ISSN 2395-1621

Torque optimization in triple offset butterfly valve

[#1]Pramod Gite[1]

[1]Department Of Mechanical Engineering, Savitribai Phule Pune University, Pune
[1]Kalson Engineering Solutions, Akurdi, Pune,India.

ABSTRACT

Valves are mechanical devices specially designed to direct, start, stop, mix or regulating the flow, pressure of a process fluid. A butterfly valve typically consists of a metal disk 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. These valves are commonly used to control fluid flow inside of piping systems. The main objective of this study is to find out minimum torque required to operate valve. This contains the information about design and development for the Butterfly Valve with Double Eccentricity using ANSYS. It comprises the calculations which are required for design of Butterfly Valve such as Shell Thickness, Disc Thickness, Stem Diameter and Calculation of Torque using ASME, IBR. Also includes the modeling and assembly of butterfly valve using Pro-E. We will discuss Finite Element Analysis/ CFD of Butterfly valve Shell, Disc stem and their assembly. The solid model will discretized into finite elements and logical constrains will applied in boundary conditions. The stress results obtained in finite element analysis will have to check whether, is there a chance for optimization of design and torque. Design Features for triple offset valve are as Zero leakage, Bi-directional, metal to metal sealing, Low operating torque, Inherently fire safe, One piece shaft with blow-out proof design. Triple offset valve is a product of engineered geometry combined with modern manufacturing techniques to achieve ZERO leakage. This metal-to-metal, bidirectional sealing valve has non-rubbing design which gives less operating torque and longer service life. First offset is between shaft axis plane and seat plane, which allows complete sealing contact around the seat.

Second offset is a distance at which shaft is displaced from the centre of the flow line, which gives camming effect & reduced rubbing rotation while opening and closing of valve. The seal is a segment taken from cone where apex of the cone is offset (3rd) from the flow line axis, which eliminates rubbing completely.

We are going to optimize operating torque, shaft dia. and sealing. We have calculated theoretical torque which is to be compare with actual operating torque.

Keywords— CFD, Zero Leakage, Offset

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Butterfly valves are widely used in various industries such as water distribution, sewage, oil and gas plants. The hydrodynamic torque applied on the butterfly valve disk is one of the most important factors which should be considered in their design and application. Although several methods have been used to calculate the total torque on these valves, most of them are based on hydrostatic analysis and ignore the hydrodynamic effect which has a major role to determine the torque of the large-size valves. For finding the dynamic-valve torque, some empirical formulas and methods have been proposed; for example in AWWA C504 standard, a relationship for calculating the dynamic torque has been given and its variation versus disk angle has been stated. However, the use of these empirical relationships is restricted due to the conditions defined in the standards.

Design Features of triple offset valve are as following

- Zero leakage
- Bi-directional, metal to metal sealing
- Low operating torque
- Inherently fire safe
- One piece shaft with blow-out proof design
- Principe Of Operation

Triple offset valve is a product of engineered geometry combined with modern manufacturing techniques to achieve ZERO leakage. This metal-to-metal, bidirectional sealing valve has non-rubbing design which gives less operating torque and longer service life.

Offset 1
First offset is between shaft axis plane and seat plane, which allows complete sealing contact around the seat.
Offset 2

Second offset is a distance at which shaft is displaced from the centre of the flow line, which gives camming effect & reduced rubbing rotation while opening and closing of valve.

Offset 3
The seal is a segment taken from cone where apex of the cone is offset (3rd) from the flow line axis, which eliminates rubbing completely.

