliably calculated by using K1. This article adopts the Huang and Kim determined equation:

$$K_1 = \left(\frac{v_1^2}{2} + \frac{P_1 - P_2}{\rho}\right) \times \frac{2}{v_2^2} - \left(1 + \frac{f \times L}{D}\right)$$

Where P1 and P2 apply to the upstream and downstream static pressure of the valve disks, and v1 and v2 are the corresponding upstream and downstream velocities, respectively. L reflects the distance between P1 and P2. D is the diameter of the hydraulic tube and is the size of the valve bore. And f is the circular pipe friction factor in the turbulence flow, 0.013 in this investigation [4].

TYPES OF BUTTERFLY VALVES

Butterfly valves have a small circular shell, a round disk, and metal-to-metal or soft seats, shaft bearings at the top and bottom, and a stuffing case. The body of a Butterfly Valve varies in design. A widely used design is the type of wafer which fits between two flanges. The lug wafer design is held in place by bolts between two flanges which connect the two flanges and pass through holes in the outer casing of the valve. Also with flanged, threaded and butt welding ends, butterfly valves are available but they are not always applied. Butterfly valves have many benefits over gate, globe, plug, and ball valves, especially for large valve applications. The most noticeable benefits are weight, space and cost savings. The repair costs are typically small since the number of moving parts is limited and there are no pockets for collecting fluids.

Butterfly valves are especially suitable for handling large flows with at relatively low pressures with liquids or gasses and for handling slurries or liquids with large amounts of suspended solids. Butterfly valves are built upon a pipe damper concept. The flow control function is a disk about the same diameter as the adjacent pipe's inner diameter, which rotates on either a vertical or horizontal axis. The valve is completely opened when the disk lies parallel to the run of the pipes. The valve is shut as the disc reaches the perpendicular position. The intermediate positions can be locked in place by handle-locking devices for throttling purposes [5].

BUTTERFLY VALVE BODY CONSTRUCTION

The body design of butterfly valves varies. The most economical is the type of wafer, which fits between two flanges of the pipeline. Another type, the lug wafer style, is held in place by bolts between two pipe flanges, which connect the two flanges and pass through holes in the outer case of the valve. Butterfly valves are available for bolting to pipe flanges with traditional flanged ends, and in a threaded finish. The stem and disk are different parts for a butterfly valve and receiving the stem is bored to the disk. There are two methods to bind the disk to the stem such that the disk rotates as the stem turns [6]. The disk is bored through in the first form, and secured with bolts or pins to the stem. The alternative approach involves boring the disk as before then shaping the bore of the upper stem to match a squared or hex-shaped stem. This way the disk will "float" and look for its core in the seat. Uniform sealing is done and external stem fasteners are removed. This assembly method is suitable for closed disks and in corrosive applications. The stem must stretch beyond the bottom of the disc and fit into a bushing in the bottom of the valve body to keep the disk in the appropriate position.

There are also one or two identical bushings along the upper portion of the stem. Such bushings must either be immune to the media being treated or sealed to avoid interaction with the corrosive material. Stem seals are made either by packing them in a traditional stuffing box or by sealing them with an O-ring. Many valve manufacturers, particularly those who are skilled in the handling of corrosive materials, put a stem seal on the inside of the valve so that no material handled by the valve can come into contact with the valve stem. When a stuffing box or external O-ring is used, the fluid that passes through the valve is in contact with the valve stem [7].

