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"DESIGN & ANALYSIS OF TURBINE INLET LARGE SIZE BUTTERFLY VALVES BY USING FEM METHOD"

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ABSTRACT

Butterfly valves are widely used in various industries such as water distribution, sewage, oil and gas plants. The hydrodynamic torque applied on the butterfly valve disk is one of the most important factors which should be considered in their design and application. Although several methods have been used to calculate the total torque on these valves, most of them are based on static analysis and ignore the hydrodynamic effect which has a major role to determine the torque of the large-size valves. The 3D modeling to be performs for butterfly valve by using CAD software. Further the stress & displacement FEM analysis of the butterfly valve to be performed by using ANSYS tool to evaluate the optimized result.

KEYWORDS: *Butterfly Valve, FEM, CAD design, Stress, Deformation, CATIA, ANSYS*

I. INTRODUCTION

Hydro power is considered as one of the most economical and non- polluting sources of energy. Power generation from the water is termed as Hydroelectricity. Hydroelectricity means electricity generated by hydro power or from the use of the gravitational force of falling water or flowing water. One of the most common forms of power generation since this form of energy neither produces direct waste matter nor it is subjected to exhaustion.

Now a day's more and more hydro electrical power plants being setup and renovated. But still the design and development of hydro electrical power plant is based on the traditional methods. Therefore there is a huge scope of utilization of modern day's technique like finite element method (FEM) for achieving maximum possible optimization.

In any power plant valves for different purposes are usually needed. Normally it is a shut-off valve just in front of the turbine. In this way the turbine may be emptied without emptying the shaft or penstock. In addition the guide vane cascade is depressurized so that leakage flow is avoided.

Butterfly valve detail: These specialized Butterfly valves are installed to protect hydro-electric installations against the possibility of penstock rupture. Butterfly valves are normally applied in front of low and medium head water turbines, i.e. heads up to 200 m. For high head power plants the butterfly valve is from time to time used as a closing device in inlet tunnels and alternatively as emergency closure valves.

The main characteristics of this butterfly valve are: nominal diameter D=2000 mm, nominal pressure Pn=1.128 MPa, hydraulic test pressure Ph=2.962 MPa

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Valves are designed to close against turbine runaway during an emergency condition. These valves act as isolating devices for inspection of penstock without dewatering entire head race tunnel. Yet another important application is for large water supply schemes fed from reservoirs through long pipelines, failure of which can cause disastrous floods. Valves by virtue of their design and robust construction, close down automatically and instantaneously in the event of the downstream pipeline failure. These valves close during over velocity condition occurring due to turbine trip or runaway condition.

Butterfly valves are normally applied in front of low and medium head water turbines, i.e. heads up to 200 m. For high head power plants the butterfly valve is from time to time used as a closing device in inlet tunnels and alternatively as emergency closure valves.

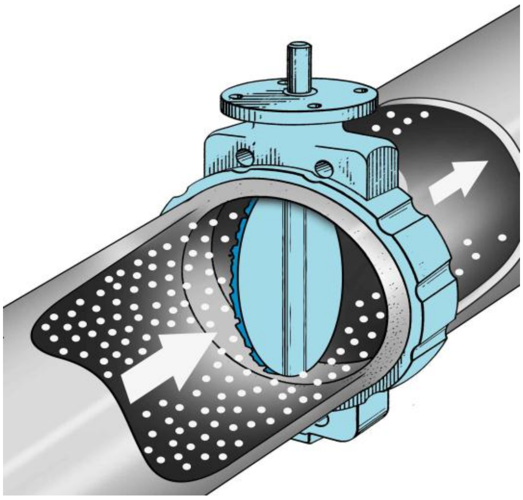

Figure 1: Butterfly valve assembly

II. RELATED WORK

However, only studying the fluid characteristics is not enough for the large diameter butterfly valve because the pressure produced by the fluid is too high, which has great effect on the stress distribution in valve. Valves are very widely used for hydro mechanical part which is used to control the flow of water under high heads.

The butterfly valve is one of the types of shut-off devices most commonly employed in hydropower station and systems. Its use is favored because of their relatively low cost, compactness, light weight, reasonable water tightness and simplicity of operation.

This dissertation describes the design optimization of butterfly valves using CAD software and ANSYS. To structural design the butterfly valve for weight optimization the von mises stress & maximum deformation value are find out by using ANSYS and compare stresses value for existing casted verses optimized fabricated design for door and body of butterfly valve.

Analysis of the butterfly valve is done to optimize the stresses and minimize the weight using ANSYS. The mathematical model of optimization is established firstly, and the FEA is carried out by using the ANSYS software. Based on the analysis of optimal result, the stress concentrates on the valve has become evaluate, which provides a better reference for redesign of valve.

