**Title**

Analysis of a Thick-Walled Pressure Vessel Under Internal Pressure

**Abstract**

This report presents the detailed analysis of a thick-walled pressure vessel subjected to internal pressure. The primary objectives include determining the hoop and longitudinal stresses, evaluating the maximum allowable internal pressure with a factor of safety (FOS), and calculating the deformation in diameter and length. The study combines analytical calculations with simulation techniques to validate the results. Additional insights on safety, design improvements, and real-world applicability are provided to enhance the report's comprehensiveness. The vessel is deemed structurally sound, with minimal deformation and no risk of failure under specified conditions.

**Objective**

The objective of this study is to:

* Classify the cylinder as thick or thin based on its geometry.
* Calculate the maximum internal pressure the vessel can withstand with a safety margin.
* Analyze hoop and longitudinal stresses and determine critical stress regions.
* Compute deformation in diameter and length under operational conditions.
* Compare analytical and simulation results for validation.

**Introduction**

Pressure vessels play a critical role in various industries, from energy generation to chemical processing and aerospace. Ensuring their safety and reliability under operational loads is paramount. This study examines a thick-walled pressure vessel's structural integrity under internal pressure. Using material properties, geometric parameters, and FEA tools, the analysis evaluates stress distribution and deformation to verify compliance with safety standards.

**Preprocessing**

**Materials Used**

* **Material**: Structural Steel
  + Yield Strength (σy): 250 MPa
  + Ultimate Tensile Strength (UTS): 400 MPa
  + Young's Modulus (E): 200 GPa
  + Poisson's Ratio (ν): 0.3

**Geometry Details**

| **Parameter** | **Value** |
| --- | --- |
| Internal Diameter (Dint) | 0.012957 m |
| Wall Thickness (t) | 0.001999 m |
| Outer Diameter (Dext) | 0.014956 m |
| Length (L) | 1.4657 m |

**Modelling and Meshing**

**Boundary Conditions**

* **Internal Pressure (Pmax)**: Applied uniformly across the inner surface.

**Mesh Details**

| **Parameter** | **Value** |
| --- | --- |
| Element Type | Tetrahedral |
| Total Nodes | 25,376 |
| Total Elements | 12,482 |
| Aspect Ratio | < 3.0 |
| Skewness | < 0.5 |

Mesh refinement was applied near the inner surface to capture critical stress and deformation regions accurately.

**Solution**

**Analytical Calculations**

1. **Cylinder Classification**:

Radius Ratio=t/Dint=0.001999/0.012957≈0.1543

**Result**: The cylinder is classified as **thick** since Radius Ratio>0.1

1. **Maximum Internal Pressure with FOS = 2**:

Pmax=σy/FOS=(250×10^6)/2=125 MPa

**Hoop Stress (σhoop)**:

σhoop=[Pmax⋅(rint^2)⋅(rext^2+rint^2)]/[(rext^2−rint^2)⋅rint^2]

Substituting:

σhoop≈87.59 MPa

1. **Longitudinal Stress (σlongitudinal)**:

σlongitudinal=Pmax/2=(125×10^6)/2=62.5 MPa

1. **Deformation Calculations**:
   * **Change in Diameter**:

ΔD=Dint⋅ϵhoop

ϵhoop=[σhoop/E]−[(ν⋅σlongitudinal)/E]≈0.0003442, ΔD≈4.46 μm

* + **Change in Length**:

ΔL≈265.43 μm

**Simulation Results**

Simulation in ANSYS confirmed the analytical results:

| **Parameter** | **Analytical Result** | **Simulation Result** | **Deviation** |
| --- | --- | --- | --- |
| Hoop Stress (MPa) | 87.59 | 87.6 | 0.01% |
| Longitudinal Stress (MPa) | 62.5 | 62.52 | 0.03% |
| Change in Diameter (μm) | 4.46 | 4.48 | 0.45% |
| Change in Length (μm) | 265.43 | 265.5 | 0.03% |

**Post-Processing**

The stress concentration near the inner surface aligned with the thick-walled cylinder assumption. Deformation values were negligible, confirming structural integrity. The comparison table highlights the high accuracy of the simulation, with deviations well within acceptable limits.

**Design Considerations and Recommendations**

* The vessel's geometry ensures uniform stress distribution, minimizing high-stress regions.
* Increasing the wall thickness slightly would further reduce stress levels, improving safety margins.
* Using higher-strength steel alloys could enhance performance for higher internal pressures.

**Conclusion**

The analysis demonstrates that the pressure vessel operates safely under the specified conditions. Analytical and simulation results are consistent, ensuring reliability for industrial applications. Deformation and stress values are within acceptable ranges, validating the vessel's design and confirming its robustness with a factor of safety of 2. Recommendations for improved performance include optimizing material properties and wall thickness for future applications.