Modeling and FEA Analysis of Ball Valve

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***Abstract* - A valve is a mechanical device which regulates either the flow or pressure of the fluid. Among the different types of valves, high pressure ball valve finds use in certain application like industrial hydraulics and marine hydraulics. The present study involves designing the high pressure valve of nominal diameter 25mm (DN 25 and PN 350). When the flow line exceeds 150bar, the valves are known as high pressure valves. With the increasing the pressure, the design of various components of the valve become critical. The designing of high pressure ball valve components depends on pressure, temperature ratings and also other factors. The design calculation is done for sealing cup, ball, connection adaptor, valve housing and operating lever. The maximum stress and deflection is calculated for different sealing cup materials under high pressure from research case study.**

***Key Words* - High Pressure, Stress, Deflection**

I .INTRODUCTION

A valve is a mechanical device which regulates either the flow or the pressure of the fluid. Its function can be stopping or starting the flow, controlling flow rate, diverting flow, preventing back flow, controlling pressure, or relieving pressure. Valves are mainly classified by following methods: Type of operation, The Nature and Physical condition of the flow, leakages and flow control types, operating method, functionality, etc. Most of the valves have two port, named inlet and outlet port. But for same applications there are multi-port configured valves. They can be three-way and four-way valves.

II. OBJECTIVE

The high pressure ball valve will be designed for a working pressure of 350bars and a temperature range of 0 to 500C. The objectives of the project are listed as follows,
1. Customer specification and need for ball valve. 2. Designing of various components of the high pressure ball valve.
3. Modeling the components using SOLID WORKS2015.
4. Meshing the components
5. Analyzing each components as follows -(ANSYS14.5)
- ❖ Determining the compressive strength of the sealing cups for each material by applying compressive force on the sealing cups.
- ❖ Determination of deflection occurred in the sealing cups.

6. Comparing the finite element analysis result with theoretical calculations.
7.Changing fluid temperature and pressure and find effect of fluid on valve using CFD analysis.

III. DESIGN

The present study deals with the design of a high pressure ball valve. The designing of valve depends upon the pressure and temperature ratings and also other factors. The critical components are analyzed using the finite element analysis. Thus obtained engineering analyses are compared with the theoretical calculations. The pressure acting inside the valve will be calculated and analyzed using the ANSYS software
Detail design of a high pressure valve:
Design high pressure valve preceded mainly it based on the rating ie pressure operating temperature of the valve and work for particular applications. Based on the aspects thesis material selection will be made and the theoretical calculations will be done here.

Product Description
•Size: DN 25 PN350
•Ends: SAE Flanged Ends
•Drill/Thrd: SAE Standards/BSPThreading
•Material Housing: Mild Steel and Trims-Stainless steel
•Inspection: Our QCD
•Additional requirement identified: -Ball - Chrome Plating Housing and Connection Adaptor - Zinc Plated Lever Type- Cranked lever with coating.
Based on the above data the following designing is been done.
Design of Ball:

Considering the nominal diameter and pressure ratings of the valve. Thus deciding the ball bore size and using Birnies equation outside diameter of the ball can be determined.
Nominal Pressure=350 Bar
Design Pressure or Test Pressure = Nominal Pressure X Factor of Safety
P = 350 x1.4 = 490 Bar
P= 49 N/mm2
As per DIN standard the new pressure of ball need to change the specific bore size on ball per standard therefore,
DN = 30mm.Which specifies the bore size of a valve and also the valve size.
Ball bore size d=30mm
Material - Stainless steel (SS304) Yield Stress of material Yc= 205 N/mm2.
To determine the outside diameter of the ball, assuming that it acts as a Thick Open cylinder.
Applying Birnies equation for thickness of open cylinders , we have, Thickness of cylinder,

$$t = \frac{d}{2} * \left\{ \left[\frac{St+(1-\mu)P}{St-(1+\mu)} \right]^{\frac{1}{2}} - 1 \right\} \quad \text{-----(1)}$$

