FEM Analysis of a globestop valve

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1 Introduction

Globe stop valves are widely used in various industries for regulating flow in a pipeline. Despite their widespread use, these valves often face issues related to pressure and stress, which can lead to operational inefficiencies or even failure.

The project aims to analyze the pressure and stress distribution in a globe stop valve under different operating conditions. The analysis should consider factors such as fluid pressure, valve material, valve design, and operational parameters.

1.1 Valve Modeling:

Develop a 3D model of a globe stop valve using a suitable CAD software. The model should accurately represent the physical and operational characteristics of a real-world globe stop valve.

1.2 Pressure and Stress Analysis:

Perform a pressure and stress analysis on the valve model using a computational fluid dynamics (CFD) software. The analysis should consider different operating conditions and valve configurations.

1.3 Result Analysis:

Analyze the results to understand the pressure and stress distribution in the valve. Identify any potential areas of concern that could lead to valve failure.

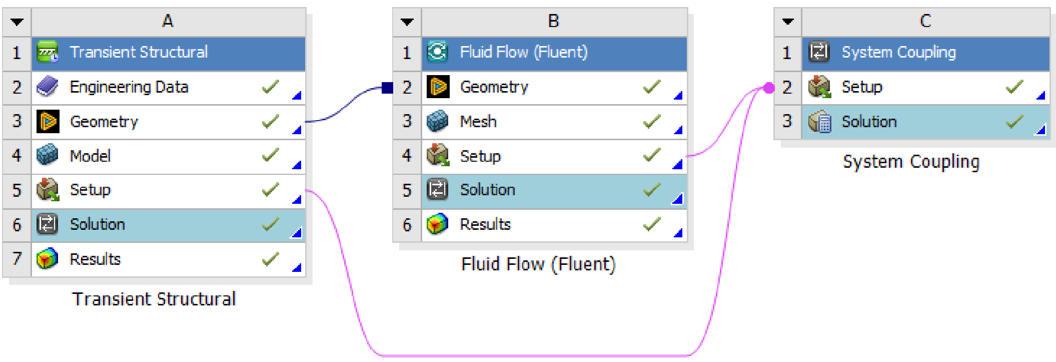


Figure 1: Workbench setup with system coupling

2 Geometry preparation and pre-processing

The geometry was used from GrabCAD [3]

All operations were performed in Ansys Workbench(Academic License).

Various parts were removed from the original geometry mainly due to two reasons:

- The parts were not relevant to the aim and held no physical significance whatsoever to the Fluid-Solid coupled("Fluid–solid interaction (FSI) applications involve the coupling of fluid dynamics and structural mechanics disciplines, in general. The basic idea is that a structural component is subjected to hydrodynamic forces exerted by a fluid and ultimately deforms. In turn, the deformed shape of the structure imparts velocity to the fluid domain and changes the flow field"-[2]) interaction during simulation. For example, the flanges of the valve body were non-participatory during the CFD simulation and were removed.
- The academic license had a cell limit of approx 1 million cells and hence irrelevant parts were removed during geometry preparation so as to not take up useful cells during meshing.

2.1 Volume extraction

Extracting the effective volume aids in determining the fluid domain in which the simulation is to be carried out. It is also useful for capping openings which can later be labeled as inlets and outlets.

The extracted volume was then labeled into three portions, the boundary conditions will be discussed later in this report.