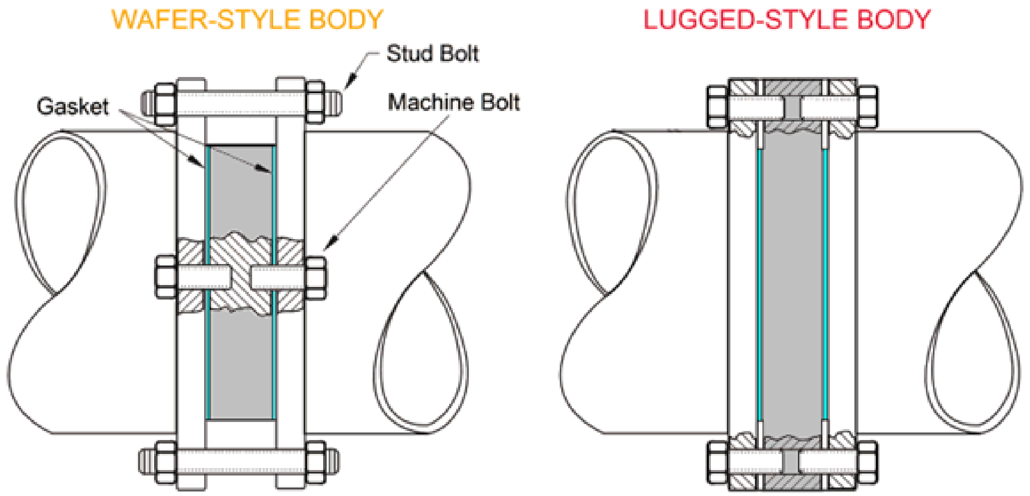

Figure 3: Butterfly Valve Body Construction

BALL VALVE VS. BUTTERFLY VALVE

The ball values short and long patterns and butterfly valves in pressure class 150 ranges from 4 "to 20" scale. ASME B16.10, Face-to-Face and End-to-End Valve Dimensions, and API 609, Butterfly Valves: double flanged lug and wafer are standards for the ball and butterfly valve face-to-face dimensions respectively are shown in Figure 3. The standard API 609 includes two types of butterfly valves. Category A is the combined disk and seat configuration and Category B has an offset disk configuration, known as an eccentric butterfly valve or high-performance butterfly valve. A double offset butterfly valve of category B in wafer design is contrasted to a ball valve here. A butterfly valve category B has been chosen for comparison, because this type of valve is more durable and needs less maintenance compared to category A. One downside to butterfly valves is that the valve disk is exposed to the flow, which causes pressure loss. Additionally, butterfly valves with lower flow capacity and higher pressure drop compared with ball valves are reduced bore. Butterfly valves are also not approved for sizes smaller than 4". The Figure 4 reveals that face-to-face measurements of butterfly valves in sizes 4 "to 20" and average pressure class 150 are around 84 per cent more compact than even short ball valves [8].

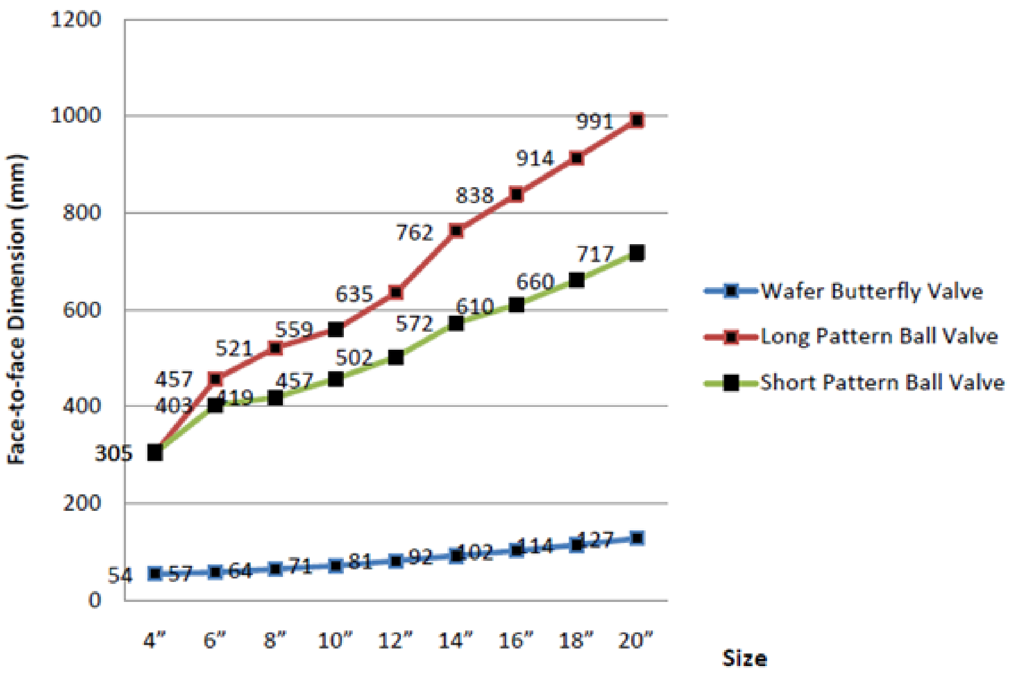

Figure 4: Comparison between Wafer Type Butterfly and Ball Valves Face-To-Face

FLUID ANALYSIS

Fluid analysis is performed to analyse the flow patterns and to calculate the coefficient of pressure loss of this butterfly valve as the butterfly valve operates with different opening positions. A half-symmetric butterfly valve CFD model is produced with a scale of 1:1 to produce a better result and to save machine time. The bolts and nuts for repairing the disk are simplified with some effects on the open position flow properties. To provide a static fluid domain, an upstream pipe L1 with a length eight times that of diameter (8D) and a downstream pipe L2 with a length ten times that of diameter (10D), checked long enough for this simulation are inserted [9].