Where, d= Bore diameter of ball St= Design stress
P= Test Pressure
μ= coefficient of Friction.
Stress St= (Ys /F.O.S)
St= 205/1.4=146.42 N/mm2
Substituting all above values in equation (1),
t= 6.99mm Hence, t≈7.0 mm.
Thus outside Diameter, D= d + (2 x t) =43.99mm.
Hence the diameter of the ball D≈44mm.
Design of Ball Seat:
Design of sealing cups is based on the compressive strength of the material, holding the required pressure. With different materials are tested calculated and compared for selection in the safe design.
•Poly Tetra Fluoro Ethylene(PTFE):
Compressive Strength of material Sc= 41.40 N/mm2 Force acting on the Sealing cup,
F= Design Pressure Px AreaA=49 x 1029.135mm2
Thus,Force, F= 50427.62N
Mean circumference of sealing cup, b = π d
Here, d= mean diameter of sealing cup = (44+25)/2 = 34.5 mm
Thus mean diameter d= 34.5mm Therefore force, b= π x 34.5 b= 108.33 ≈109mm.
Mean circumference of sealing cup =109 mm
Arc Length, l= r x μl= 4.3125mm.
Crushing Area can be calculated as, Ac=b x l =4.3125 x 108.33=467.17mm2.
Crushing Strength or Compressive Strength on sealing Cups is given by,

$$\sigma c = \frac{F}{Ac}$$

σ c = 107.942N/mm2. σ c ≈108 N/mm2.
Factor of safety F.O.S=
F.O.S = 0.3835
Since the F.O.S = 0.3835 for PTFE material, thus it cannot be used for Design(Test) pressure valves.

Table 1: Theoretical results for different materials

Material	Theoretical Calculations		
	Sc in N/mm^2	σc in N/ mm2	F.O.S
PTFE	41.40	107.942	0.3835
RPTFE	50.0	107.942	0.4632
UHMWPE	51.675	107.942	0.4787
PEEK	138	107.942	1.2784
TFM	316.94	107.942	2.9362

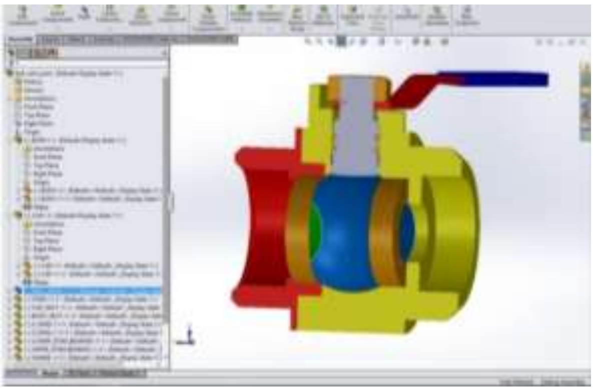

Fig 1. ball valve model (section view)

IV.ANALYSIS

Doing the FEA analysis of the high pressure ball Valve:

- Doing the FEA analysys of the high pressure ball valve as below:
  1. Modeling the components using SOLID WORKS2015.
  2. Meshing the components
  3. Analyzing each components as follows -(ANSYS14.5)
- Determining the compressive strength of the sealing cups for each material by applying compressive force on the sealing cups.
- Then finding the frictional effect between ball and the sealing cups.
- Determination of deflection occurred in the sealing cups.