III. BASIC DESIGN CRITERIA FOR BUTTERFLY VALVE COMPONENT

For design of valve components (valve disc, valve body & valve trunnion) reference consideration are taken from the IS 7326 (Part 1): 1992 deals with the structural and hydraulic aspects of design, formulas are taken from various design books (e.g. Roark’s formulas for stress & strain, design data book etc.) & various reference from other existing designs.

The main characteristics of this butterfly valve are: nominal diameter D=2000 mm, nominal pressure Pn=1.128 MPa, hydraulic test pressure Ph=2.962 MPa.

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Valve Body Design consideration

- The body may be made in a single piece or in parts for convenience of manufacture, transport to site and erection.
- In case of butterfly valves used as a turbine inlet valve, the body should be designed to avoid abrupt changes in velocity. The shell of the body should be designed such as to sustain maximum static head including pressure rise. Supporting feet for installing the valve on its foundation should be provided.
- The body should have two hubs for trunnion bearing housings.
- The fasteners should be of corrosion resistant steel; otherwise they should have corrosion resistant coating.

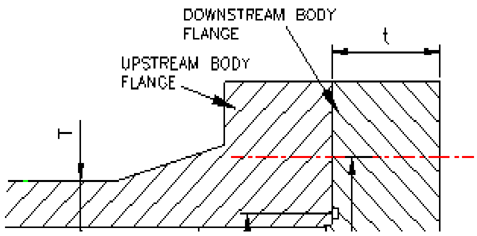

Figure 2: Butterfly valve body section

$$\textbf{Hope Stress } \sigma = \frac{PD}{2t}$$

Table1: Refer existing data

Body shell diameter	D	2000	mm
Thickness of body shell (existing)	t	65	mm
Stress	σ	30.18	Mpa

Table2: Valve body shell thickness calculation for different material grades

S.no.	Material Grade	Yield stress	Allowable yield stress	Body shell thickness
1	Cast G 340-570	340	113.3	17.3
2	S355J2+N	335	111.7	17.6

Valve Disc Design consideration

- The design of all types of discs should be such as to offer minimum head loss in the open position and to sustain the full differential pressure across the closed valve.
- The disc may be split in parts for ease of manufacture, transport and erection. Disc should be stress relieved before taking up for machining operation.
- The angular travel of disc should be nearly 90^0 from open to shut-off position.
- Thrust collar should be provided to hold the disc in the center of valve body.

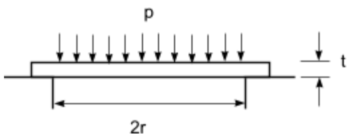

Figure 3: Uniform load “p” N/mm^2 on plate thickness “t” mm

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Table3: Valve disc plate thickness calculation for different material grades

S.no.	Material Grade	Yield stress	Allowable yield stress	Disc plate thickness
1	Cast G 340-570	340	113.3	10.7
2	S355J2+N	335	111.7	10.8

IV. MODEL GEOMETRY DESCRIPTION

3D modeling is carried out with the help of CAD software CATIA ver 5.0 by using the existing design details. A separate model is prepared for the analysis of exiting & optimized valve disc & body.