- Fluid wall
- Inlet
- Outlet

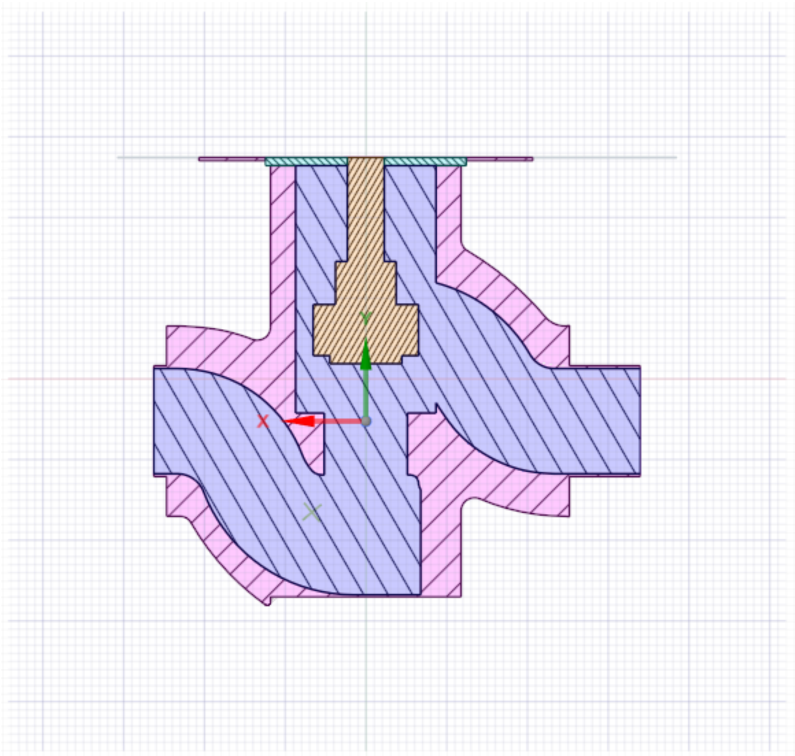


Figure 2: Configuration 2

2.2 Sharing topology

The shared topology feature ensures continuity between meshes of different bodies, this continuity ensures a smoother stress transfer effect between bodies that are in contact. In our case, the topology was shared between the walls of the valve-volume, stem body-volume, stem body-seal and seal-valve body.

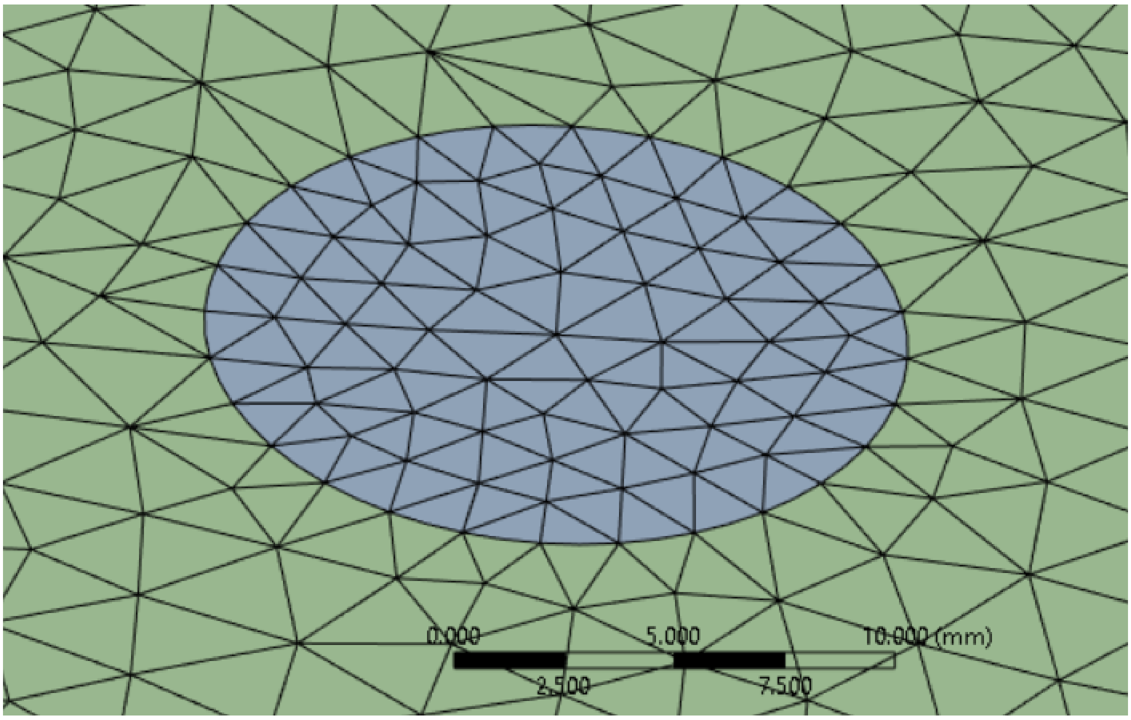


Figure 3: Continuity between mesh of the seal(outer) and the stem(inner)

2.3 Contact region and material property

The regions of contact in the geometry were:

- Valve body and seal
- Seal and Stem

The material properties were:

Grey Cast Iron	Poisson's ratio=0.255	Young's modulus=150Mpa
Structural Steel	Poisson's ratio=0.3	Young's modulus=210Mpa

