Introduction to Design of Trunnion Mounted Ball Valve

(Size- DN1200, Rating- 150#)

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Abstract - *Ball valve opens by turning a handle attached to a ball inside the valve. The ball features a hole, or port, through the center, so as that when the port is in line with both ends of the valve, flow will occur. When the valve is closed, the opening is perpendicular to the ends of the valve, and flow is blocked. valve was evolved from plug valve, so it is also named ball type plug valve. The ball, which may make 1 / 4 turn (90°) round the spin axis, is that the on/off control of the valve.*

Key Words: *Trunnion, Pre-processing, Post-processing, Stem, Meshing, Bending Stress, Poisson's Ratio, Actuators, Hydrostatic Seat Test, etc.*

1. INTRODUCTION

The trunnion ball valve forms a quarter-turn valve using a hole, which is polished and repaired/supported ball to control the flow through it. The valve installed in the trunnion means that the ball is limited to bears and is only allowed to rotate. Most of the pressure on them is supported by systemic issues, which leads to lower stress as well no shaft fatigue. The line pressure moves upwards sit against a standing ball for line pressure forces the climbing chair into the ball to make it close. The mechanical suspension of the ball pulls momentum from the pressure of the line, to prevent excessive friction between the ball and the seats, so even in the torque of the rated operating range remains low. This is especially so there is an advantage when a ball valve is used because reduce the size of the actuator that's all the cost of the actuation package. The advantages of trunnion ball design are low performance torque, ease of use, reduced seat wear (Stem / ball separation prevents side loading and wear of lower seats improve performance and service life), high marking performance of high and low pressure (a different spring and river path line pressure is used as a stop mark low pressure ball and high-pressure applications). Trunnion is available in all sizes and with all pressure's classes but not suitable for cross purposes.

A valve installed in the trunnion means that the ball is forced by direction and you are only allowed to open. Lessons are followed millions that could be important in football, or in power relying solely on valve structure. The part is that the ball does not move as it does when it was swept away valve pressure ball on the lower seat. Instead, the line pressure enables the ascending seat into the ball to perform mark. As a field where weight display is very low, the amount of energy used is correct very small, which creates low rubbing rates and littler actuators or fraud boxes. In this work the investigation center next to the check of the structure of the ball, body and body by diagnostic strategy and its approval by test results. Additionally, this paper will test the standard action of the ball is part of the valve.

1.1 Background

This research includes the design of a high-pressure ball valve according to the requirements. The pressure and temperature required for the design are 525 bar and 60°C, respectively. The sealing cup, ball, connection adapter, valve housing and operating lever are designed. We get the following result: Design calculations are performed for valve components such as balls, sealing cups, connecting adapters, valve housings and operating levers. Acetal (polyoxymethylene) sealing cups can withstand a test pressure of 525 bar under maximum working conditions compared to other sealing materials such as polytetrafluoroethylene, Delrin-100.

The physical properties of the fluid and ball valve affect the flow characteristics of the fluid flowing through the flow control ball valve. The physical properties of a ball valve are determined by the valve coefficient, which adjusts the fluid flow rate as the cross-sectional area of the opening changes. The experimental results confirmed that the valve coefficient depends on the cross-sectional area of the opening, the shape and position of the hole passing through the valve ball. By modifying these factors, the fluid flow profile can be adjusted linearly with respect to the ball valve.

FEA provides a solution to the challenge of predicting failure due to unknown stresses by showing material problem areas and allowing designers to see all theoretical internal stresses. This method of product design and testing compensates the production costs that would have been incurred in the case of manufacturing and physical testing of each sample. From the above structural analysis of the valve assembly in different opening positions of the ball, the maximum stress in the ball was obtained as 142.65 MPa. The yield stress at 50% open is less than 270 MPa.

2. PROBLEM STATEMENT

There is currently no suitable 48-inch ball valve design on the market that meets the specific needs of the industry. Existing valve designs may not adequately address the challenges posed by high-pressure, high-temperature applications, resulting in extreme performance, reliability, and thus performance. which can effectively manage operating conditions.