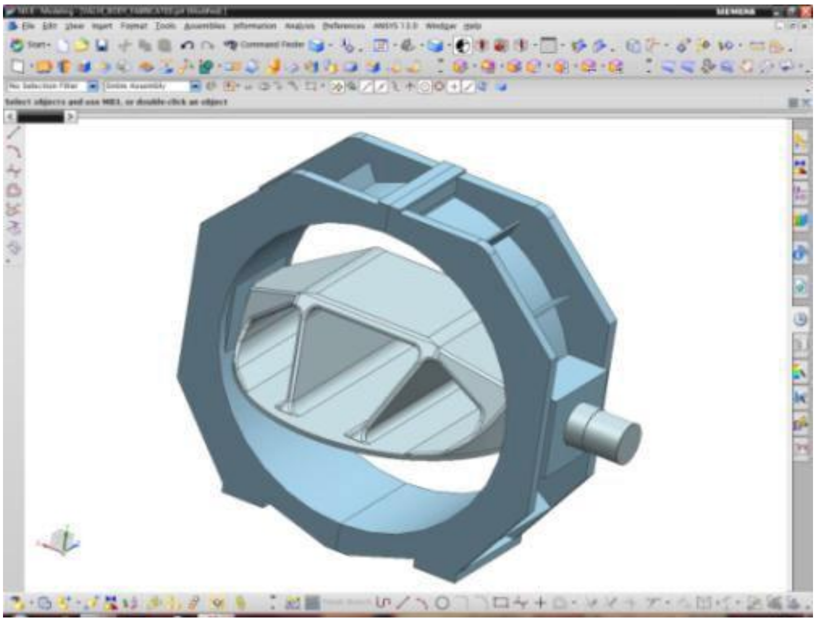

Figure 4: 3D isometric view of Butterfly valve assembly

V. MESSING OF BUTTERFLY VALVE

Meshing is carried out with ANSYS software, a tetrahedral element were used for meshing the model with prism layer for modeling boundary layer with smooth transition as shown in next slide. After meshing we obtained 11898 nodal points and 6625 coarse elements for Disc & 19970 nodal points and 11420 coarse elements for Body.

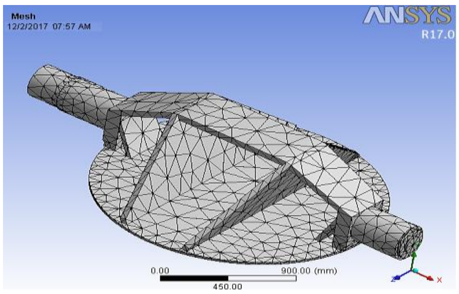

Figure 5: Mesh view for Butterfly valve disc optimized design

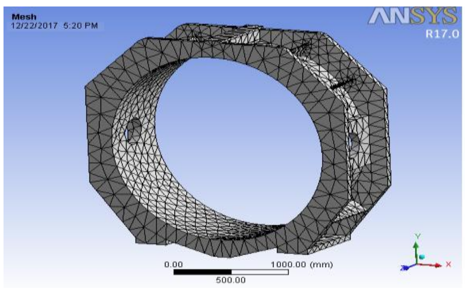

Figure 6: Mesh view for Butterfly valve body optimized design

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VI. BOUNDARY CONDITION & LOADING FOR FEA ANALYSIS

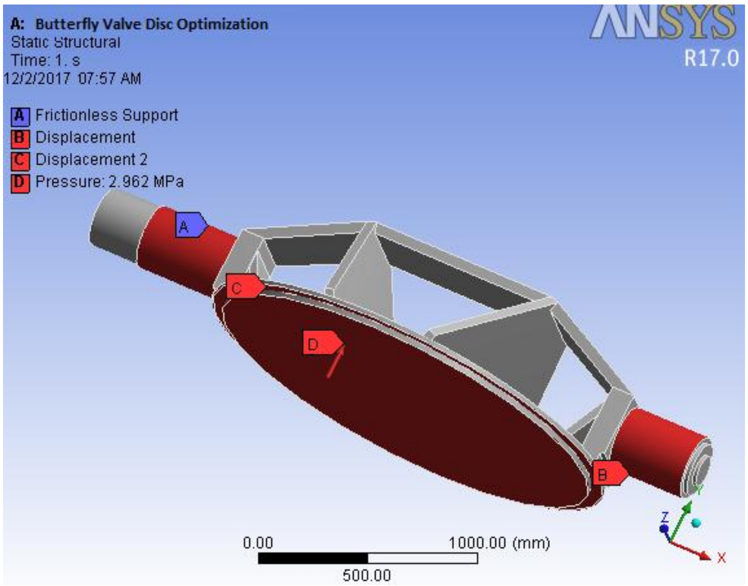

Figure 7: Static structure loading & boundary condition

Frictionless support, over trunnion of the disc

A. Zero displacement after X And Y directions for A point located Ii the middle of the trunnion
B. Zero displacement in the axial direction on the surfaces after contact with stopper and valve body
C. Loads: At normal pressure on the disc surface Pn=2.9621 Mpa, the load on the disc