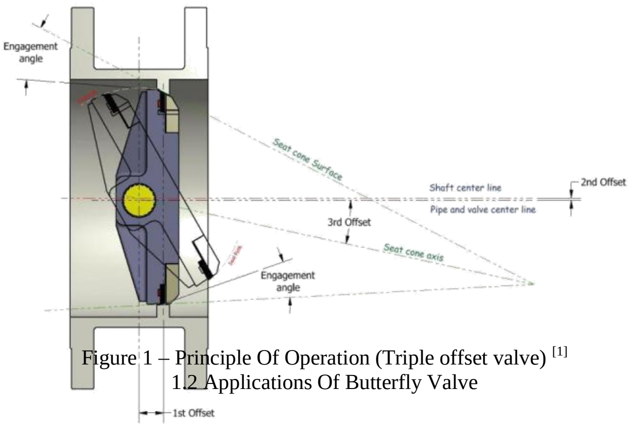

Figure 1 – Principle Of Operation (Triple offset valve) [1]

1.2 Applications Of Butterfly Valve

a) Refinery
b) Petrochemicals
c) Utilities
d) Power Plant

II. CALCULATION OF OPERATING TORQUE

Total torque required to operate butterfly valve is nothing but the addition of different torque as shown below;
Total torque / Breaking torque = (unseating torque + Bearing friction torque + Stuffing box Torque + Torque due to eccentricity)

Operating torque varies as rating of valve changes; For different ratings of valve size of bore and hydrostatic pressure are different. For example , We will take following rating of valve and calculate torque for it;

Valve Type: Triple offset butterfly valve. Valve rating: CLASS 150
Valve size: DN 100
Reference: AWWA M49 Manual

1.Bearing Friction torque:

Tb = π/8*Dc^2*Ds*ΔP*Cf
Dc = Disc Diameter = 90 mm

Ds = Diameter of Shaft = 20 mm ΔP = Line pressure = 2.2 Mpa
Cf = Coefficient of friction = 0.25
By putting all values in above formulae; Tb = 35 Nm

2.Stuffing Box Torque:

Ts= π*Stuffing box bore*Stuffing box depth*μ*1.5*ΔP*(Ds/2) Stuffing Box bore= 33 mm

Stuffing box depth= 38 mm
By putting all values in above formulae; Ts = 19.5 mm

3.Torque Due To Eccentricity:

Te = π/4*Dc^2*ΔP*e

e = Eccentricity = 2.5 mm = second offset By putting all values in above formulae; Te = 35 mm

4.UnSeating Torque:

$$P = \frac{\Delta}{\frac{D_{hi}}{E_h}\left(\frac{D_{ho}^2 + D_{hi}^2}{D_{ho}^2 - D_{hi}^2} + v_h\right) + \frac{D_{so}}{E_s}\left(\frac{D_{so}^2 + D_{si}^2}{D_{so}^2 - D_{si}^2} - v_s\right)}$$

Dhi = Seat ID = 84 mm

Dho = Seat OD = 100 mm
Eh = Elastic modulus of Seat = 250000 Mpa
Dso = Seal OD = 84 mm Dsi = Seal ID = 64 mm

Es = Elastic modulus of Seal = 200000 Mpa vh = Poission's ratio of Seat = 0.29
vs = Poission's ratio of Seal = 0.29
= Diametrical Interference = 0.05 mm Seat Width = 5.6 mm

Friction Coefficient (Between Seal and Seat) = 0. 05 Turning Radius = 44 mm

By putting all values in above formulae; P = 14.27 Mpa

Resultant Force = Pressure * Contact Area * Friction Coefficent

Contact Area = 1478 mm^2 Resultant Force = 1054.2 N

Unseating Torque= Resultant force * Turning Radius

Tus = 46 Nm

Thus, adding all these torques we get total operating / breaking torque

Breaking Torque= 136 Nm

Above calculated torque is theoretical torque which is to be compare with actual torque.

III. COMPUTATIONAL ANALYSIS

The manufacturing and testing of large butterfly valves is expensive; therefore, there is a general trend to use numerical methods to study the hydro-mechanical behavior of these valves. In this way, any malfunction or short-coming in their design would be identified and solved before starting the actual manufacturing process [3].

IV. SOLUTION METHODOLOGY AND BOUNDARY CONDITIONS

Generally, large butterfly valves are manufactured in casting or they may be produced using metal forming processes. Because of the application and manufacturing conditions, large butterfly valves are usually designed with single offset, and rarely, symmetric or double offset types are produced.

Nominal operating pressure is usually 10, 16 or 25 bar. According to the manufacturing method and its quality, surface smoothness can be different; however, the inner and outer surface of the valve are painted to increase the corrosion resistance, so the valve body can be considered as a smooth surface.