2.1 Objectives

1. Design a 48-inch ball valve that can withstand high pressure and high temperature conditions.
2. Optimize valve design for efficient flow control and low pressure drop.
3. Ensures reliable sealing performance and positive cut-off performance in both high and low-pressure scenarios.
4. Choose suitable materials with corrosion resistance and good mechanical properties for the intended use.
5. Determine the excitation mechanism and torque specifications required for smooth and reliable operation.
6. In accordance with relevant industry standards, standards and regulations governing the design and manufacture of large ball valves.
7. Conducting complete tests such as pressure test, seat leakage test and functional tests to check the performance, reliability and compliance of the designed valves.

3. DESIGN METHODOLOGY

The Design Methodology includes following steps,
1) Identifying Requirements.
2) Pre-processing (3D Modelling).
3) Processing.
4) Post-processing (Virtual Analysis).
5) Comparing Virtual and Theoretical Results.
6) Testing and Quality Control.

3.1 Identifying Requirements

Table -1: Requirements

Type of Ball Valve	Trunnion Mounted
Body type	3 Piece
Bore size	DN 1200 (1200 mm)
Rating	150#
Operating Pressure	0.1 to 19.6 bar (max.)
Operating Temperature	-29 to 38 °C
Body Material	A216 Gr. WCB

3.1.1 Theoretical Calculations

A) Ball Deformation –

Table -2: Input Data for Ball

Ball Material	ASTM A 182 Gr. F316
Size of Valve (*DN*)	1200×1200 mm
Allowable Stress of Material (*ASME Sec. II, Part D*) (f)	115 N/mm²
Modulus of Elasticity (E)	195000 N/mm²
Poisson's Ratio (γ)	0.30
Ball OD (*OD*)	1750 mm
Ball ID (Bore) (d)	1166 mm
Ball Radius (R)	875 mm
Working Pressure (*ASME B16.34*) (P_w)	19.6 bar
Seat insert inner diameter (d_i)	1190 mm
Seat insert outside diameter (d_o)	1214 mm
Contact Radius (a)	601 mm

Table -3: Calculations for Ball Deformation

Parameter	Formula	Value
Design Pressure (Hydrostatic Seat test pressure)	$PD = 1.1 \times Pw$	21.56 bar
Insert Mean Diameter (Contact Dia.)	$d_c = \frac{(d_o + d_i)}{2}$	1202 mm
Ball Thickness at seat contact point	$T = \sqrt{R^2 - a^2} - \frac{d}{2}$	52.94 mm
Ball Sector height	$h = R - \frac{1}{2}\sqrt{4R^2 - d_c^2}$	239.06 mm
Load per unit area	$q = P_D = 21.56\ bar$	2.156 N/mm²
Total Thickness	$t = T + (2 \times \frac{h}{3})$	212.31 mm
Deflection	$y_c = \frac{qa^4}{2D}[\frac{L_{17}}{1+\gamma} - 2L_{11}]$	0.10485 mm
Moment	$M_c = qa^2 . L_{17}$	160617.1 N.mm

B) Shaft Design –

Table -4: Input Data for Shaft

Material of Shaft	ASTM A182 F6a
Yield Stress (τ)	275 MPa
Design stress intensity value (*API 6D*) (τ_{max})	147.4 MPa
Diameter at Ball Joint ($D1$)	254 mm
Across Flat at Ball Joint (t_1)	165 mm
Diameter of Stem at Sealing (D_3)	190 mm
Diameter of Stem at Operator side (D_4)	185 mm

Table -5: Calculations for Shaft Design

Parameter	Formula	Value
Design Torque	T = T' × 2.0	90076 N-m
Radius at Operator side Diameter (r_4)	$r_4 = D_4/2$	92.500 mm

Radius of Sealing Diameter (r_3)	$r_3 = {D_3}/{2}$	95.0 mm
Actual Torque for simple circular c/s (T_C)	$T_c = \frac{\tau \times \pi \times r^3}{2 \times 1000}$	198513 N-m
Radius of Ball Joint (r)	$r = {D_1}/{2}$	127.0 mm
Actual Torque at Ball Joint (T_1)	$T_1 = \frac{\tau \times r^3}{B \times 1000}$	221993 N-m