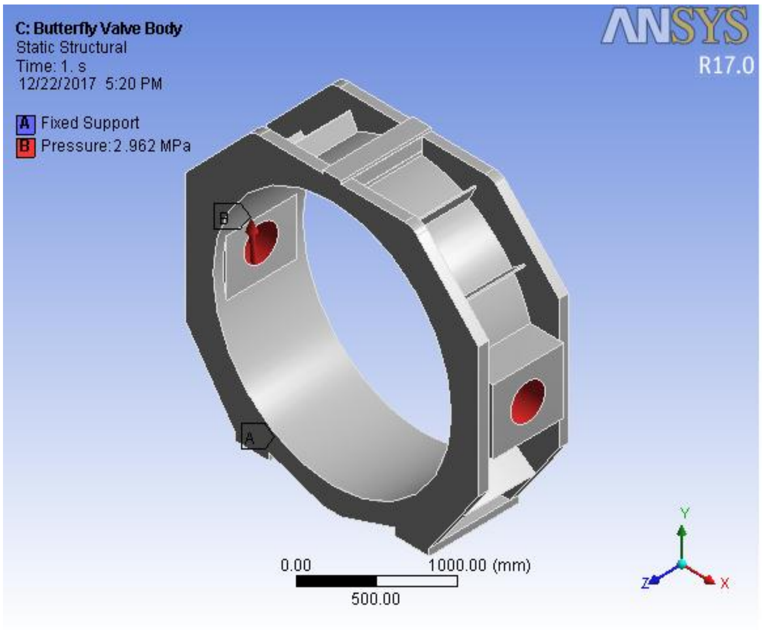

Figure 8: Static structure loading & boundary condition, when valve in fully open condition

- Fixed support at valve body pedestal
- Loads: At normal pressure on the trunnion contact surface Pn=2.9621 Mpa, the load on the body

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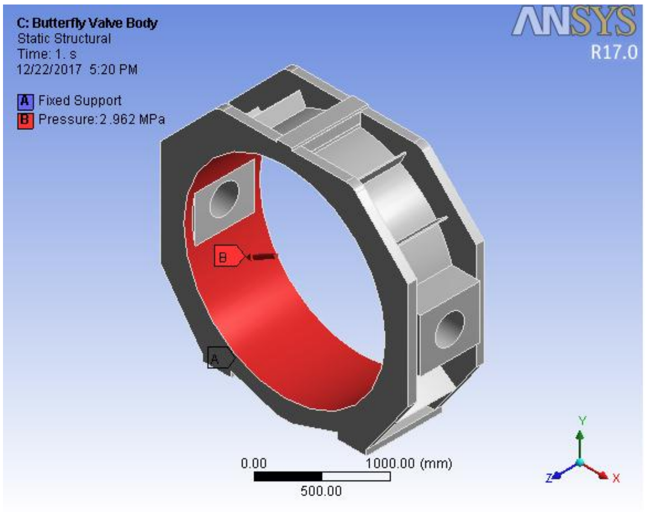

Figure9: Static structure loading & boundary condition, when valve in fully closed condition

- Fixed support at valve body pedestal
- Loads: At normal pressure on the inner cylindrical surface Pn=2.9621 Mpa, the load on the body

VII. FINITE ELEMENT ANALYSIS RESULT

FEA result for valve disc: As a result of finite element analysis, were obtained the von Mises equivalent stress & total deformation shown in figure for disc casted & disc fabricated variant of the butterfly valve.
The major parts of equivalent stresses do not exceed σ=225 N/mm^2, which are smaller than admissible stress value σa=1.5x150=225 N/mm^2.The maximum total deformation value for disc in closed position is 0.3426 mm (exiting) & 0.8499 mm (optimized) at centre of the disc.

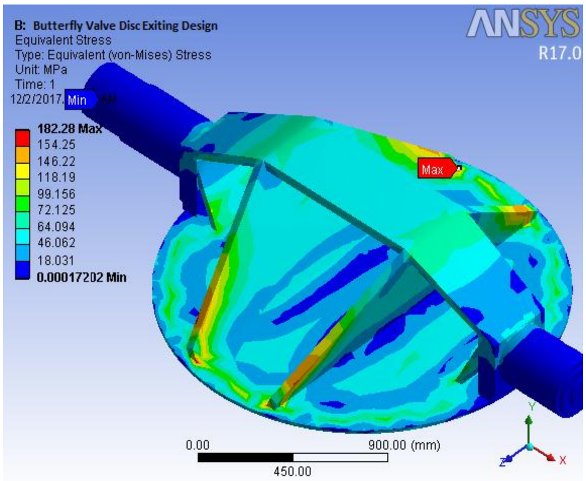

Figure 10: von Mises equivalent stress for valve disc exited

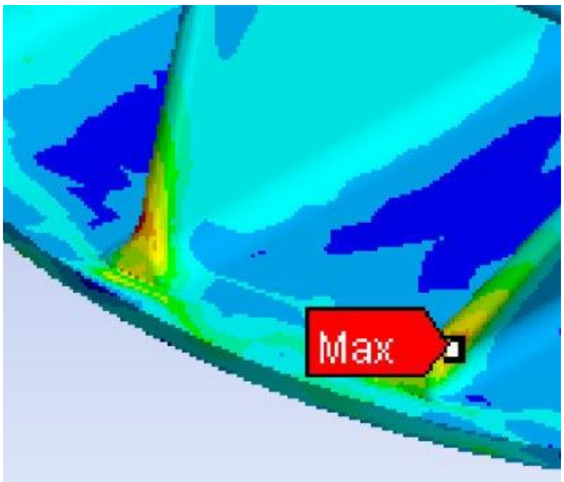

Figure 11: Detail showing the area of maximum von Mises equivalent stress for Butterfly valve disc casted

