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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.

During project, we will discuss Finite Element Analysis of Butterfly valve Shell, Disc stem and their assembly. 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.

Keywords: *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

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	5
Material	WCB	WC6	WC9	CF3	CF8
Ref. *Table*	UCS-23	UCS-23	UCS-23	UHA-23	UHA-23
Ref. *Page*	286	294	294	400	400
Min. Yield Strength *ksi*	36	40	40	30	30
Spec. Min. Yield Strength *ksi*	70	70	70	70	70
Allowable Stress *ksi*	17.5	17.5	20.5	17.5	17.5
Maximum *ksi*	14	14	16.4	14	14

Sr. No.		1	2	3	4	5
Material		WCB	WC6	WC9	CF3	CF8
Allowable Stress	***MPa***	96.5	96.5	113	96.5	96.5
	Kg/ cm²	984	984	1153	984	984

III. DESIGN CALCULATIONS

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 [7]

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

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

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.

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

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

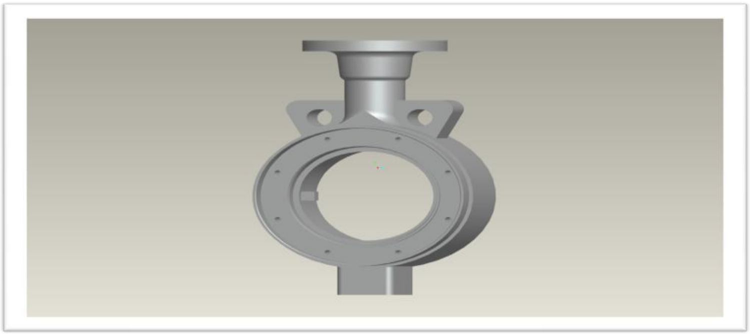
After putting the values for all variable used in the above formulae, we got thickness value of Disc at various distance from center of Disc which are noted in following table.

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

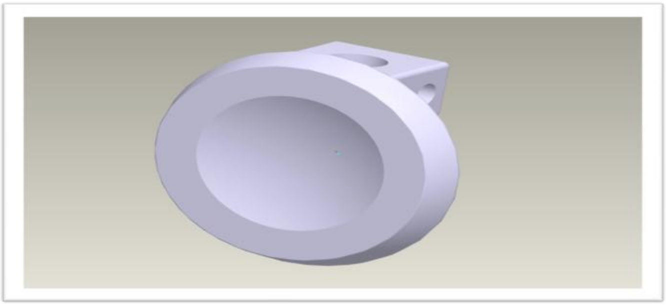
Sr. No.	**Radius (mm) from center**	**Thickness (mm)**
1	0 (at center)	8.92
2	14.25	8.64
3	28.5	7.89
4	42.75	6.24
	Provided Disc Thickness at Center	9.00

IV. D MODELING

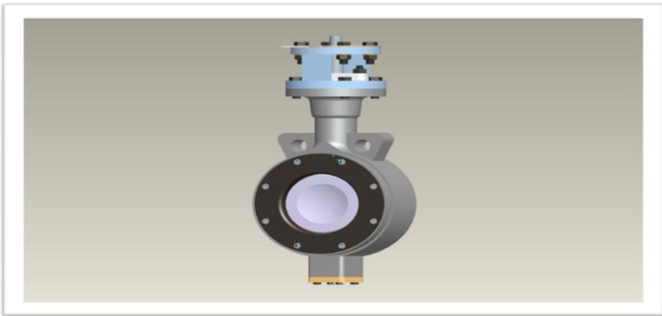
4.1 Body



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 and CF8 for Body and Disc. For Stem material, we considered ASTM A276-Type 410.