C) Trunnion Plate Design –

Table -6: Input Data for Trunnion Plate

Material	ASTM A216 Gr. WCB
Length (a)	1074 mm
Width (b)	900 mm
Thickness (t)	175 mm
Modulus of Elasticity (E)	200000 N/mm²
Bending Stress (σ)	235 N/mm²
Poisson's Ratio (υ)	0.30
Total Area (A)	966600 mm²
Load application radius (r_0)	213.500 mm
Load (P)	88290 N

Table -7: Calculations for Trunnion Plate

Parameter	Formula	Value
Uniform loading pressure over entire plate	$q = {P}/{A}$	0.091340782
Total load applied	$W = q \times A$	88290 N
Uniform over small concentric circle of r_0	$q_0 = {W}/{\pi r_0^2}$	0.616546569 N/mm²
Total load applied to center	$W_0 = q_0 \pi (r_0')^2$	88290 N
Center displacement	$Y_{max} = \frac{-\alpha q b^4}{E t^3}$	-0.0034 mm
Bending stress at center	$\sigma_b = \frac{\beta q b^2}{t^2}$	0.9058 N/mm²
Reaction load at center of long side	$R_{max} = \gamma q b$	37.1706 N/mm²
Bending stress at center of plate (σ_{max})	$\frac{3W}{2\pi t^2}[(1+\vartheta)l_n \frac{2b}{\pi r_0'} + \beta]$	2.65 N/mm²

3.2 Pre-Processing

Pre-processing includes following,
1) Define the geometric domain of the problem.
2) Define the material properties of the element.
3) Define the element's geometric properties (length, area, etc.).
4) Define the element connection (mesh the model).
5) Define load.

3.2.1 Defining Geometry (3d Modelling)

These 3D models are prepared on modelling software by Dassault System's SolidWorks 2022 version. Dimensions of components are from theoretical calculations and other parameters are from ASME B16.34 and ASME B16.47.