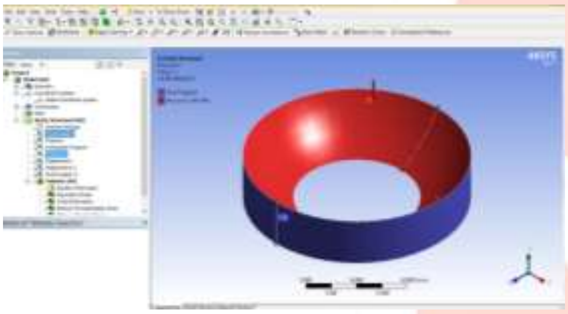

Fig 2. Seat Boundary condition

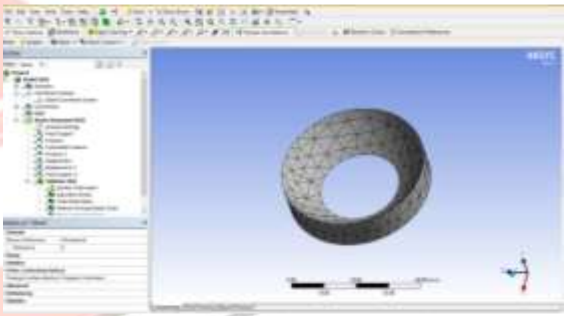

Fig 3. Seat Mashing

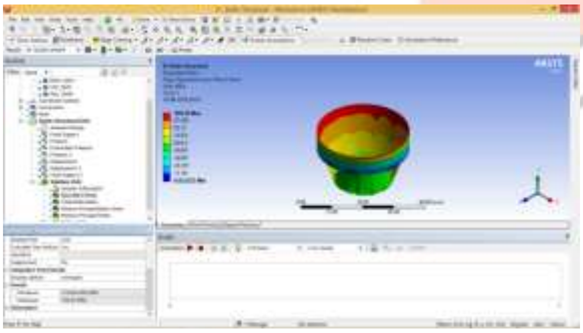

Fig 4. Stress in PTFE Seat

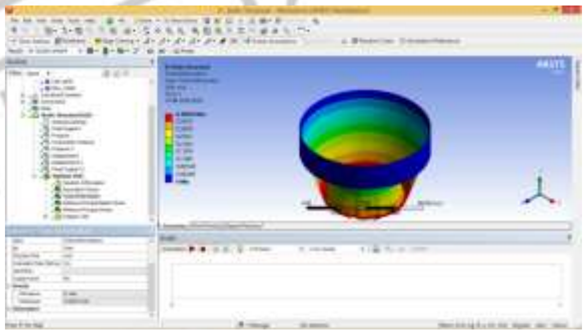

Fig 5. Deformation in PTFE Seat

Result obtain from above analysis as per below

Table 2: FEA result

	E.Stress(Pa)	Deformation(mm)
PTFE	109.45	0.3841
PEEK	109.45	0.0011
TFM	109.45	0.0321

Table 3: Comparison result

	Theoretical		Analytical			
	Sc (MPa)	E.Stress (MPa)	E.Stress(MPa)	Deformation (mm)	FOS	Temp Range(F)

PTFE	41.4	107.94	109.45	0.3841	0.3835	450
PEEK	138	107.94	109.45	0.0011	1.2784	600
TFM	316.94	107.94	109.45	0.0321	2.9362	500

Now, CFD analysis:

General purpose CFD software ANSYS 14.5 Workbench is used to investigate the model. The work file is exported to CFD analysis software.The simulation is performed for the flow through the valve. Predicted performance factors for the flow properties and mechanical are then studied for efficient flow analysis . In this case, the simulations were carried out for different flow rate and temperature of the fluid in the variable range.

Fig 6. Mashing of Domain

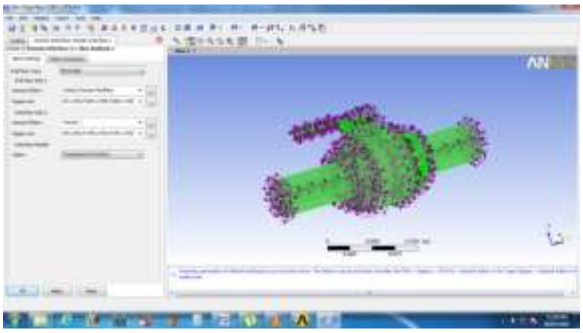

Fig 7. Boundary Condition

Now applying fluid temperature to valve and shows the effect to different parts the temperature effect shown here:

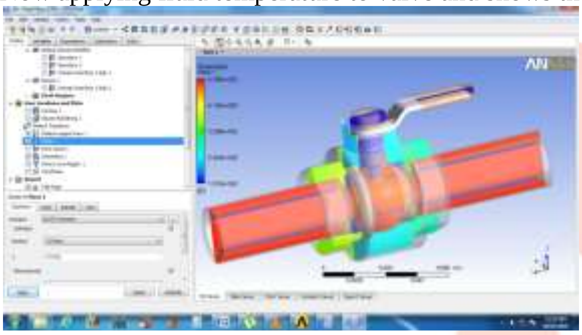

Fig 8. Temperature Distribution on Valve(Section)

