Design, Development and Testing of Butterfly Valve Leakage Test Rig

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Abstract - Here we are trying to reduce the ideal time and improve the production rate. In Butterfly valve, body and seat test are two important tests which are carried out after assembly of valve. For this purpose clamping of valve is necessary. Previously time consumption was more in clamping thus we are reducing it to few seconds. Also the valve can be clamped without drilling the flanges of valve these advantages has reduced ideal time and improve production rate of company. Here we are testing centric butterfly valves as well as eccentric double flange type butterfly valves. Mainly two tests are necessary that are body test and seat test, for seat testing the additional requirement is cage development. Whole machine works on PLC programming as well as manually.

Keywords - Contact pressure; Metal seal; No-leakage; Seat tightness.

INTRODUCTION

Valve is a device that regulates the flow of fluid (gases, fluidized solids, slurries or liquids) by opening, closing or partially obstructing various passageways. Valves are technically pipe fittings, but are usually discussed as a separate category. Valves are also found in the human body to control the flow of blood in the chamber of heart and maintain the correct pumping action. Valves are used in variety of contexts, including industrial, commercial, residential and transportation. Oil and gas, power generation, mining, water recirculation, sewerage and chemical manufacturing and the industries in which the valves are used.

Valves may be operated manually, either by hand wheel, lever or pedal. Valves may be automatic, driven by changes in pressure, temperature or flow. These changes may act upon a diaphragm or a piston which in turn activates the valves, examples of this types of valves found commonly are safety valves fitted to hot water systems or steam boilers.

Valves may be categorized by how they are operated:

- Hydraulic/pneumatic
- Manual
- Solenoid

Fig. 1: Eccentric and Centric type Butterfly valves

CONSTRUCTIONAL FEATURES OF ECCENTRIC BUTTERFLY VALVES:

**Body**

Wafer/ Double flanged short/ long valve body designed to withstand specified pressures. Integral cast feet as standard scope of supply for above 1200 mm NB Sizes.

**Disc**

Streamlined Single/ Double eccentrically mounted disc to ensure complete shut-off

**Body Seat Ring**

Accurately machined to close tolerances to match with body
**Shaft**

Stub type design, sealing with unique combination of ‘O’ Ring and ‘U’ Cup Seal to prevent leakage from drive end side.

**Clamping Ring**

Unique clamping ring design ensures controlled and uniform seat compression and facilitates easy replacement of seal.

**Journal Bearing**

Low friction self-lubricated journal bearings for supporting shaft outside fluid flow.

**Accessories (Optional)**

Extension shafting and floor stand Disc locking arrangement at Non Driving End Chain and chain wheel arrangement

**Design Advantages of Centric Butterfly valves:**

**Valve Body**

1. Ductile cast iron with an electro-statically applied fusion bonded epoxy coating to a thickness of between 50-150μm.
2. The coating provides superior anti-corrosive properties and excellent resistance to abrasion and impact.
3. Body material is hammer and pressure proof.
4. Able to be installed between all flange types.

**Seats**

1. Fully vulcanized to provide strength, elasticity, durability and maximum tightness therefore guaranteeing seat stability and a drop-tight seal
2. Designed to prevent corrosion of the seat and between the seat and the valve body
3. Choice of rubbers is available to provide a cost effective solution for all use situations

**Discs**

1. Specially designed to provide a tight seal; the smooth, contoured edge minimizes friction loss resulting in lower head losses
2. Designed to ensure smooth through-flow thus reducing pressure drop and operation torque

**Disks are available in a variety of materials including:**

1. Ductile iron coated with withRilsan®, Halar® ECTFE or enamel
2. Stainless steel
3. Duplex
4. Aluminium bronze

**Shafts**

1. Leaks are prevented by our fully sealed dry shaft
2. Our tightly sealed shaft ensures long valve life even in high cycling applications without the need for routine maintenance.

**Present Testing procedure of butterfly Valves:**

It is the procedure of testing the performance of product called BFV. We got the information regarding the same in previous session. Before testing, flanges of body have to be drilled. After drilling they are clamped to the body for hydro testing.

