Static, Thermal and Hormonic Analysis of Butterfly Valve using FEA

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Abstract— Design validation of butterfly valve for static pressure loading is performed as per maximum Von-Misses Stress theory. The different component of butterfly valve assembly is Extracted and displacement in X, Y and Z direction and resultant displacement plot is extracted. The dynamic behavior of the butterfly valve is performed by performing modal analysis of the butterfly valve. The first fifteen natural frequencies and mode shapes are extracted for the butterfly valve assembly. Modal analysis is performed out to evaluate different component butterfly valve assembly. The butterfly valve is subjected PSD loading. The maximum stress is compared with the ultimate tensile strength of material for evaluation of design. The thermal analysis is performed on the butterfly valve subjected to thermal gradient. The temperature distribution plot for different component of butterfly valve is extracted.

Key words: Von-Misses stress, Finite Element Analysis, Vibration Displacement, Descretization

I. Introduction

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

- Stopping and starting fluid flow.
- Throttling the amount of fluid flows controlling the direction of fluid flow.
- Controlling downstream system or process pressure.
- Relieving component or piping over pressure.

Some valve are capable of throttling flow, other valves type can only stop flow, others work well in corrosive system , and others handle high pressure fluids. The Aero-derivative valves are used in the fluid of gas turbine and aero space application. The butterfly valve can be used for isolating or regulating flow. The closing mechanism takes the form of a disk. Operates like a ball valve, which allows for quick shut off. Butterfly valve are preferred due to the lighter weight, no support is required. Rotating the actuator turns the disc either parallel or perpendicular to the flow. The disc is present in the flow; therefore a pressure drop is always induced in the flow, regardless of valve position. The “Butterfly” is mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passage way. When the valve is fully opened, the disc is rotated a quarter turn so that it allows almost unrestricted passage of the fluid. There are different kinds of butterfly valves, each adapted for different pressures and different usage. The flexibility of rubber used by the resilient butterfly valve has the lowest pressure rating. The high pressure butterfly valve features a slight offset, which increases the valve to sealing ability and decreases its tendency to wear.

In metallurgy, stainless steel, also known as inox alloy contains 10.5% or 11% chromium by mass. Advantages of using stainless steel are it does not stain, corrode, or rust as easily as ordinary steel, but it is not stain-proof. Stainless steels are available with different grades and surface finishes.

Material Name	Young’s Modulus, E, N/mm^2	Poisson’s ratio, μ	Density, ρ, $Tonnes/mm^3$
Stainless Steel	317000	0.346	9.931e-9

Table 1: Mechanical properties of stainless steel

Material Name	Thermal Conductivity [K]	Specific Heat Capacity [C]	CTC [α]
Stainless Steel	0.03 w/mm-K	620 J/kg-K	21.1e6

Table 2: Therrmal properties of stainless steel

II. Literature Survey

A. T Bhosale and A. S. Dhekane have studied on finite element analysis of butterfly valve disc using CATIA V5 for solid modeling. The model is divided into small elements called geometrical regions are applied in boundary conditions. The results have high chances for optimization of design [1]. H. F. Elbakhshawangy worked on comprehensive study of the effect of inlet velocity on the variation of flow characteristics with valve positions.[2].

M. J. Morris and J. C. Dutton studied on Two valve disk shapes in a planar, two-dimensional test section, a generic biconvex circular arc profile and the mid plane cross-section of a prototype butterfly valve. The valve disk angle and operating pressure ratio have also been varied in the experiments [3]. In the year 2007 Weerachai Chaiworapuek presented a numerical simulation of flow past the butterfly valve in static and dynamic analysis using commercial fluid dynamics software FLUENT. In static analysis, the positions of the disk were set to be 0^0, 30°, 45°, 60° and 75° under 1, 2 and 3 m/s water speed. The values of angular velocity were set to be 0.039 and 1.57sradunder 1m/s water speed in dynamic analysis [4]. Later in the year 2015 Sachin K. Pisal Experimentation is conducted to observe the flow patterns and to measure valve flow coefficient when butterfly valve with various opening degrees. Furthermore, the results of experiment are compared with ANSYS FLOTRAN results [5].