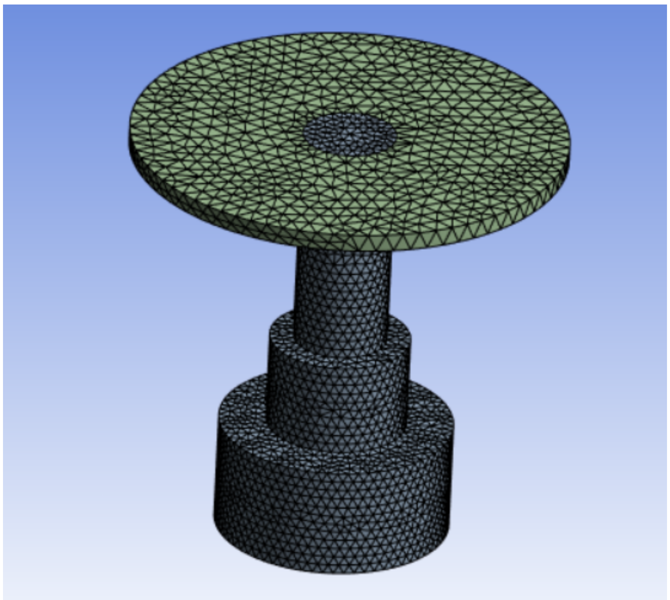
Table 1: Material Properties

3 Meshing

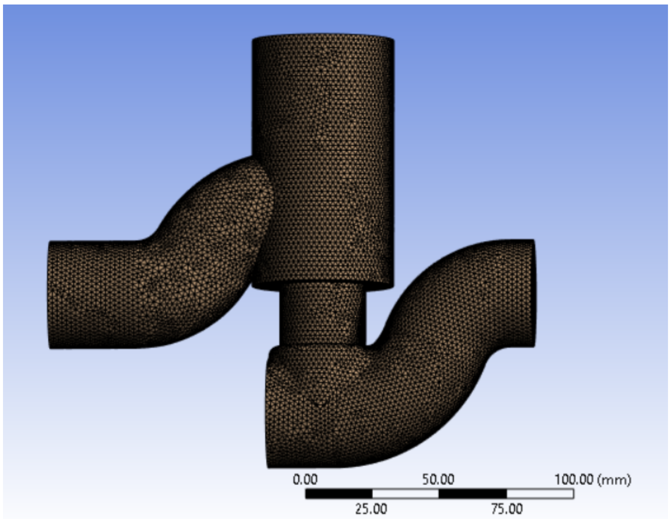
We have used 3D tetrahedral elements and the element order was chosen quadratic to increase the cell count at the edges in both the fluid domain and the solid domain.

Cell sizing function was performed on the stem(1.8mm) as well as the seal(3mm) to capture the equivalent Von Mises stress effects more accurately.

The mesh for the valve body was not refined(coarse) as the structural study of the valve body was not of consideration.



(a) Solid Mesh



(b) Fluid mesh(2mm)

3.1 Dynamic Meshing

Since there exists a coupled movement between the fluid and the solid, dynamic meshing will be applied in the inner walls of the fluid where the fluid volume and stem walls intersect in Fluent.

4 Boundary conditions

The Boundary conditions for the fluid domain were referred from Bureau of Indian Standards[1] which stated that the hydrodynamic pressure of the inlet for a DN16 PN40 Globe valve to be 2.5MPa Gauge pressure. terms used: P=Pressure F=force A=area ρ=Density of water v=velocity d=diameter of inlet(40mm)

$$P = F/A$$
$$A = \pi * d^2/4$$

From the above equations, the Force exerted by water was approximated to be 3141.6642N.

$$\rho * A * v^2 = F$$

The velocity of water was calculated to be approx 50m/s at the inlet.
The upper face of the seal was a fixed support whereas the stem and the inner walls of the valve body were fluid-solid interacting bodies.

5 Processing

In Ansys Fluent(Transient), the Coupled solver was selected since the transient structural and fluent were dependent on each other for the physical response. All calculations were performed in "Second-order upwind" which provided more accurate results at the expense of time. Hybrid Initialization was used to initialize the calculations which showed convergence in the first ten iterations.

In the system coupling setup, the iterations were chosen to run for 20s with the time-step being 1s.