**Drawbacks of present practice:-**

Clamping is a time consuming process. It requires minimum 15 minutes to clamp the small bodies and about ½ an hour for large bodies with the help of nuts and bolts. Hence, a lot of productive time is wasted in clamping and declamping.

**Objectives**

As the method of testing of butterfly valves by clamping of butterfly valves is time consuming, thus there is need of new system to reduce testing time.

To increase the production rate because with current method it is not possible to fulfill the demand of customer within due period. To reduce the material handling time and to increase worker efficiency.

**Design of the system - Rectangular plate in bending,**

subjected to a load \( P \) over a central circular area of diameter \( \text{do} > 0.25 \text{b} \)

Moment per unit width in span \( b \) at the centre of edge where the condition is when all edges are fixed,

\[
M = \frac{P}{(6+2\alpha^5) a} = b/a \quad \text{where} \quad a = \text{longer side} \\
\text{b = shorter side} \\
\text{We have assumed} \quad a=b, \quad \alpha = 1 \\
\text{M=15000*9.81}/ (6+2) \\
\text{M=18393.75 N mm.} \\
\text{Load =15000*9.81=147150 N.} \\
\text{Area =500*500=250000 mm^2} \\
\text{I=br^2/12 =500r^2/12 & y=t/2} \\
\text{ob = MbY/I} \\
\text{147150/250000 = 18393.75*t*12/(500*t^3)}
\]
\[ t^2 = 750 \]
\[ t = 27.39 \text{ mm}. \]

Load on each pillar is \[ 3750 \text{ kg} \ast 9.81 \text{ m/s}^2 \]
\[ = 36787.5 \text{ N}. \]

\[ P_b = \frac{n \Pi^2 Ea}{(L/r)^2} \text{ for } L/r > 120 \text{ (steels)} \]

Where \( P_b \) = buckling load, \( n \) = coefficient of end condition,
\( E \) = young’s modulus, \( a \) = area of cross section.
\( L/r \) = slenderness ratio.
\( E = 2.06 \times 10^5 \text{ N/mm}^2 \)

Assume the end condition \( n = 0.25 \frac{L}{r} = 130 \) taken
\[ 36787.5 = 0.25 \times \Pi^2 \times 2.06 \times 10^5 \times \frac{a}{130^2} \]
\[ a = 36787.5 \times 130^2 / (0.25 \times \Pi^2 \times 2.06 \times 10^5) = 1223.15 \]
\[ d = 19.73 \text{ mm}. \]
for the safe design we take thickness and diameter as 40 mm.

**Modelling and analysis of the test rig.**

Modelling of the test system is done in CATIA V5 R20. The assembly of the system is shown in figure 3. As the test system is designed for the 15 ton load the analysis has been done for the same load. The test rig is suitable for the valves of dimensions from 50 mm diameter to 200 mm, this includes PN 10 and PN 16 series valves.

As shown in figure 2 the test system is simply made up of top plate and bottom plate, both are connected with the four columns at four corners of both the plates. The top plate has centrally bored to place the hydraulic cylinder or press. The plate that will press the force against the valve is attached to the piston rod. The height of column is determined by using the largest valve on the system and also the stroke length of hydraulic press is taken into account.

The fixture plates that are directly coming into contact are of stainless steel to avoid the corrosion of the particular part. The fixture plates for each valve are different because of variation in dimensions.

**Fig. 2:** General drawing of the test system

**Fig. 3:** Modelling of system.

As shown in figure 4 the von mises stresses in the system are in the safe limit. This is done in MS Nastran and results made from the analysis are shown in figure 4. The highly stressed area is cylinder flange, where maximum stresses are induced.

**Fig. 4:** Von mises stresses

As shown in figure 4 the von mises stresses in the system are in the safe limit. This is done in MS Nastran and results made from the analysis are shown in figure 4. The highly stressed area is cylinder flange, where maximum stresses are induced.
Fig. 5: Displacement maximum and minimum

The analysis done in MS Nastran for the displacement is as shown in the figure 5. The results obtained from this are in the useful limits. In actual practice the load of 15 ton is not applying, instead of this the maximum load applied for clamping is about 12 ton.