III. FE Modeling of Butterfly Valve

The FE modeling of the butterfly valve is carried using hyper mesh. Element type consider for FE modeling is tetrahedral. Below figure shows FE modeling for different components of butterfly valve.

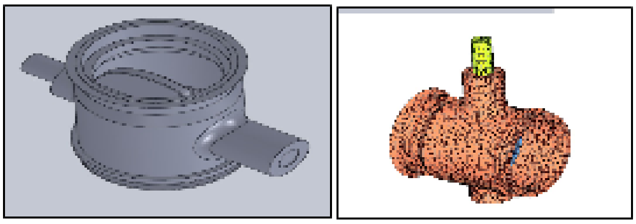

Fig. 1: Geometry and FE Model Butterfly Valve assembly

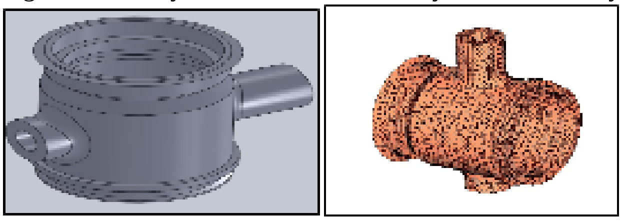

Fig. 2: Geometry and FE Model Valve Body

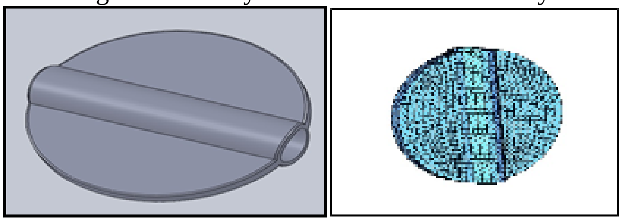

Fig. 3: Geometry and FE Model Butterfly Disc

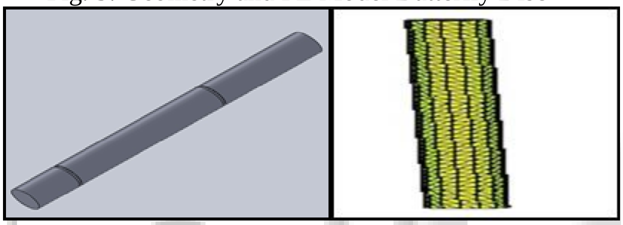

Fig. 4: Geometry and FE Model Butterfly Shaft

IV. Analysis Procedure

A. Procedure for Static analysis

Step-1: Preprocessing using Hyper mesh

1) FE Modeling of the Butterfly using Hyper mesh
2) Element type is updated using Hyper mesh
3) Material Properties is created and updated to FE Model using Hyper mesh.

The FE Model of the Butterfly Valve is shown in below figure.

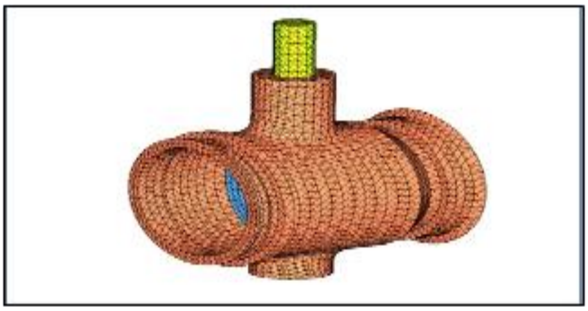

Fig. 5: FE Model Butterfly Valve Assembly

Step-2: Updating of element type to Butterfly Model using Ansys.

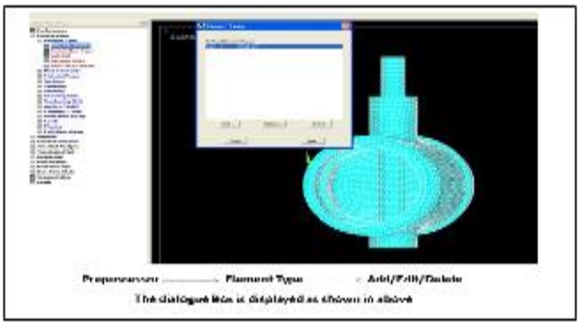

Fig. 6: Butterfly Model using Ansys

Step-3: Updation of the material properties to the Butterfly valve using Ansys.