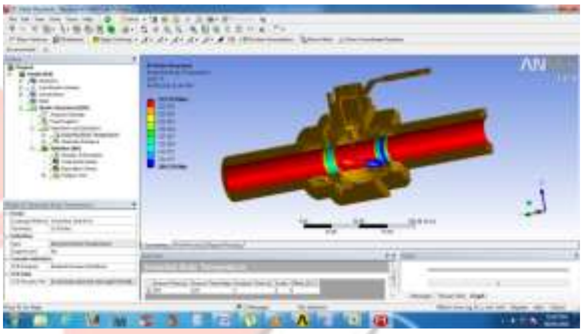

Fig 9. Temperature Effect on valve

Now taking this variable temperature and apply to the valve and get the following effect:

Same procedure for pressure on valve we get the below result

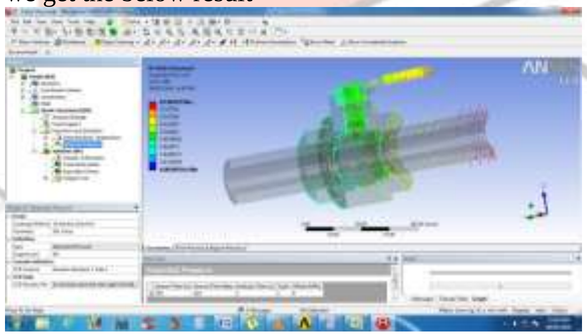

Fig 10. Pressure Distribution on valve

We get the following result at constant velocity 50 m/s with different temperature:

From the CFD Analysis we got the different temperature and pressure effect on ball seat and ball which is depend on fluid velocity and fluid temperature

- As we increase the temperature of fluid the temperature in valve increased from this study we find that the temperature in seat is lower than the ball temperature.
- We obtain that Variable temperature did not effect on fluid pressure.
- With the changing velocity the pressure in valve change ,here the pressure on seat is morebthan the ball so we need high strength seat material.
- Velocity of fluid have negotiable effect on valve temperature.
- All of above points suggest that the fluid condition is more important for effective selection of ball valve for batter efficiency.

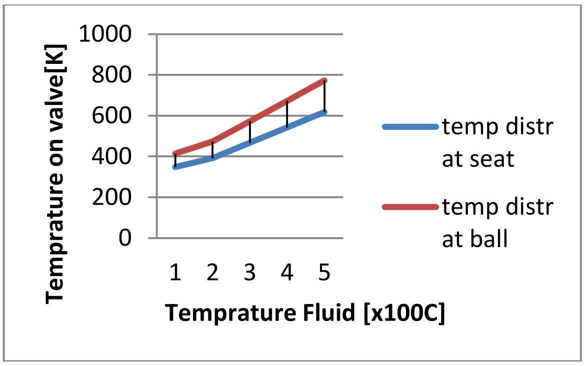

Fig 11. Temperature Chart

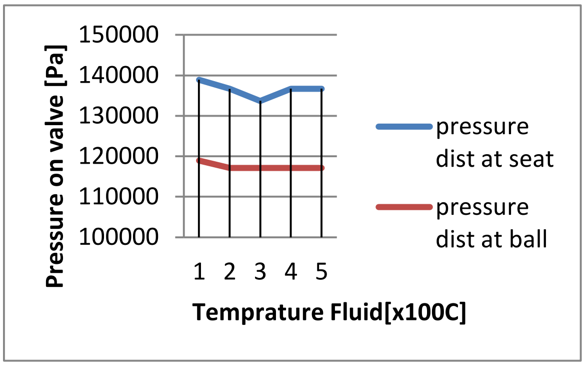

Fig 12. Pressure Chart

V. CONCLUSION

The present study involves the design of high pressure ball valve to the requirements. The pressure in the designing are 490. The following conclusion can be derived.

1.Design calculation for valve components like, ball,sealing cups are done.

2.Sealing Cups of material TFM is able to sustain the test pressure of 490 bar under maximum working conditions compared to other sealing materials like PTFE(Poly Tetra Fluoro Ethylene), PEEK(Polyetheretherketone)etc.

3. The minimum deflection in the sealing cup for material PEEK is 0.0011mm as compare to other sealing cup materials.

4. Sealing Cups (PTFE,PEEK and TFM) are analyzed for test pressure of 490bar and using ANSYS software. Obtained ANSYS results are compared with theoretical calculations and are found nearer to calculated values.

5. Temprature increase with the fluid temperature and pressure on seat and ball constant with same velocity

6. While changing velocity the pressure changes and constant temperature found in Ball Valve

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