**Working principle of the test system:**

The total machine manufactured is of structural steel. The machine works as the valve or test component is placed on the slider, valve is brought to the platform then the fixture is placed above and below the valve. The fixture contains the O-Ring for the proper sealing purpose. After placing the fixture the clamping is done with the help of hydraulic cylinder placed at the top plate. After clamping the pressurized water is supplied to the valve body. When the body volume is completely filled with water, the supply is done upto 30 seconds for stabilization. And after stabilization the testing time starts; now it is about 60 seconds. If leakage exists the pressure drop has been shown analytically as well as digitally. This is the body testing of the Butterfly valve.

The seat test is carried out in the same fashion but only the difference is the fixture plate at the top side is removed and the cage is introduced to see the seat behavior very easily by the operator. In the seat test the valve is at completely closed position and in body testing valve is at normally opened condition.

**PLC (Programmable Logic Controller) PROGRAMMING:**

PLC Program for the Butterfly valve leakage test rig is according to following sequence;

**PLC sequence:**

1. Slider is at extension position
2. Particular fixture plates are placed on the base plate then valve is placed on this plate. On the valve top plate is placed.
3. Parameter setting is done,
   a. Filling pressure
   b. Stabilization time
   c. Test time
   d. Limit
   e. Clamping pressure
   f. Valve size
   g. Test pressure
4. Power pack activation
5. Retraction of the slider.
6. Clamping of the valve by pressing hydraulic cylinder.
7. Water pumps activation.
8. Water Filling on.
11. Water pump off.
12. Water drain on.
13. Declamp the valve or test component.
14. Slider extension.
15. Remove the valve.

Repeat the procedure for another valve size by changing the fixture plates. If any query exists in the running cycle, the emergency stop is provided for the safety purpose. When the water filling is going on the air inside the valve body is thrown outside from the top plate.

The clamping of the various valves can be done by using the data made by the company as per the valves casting capacity. The chart shown below represents the clamping pressure, body pressure, seat pressure

**Development of cage:**

The fixture plates that are designed for the sealing of valve body are placed by developing cage. The cage helps to minimize the working stroke of the hydraulic cylinder for eccentric double flange type butterfly valve. The cage is useful at the time of seat testing. When the seat testing is going on, operator must see the behavior of the seat and if leakage is present then it is detected.

Testing of the centric type butterfly valve creates the problem of cylinder stroke but with the help of cage
the problem of stroke is minimized efficiently. The maximum height of centric butterfly valve that we are going to test is not more than 50 mm.

Fig. 6: Cage for seat testing

The main plates that are subjected to maximum stresses are top plate and bottom plate, but the plates above and below the valve are also subjected to comparatively maximum stresses. So in between this plate of upper side and valve the cage is placed. These cages as well as the fixture plates are placed with the reference of inner diameter or the outer diameter of the respective valve. In the development of cage we have to develop the cage for each valve separately.

The chart shown in figure 7 is of clamping pressure for body testing and seat testing this is obtained from the formula.

$$P_c = P_t * A_v / A_c$$

Where $P_c$ = clamping pressure; $P_t$ = test pressure; $A_v$ = valve area; $A_c$ = clamping area.

This is company generated data for the safety of valves to avoid the damage to the casting of valve.

The values of test pressure $P_t$, valve are $A_v$ and clamping area $A_c$ are given by the company, value of clamping pressure $P_c$ is calculated from these values.