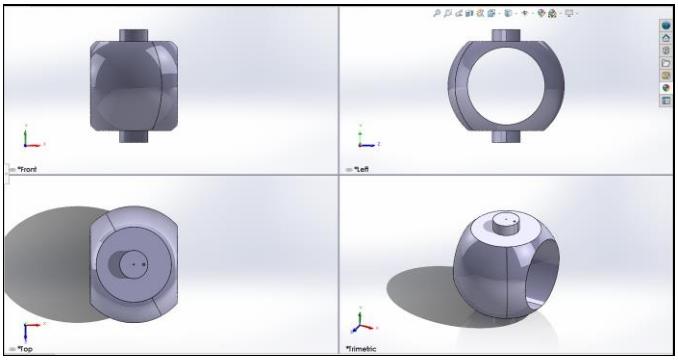

Fig. -1: Ball

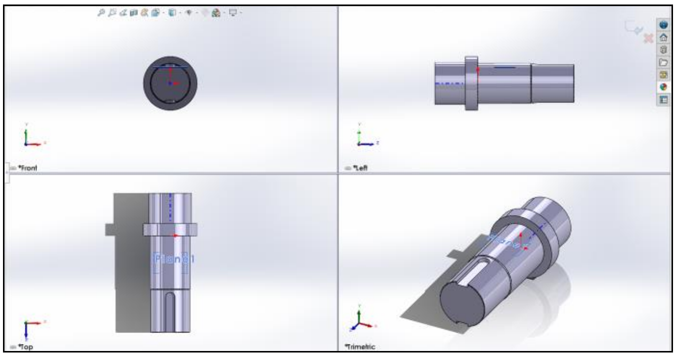

Fig. -2: Shaft

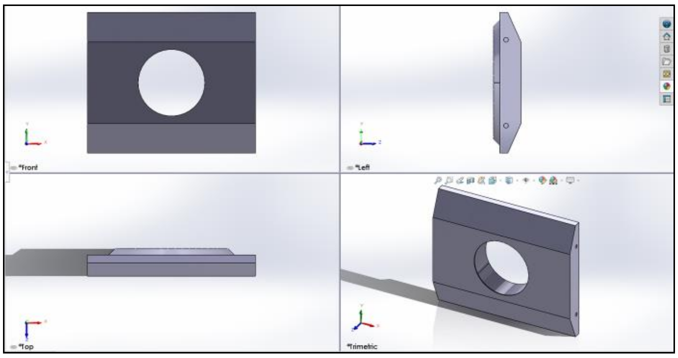

Fig. -3: Trunnion Plate

3.2.2 Defining Material Properties

Table -8: Material Properties

Component	Material (ASTM Grade)
Ball	ASTM A 182 Gr. F316
Shaft	ASTM A182 F6a
Trunnion Plate	ASTM A216 Gr. WCB

Material Properties are imported from material library of ANSYS.

3.2.3 Defining Meshing And Loads

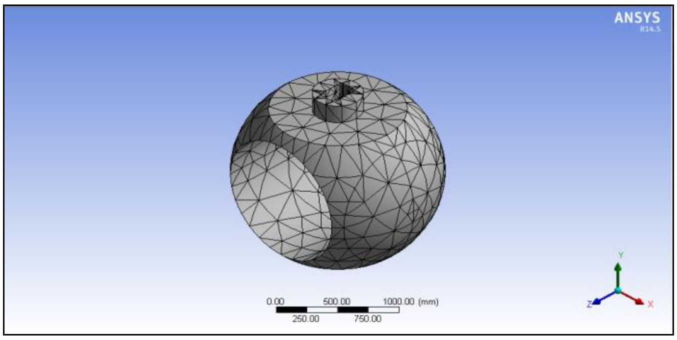

Fig. -4: Meshing of Ball

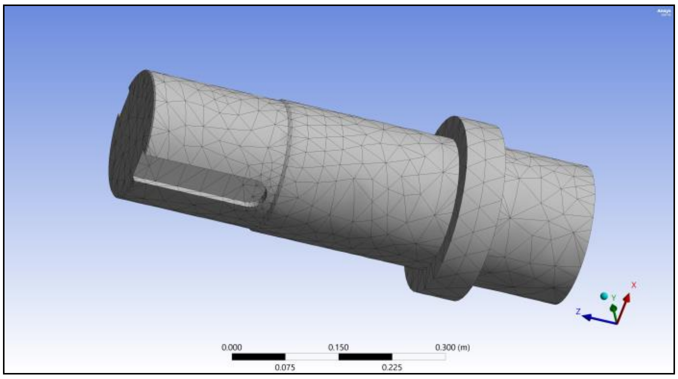

Fig. -5: Meshing of Shaft

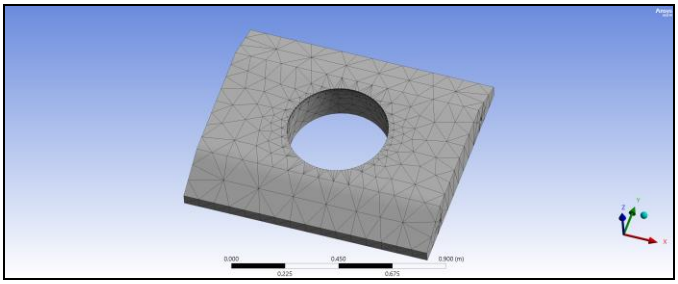

Fig. -6: Meshing of Trunnion Plate

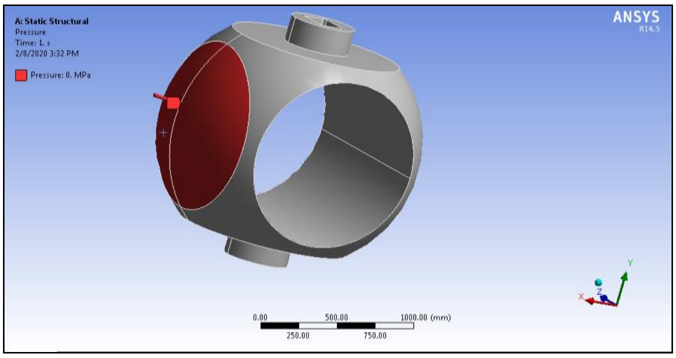

Fig. -7: Load Definition – Ball

Table -3: Component Loadings

Component	Type of Loading	Value
Ball	Moment	160617.1 N.mm
Shaft	Bending Moment	90076 N-m
Trunnion Plate	Point Load	88290 N

