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Design & Analysis of Truinnion Mounted Ball Valve

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Abstract:

This paper consist of design & analysis of trunnion mounted ball valve. The project work consist of verification of design of ball component of ball valve. Also the verification of design body & stem.The valve which is in consideration is of size 6 inch and ANSI pressure rating of 900 class gear operating full port type operating in water media. The valve constitutes of body and end connector material of casting grade ASTM A351 CF8M. The ball of trunnion mounted ball valve is made by forging process. Material of ball of forging grade F51.In this project static analysis of ball component is carried out. The stress values are calculated from stress calculations manually first. Then to determine the stresses in software a 3D CAD model created in CAD software Creo 3.0. The static analysis carried same software. The result from static analysis are compared with the experimental results. According to the result comparison if required the design changes suggested to the manufacturer**.**

Keywords *: Ball valve,design,static analysis,validation*

I. Introduction

A trunnion mounted valve means that the ball is constrained by bearings and is only allowed to rotate. The bearings act on the trunnions which may integral to the ball, or may be separate depending on the valve design. The key feature is that the ball does not shift as it does in a floating valve to press the ball into the downstream seat. Instead, the line pressure forces the upstream seat onto the ball to cause it to seal. As the area on which the pressure acts is much lower, the amount of force exerted on the ball is much less, leading to lower friction values and smaller actuators or gear boxes. In this paper the study focus is around the design verification of ball, body & stem by analytical method and validation of it with experimental results. Also this paper will verify the standard practice of design of ball component of valve.

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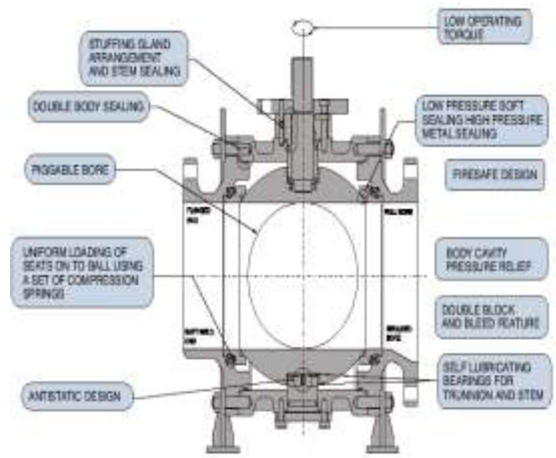

Fig 1. Layout of Truinnoin mounted ball valve

A. Product Specification

Name of Product	Truinnion Mounted Ball valve
Size	6 Inch
Pressure Rating	900 Class
Temp	0° to 80°
Media	Water
End Connection	Flanged End
Operating	Gear operated
Body	ASTM A351 CF8M
End Connector	ASTM A351 CF8M
Stem	SS316SH
Ball	F51
Seat	Duplex ss

II. Design of Valve

A. Design aspect of Ball

1. Ball should be precisely machined for valve
2. Solid ball type is to be designed to sustain desired pressure rating of valve
3. Surface finish of 8 Ra or better to be maintained for bubble tight shut off

4. Blended curvatures are to be provided on the ball to reduce seat wear and provide a high cycle life

B. Design aspect of Body

1. Body to be constructed in Two piece construction with bolting joint between body and connector
2. Surface of the body to be maintained as of radiographic quality
3. Shell thickness of body to be designed such that it exceeds thickness provided by ANSI B 16.34
4. Proper connections for Bosses for Vent, Drain, Sealant are to be provided
5. Media should pass smoothly through cylindrical port
6. Top mounting of body is designed as per ISO – 5211 Mounting Flanges
7. Specially processed valves for NACE and low temperature service
8. Smooth casting finish are achieved to achieve desired surface finish

C. Design aspect of stem

1. Stem are designed in such a way to withstand Break away Torque.
2. Stem material used is AISI ss 410 / 13 % Cr. Steel.
3. For the stem ground seating area is provided to establish engagement
4. Sound cross section is provided for stem to achieve positive Ball drive
5. Anti blow out stem permit replacement of the stem seals with the Valve in fully closed position.
6. Self adjusting sealing utilizing Belleville washers that automatically adjust to compensate for changes in temperature and wear.
7. Independent packing gland can be easily adjusted without removing mounting hardware or operator
8. Belleville washers can be added for a self adjusting live load, providing a continuous compression seal and anti-vibration protection
9. Packing gland and packing followers are V slotted to more equally distribute the load in the event one side is over tightened

III. Design Calculations

A. Design of Body

1. Shell Thickness:
   Minimum shell thickness

$$T_{bd} = \frac{P \times D}{(2 \times f) + p}$$

$$T_{bd} = 19.13\ mm \qquad (1)$$

(as per IBR at room temp)
Total Shell Thickness
T = Min shell thick + Corrosion allowance
T = 22 mm

B. Design of Ball

Considering the nominal diameter and pressure ratings of the valve. Thus deciding the ball bore size and using Birnies equation[1] outside diameter of the ball can be determined

Design Pressure or Test Pressure = Nominal Pressure X Factor of Safety

$$P = P_N \times 1. \qquad (2)$$

$$= 225\ MPa$$

DN = 150mm.