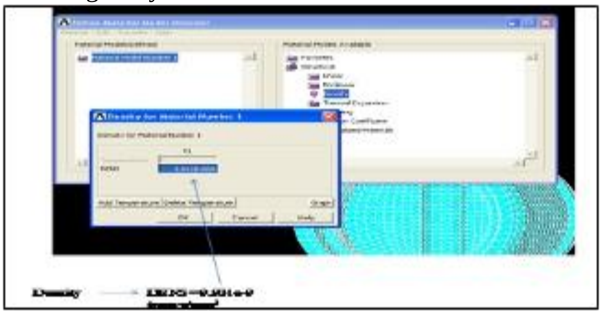

Fig. 6: Material properties to the Butterfly valve

Step-4: Application of the Pressure to the Butterfly valve using Ansys.

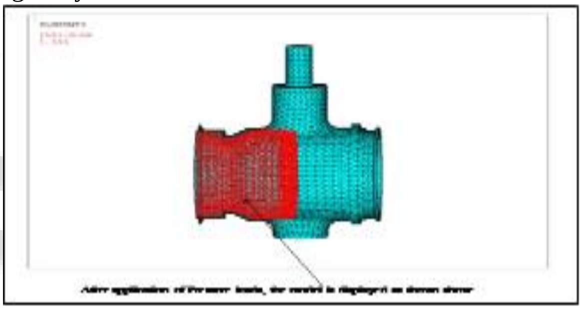

Fig. 7: Pressure Loads

Step-5: Application of the Boundary Conditions to the Butterfly valve using Ansys.

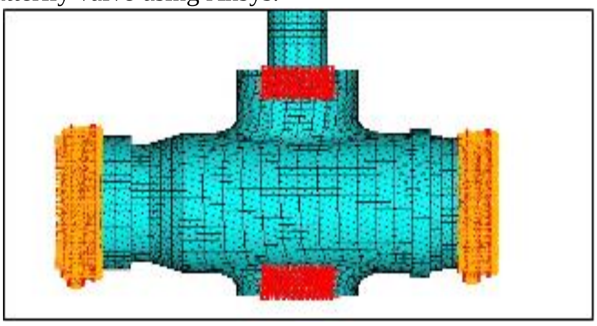

Fig. 8: Boundary Conditions

Step-6: Setting of Analysis Options for Static Analysis.

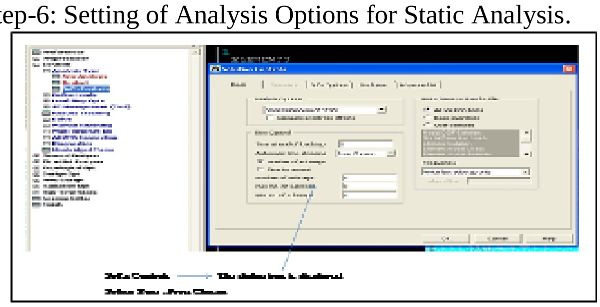

Fig. 9: Boundary Conditions

B. *Procedure for Thermal Analysis*

Step-1: Preprocessing using hyper mesh

1) FE Modeling of the Butterfly is performed using Hyper mesh
2) Ansys Input .cdb file is created using Hyper mesh.

The FE Model of the Butterfly Valve is shown in below figure.

