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Design and Development of Double Offset Butterfly Valve

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Abstract **- Valves are mechanical devices specially designed to direct, start, stop, mix or regulating the flow, pressure of a process fluid. A butterfly valve typically consists of a metal disk formed around a central shaft, which acts as its axis of rotation. As the valve's opening angle is increased from 0 degrees (fully closed) to 90 degrees (fully open), fluid is able to more readily flow past the valve. These valves are commonly used to control fluid flow inside of piping systems. The main objective of this study is to find out stresses developed in butterfly valve Shell and Disk.**

This report contains the information about design and development for the 4'' X 150# Butterfly Valve with Double Eccentricity using ANSYS. It comprises the calculations which are required for design of Butterfly Valve such as Shell Thickness, Disc Thickness, Stem Diameter and Calculation of Torque using ASME, IBR. Also includes the modeling and assembly of butterfly valve using Pro-E.

After this work, we will discuss Finite Element Analysis of Butterfly valve Shell and Disc. The solid model will discretized into finite elements and logical constrains will applied in boundary conditions. The stress results obtained in finite element analysis will have to check whether, is there a chance for optimization of design.

Index Terms **- Valves, Butterfly Valve, Double offset Butterfly Valve, ASME, IBR.**

I. INTRODUCTION

A valve is a mechanical device that controls the flow of fluid and pressure within a system or Process. A valve controls system or process fluid flow and pressure by performing any of the following functions:

- Stopping and starting fluid flow
- Varying (throttling) the amount of fluid flow
- Controlling the direction of fluid flow
- Regulating downstream system or process pressure
- Relieving component or piping over pressure

There are many valve designs and types that satisfy one or more of the functions identified above. A multitude of valve types and designs safely accommodate a wide variety of industrial applications. Regardless of type, all valves have the following basic parts: the body, bonnet, trim (internal elements), actuator, and packing.

II. OBJECTIVE OF PROJECT

Design and development for the 4'' X 150# Butterfly Valve with Double Eccentricity

TABLE I. DESIGN INPUT DATA SHEET

Sr. No.	Input	Details
1	Product	Butterfly Valve
2	Size	4"
3	Pressure Rating/ Class	150 #
4	Maximum Operating Pressure	20 Bar

TABLE II. ALLOWABLE DESIGN STRESS VALUE

Allowable Design stress value for various materials as per ASME Boiler and Pressure Vessel code Section VII division I is as below,

Sr. No.		1	2	3	4
Material		WCB	WC6	WC9	CF3
Ref. *Table*		UCS-23	UCS-23	UCS-23	UHA-23
Ref. *Page*		286	294	294	400
Min. Yield Strength *ksi*		36	40	40	30
Spec. Min. Yield Strength *ksi*		70	70	70	70
Allowable Stress *ksi*		17.5	17.5	20.5	17.5
Maximum Allowable Stress	***ksi***	14	14	16.4	14
	MPa	96.5	96.5	113	96.5
	Kg/ cm²	984	984	1153	984

Sr. No.		5	6	7	8
Material		CF8	CF3M	CF8M	CF8C
Ref. *Table*		UHA-23	UHA-23	UHA-23	UHA-23
Ref. *Page*		400	420	420	448
Min. Yield Strength *ksi*		30	30	30	30
Spec. Min. Yield Strength *ksi*		70	70	70	70
Allowable Stress *ksi*		17.5	17.5	17.5	17.5
Maximum Allowable Stress	***ksi***	14	14	14	14
	MPa	96.5	96.5	96.5	96.5
	Kg/ cm²	984	984	984	984

III. DESIGN CALCULATION

3.1 Calculation for Shell Thickness of Valve Body

3.1.1 Thick Cylinder (As per IBR 290(d))

$$t = \frac{w_p * D}{2f + w_p} + C$$

Where,
WP = Maximum Working Pressure, Kgf/mm2
D = External Diameter of Chest, mm
F = Allowable Stress, Kg/mm2
Lower of the two expression i.e. $\frac{UTS}{2.7}$ & $\frac{YS}{1.5}$
C = Minimum Positive Tolerance, mm
(5 mm for Carbon Steel and 2.5 mm for Stainless Steel)

3.1.2 Thin Cylinder

$$t = \frac{P*D}{2*S}$$

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

3.1.3 From Valve Design Book by Pearson

$$t = \frac{P*D}{2*f} + c$$

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

3.1.4 By Formula ASME see VIII Div-1

$$t = \frac{P*R}{(S*E) - (0.6*P)}$$

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

After putting values for all variables in the above formulas, we got a result for shell thickness as given in the following table.