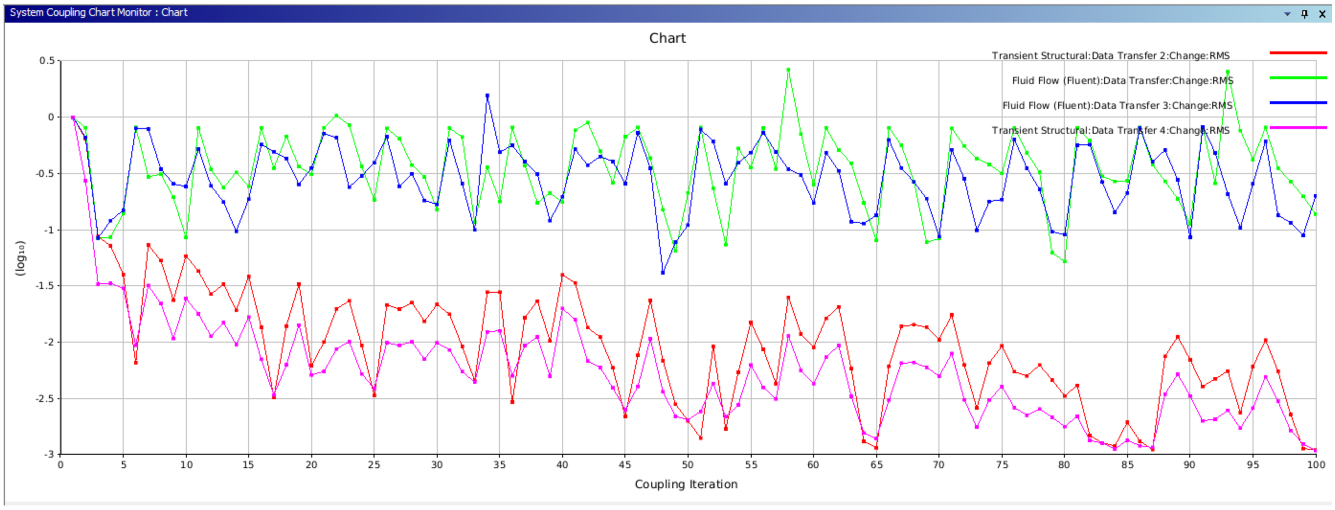


Figure 5: Calculation Convergence

6 Post-processing and Results

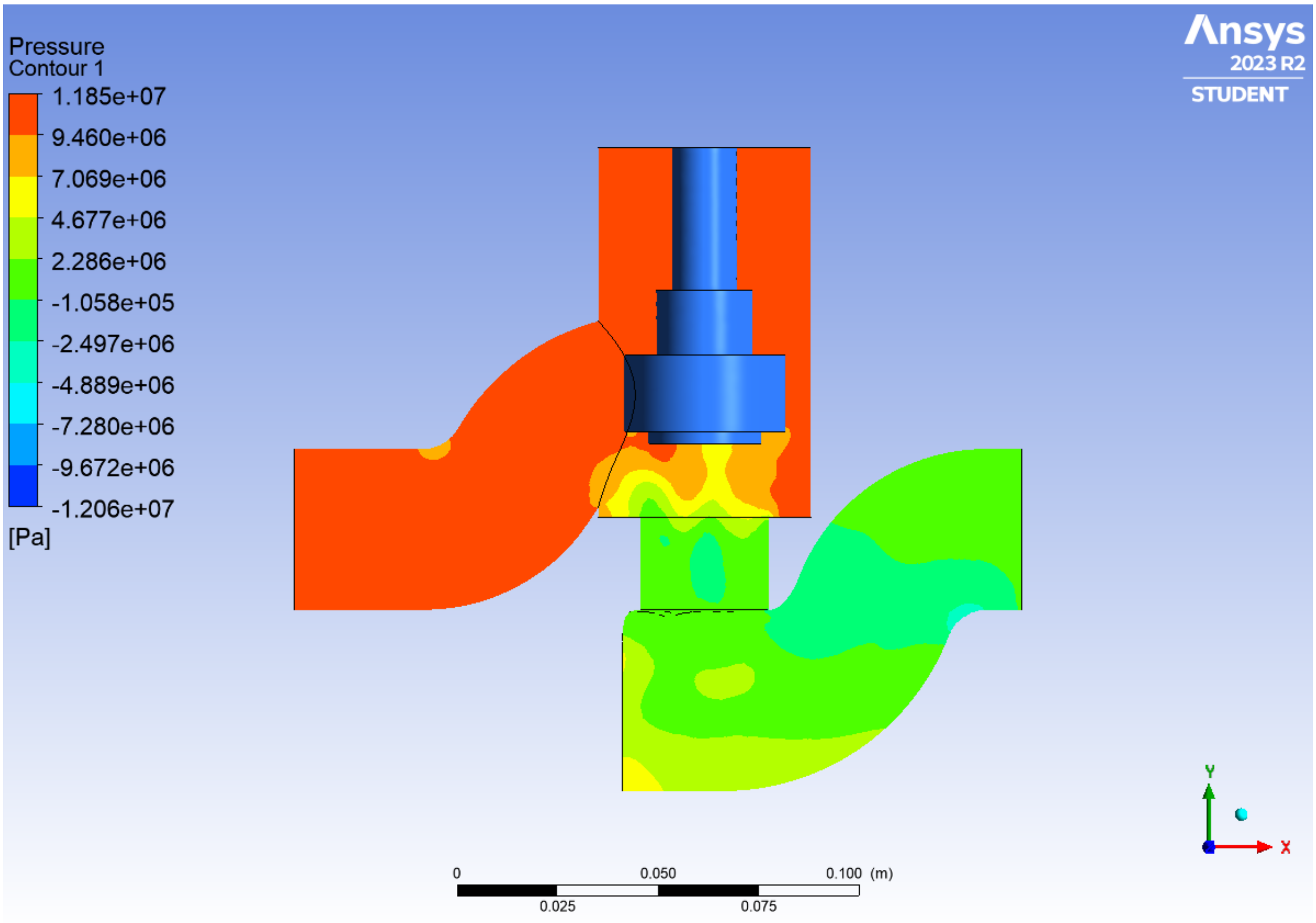


Figure 6: Results of CFD

From the CFD results, it was observed that a uniformly distributed force was being applied on the stem transversely to the stem's axis being held in a freely suspended state(cantilever). From preliminary knowledge of "Strength of materials", The maximum stress was supposed