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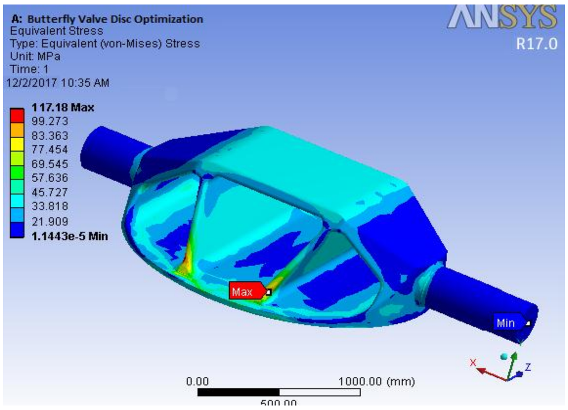


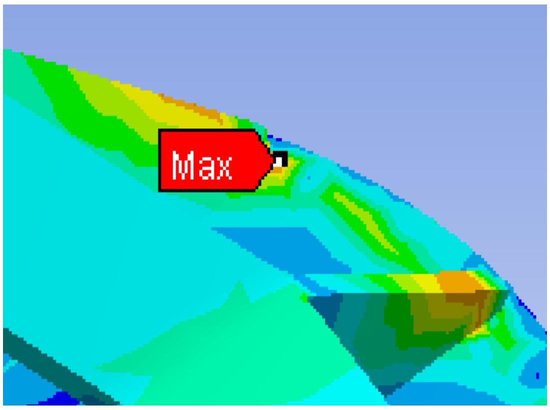
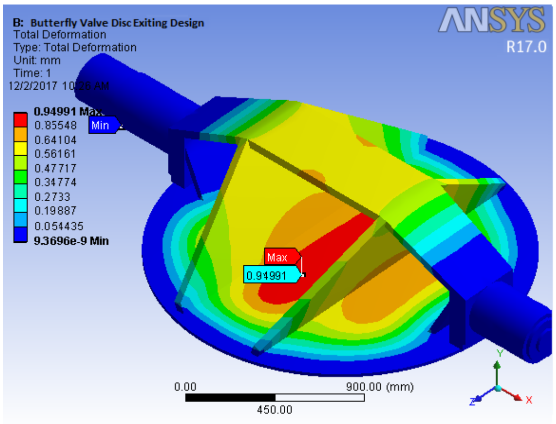


Figure 12: von Mises equivalent stress for valve disc Optimized

Figure 13: Detail showing the area of maximum von Mises equivalent stress for Butterfly valve disc fabricated



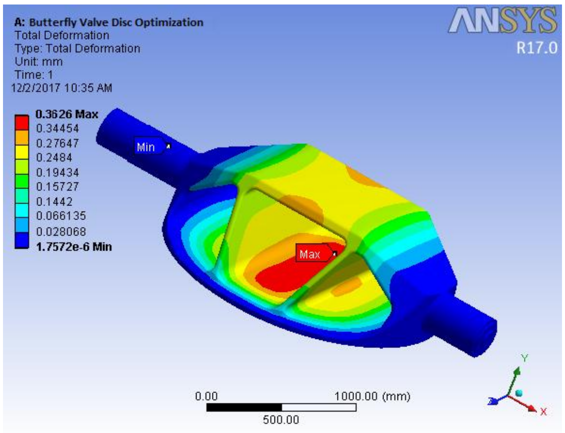
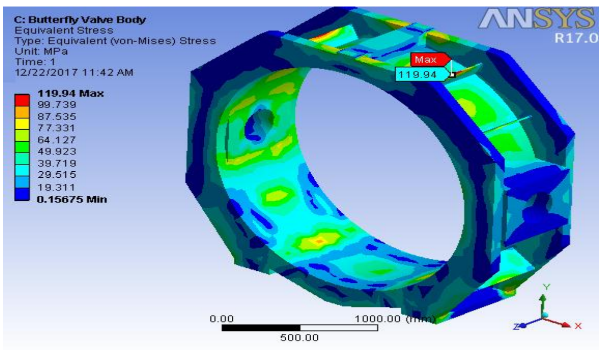


Figure 14: Total deformation for valve disc casted

Figure 15: Total deformation for valve disc optimized

FEA result for valve body: As a result of finite element analysis of equivalent stress (von Mises) at working pressure of 2.962 N/mm^2 are within the allowable stress range for the most required areas for both the situation in which the disc is in the open position and the situation in which the disc is in the closed position. Also we obtained the maximum values for the equivalent stresses in these areas.