TABLE III. SHELL THICKNESS ACCORDING TO DIFFERENT FORMULAE

Sr. No.	As per Formulae	Shell Thickness (mm)
1	Thick Cylinder (As per IBR 290 (d))	5.24
2	Thin Cylinder	1.04
3	Valve Design Book by Pearson	6.72
4	ASME (VIII Div. 1)	1.04
	Provided Shell Thickness	**9.0**

3.2 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.

$$t = \sqrt{\left\{\frac{3*W}{8*\pi*M*f}\left((3*M+1)*\left(1-\frac{4*r^2}{D^2}\right)\right)\right\}}$$

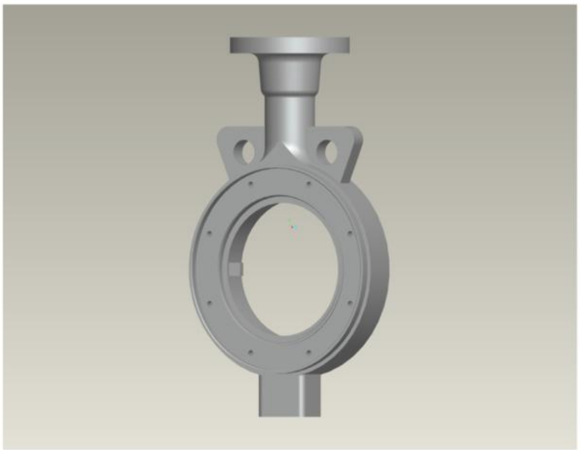
Where,
W = Total Load acting on Disc
M = Reciprocal of Poisson's ratio = 3.4
f = Maximum Allowable Working Stress
r = Distance at which thickness to be determine

TABLE IV. DISC THICKNESS AT VARIOUS DISTANCE FROM CENTER OF DISC

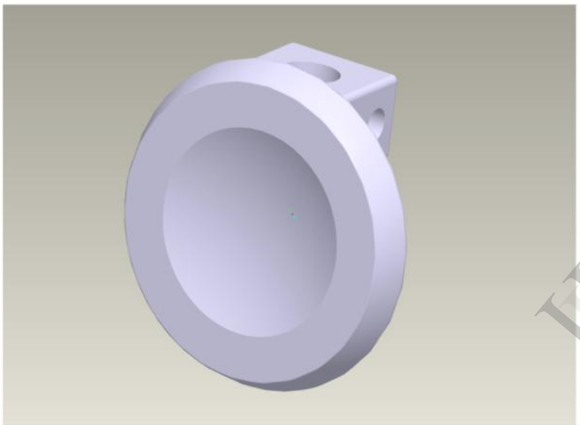
Sr. No.	Radius (mm) from center	Thickness (mm)
1	0 (at center)	8.92
2	14.25	8.64
3	28.5	7.89
4	42.75	6.24
	Provided Disc Thickness at Center	9.00

IV. 3 D MODELING

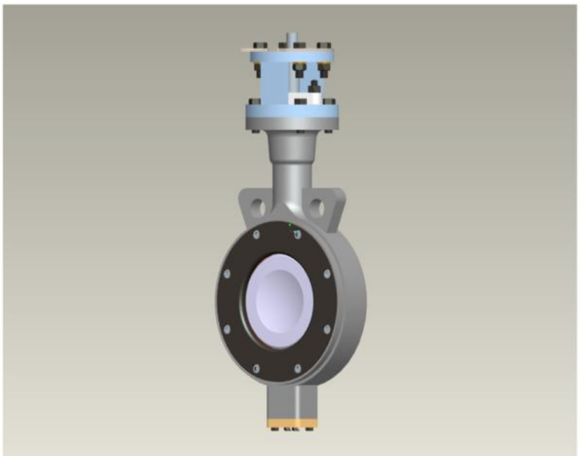
4.1. Body



4.2. Disc



4.3. Assembly



V. STRESS ANALYSIS USING ANSYS R10

5.1. Introduction

The stress analysis can be linear/elastic or nonlinear/plastic depending on the addressed failure mode and on the applied code rule. In this analysis, the scope is concerned with the calculation of Displacement and Von Mises Stress using FEA numerical solver. Finite element analysis is carried out on the various parts of butterfly valve. The parts are listed as given below,