to be at the fixed support of the stem. From the coupled analysis, the assumptions were confirmed to be true.

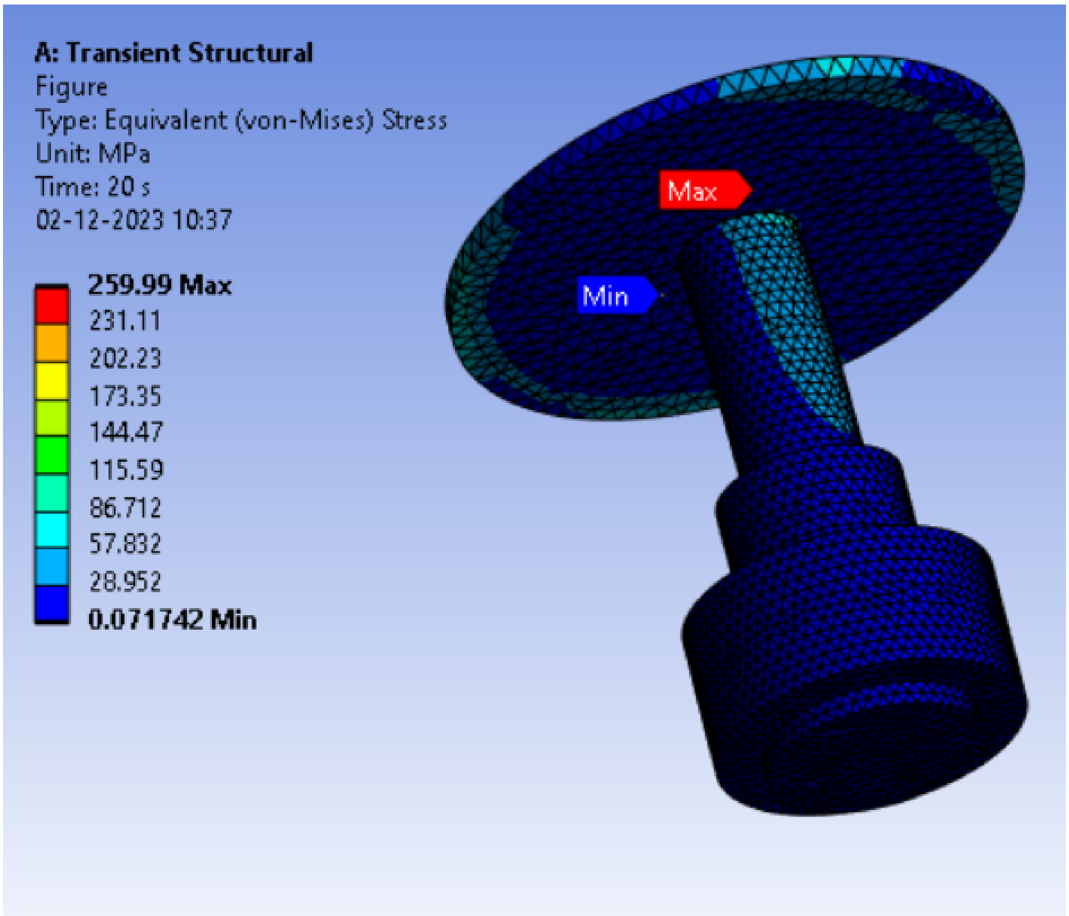


Figure 7: Von misses stress

7 Research References

References

[1] Cast iron screw-down stop valves and stop and check valves for water works purposes, 1998.

[2] Peksen, M. *Multiphysics Modeling: Materials, Components, and Systems*. Academic Press, 2018.

[3] vip1990. Globe stop valve dn40, 2021.