There are numerous forms of the dimensionless number or parameter which have been used to mathematically describe cavitation. The cavitation parameter or index is a dimensionless ratio used to relate the conditions which inhibit cavitation (P2 −PV) to the condition which causes cavitation (UP).

Hence, the fundamental form of this parameter is σ2 = (P2-Pv)/P which uses the downstream valve pressure (P2), the vapour pressure of the liquid (PV), and the pressure drop of the valve (<P). It is necessary to use this parameter for determining specific cavitation effects such as size and scale effects. If the value of σ2 calculated for the actual operating pressures of a valve is less than the value of σ2 for a cavitation limit, the valve will experience a level of cavitation more severe thanthat associated with the limit. The results have shown that in all types of disk shapes, cavitation occurs in disk opening angles below 25 degrees, and above this angle there is no cavitation [2].

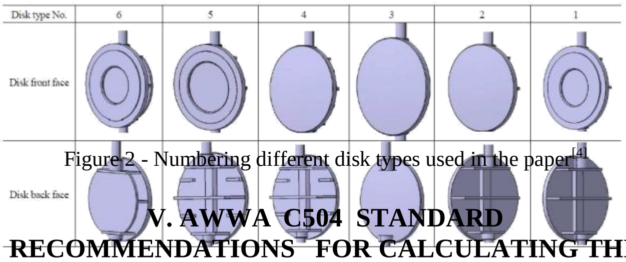

Figure 2 - Numbering different disk types used in the paper [4]

V. AWWA C504 STANDARD RECOMMENDATIONS FOR CALCULATING THE HYDRO-DYNAMIC TORQUE IN BUTTERFLY VALVES

The AWWA C504 standard is one of the most reliable references for designing and manufacturing of the butterfly valves. According to this standard, the hydrodynamic torque can be calculated usin

$$T_d = (C_t D^3 \Delta P) \qquad (2)$$

where Td is hydrodynamic torque; Ct is dynamic torque factor; <P is the pressure loss in two sides of the valve; and, D is the disk diameter. Dynamic torque factor can be calculated using Eq. (3) in which <P is replaced by ρV2 in Eq. (2).

$$C_t = \frac{T_d}{\rho V^2 D^3} \qquad (3)$$

In this equation ρ is fluid density and V is average fluid velocity. According to this code, the maximum torque may occur at the opening disk angle of between 9 and 50 degrees.

Using the CFD model and numerical solutions, the distribution of the up and downstream pressures can be obtained and their average values have been calculated at the specified sections for different disk shapes and opening angles [1].

VI. CONCLUSIONS

1.As the disk-offset increases, torque values decrease with almost constant rate.
2.Also, increasing the offset value provides initial zero torque angle and reduces the second zero torque angle.

3.Theorotical operating torque as per calculation is 136 Nm.
4.Hydrostatic torque can not be optimized . It changes as valve rating changes.

5.For non-rubbing action , sealing of valve should be at 0 degree.

6.Unseating torque , Bearing torque, Stuffing box torque and torque due to eccentricity can be optimized.

ACKNOWLEDGEMENT

Thanks to Mr. Pramod Kalyani for his valuable contribution in developing and working on this artical.

REFRENCES

1)Farid Vakili-Tahami1, Mohammad Zehsaz , Mahdi

Mohammadpour and Ali Vakili-Tahami - Analysis of the hydrodynamic torque effects on large size butterfly valves and comparing results with AWWA C504 standard recommendations.

2) Piyush P. Nagpurkar , Prof. R. S.Tajane - Design and Development of Double Offset Butterfly Valve.

3) M.S. Kalsi , B. Eldiwany , Vinod Sharma , Aaron Richie – Effect of butterfly valve disc shape variations on torque requirements for power plant applications.

4) Sachin K. Pisal, Suresh M. Sawant – Testing and performance evaluation of butterfly valve.

5) C K Kim, J Y Yoon and M S Shin – Experimental study for flow characteristics and performance evaluation of butterfly valves.