1) Body
2) Disc
3) Assembly

Finite element analysis is carried out using different material Grade in Carbon Steel and Stainless Steel such as WCB, CF8 and CF8M for Body and Disc. For Stem material, we considered ASTM A276-Type 410.

The objectives of the analysis are

i) To estimate the maximum stress and to understand the distribution of various stresses.
ii) To estimate the maximum deflection and understand the details of deflection in various direction.

To create 3D model of various parts of butterfly valve, we used PRO-E Wildfire 2 and for analysis ANSYS Ver. 10.

5.2. Material Properties

The elements are attributed with the material properties as shown in the table below,

TABLE V. MATERIAL PROPERTIES OF DIFFERENT MATERIALS

Sr. No.	**1**	**2**	**3**
MATERIAL NAME	ASTM A216 Gr WCB	ASTM A351 Gr CF8	ASTM A276 Type 410
YOUNG'S MODULUS	210 GPa	194 GPa	199.982 GPa
POISSION'S RATIO	0.3	0.265	0.285
YIELD STRENGTH	249.2 MPa	206 MPa	275.76 MPa
ULTIMATE STRENGTH	482.6 MPa	483 MPa	483 MPa

5.3. *Result of Analysis*

5.3.1. *Body*

5.3.1.1. *Von Mises Stress*

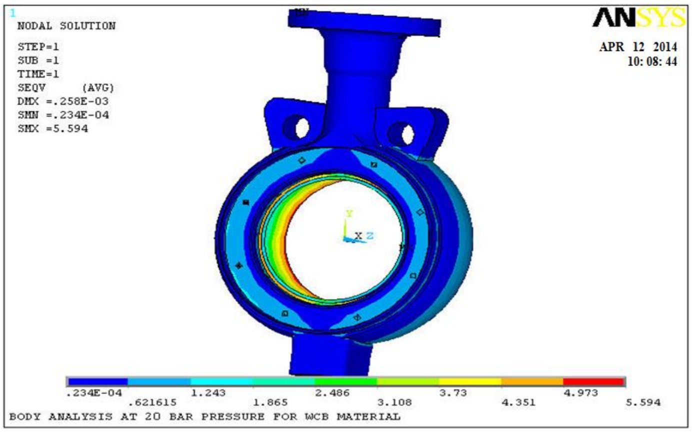


Fig 5.3.1.1 Von Mises Stress for WCB Material (Max. Value 5.594 MPa)

5.3.1.2. *Displacement Sum*

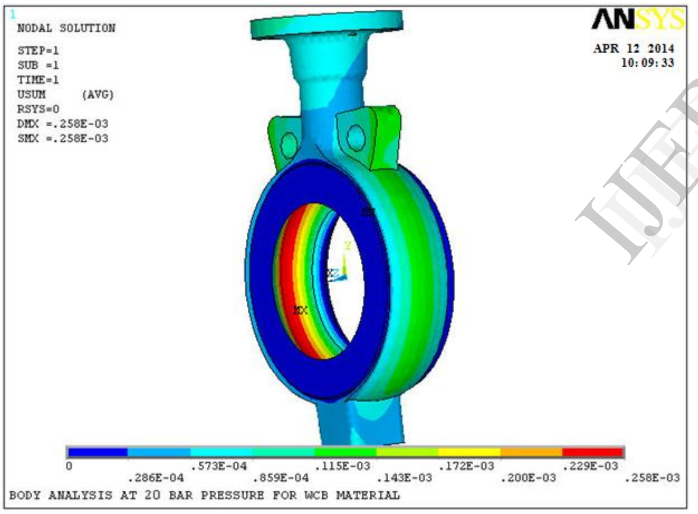


Fig 5.3.1.2 Displacement Vector Sum for WCB Material (Max. Value 0.000258 mm)