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

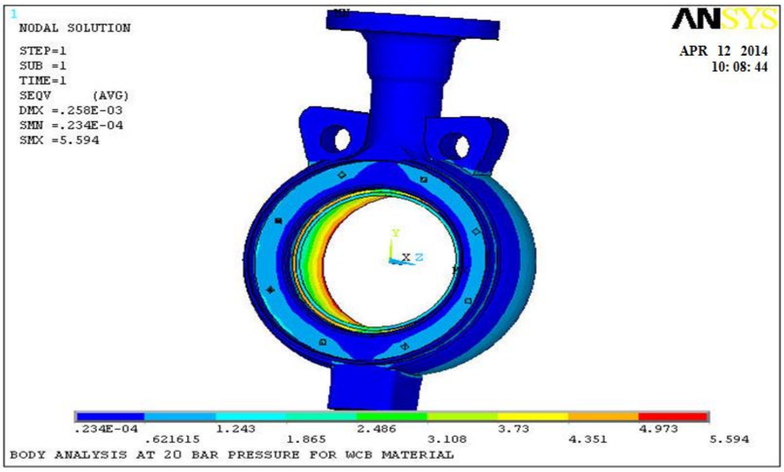


Fig 5.3.1.1 Von Mises Stress for WCB Material (Max. Value 5.594 MPa)

5.3.1.2. Displacement Sum

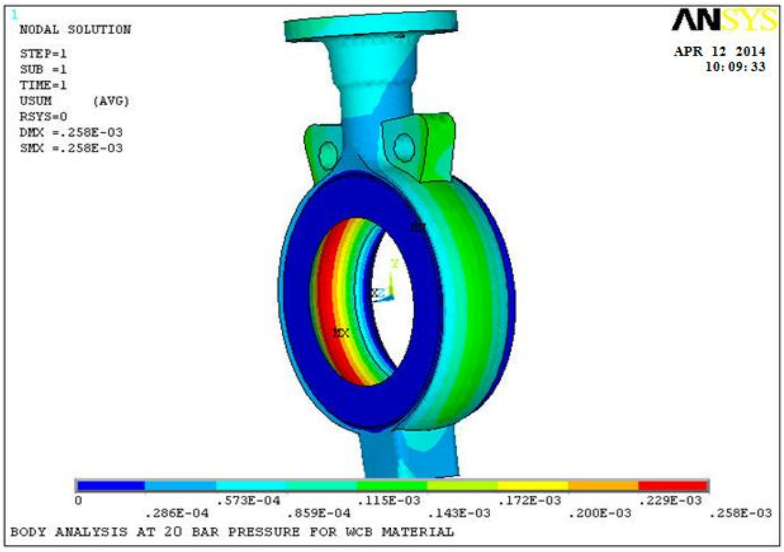


Fig 5.3.1.2 Displacement Vector Sum for WCB Material (Max. Value 0.000258 mm)

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

5.3.2 DISC

5.3.2.1 Von Mises Stress

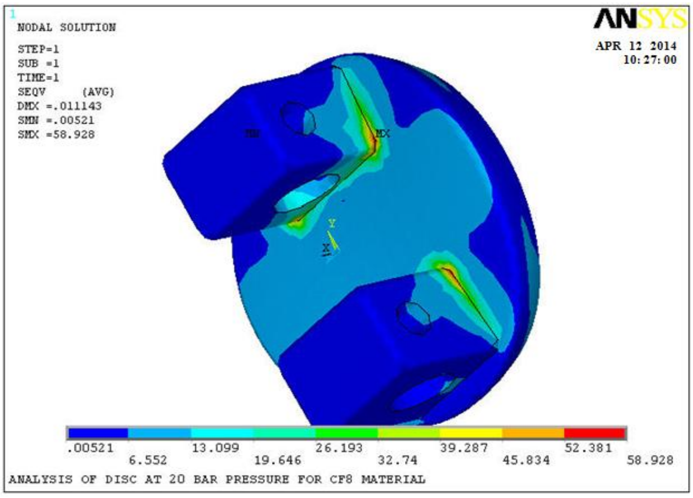


Fig 5.3.2.1 Von Mises Stress for CF8 Material (Max. Value 58.928 MPa)