This specifies the bore size of a valve and also the valve size

Ball bore size d=25mm

Design Pressure P = 52.5 N/mm2

Assuming Factor of Safety F. O.S =1.5

Ball Material – Duplex Stainless steel (F51)

Yield Stress of material Yc= 450 N/mm2.

To determine the outside diameter of the ball, assuming that it acts as a Thick Open cylinder.

Applying Birnies equation(1) for thickness of open cylinders,

$$Tb = \frac{d}{2}\left[\left\{\frac{S_t+(1-0.3)\times 22.5}{S_t-(1+0.3)\times 22.5}\right\}^{0.5} - 1\right] \qquad (3)$$

$$\mathrm{Tb} = 45.75\ \mathrm{mm}$$

Where, d= Bore diameter of ball
St= Design stress
P= Test Pressure
μ= coefficient of Friction.
Stress St= (Ys /F.O.S)
St= 300 N/mm2

Thus outside Diameter,

$$D = d + 2 \times T_b \quad (4)$$
$$D = 241.5\ mm$$
$$D \approx 250\text{mm}$$

C. Design of stem

Diameter at Ball Joint $D_2 = 75mm$

Across Flat at Ball Joint $t_1 = 55mm$

Square at Ball Joint $t_1 = 46mm$

Diameter of Stem at Sealing $D_3 = 65mm$

Diameter of Stem at Operator side

$$D_4 = 55mm$$

Valve Torque

$$T' = 1639\ NM$$

Design Torque

$$T = 2 \times T' \quad (5)$$
$$T = 3278\ NM$$

1. Actuator Side Joint

Actual Torque for Circular cross section

$$T_4 = \frac{\tau \times \pi \times {r_4}^3}{2 \times 1000}$$

$$T_4 = 9702NM \quad (6)$$

2. Sealing Diameter

Actual Torque for Simple circular cross section

$$T_3 = \frac{\tau \times \pi \times {r_3}^3}{2 \times 1000}$$

$$T_3 = 16015\ NM \quad (7)$$

3. Ball & Stem Joint

Radius of Ball Joint

$$r = \frac{D_1}{2} = 37.5mm$$

Half the width of Ball Joint Across Flat

$$w = \frac{t_1}{2} = 27.5$$

Difference of distance between radius and half the width of across flat

$$r - w = 10$$

Actual Torque for Circular with flattened ends cross section at ball Joint:

$$T_1 = \frac{\tau \times r^3}{B \times 1000}$$

$$T_1 = 11696\ NM \quad (8)$$

III. Analysis Results of BALL

1.

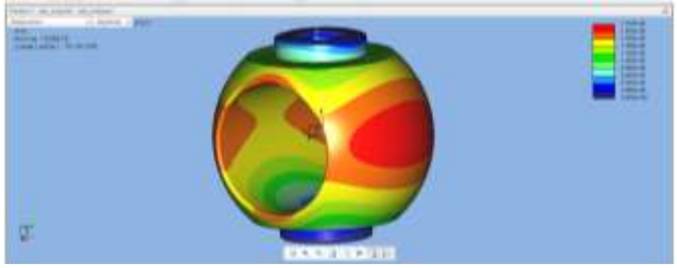

Fig.2 Ball Analysis Max displacement

Max Disp. =0.01789

2.

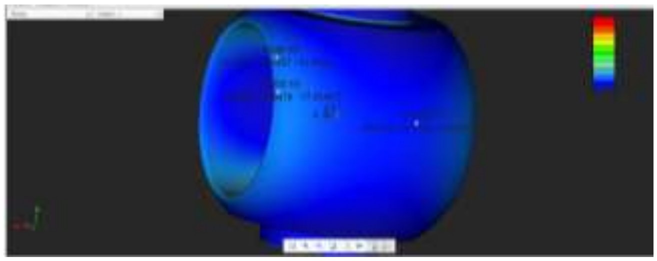

Fig. 3 Von Mises Stress

Maximum stress = 179 MPa

3.

Fig 4 Principal Stress

Avg stress = 120 MPa

4

Displacement versus Curve arc length

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4.

Von Mises Stress versus arc length

IV. Results

The valve shows No Leak condition, For the Hydrostatic Shell Test, Pneumatic seat test. Also valve shows torques in permissible limits for pressure closure test.

A. Body

The Shell thickness calculated for body & end connector are compared with the standard thickness & checked physically by measuring instrument .The safety & working of valve with shell thickness is tested by Hydrostatic Seat test.

Shell Thickness physical	ASME B16.4	BS EN 12516 - 2 - 2005
22	18	16

B. Ball Test

The material selected for ball duplex steel sustain the stress as it has Yield strength 450 Mpa From the simulation we get only up to 179 MPa Maximum Load

C.Stem

The valve withstand with the Break to close torque for 1500NM By the reference of Testing of Valve on open closure test & Stem is sustaining more torque Therefore the Design of stem is safe for the dimension

V. Conclusion

1. As the valve shows good performance in valve tests it can be conclude that the design verification of ball ,body & stem component is achieved through numerical calculation, analysis and experimentation
2. Standard industrial practice of selection of ball diameter is verified with mathematical calculations.
4. Study of Graph Shows variation in the angle results into Change in displacement of curve length & Von mises stress

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