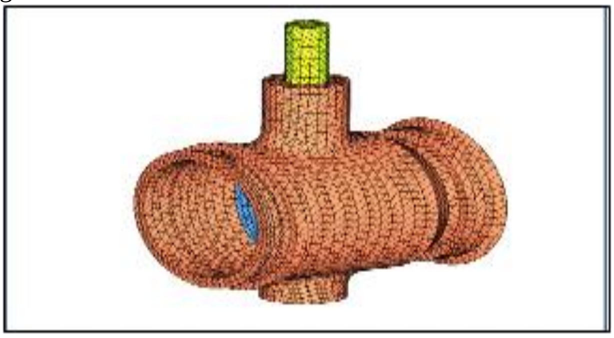

Fig. 9: FE Model Butterfly Valve Assembly

Step -2: Define the Preferences

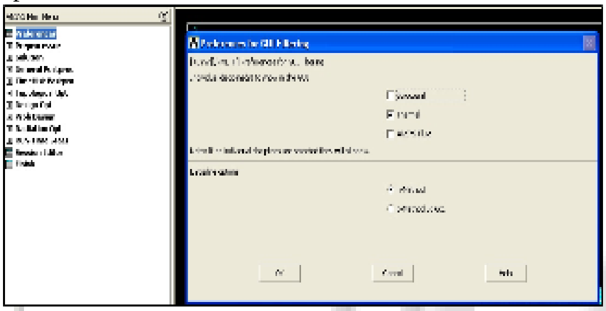

Fig. 9: Defining preferences

Step-3: Importing the Ansys input file (.cdb)