5.3.2.2. Displacement Sum

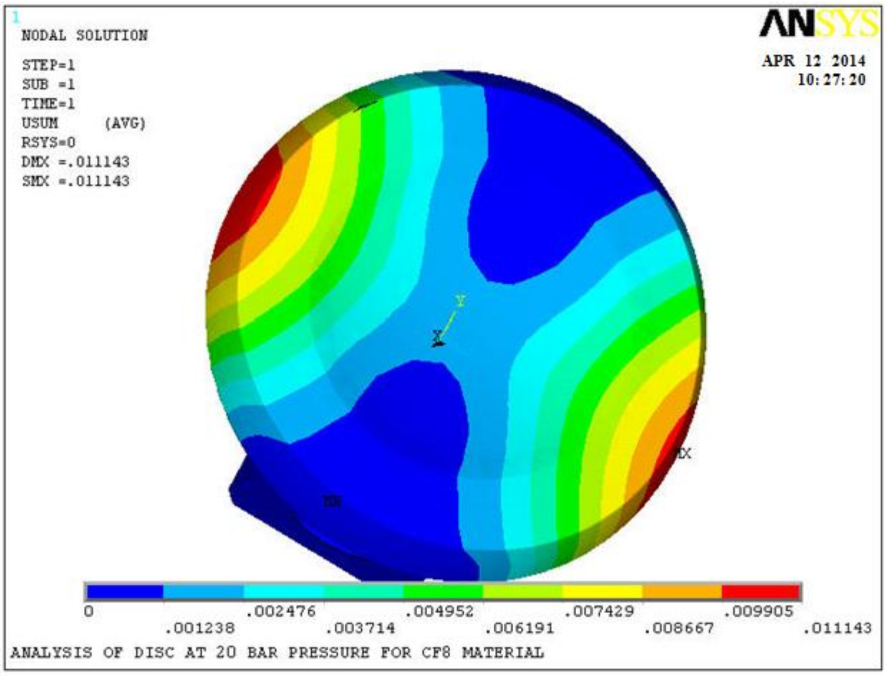


Fig 5.3.2.2 Displacement Vector Sum for CF8 Material (Max. Value 0.011143mm)

