Stress analysis of butterfly valve and its parametric optimization

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ABSTRACT

Butterfly valves are versatile components widely used in hydraulic systems as shutoff and throttling valves. Butterfly valve components must be able to withstand the forces and torques that are generated with use. These 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 shutoff valves or as throttling valves. As shutoff valves, butterfly valves offer excellent performance within the range of their pressure rating. Typical uses would include isolation of equipment, fill/drain systems, bypass systems 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. 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. The objective of this research is to examine the effect of pressure and temperatures on valve components, its analysis and optimization. The stress results obtained in finite element analysis will have to check whether, is there a chance for optimization of design.

Keywords—Butterfly Valve, Optimization, Stress Analysis

I. INTRODUCTION

Butterfly valves are versatile components widely used in hydraulic systems as shutoff and throttling valves. Butterfly valve components must be able to withstand the forces and torques that are generated with use (American Water Works Association 2012). It is also necessary to know the maximum torque required for valve operation in order to design/select the proper lever or actuator that will be used to open and close the valve under every operating condition as well as properly size the shaft or stem of the valve. Dynamic torque data are usually obtained in a test lab with the system operating at a steady state condition; however the dynamic torque under transient (unsteady flow) conditions may vary significantly from the steady state laboratory conditions. The objective of this research was to examine the effect of pressure and temperatures on valve components its analysis and optimization. The valve is the fluid device for the control of the fluid characteristics such as flow rate, direction, pressure and temperature, which it was basically performed four functions such that on-off, throttling, non-return and overpressure. In generally, a variety of control valves such as the butterfly valve, the ball valve, the globe valve, and the gate valve. A butterfly valve is used to open and close the pipeline, and to control the flow rate by rotating a disc with relatively low pressure. According to the location of the rotating axis of the valve disc, butterfly valves are classified into the concentric butterfly valve and the eccentric butterfly valve[2]. The objective of this research is to carry out stress analysis of butterfly valve and its parametric optimization.

Fig.1 Geometrical Representation Of Butterfly valve
II. DESIGN CALCULATION

2.1. Calculation for Shell Thickness of Valve Body$^{[6]}$

2.1.1. Thick Cylinder (As per IBR 290(d)):

\[ t = \frac{WP \times D}{2f + WP_D} + C \]

WP = Maximum Working Pressure, Kgf/mm²
D = External Diameter of Chest, mm
F = Allowable Stress, Kg/mm²
C = Minimum Positive Tolerance, mm
(5 mm for Carbon Steel and 2.5 mm for Stainless Steel)

2.1.2. Thin Cylinder:

\[ t = \frac{P \times D}{2s} \]

t = Shell thickness mm
P = Maximum Working Pressure, MPa
D = Maximum Internal Diameter of Body, mm
S = Maximum Allowable Working Stress, MPa

2.1.3. From Valve Design Book by Pearson:

\[ t = \frac{P \times D}{2s} + C \]

P = Working Pressure, MPa
D = Inside Diameter or Port Opening, mm
S = Maximum Allowable Working Stress, MPa
C = Constant (8 mm for CI and 6.5 mm for Carbon Steel)

2.1.4. By Formula ASME see VIII Div-1

\[ t = \frac{PR}{(S \times E) - (0.6 \times P)} \]

P = Design Pressure, Kg/cm²
R = Inside Radius of Shell, cm
S = Maximum Allowable Stress Value Kg/cm²
E = Joint Efficiency = 1

2.2. Calculation of Disc Thickness:

By using following formula, we can calculate the thickness of Disc. In this calculation, we consider a disc as a simply supported flat plate with a uniform distributed load.

\[ t = \sqrt{\frac{3 \times w}{8 \times \pi \times M + 1} \times \left(1 - \frac{4 \times r^2}{d^2}\right)} \]

After putting the values for all variable used in the above formulae, we got thickness value of Disc at various distance from centre of Disc$^{[6]}$

w = Total Load acting on Disc
M = Reciprocal of Poisson’s ratio = 3.4
f = Maximum Allowable Working Stress
r = Distance at which thickness to be determine

III. MATERIALS

Allowable design stress value for various materials as per ASME Boiler and Pressure Vessel code Section VII division I is as below$^{[6]}$.

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<thead>
<tr>
<th>Sr No.</th>
<th>Material</th>
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<th>3</th>
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<th>5</th>
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<td>96.5</td>
<td>11</td>
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<td>9</td>
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<tr>
<td>2</td>
<td>C6</td>
<td>98</td>
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<td>84</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>F3</td>
<td>6.5</td>
<td>6.5</td>
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<tr>
<td>5</td>
<td>F8</td>
<td>6.5</td>
<td>6.5</td>
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</table>

IV. MODELLING

4.1 Body

4.2 Disc

4.3 Assembly

V. STRESS ANALYSIS

The stress analysis can be linear/elastic or nonlinear/plastic depending on the addressed failure mode and on the applied code rule. 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 behaviour of these valves. In this way, any malfunction or shortcoming in their design would be identified and solved before starting the actual manufacturing process. Finite element analysis is will be carried out on the various parts of butterfly valve.
The parts are listed given below[6],
1) Body
2) Disc
3) Assembly

4.1 Material Properties:

<table>
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<th>Sr No</th>
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<th>3</th>
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<tbody>
<tr>
<td>MATERIAL NAME</td>
<td>ASTM A 216 Gr WCB</td>
<td>ASTM A 351 Gr CF8</td>
<td>ASTM A276 Type 410</td>
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<td>YOUNGS MODULUS</td>
<td>210 GPa</td>
<td>194 GPa</td>
<td>199.982 GPa</td>
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<td>POISSON'S RATIO</td>
<td>0.3</td>
<td>0.265</td>
<td>0.285</td>
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<td>YIELD STRENGTH</td>
<td>249.2 MPa</td>
<td>206 MPa</td>
<td>275.76 MPa</td>
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<td>ULTIMATE STRENGTH</td>
<td>482.6 Mpa</td>
<td>483 Mpa</td>
<td>483 Mpa</td>
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</table>

VI.5. EXPERIMENTAL TESTING

It includes conducting an experimental testing on a Butterfly valve with proper testing set up, to extract stress analysis on valve and valve components. Applying specified pressure & temperature parameter on a valve through flowing media (example-water). Measuring Opening and closing torque (force required to OPEN/CLOSE the valve). Conducting validation trial by operating valve for specified number of cycle (100-1000 cycle) with the help of electric or pneumatic actuation. Then observing performance of valve & valve components and its comparison with results obtained through FEA Analysis. (Validation of result)

VII. 6. EXPECTED OUTCOME / RESULT

Detailed analysis of Butterfly valve and valve components subjected to stresses beyond yield limit, and leads to failure. Parametric optimization of valve components based on observed results plays an important role in improved
1) design of Butterfly valve
2) Performance of Butterfly valve
3) Reliability
4) Use of efficient and effective composite materials.

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REFERENCES