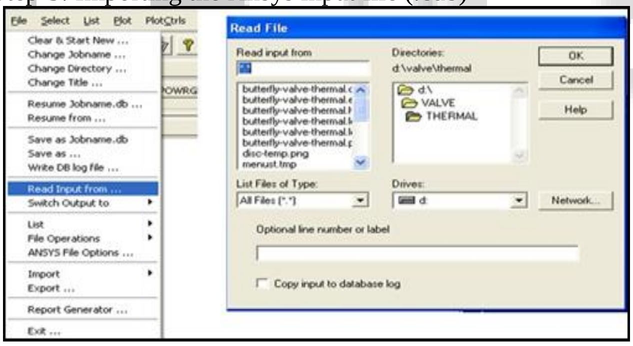

Fig. 10: Ansys input file

Step-4: Updating of Element Type

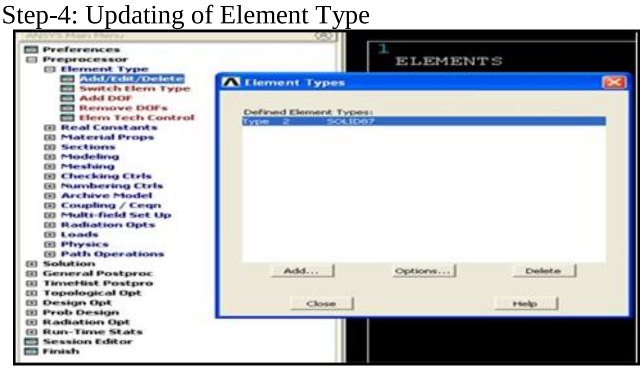

Fig. 11: Element Type

Step-5: Updating of Material Properties to the Butterfly valve

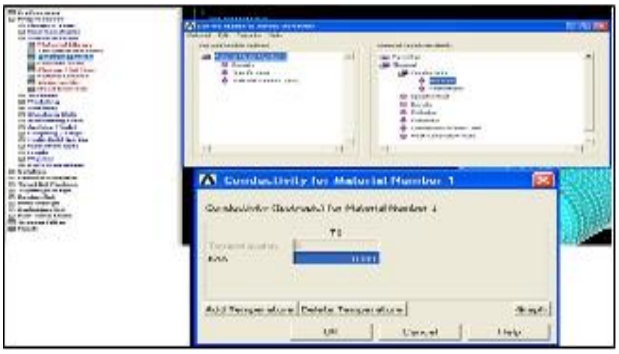

Fig. 12: Material Properties

Step-6: Define Analysis Options

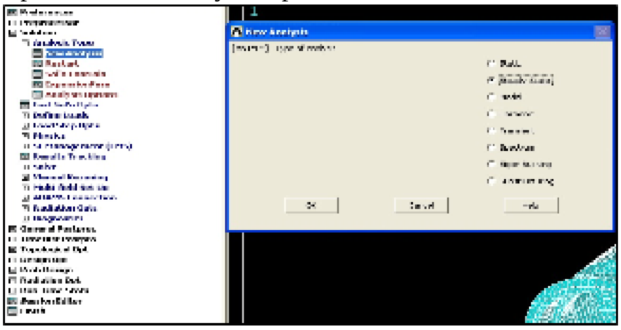

Fig. 12: Analysis Options

Step-7: Extraction of the Temperature Distribution plots

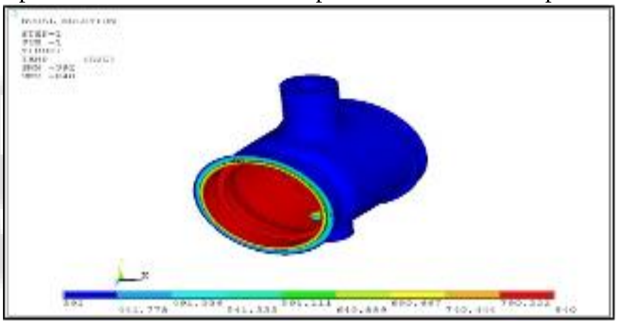

Fig. 13: Temperature Distribution Plot

C. *Procedure For Modal Analysis*

Step-1: Pre processing using Hyper mesh

1) FE Modeling of the Butterfly is performed using Hyper mesh
2) Element type is updated using Hyper mesh
3) Material Properties is created and updated to FE Model using Hyper mesh.
4) Ansys Input .cdb file is created using Hyper mesh

The FE Model of the Butterfly Valve is shown in below figure.