TABLE VI. SUMMARY OF VON MISES STRESS AND DISPLACEMENT VECTOR SUM OF BODY

Material	Maximum Von Mises Stress (MPa)	Maximum Displacement (mm)
ASTM A216 Gr WCB	5.594	0.000258
ASTM A351Gr CF8	5.728	0.000276
ASTM A351 Gr CF8M	5.728	0.000278

5.3.2. *DISC*

5.3.2.1. *Von Mises Stress*

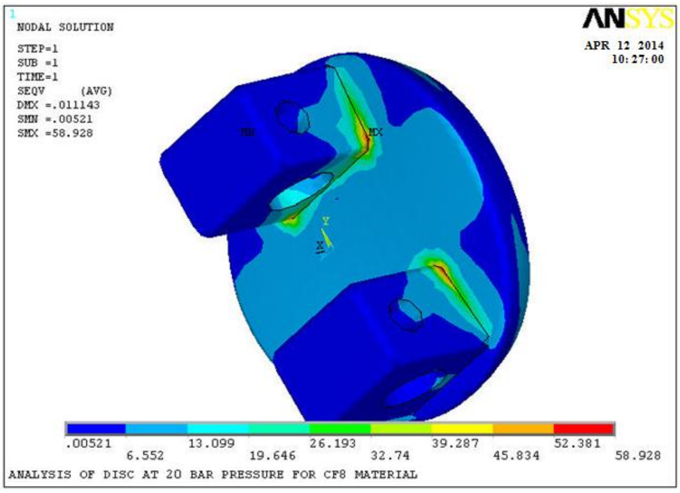


Fig 5.3.2.1 Von Mises Stress for CF8 Material (Max. Value 58.928 MPa)

5.3.2.2. *Displacement Sum*

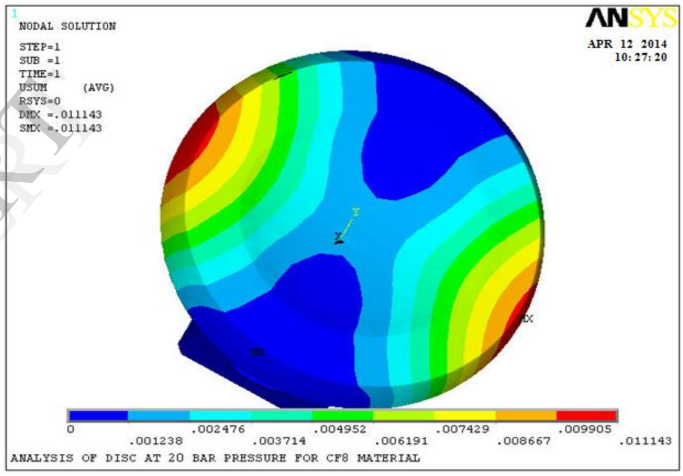


Fig 5.3.2.2 Displacement Vector Sum for CF8 Material (Max. Value 0.011143mm)

TABLE VII. SUMMARY OF VON MISES STRESS AND DISPLACEMENT VECTOR SUM OF DISC

Material	Maximum Von Mises Stress (MPa)	Maximum Displacement (mm)
ASTM A351Gr CF8	58.928	0.011143
ASTM A351 Gr CF8M	61.662	0.011201

5.3.3. *ASSEMBLY*

5.3.3.1. *Von Mises Stress*

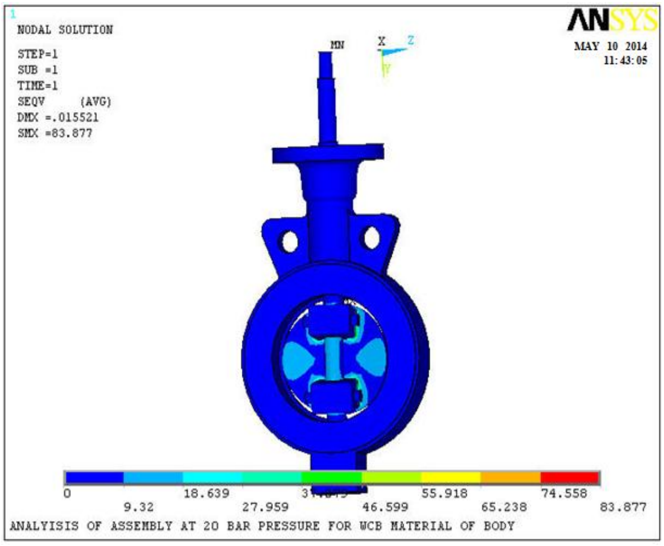


Fig 5.3.3.1 Von Mises Stress for WCB Material (Max. Value 83.877 MPa)