Figure 5: Configuration of The Butterfly Valve's Disc

The steady-state simulation is carried out without considering the transfer of heat and water is used as a working fluid and thus the flow is incompressible at a standard temperature of 25°C. Because of its robustness, economy and reasonable accuracy, the standard k – ÿ model is chosen for predicting turbulent flow calculations. The maximum velocity through this valve cannot be greater than 4.88 m/s, according to the American Water Works Association specification. Therefore at the inlet boundary a uniform velocity of 4.88 m/s is put. Figure 5 shows the pressure contour and velocity vector for the 15 and 90 valves opening on the symmetry plane near the disk area. Through the distribution of the velocity one can see how the butterfly valve influences the fluid that flows through it.

Due to the apparent difference between the opening region at 15 and that at 90 ranges, the velocity across the disk at 15 ranges is slightly higher than at 90 ranges, and thus the pressure distribution is more consistent with the 90 ranges opening. The configuration of butterfly valve disc is shown in Figure 5. Those contours cannot be used directly to estimate the valve output. To estimate the butterfly valve output the pressure loss coefficient K1 is needed. For this form of butterfly valve the coefficient of pressure loss should be as small as possible. Since this valve only operates at 90 rpm full opening, only the pressure loss coefficient at 90 rpm is measured and optimized in this article; using equation this butterfly valve's pressure loss coefficient is found to be around 0.48 at 90 rpm [10].

PRINCIPLE OF OPERATION

Butterfly valves have a relatively simple construction. The main components of a butterfly valve are the body, seal, and disc and stem which is shown below in Figure 6. A typical butterfly valve has the disc positioned in the centre of the connected pipe and a stem that is connected to an actuator or handle on the outside of the valve. In the closed position, the disc is perpendicular to the flow as shown in Figure 3 and is sealed by the valve seat. The stem is also sealed by the use of an O-ring. When the actuator or handle rotates the stem back 90 degrees, the disc moves away from the valve seat and positions itself parallel to the flow. Partial rotation allows for the flow to be throttled or proportional [11].

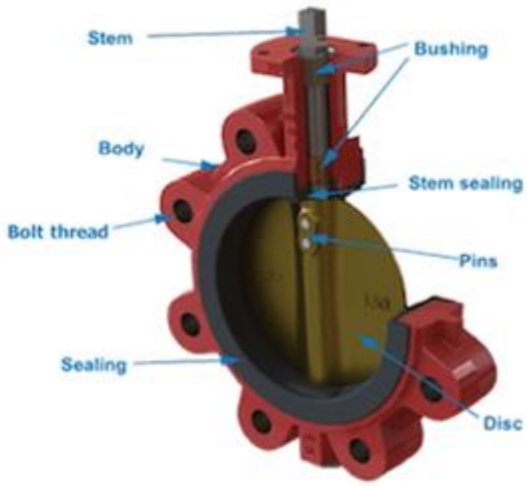

Figure 6: Anatomy of a Typical Butterfly Valve

Eccentric butterfly valves do not pass through the centreline of the disc. When the stem is located right behind the centreline of the disc, the valve is called single-offset. This design was developed to reduce the disc contact with the seal before full closure of the valve with the aim of improving service life of the valve. Today, single-offset valves have given way to double offset and triple offset butterfly valves. In a double-offset or doubly eccentric butterfly valve, the stem is located behind the disc with an additional offset to one side. This double eccentricity of the stem enables the rotating disc to rub over the seat for only about one to three degrees. A triple offset butterfly valve (TOV or TOBV) is often used in critical applications and is designed similar to a double offset butterfly valve. The third offset is the disc-seat contact axis. The seat surface takes a conical shape which coupled with the same shape at the ridge of the disc, results in minimal contact before full closure of the valve. A triple offset butterfly valve is more efficient and allows for less wear. Triple offset valves are often made of metal seats to create a bubble-tight shut-off. The metal seats allow butterfly valves to be used in higher temperature ranges. High performance butterfly valve designs use the pressure in the pipeline to increase the interference between the seat and the disc edge. These butterfly valves have higher pressure ratings and are prone to less wear [12].

CONCLUSION

Butterfly valves are smaller than ball valves and have more compact face-to-face qualities. They also require less torque to operate which leads to space, weight, and cost savings on the actuator. In reality, offshore platforms have a lot of space limitation as compared to onshore units. During fluid control operations straight pattern globe valves that are used in the oil and gas industry are at high risk of cavitation. Alternatively in process services such as hydrocarbon more costly valves such as the Y-type globe and axial valves may be used for fluid control. To raising the weight of the disk as well as to keep the stress and pressure loss coefficient within the allowable range, an optimization technique of the valve disc is applied. The weight of the disk is set as the primary feature. However, the cost of the raw material is not only dictated purely by the weight of the final design but also by the output. Therefore, in terms of the feasibility of optimization, the used objective function is perfect, but in future research a more in-depth function should be adopted. Butterfly valves have a small circular shell, a round disk, and metal-to-metal or soft seats, shaft bearings at the top and bottom, and a stuffing case. The body of a Butterfly Valve varies in design.

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