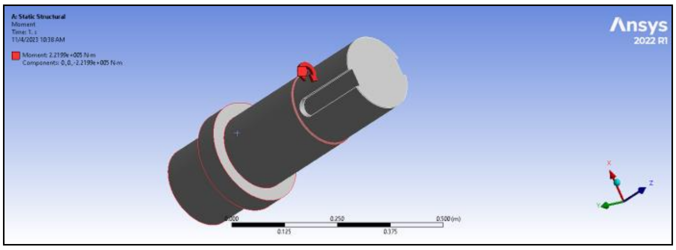

Fig. -8: Load Definition – Shaft

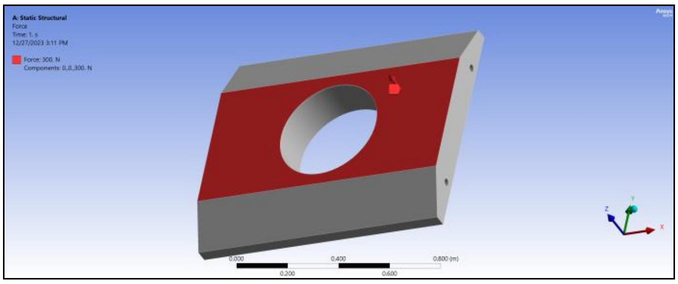

Fig. -9: Load Definition – Trunnion Plate

3.2.4 Post-Processing

In this step we are going to analyze and visualize the results using ANSYS post-processing tools. This includes generating diagrams, animations, and other visualizations to understand the performance and behavior of simulated systems.