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

5.3.3 Assembly

5.3.3.1 Von Mises Stress

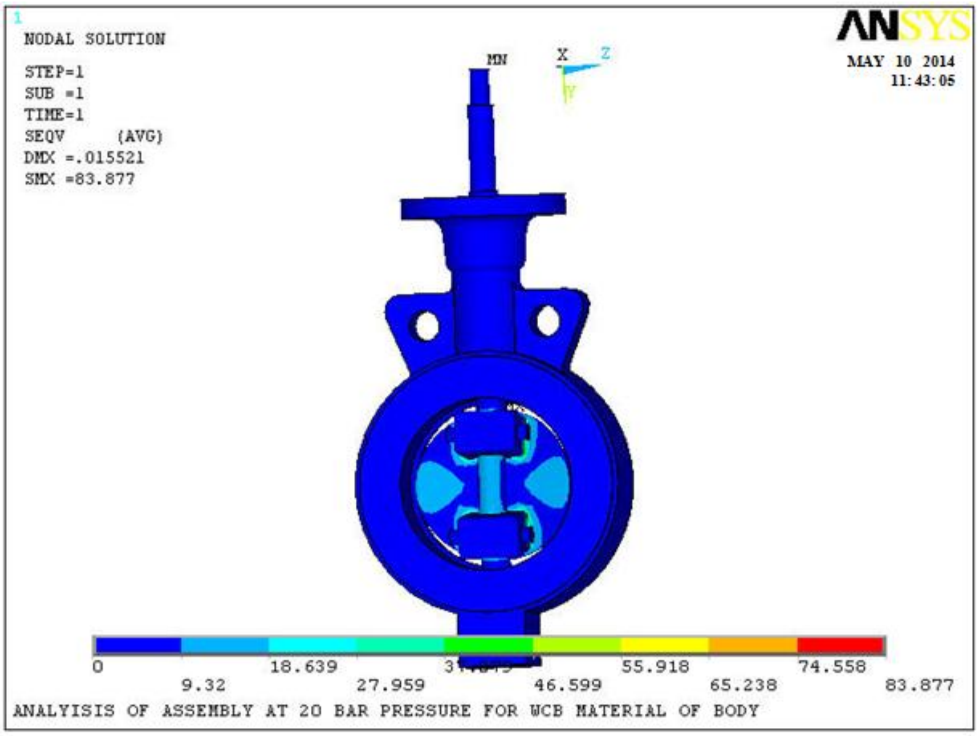


Fig 5.3.3.1 Von Mises Stress for WCB Material (Max. Value 83.877 MPa)

5.3.3.2. Displacement Sum

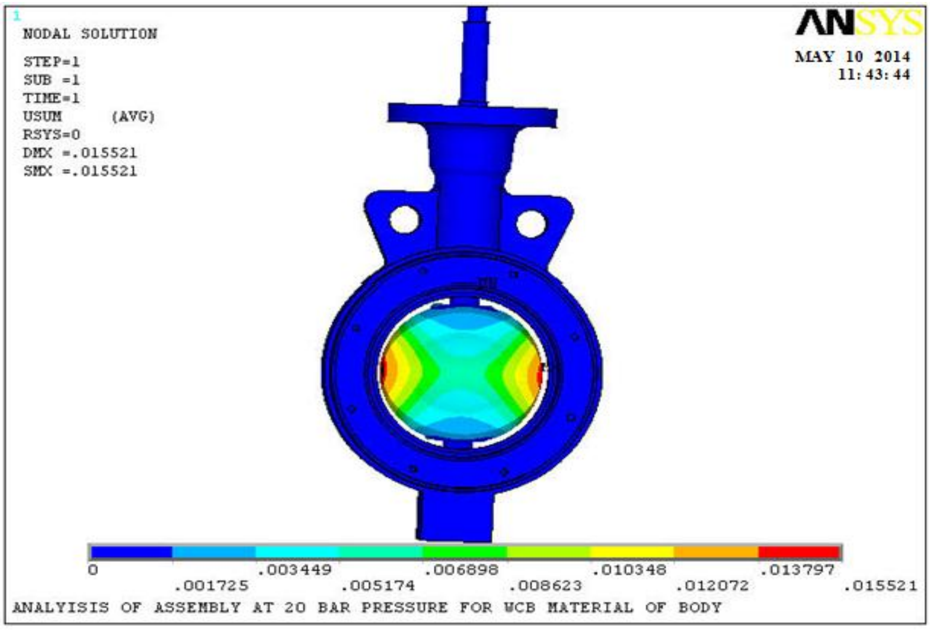


Fig 5.3.3.2 Displacement Vector Sum for WCB Material (Max. Value 0.015521mm)

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

5.4 Summary of Result

TABLE IX. SUMMARY OF ANSYS ANALYSIS

Part / Material (Yield Strength)	Body		Disc		Assembly	
	VM (MPa)	DISP (mm)	VM (MPa)	DISP (mm)	VM (MPa)	DISP (mm)
WCB (249.2 MPa)	5.594	0.000258	NA	NA	83.877	0.01552
CF8 (206 MPa)	5.728	0.000276	58.928	0.011143	85.896	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] Naseradinmousavi, P., & Nataraj, C. (2011), Nonlinear mathematical modeling of butterfly valves driven by solenoid actuators, Applied Mathematical Modeling, 35(5), pp. 2324-2335.
[2] Kwuimy, C. K., & Nataraj, C. (2012), Modeling and dynamic analysis of a butterfly valve, 70(1), pp. 435-451.
[3] 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.
[4] 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.
[5] Kimura T, Tanaka T, Fujimoto K and Ogawa K (1995), Hydrodynamic Characteristics of a Butterfly - Prediction of Torque Characteristics ISA Transactions pp. 327-333.
[6] 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.
[7] Pearson G. H., "Valve Design", Mechanical Engineering Publication Ltd, London.