Performance Parameters of Butterfly Valve - A Review

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Abstract - Butterfly Valves are commonly used in industrial applications to control the internal flow of both compressible and incompressible fluids. A butterfly valve typically consists of a metal disc formed around a central shaft, which acts as its axis of rotation. As the valve's opening angle is increased from 0 degrees (fully closed) to 90 degrees (fully open), fluid is able to more readily flow past the valve. Characterizing a valve's performance factors, such as pressure drop, hydrodynamic torque, flow coefficient, loss coefficient, and torque coefficient, is necessary for fluid system designers to account for system requirements to properly operate the valve and prevent permanent damage from occurring. This comparison study of a butterfly valve's experimental performance factors is done using Computational Fluid Dynamics (CFD), CFD was able to appropriately predict common performance factors for butterfly valves.

Keywords- *Pressure drop, Hydrodynamic Torqe, Flow Coefficient, Torqe Coefficient,CFD.*

I. INTRODUCTION

Butterfly valves are commonly used as control valves in applications where the pressure drops required of the valves are relatively low. Butterfly valves can be used in applications as either shut off valves (on/off service) or as throttling valves (for flow or pressure control). As shut off valves, butterfly valves offer excellent performance within the range of their pressure rating. Typical uses would include isolation of equipment, fill/drain systems, bypass system and other like applications where the only criteria for control of the flow/pressure is that it be on or off. Although butterfly valves have only a limited ability to control pressure or flow, they have been widely used as control valves because of the economics involved. The control capabilities of a butterfly valve can also be significantly improved by coupling it with an operator and electronic control package. Butterfly valves allow high flows with relatively low pressure loss from the valves, and are typically used for flow control for valve openings from 30 to 70 degrees of full open. At valve openings greater than 70 degrees, the pressure loss of a butterfly valve is too low to produce any significant effect on flow or the energy loss of a flow system. Two special applications for a butterfly valve include the use of a valve for free discharge and the use of a butterfly valve for flashing or choking cavitation service. Free discharge typically produces high pipe velocities at moderate pressure drops, and choking cavitation typically produces high velocities with large pressure drops.

II. LITERATURE REVIEW

Adam Del Toro [1]stated that as the valve's opening angle is increased from 0 degrees (fully closed) to 90 degrees (fully open) fluid is able to more readily flow past the valve. Characterizing a valve's performance factors, such as pressure drop, hydrodynamic torque, flow coefficient, loss coefficient, and torque coefficient, is necessary for fluid system to account for system requirements to properly operate the valve and prevent permanent damage from occurring. an optimization procedure of the valve disc is applied in order to reduce the weight of the disc as well as to keep the stress and pressure loss coefficient in the allowable range.

Ghaleb Ibrahim et.al [2] discussed that the Numerical analysis technique has become popular and reliable method in design of butterfly valves. It is possible to visualize and observe the flow characteristics around the valve and to estimate its performance. A numerical simulation for flow of water past over a butterfly valve using commercial fluid dynamics software FLUENT, has been implemented. In the analysis, the positions of the disk were set to be 0° (fully opened), 20°, 30°, 55° and 75°. Velocity profile, pressure distribution, turbulence kinetic energy and turbulence intensity are the parameters used to present the characteristic of flow. From the results obtained, turbulence in flow starts at the edges of valve disc and gets growing according to the specified case. These vortices and circulation region are generated always in downstream region behind the valve disc. They are formed due to contact between higher and lower velocities paths. It was found that the flow has a small effect with increasing closing angle till it reaches 55°, where the flow around the valve started to become highly turbulent.

S. Y. Jeons et.al [3] manufactured the butterfly valves in various shapes but a fitting performance comparison is not made up. For this reason, they carried out numerical analysis of some kind of butterfly valves for water supply and drainage pipeline using commercial CFD code FLUENT, and made a comparative study of these results. Also, the flow coefficient, the loss coefficient, and pressure distribution of valves according to valve opening rate were compared each other and the influence of these design variables on valve performance were checked. Through flow around the valve disk, such as pressure distribution, flow pattern, velocity vectors, and form of vortex, they grasped flow characteristics. The experimental results shows that there was not much in the valve performance between the single disk type and the double disk type butterfly valve. However, the double disk type butterfly valve showed more complex flow pattern, recirculating eddies, at the rear of valve disk compared with the single disk type butterfly valve.