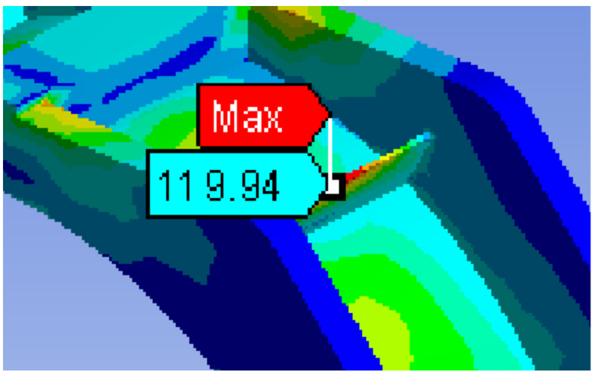


Figure 16: von mises stress for valve body dics open

Figure 17: Detail showing the area of maxi von Mises equivalent stress for Butterfly valve body when disc in opened position

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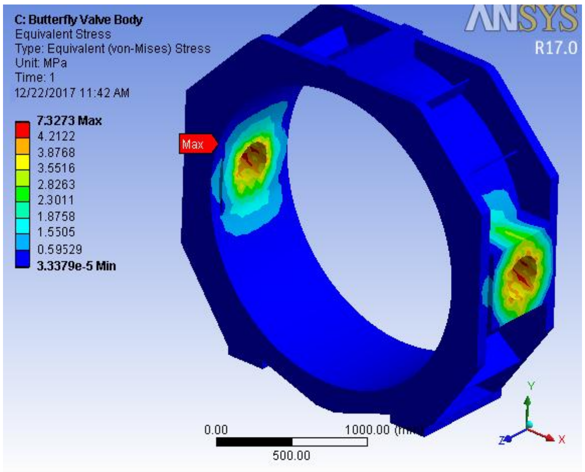