<table>
<thead>
<tr>
<th>Butterfly Valve Size in mm</th>
<th>PN10 Body Pressure Kg/cm²</th>
<th>PN10 Clamp Pressure Kg/cm²</th>
<th>PN10 Seat Pressure Kg/cm²</th>
<th>PN10 Clamp Pressure Kg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>16</td>
<td>2.04</td>
<td>11</td>
<td>1.4</td>
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<td>16</td>
<td>3.44</td>
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<td>5.23</td>
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<td>3.59</td>
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<td>16</td>
<td>8.16</td>
<td>11</td>
<td>5.61</td>
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<table>
<thead>
<tr>
<th>Butterfly Valve Size in mm</th>
<th>PN16 Body Pressure Kg/cm²</th>
<th>PN16 Clamp Pressure Kg/cm²</th>
<th>PN16 Seat Pressure Kg/cm²</th>
<th>PN16 Clamp Pressure Kg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>25</td>
<td>3.18</td>
<td>17</td>
<td>2.16</td>
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<tr>
<td>65</td>
<td>25</td>
<td>5.37</td>
<td>17</td>
<td>3.65</td>
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<tr>
<td>80</td>
<td>25</td>
<td>8.16</td>
<td>17</td>
<td>5.55</td>
</tr>
<tr>
<td>100</td>
<td>25</td>
<td>12.74</td>
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<td>25</td>
<td>28.65</td>
<td>17</td>
<td>19.7</td>
</tr>
<tr>
<td>200</td>
<td>25</td>
<td>51.01</td>
<td>17</td>
<td>34.68</td>
</tr>
</tbody>
</table>

Fig. 7: Value chart for various of PN 10 series and PN 16 series valves.

Main components used in the system are as follows,

**Manifold**

Designed especially for multistation direction control valves.

Fig. 8: Manifold

Number of stations may vary from minimum 2 to maximum 10. The manifold is made up of cast iron solid block. At the three faces of cast iron solid block, the holes of different lengths are drilled, as per requirement of component which will be placed at the three faces of this block. At the upper face there is directional control valve is placed, at another side there is inlet port and outlet port is made by proper drilling.

**O-Ring selection**

The O-Ring is an efficient, cost-effective sealing element for a great diversity of applications. It is extensively used virtually in all branches of industry. Elastomer materials in different formulations ensure that almost any medium can be reliably sealed off. The O-
Ring is torus, providing an endless round sealing with a circular cross-section.

![Fig. 9: O-Ring](image)

- O-Ring failure is usually gradual and easily identified.
- They are cost-effective.

O-Rings are used because of its elastic behavior means after releasing the pressure applied on the valve it regains its original shape. One more reason behind using O-Ring is easily availability. The maintenance cost in the whole process is hydraulic oil, water replacement and O-Ring. These all are cost effective so the maintenance cost is also less. For the fitment of O-Ring in the fixture plate the plates are machined and the grooves are made to fix it easily. The chances of bursting of O-Ring are because of excess pressure in the system.

**Solenoid operated directional valve:**

![Fig. 11: Solenoid operated directional valve](image)

The solenoid operated directional valves are operated electronically as well as programmable logic controller. Figure 11 shows the solenoid operated directional valve.

The two solenoid operated directional valves are used, one is used for directing hydraulic pressure towards the manifold. This is supplied to hydraulic cylinder at top and bottom ports for expansion and retraction of the piston. The another is used for same operation for sliding cylinder for the ease of material handling.

**Finishing processes**

**Blackening**

This is the process of finishing of metal parts. This process will not work on stainless steel or non-ferrous metals such as Brass, Aluminum and Pot Metal. Steps for preparing the parts for blackening as follow,

1. Disassemble iron or steel object to be blackened.
2. Remove all grease, oil, paint, rust or old plating prior to blackening.
3. Wear rubber or vinyl gloves to protect skin from contact with blackening solution.

Advantages of O-Rings

- They seal over a wide range of pressure, temperature and tolerance.
- Ease of service or re-tightening.
- O-Rings require very little room and are light in weight.
- In many cases an O-Ring can be reused, an advantage over non-elastic flat seals and crush-type gaskets.