Arun Azad et.al [4] discussed that the butterfly valves are widely used in hydro power plants to regulate and control the flow through hydraulic turbines. That's why it is important to design the valve in such a way that it can give best performance so that optimum efficiency can be achieved in hydraulic power plants. Conventionally that the models of large size valves are straight in the laboratory to determine their performance characteristics. This is a time consuming and costly process. High computing facility along with the use of numerical techniques can give the solution to any fluid flow problem in a lesser time. In this research work flow analysis through butterfly valve with aspect ratio 1/3 has been performed using computational software. For modelling the valve ICEM CFD 12 has been used. Valve characteristics such as flow coefficient and head loss coefficient has been determined using CFX 12 for different valve opening angle as 30°,60°,75°, and 90° (taking 90°as full opening of the valve) for incompressible fluid. Value of head loss coefficient obtained from numerical analysis has been compared with the experimental results.

X.G. Song et.al [5] estimated that analyses and optimization are of special important in the design and usage of butterfly valves. For the analysis, finite element method (FEM) is often used to predict the safety of valve disc, and computational fluid dynamics (CFD) is commonly used to study the flow characteristics of valve. However, it is difficult to obtain accurate results for the optimization of butterfly valve due to the high non-linear ties. For this reason, metamodels or surrogate model methods are extensively employed. This integrates metamodel with FEM and CFD analysis to optimize a traditional butterfly valve, where the weight of the valve disc is the design objective, and the strength safety of disc and the pressure loss coefficient of valve are constraints.

M. S. Kalsi et.al [6] discussed that under the basic conditions, Torque requirements in a single offset valves with a shaft downstream were found to be, self opening instead of self closing as predicted by valves manufacturers. It was also found that variations in butterfly disc are quite large and the influence of disc shape, Upstream piping configuration ΔP and unchokedvs choked flow conditions on torque requirements in compressible and incompressible flows had not adequately addressed by the industry.

III.PERFORMANCE PARAMETERS

The valve flow characteristic represents the relationship between the flow rate through a valve and the degrees of rotation of the valve disc. This relationship is usually illustrated in the form of a graph. The characteristic that is usually graphed is the Inherent Flow Characteristic. This relationship is determined in a laboratory using a constant pressure drop across the valve regardless of the flow rate. There are three generic types of inherent flow characteristics. They are: quick opening, linear, and equal percentage as shown in figure 1.

In a real hydraulic system the pressure drop across a valve cannot be held constant. Therefore, the inherent valve characteristic will no longer be valid. The resulting valve flow characteristic is normally called the Installed Flow Characteristic.

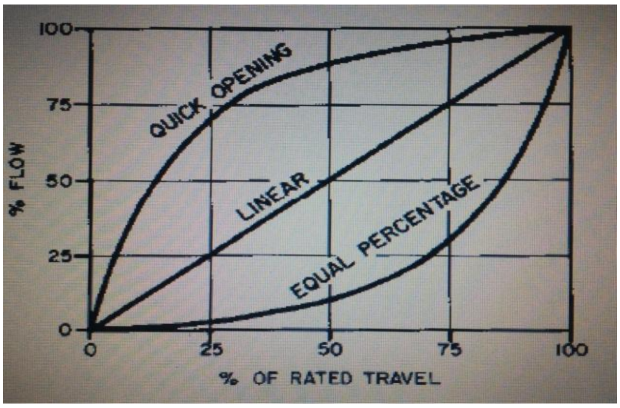

Figure 1: Flow Characteristics of Butterfly Valve

The performance parameters of butterfly valve are as described below.

A. *Pressure Drop*

Pressure loss across a valve is often attributed to disruptions caused in the flow field such as obstruction, flow separation and mixing. For butterfly valves, pressure losses vary depending on the disk angle configuration, and flow rate, Q. The pressure loss is represented by the absolute pressure differential between the measured pressure upstream, P_u and the measured pressure downstream, P_d as given in Eq^n (1)

$$\Delta P = P_u - P_d \quad (1)$$

For a given flow rate, pressure losses will generally decrease as the valve's opening angle increases due to less interference in the flow. In this study, the upstream and downstream pressures were measured at a point two diameters upstream and six diameters downstream respectively. It should also be noted that this pressure loss represents a gross measurement instead of net measurement. This means that head losses due to pipe friction length between measurement points (which are minimal), are included in the ΔP measurements, and thus affect other performance factors to be discussed.