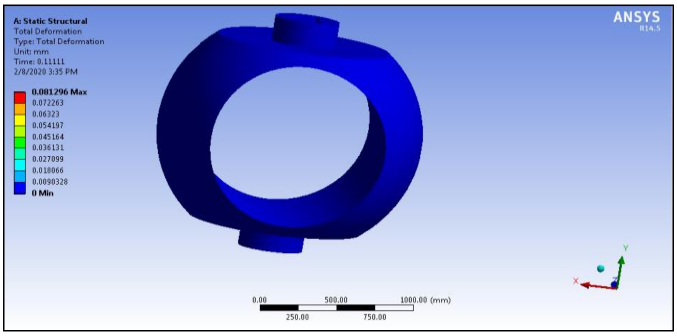

Fig. -10: Ball – Total Deformation

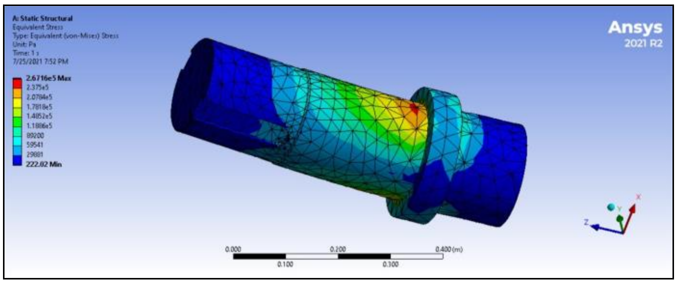

Fig. -11: Shaft – Equivalent Stress

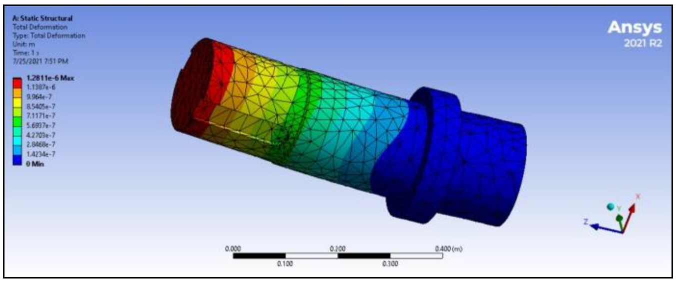

Fig. -12: Shaft – Total Deformation

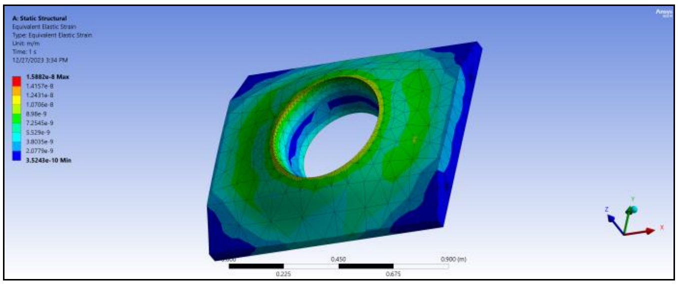

Fig. -13: Trunnion Plate – Equivalent Elastic Strain

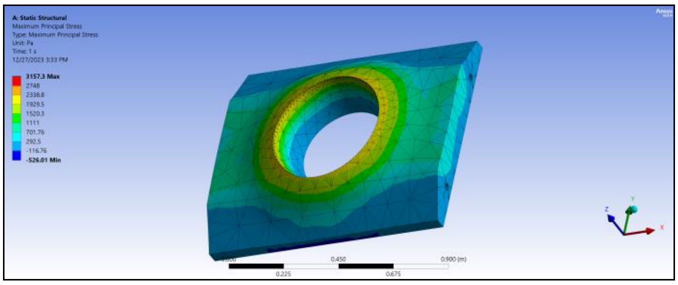

Fig. -14: Trunnion Plate – Maximum Principal Stress

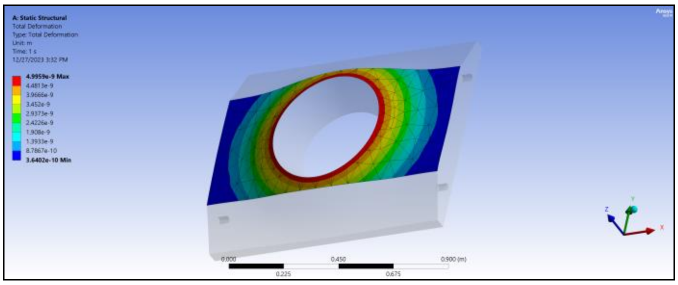

Fig. -15: Trunnion Plate – Toal Deformation

3.3 Testing and Quality Control

1) Pressure Testing - The valve demonstrated no leakage or permanent deformations, ensuring its ability to withstand the maximum operating pressure.

2) Seat Leakage Testing - The seat leakage rate meet or exceed the specified requirements, ensuring proper sealing and preventing any leakage through the valve.

3) Functional Testing - The valve demonstrated smooth and reliable operation within the specified torque requirements, ensuring its suitability for the intended application.

The valve must exhibit smooth and reliable operation within the specified torque requirements to ensure suitability for the intended application. A variety of quality control measures are used, including raw material inspection, dimensional inspection during manufacture, weld inspection, surface inspection, and finished product inspection. Quality control measures must ensure that manufactured valves meet all design specifications, industry standards, and quality requirements.

4. CONCLUSIONS

The design process includes a thorough analysis of various factors such as fluid mechanics, material selection, structural integrity, and operational efficiency. Using advanced modeling and simulation techniques, we optimized the valve's performance in different operating conditions and ensured flexibility and durability in different environments.

Our commitment to quality is reflected in our selection of quality materials, precision machining and adherence to industry standards. The combination of innovative features and advanced technology enhances the valve's capabilities, making it an outstanding solution for critical applications in sectors such as oil and gas, petrochemicals and power generation.

Throughout the paper, collaboration and communication played a key role in success. The interdisciplinary nature of this effort required seamless coordination between different teams, each contributing expertise in different aspects of the design process. This collaborative approach not only enriched the project, but also fostered a culture of knowledge sharing and continuous improvement.

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