5.3.3.2. *Displacement Sum*

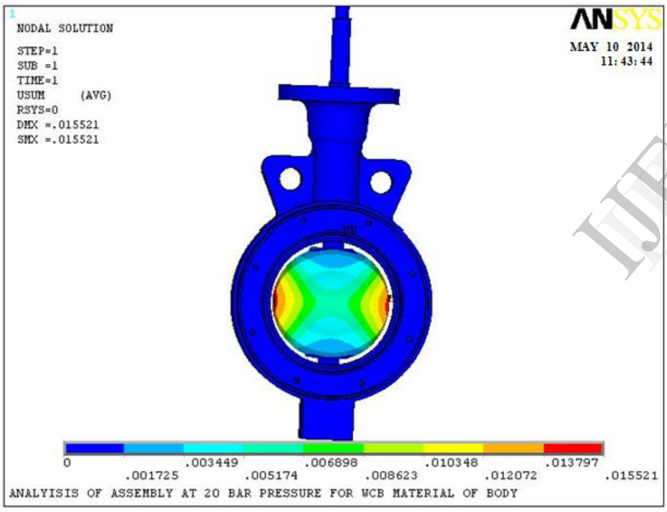


Fig 5.3.3.2 Displacement Vector Sum for WCB Material (Max. Value 0.015521mm)

TABLE VIII. SUMMARY OF VON MISES STRESS AND DISPLACEMENT VECTOR SUM OF ASSEMBLY

Material	**Maximum Von Mises Stress (MPa)**	**Maximum Displacement (mm)**
ASTM A216 Gr WCB	83.877	0.015521
ASTM A351Gr CF8	85.896	0.015514
ASTM A351 Gr CF8M	85.896	0.015514

5.3.4. *Summary of Result*

TABLE IX. SUMMARY OF ANSYS ANALYSIS

Part / Material (Yield Strength)		WCB (249.2 MPa)	CF8 (206 MPa)	CF8M (206MPa)
Body	VM (MPa)	5.594	5.728	5.728
	DISP (mm)	0.000258	0.000276	0.000279
Disc	VM (MPa)	NA	58.928	61.682
	DISP (mm)	NA	0.011143	0.011201
Assembly	VM (MPa)	83.877	85.896	85.896
	DISP (mm)	0.01552	0.01551	0.01551

VI. CONCLUSION

As from the summary of the result, we see that, the Von Mises Stress induced in the parts of Butterfly Valve because of applied pressure of 20 bars, are less than the yield strength of the material.

Hence we conclude that, Design of Butterfly Valve for Chosen Material is safe.

REFERENCES

[1] Kwuimy, C. K., & Nataraj, C. (2012), Modeling and dynamic analysis of a butterfly valve, 70(1), pp. 435-451.
[2] Song, X. G., Wang, L., Baek, S. H., & Park, Y. C. (2009), Multidisciplinary optimization of a butterfly valve. ISA transactions, 48(3), pp. 370-377.
[3] Kim, S. W., Kim, J. H., Choi, Y. D., & Lee, Y. H. (2009), New Trends in Fluid Mechanics Research Springer Berlin Heidelberg, pp. 463-466.
[4] Kimura T, Tanaka T, Fujimoto K and Ogawa K (1995), Hydrodynamic Characteristics of a Butterfly - Prediction of Torque Characteristics ISA Transactions pp. 327-333.
[5] Boesch, B. E., A. S. Humpherys, and D. A. Young. 1981. How scheduling fits in the irrigation program in the Grand Valley of Colorado. Proc. Am. Soc. Agric. Engr. Irrig. Scheduling Conf., (Dec. 1981), pp. 159-165.
[6] Pearson G. H., “Valve Design”, Mechanical Engineering Publication Ltd, London.