Figure 18: von Mises equivalent stress for closed valve body disc-closed

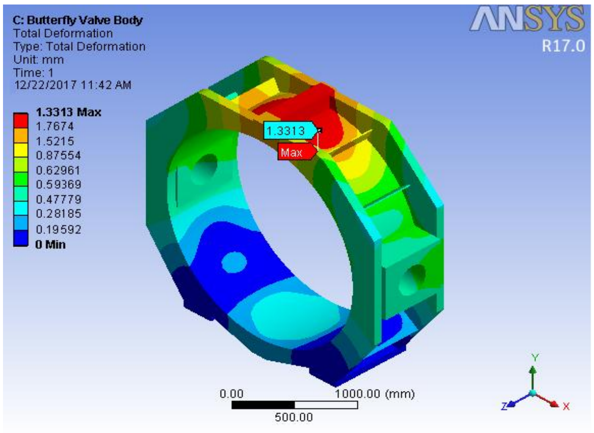

Figure 19: total deformation for valve body disc-

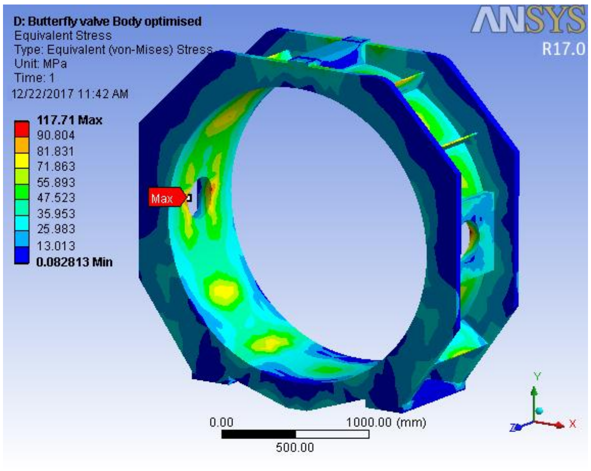

Figure 20: von Mises equivalent stress for valve body optimized disc-opened

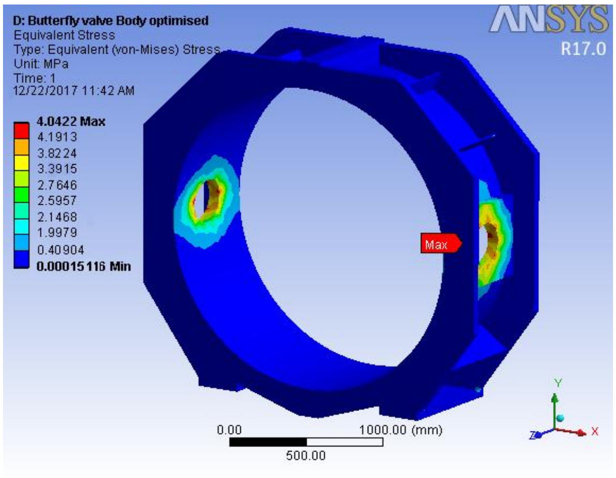

Figure 21: von Mises equivalent stress for valve body optimized disc-closed

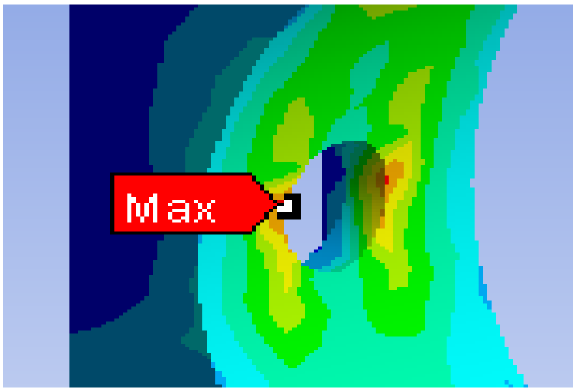

Figure 22: Detail showing the area of maxi von Mises equivalent stress for Butterfly valve body when disc in closed position

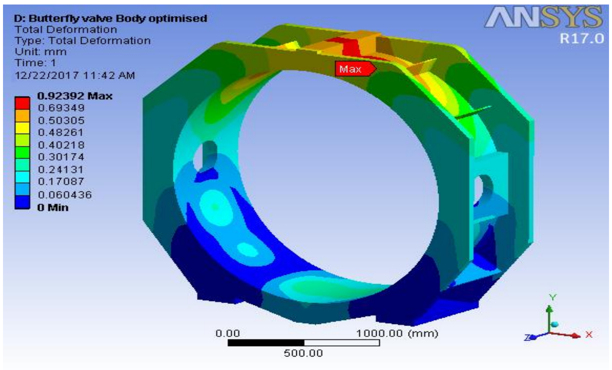

Figure 23: total deformation for valve body disc-closed

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VIII. RESULT SUMMERY & CONCLUSION