While taking the safe and efficient sealing considerations the company has recommended to use the O-Ring of size 10 mm diameter d2 and the diameter d1 should be as per the valve dimensions. The material used for O-Ring is Nitrile. Because of following advantages O-Rings are better to use,

Steps for preparing the parts for blackening as follow,

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2. Remove all grease, oil, paint, rust or old plating prior to blackening.
3. Wear rubber or vinyl gloves to protect skin from contact with blackening solution.
elements, auto and construction industry, plant engineering.

**Testing results:** Testing results of the various valves (specimens) having dimensions from 50 mm to 200 mm diameter provided by the company for PN 10 series eccentric type flanged butterfly valve validated for body leakage and seat leakage as are follows,

<table>
<thead>
<tr>
<th>Valve dimension (in mm)</th>
<th>Body leakage testing</th>
<th>Seat leakage testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clamping pressure (bars)</td>
<td>Testing pressure for body (bars)</td>
</tr>
<tr>
<td>65</td>
<td>3.44</td>
<td>16</td>
</tr>
<tr>
<td>80</td>
<td>5.23</td>
<td>16</td>
</tr>
<tr>
<td>100</td>
<td>8.16</td>
<td>16</td>
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<tr>
<td>150</td>
<td>18.36</td>
<td>16</td>
</tr>
<tr>
<td>200</td>
<td>32.64</td>
<td>16</td>
</tr>
</tbody>
</table>

Testing results of the various valves (specimens) having dimensions from 50 mm to 300 mm diameter provided by the company for PN 16 series eccentric type flanged butterfly valve validated for body leakage and seat leakage as are follows,

<table>
<thead>
<tr>
<th>Valve dimension (in mm)</th>
<th>Body leakage testing</th>
<th>Seat leakage testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clamping pressure (bars)</td>
<td>Testing pressure for body (bars)</td>
</tr>
<tr>
<td>50</td>
<td>3.18</td>
<td>25</td>
</tr>
<tr>
<td>80</td>
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<td>12.74</td>
<td>25</td>
</tr>
<tr>
<td>150</td>
<td>28.65</td>
<td>25</td>
</tr>
</tbody>
</table>


## DISCUSSION ON TESTING RESULTS OF BUTTERFLY VALVE LEAKAGE TEST RIG:

As per the testing results, the valves provided by the company are tested and the results are verified as per the original data. In this the leak components showing leakage on the test rig and no leak components does not show the leak on the test rig. The tolerance limit of the leakage on for the test system is upto 1 bar i.e. when the leakage is 1 bar or above 1 bar the component is leak and when the leakage is below 1 bar then the valve is no leak and valve is acceptable. The drop in pressure present in the valve body as well as in the valve seat is shown on the analog as well as digital screen. The pressure required to clamp the valves of diameter of 50mm, 65mm, 80mm and 100 mm are less because the improper clamping. So the clamping pressure is increased to 2 to 3 times the calculated clamping pressure value while taking the consideration of casting capacity of the particular valve provided by the company. The test system developed is working as per requirement of the company.

## CONCLUSION

We would like to illustrate the comparison with the help of example of any dimensional Butterfly valve. Previously the time required for clamping and testing combinely of Butterfly valve was about 30 minutes. In that clamping time was 15 to 20 minutes for drilling the flanges of valves and then clamped with the help of nuts and bolts. After clamping, testing procedure does not required considerable time as compared to clamping. In seat testing the upper plate has to be removed by keeping bottom plate clamp as it is. Hence body and seat testing requires 10 to 15 minutes approximately. In this dissertation work we had tried to minimize the time required for clamping of the valve. Clamping of the valve has done by using hydraulic clamp. So the clamping time had reduced in considerable amount and thus the labour cost is also reduced.

## REFERENCES


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<table>
<thead>
<tr>
<th>valve dimension in mm</th>
<th>seat leakage testing</th>
<th>remarks</th>
<th>original status of valve</th>
<th>result</th>
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<tbody>
<tr>
<td></td>
<td>clamping pressure (bars)</td>
<td>testing pressure for seat (bars)</td>
<td>leak/no leak</td>
<td>ok tested</td>
</tr>
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<td>5.55</td>
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