B. *Hydrodynamic Torque*

Dynamic torque (T_d) occurs when the position of the disc is between the closed position 0° and the wide open position 90°. With the disc in the partially open position, velocity of the fluid passing the leading disc edge is less than the velocity passing the trailing edge. This variance in velocity past the leading disc edge and trailing disc edge results in an unbalanced distribution of forces across the face of the disc. The total forces acting perpendicular to the disc face on the leading edge half of the disc are greater than the total forces acting perpendicular on the trailing half of the disc. This uneven distribution of forces acting on the disc face results in a torsional moment which tries to turn the disc to the closed position. The magnitude of Td is greatest when the disc is between 75° and 85° of rotation. To determine dynamic torque, the following equation is applied:

$$Td = C_{dt} \times D^3 \times \square P \quad (2)$$

Where,
Td = Dynamic Torque, in-lbs.
C_{dt} = Coefficient of Dynamic torque.
D = Diameter of Disc, inches.
P = Differential Pressure across the Valve, psi.

Based on Eq^n (2) the dynamic torque is directly proportional to the pressure loss caused by the valve. Although this equation has a simple form, at the absence of experimental data concerning factor C_t, it is very difficult to use it for practical purposes. Also, to use this equation, the upstream and downstream pressures should be obtained at two sections far from the valve (with the distance two pipe diameters at the upstream and at least six pipe diameters at the downstream). This is for reducing the disturbance effects at these sections. It should be highlighted that at these sections, the pressure changes at different points, and therefore, average pressure should be used. Both the Ct (dynamic torque factor) and □P (pressure drop at the valve) strongly depend on the disk shape. Calculating the Ct (dynamic torque factor) for different valves and at different disk opening angles is a very difficult task, and therefore, for using the above equations, experimental data is necessary. However, by the implementation of the numerical methods, the hydrodynamic torque can be calculated before the valve has been actually manufactured.

Dynamic torque may be minimized by proper installation of the valve with regard to orientation of the shaft, distance in the pipeline from elbows, other valves, etc.

C. *Flow Coefficient*

The valve coefficient, C_v, is a number which represents the capability of a valve (or any flow component) to flow a fluid. The larger the C_v, the larger the flow at a given pressure differential. C_v is the number of U.S. gallons per minute that will pass through a valve with press drop of 1 psi. For example, a Cv of 150 would then equate to 150 gpm of water at 60° F with a differential pressure of one psi. The valve flow coefficient have respect to valve type, diameter of valve, opening rate of valve and operating fluids. This valve flow coefficient is an important characteristic to investigate a valve performance and determined by differential pressure between upstream and downstream.

The valve flow coefficient, Cv, is a measure of the flow rate of water through a valve at temperature T and at pressure drop P as seen in Equation (3)

$$C_v = Q\sqrt{\frac{SG}{\Delta P}} \quad (3)$$

Where,
Q is the flow rate in gpm
SG is the specific gravity of the fluid in use,
ΔP is the pressure drop across the valve in psi.

The valve flow coefficient is useful to manufacturers and users in understanding the flow capacity of valves.

D. *Loss Coefficient*

The flow resistance coefficient, commonly known as the loss coefficient, K, is a dimensionless value commonly used in the design of thermal fluid systems to predict head losses present due to the presence of various components. The loss coefficient is shown below in Equation (4)

$$K = \frac{2*g*hl}{Vavg} \quad (4)$$

Where,
G is the gravity constant of 9.81 m/s^2,
h_L is the head loss between any two reference points in a system.

$$V_{avg} = Q*A \quad (5)$$

V_{avg} is the average velocity of the fluid flow,
Q is the flow rate, and
A is the cross-sectional area of flow.

The head loss, h_L is further defined in Eq^n (6)

$$HL = \frac{\Delta P}{\rho g} \qquad (6)$$

Where,
ΔP is the pressure loss measured across the points previously described, and
ρ is the density of the fluid in use.

Simplifying above Equations

$$K = \frac{2\Delta P}{\rho V_{avg}} \qquad (7)$$

E. Torque Coefficient

The torque coefficient, Ct, is a dimensionless quantity used by manufacturers and users to determine the torque and power requirements of valves scaled relative one to another.

Torque coefficient is defined in Equation below,

$$C_t = \frac{Td}{D3 * \Delta P} \qquad (8)$$

Where,
T_d = Dynamic Torque.
D = Diameter of Disc, inches.
ΔP is the pressure drop across the valve in psi.

CONCLUSION

It can be conclude that the performance parameters of Butterfly valve are varies with the various factors such as flow, Pressure of fluid, shape of disc.

As pressure drop increases performance of butterfly valve decreases.

Performance of Butterfly valve increases with increase in Flow coefficient also increases with decrease in Loss coefficient.

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