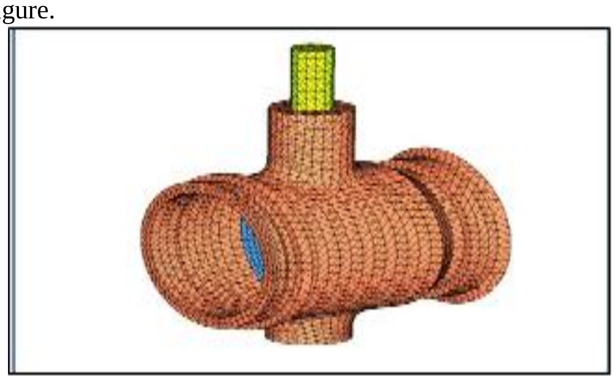

Fig. 14: FE Model Butterfly Valve Assembly

Step-2: Preferences for the Analysis is defined

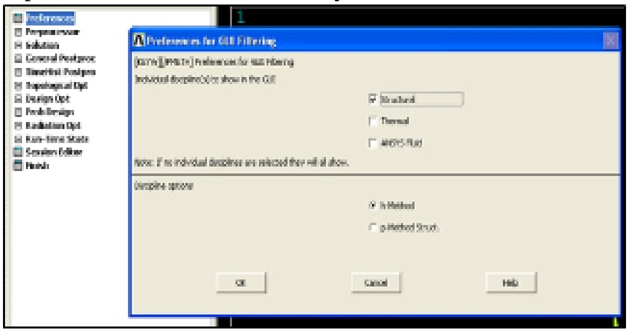

Fig. 15: Defining preferences

Step-3: Importing the Ansys input file into ansys platform

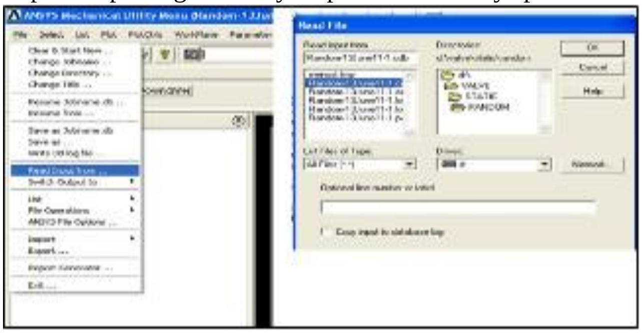

Fig. 16: Importing the Ansys file platform

Step-4: Post processing Results summary

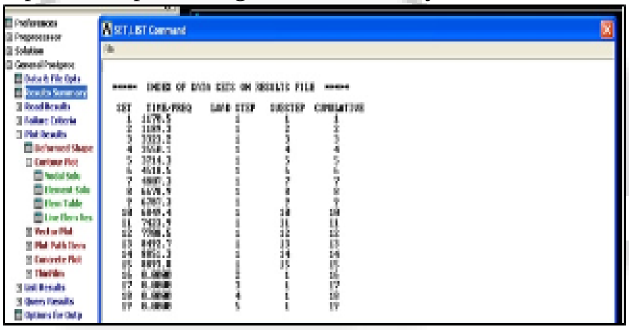

Fig. 17: Result summary

Step-5: Post processing Stress Plot

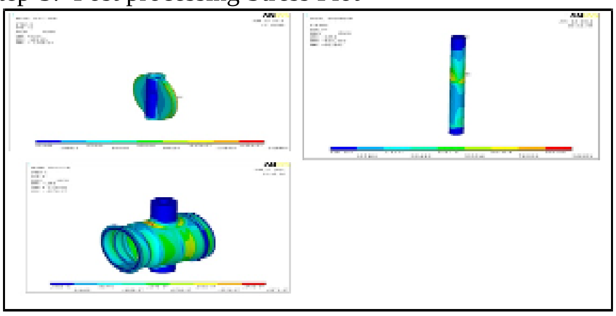

Fig. 18: Stress Plots

V. Results and Discussion

A. *Results of the Static Analysis*

The Static Analysis is carried by applying Pressure Loads on the Butterfly Disc and different components are extracted by the displacement plots of the butterfly valve assembly are extracted. The below figure shows the pressure application:

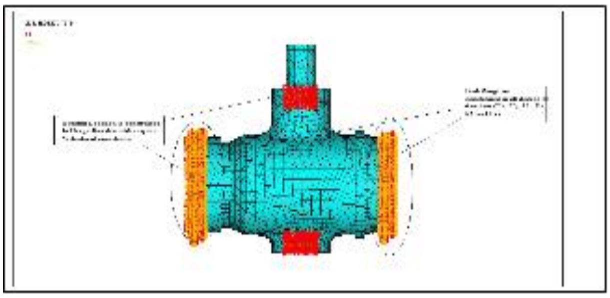

Fig. 18: Boundary Conditions

B. *Displacement Plots*

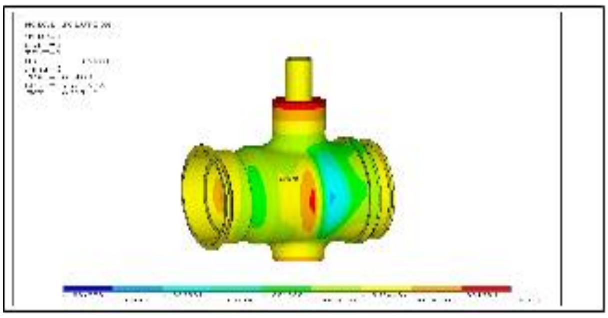

Fig. 19: Displacement in X-direction: 0.002142 mm

C. *Results of the Thermal Analysis.*

The Thermal Analysis is carried by applying thermal loads and thermal distribution plots for different components of the butterfly valve assembly are extracted.