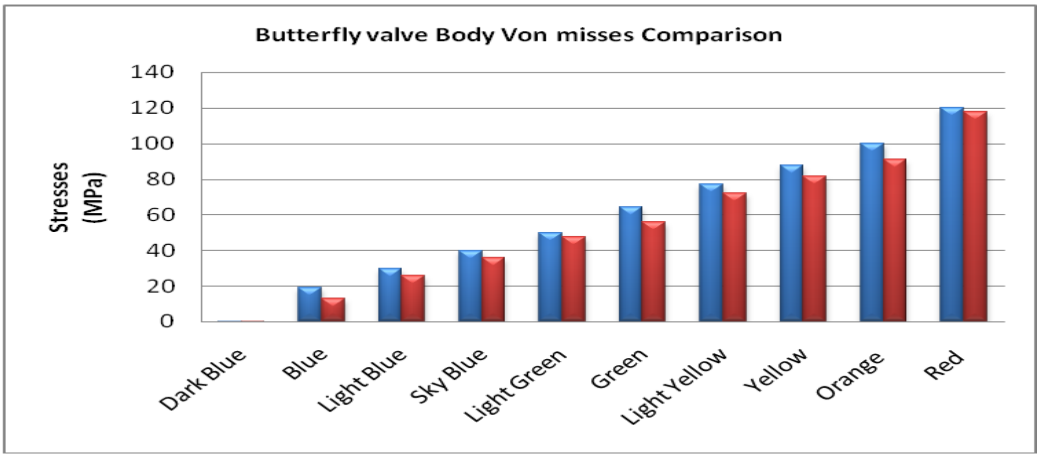

Figure 24 Butterfly valve von mises comparison disc open

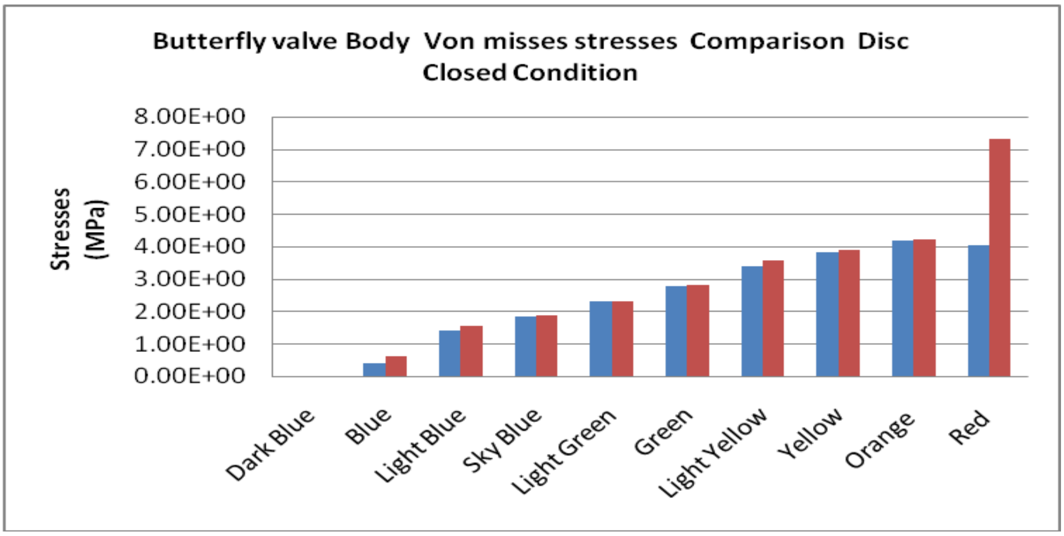

Figure 25 Butterfly valve von mises comparison Closed Condition

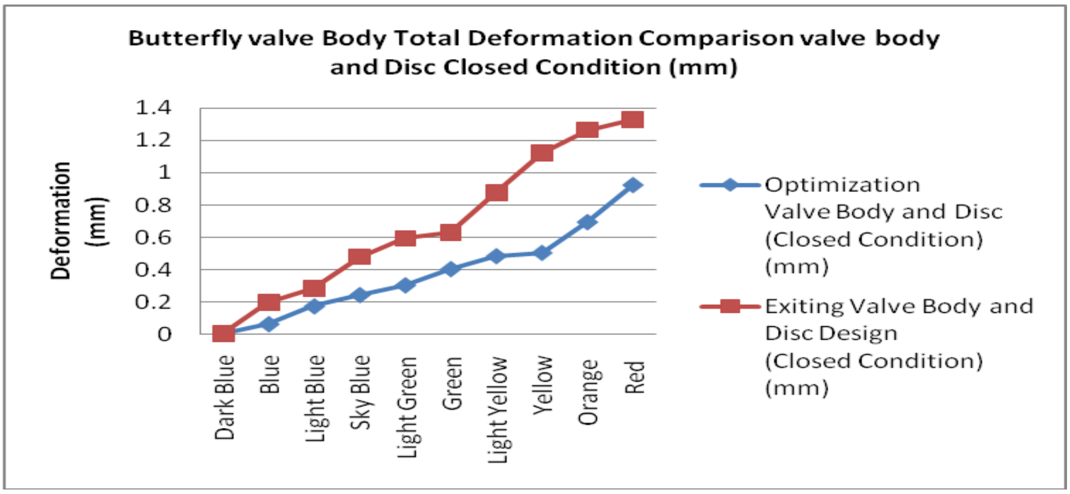

Figure 26 Butterfly valve total deformation comparison valve body and disc closed condition comparison

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Results

Table 1: Weight optimization compression sheet for butterfly valve disc of different material grade

S.no.	Material Grade	Yield stress	Allowable yield stress	mass in kg(approx.)	% difference
1	Casting G 340-570	340	228	4585	100%
2	S355J2+N	335	224	2780	61%

Table 2: Weight optimization compression sheet for butterfly valve body of different material grade

S.no.	Material Grade	Yield stress	Allowable yield stress	mass in kg(approx.)	% difference
1	Casting G 340-570	340	228	5270	100%
2	S355J2+N	335	224	2800	53%

Result Summary:

Static analysis of finite element of butterfly valve disc &body allows quantitative and qualitative assessment of the state of stress and strain by highlighting critical areas:

- Valve disc - equivalent stress appear in the transition area between support rib and disc seat area.
- Valve body – equivalent stress appear in the surface contact between trunnions disc and hub body.

Von Mises equivalent stresses do not exceed = 225 N/mm^2; than admissible stress value σ_a = 1.5x150 = 225 N/mm^2. Accordance to maximum deformations is produced on the top and bottom of the valve body& valve disc and does not exceed 1.3 mm.

The maximum value of von Mises equivalent stress of 117.18 Mpa is obtained at a single point on valve disc and is due to boundary conditions.

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