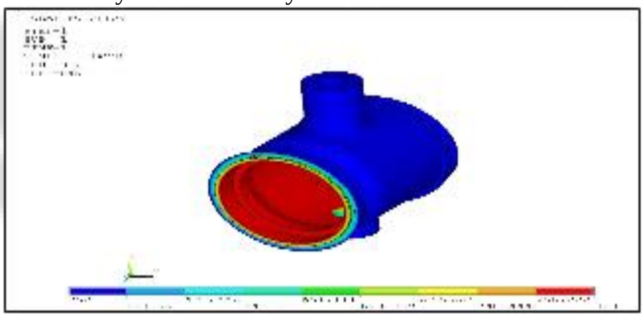

Fig. 20: Temperature Distribution Plot of Valve Body

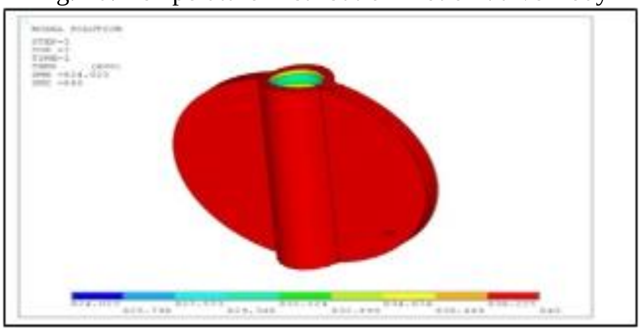

Fig. 21: Temperature Distribution Plot of Butterfly Disc

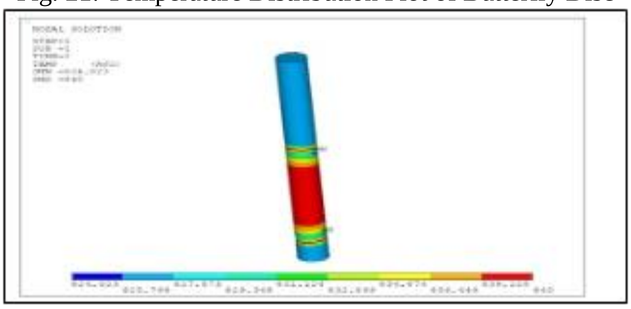

Fig. 22: Temperature Distribution Plot of Butterfly Shaft

D. Results of the Modal Analysis.

Modal Analysis is performed to study dynamic behavior of the Butterfly valve and the first fifteen natural frequencies and modes shapes are extracted. Below figure shows fifteen modes shapes of the Butterfly Valve

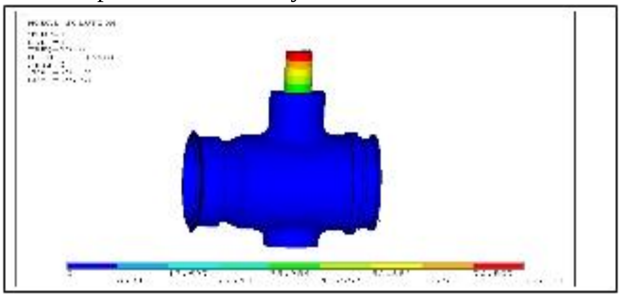

Fig. 23: First mode shape of butterfly valve

Similarly the results for the remaining fourteen modes have been obtained and tabulated as shown in below table.

Sl.No	Mode No	Frequency in Hz
01	01	1356
02	02	1379
03	03	3598
04	04	3772
05	05	4436
06	06	4811
07	07	5705
08	08	7596
09	09	7736
10	10	8162
11	11	8401
12	12	8563
13	13	9707
14	14	9872
15	15	10283

Table 2: Result summary of Modal Analysis

VI. FURTHER SCOPE OF WORK

The further study can be carried out for the butterfly valve by coupling static pressure load and thermal load due to temperature gradient and shock analysis. Dynamic study can be carried out for shock pulse.

VII. CONCLUSIONS

From static analysis the butterfly disc, butterfly shaft, and valve body has maximum Von-Misses stress within the ultimate tensile strength of the material. The design is safe as per maximum Von-Misses stress theory of failure.

The displacement of the butterfly valve assembly in all three directions (Ux,Uy,and Uz) and result displacement are very small for static pressure loading. The dynamic behavior of the butterfly valve is carried by performing modal analysis: Table-3:Shows the natural frequency of the butterfly valve is very high. The dynamic behavior of the valve body is studied by performing Random Analysis subjected to PSD spectrum loading the one sigma stresses for valve body and butterfly disc is slightly high and need to be optimized for random loading. Further studied can be carried out by optimizing the design of the valve body and the butterfly disc.

The first frequency of modal analysis is same as first frequency of random vibration. Thermal analysis is carried out for butterfly valve subjected to thermal gradient due to hot fluid flowing through the valve.

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