A Project Report on

RESEARCH AND ANALYSIS ON TEMPERATURE VARIATION WITH RESPECT TO TIME OF NITROGEN INSIDE A PRESSURE CHAMBER

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Under Guidance Of

Prof. D. M. Pawar

'येथे बहुतांचे हित ।'

Department of Mechanical Engineering

Marathwada Mitra Mandal's

College of Engineering,

Karvenagar, Pune

[2023-24]

A Project Report on

TEMPERATURE VARIATION OF FLUID INSIDE A CHAMBER DUE TO ENVIRONMENTAL EFFECTS

By: -	**Signature**
Jay Bhortake	
Tejas Chippa	
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Under the Guidance of: -	**Signature**
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RDE/90008/IMSG

04 Sept 2023

To,

The, Head of Mechanical Engineering
Marathwada Mitra Mandal's,
College of Engineering, Karvenagar,
Pune – 411 052.

Subject : **GRANT OF PERMISSION FOR STUDENT PROJECT**
Letter No :- MMCOE/MECH/PROJECT/23-24 dt. 17/08/2023
Dear Madam/Sir,

1. I am pleased to inform you that following Student(s) has been granted permission to do Student Project work at this establishment for the period from **01 Sept 2023 To 30 Feb 2024.**

Name of the Student(Mr/Ms)	Subject	Guide from Establishment & Title of the Project	Guide from College
Mr. Deven Dhore **Mr. Jay Bhortake** **Mr. Harsh Bokil** **Mr. Tejas Chippa**	B.E. (Mechanical Engineering)	**Mr. Paras Ram, Sc 'E', SPG** Topic : **Temperature Variation of Fluid Inside a Chamber due to Environmental Effects.**	Mr. D.M. Pawar, (Assistant Professor)

2. It is expected that the student will observe the normal rules contained therein to maintain discipline. They will abide to the COVID-19 SOP of the establishment.
3. After completion of the project work, it may please be ensured that **two copies** of the Project report are submitted to this establishment. The design/model developed by the student (s) will be given to them for presentation at the time of examination. However, after the examination, this establishment will retain the models.
4. Kindly note that the Student(s) will not be granted stipend, TA/DA, lodging/boarding facility etc.
5. Please acknowledge receipt of this letter.

With regards,

(Ms Sarita P. Gusain)
Technical Officer 'C'
HRD Coordinator
For DIRECTOR

Copy to:

Mr. Paras Ram, Sc 'E', (through GD/GH SPG): Responsibility of Internal Guide of The Estt: (Bulletine No.20210031013 dt 02 Dec 21):-

- To ensure that the student maintains discipline and abide by the COVID-19 SOP of the Establishment.
- To liaison with the Head Security /Gate Office for issue of student Gate pass for allowing entry in the Estt and after completion Of Project/Internship, deposit of temporary gate passes be ensured.
- Design /model developed by the student(s) to be given to them for presentation at the Time of examination. However, after the examination, the establishment will retain the models, which has to be ensured by the internal Guide.
- After Completion of the project work, the internal guide will ensure that a soft copy of the Project/Internship report is to be uploaded on PDOC site and hard copy of the same is submitted to TIC under intimation to IMSG.
- **Issue of project/Internship completion certificate**: The certificate will be issued by Internal Guide Duly Countersigned by GD IMSG. Student(s) has to produce Project/Internship Report While Seeking countersignature From GD IMSG.
- To ensure that all the formalities such as timely return of temporary gate passes, books And demo Hardware are Followed as per procedure of the estt.
- **For Security Pass**: Send request ION to Head Security along with encls ie, Copies Of Permission letter, college letter, Undertaking of indemnity, Adhar & Passport.

1. **Head TIC (PDOC)**: for info & n.a.pl.

Marathwada Mitra Mandal's

College of Engineering,

Karvenagar, Pune

'येथे बहुतांचे हित ।'

C E R T I F I C A T E

This is to certify that the project report entitled by Jay U. Bhortake has successfully completed the Project-II entitled ''**Research and Analysis on Temperature Variation with Respect to Time of Nitrogen Inside a Pressure Chamber**'' under my supervision, in partial fulfillment of Bachelor of Engineering - Mechanical Engineering of Savitribai Phule Pune University.

Date:

Place: Pune

Project Guide- Prof. D. M. Pawar

External Examiner

Dr. V. R. Deulgaonkar
Head Dept. of Mech. Engg.
MMCOE, Pune

Dr. V. N. Gohokar
Principal
MMCOE, Pune

ACKNOWLEDGEMENT

We take this opportunity here to thank all those who had helped us in making this project a reality.

First of all, we express our deep gratitude to our project guide Prof. D. M. Pawar for his valuable support, help & guidance from time to time during the project work. We are also grateful to our Head of Department, Dr. V. R. Deulgaonkar and Principal Dr. V. N. Gohokar for giving us this opportunity to present this project report.

We are highly indebted to Mr. Paras Ram Sc ‘F’ of R&DE (E) for granting us this project and for his guidance which we were privileged to receive. We convey our heartfelt gratitude to him for taking out time from his busy schedule and leading us through this project.

Last but not the least; we would like to thank our entire teaching staff who assisted us directly or indirectly throughout the duration of this project.

Name of student	**Exam Seat No.**	**Sign.**
Jay U. Bhortake		
Tejas S. Chippa		
Deven Dhore		
Harsh R. Bokil		

ABSTRACT

This project is motivated by the need to enhance the efficiency of pressure chambers used in aircraft by strategically managing time, material, and thickness. The fundamental research problem addressed is the loss of effectiveness of nitrogen in pressure chambers at a given temperature, which has implications for aerospace, automotive, and transportation industries. The aim of the study is to determine the time required for nitrogen to reach a critical temperature due to external conditions, in order to schedule system operations and plan maintenance and replacement activities. The methodology involves the design of pressure chambers made of different materials and capacities, contained within a cubic enclosure with controlled surface temperature, and the determination of heat transfer, time required to reach critical temperatures, and the optimization of chamber thickness and materials. The results include the development of effective thermal management strategies, predictive modeling, material optimization, and insights into fluid behavior and heat transfer mechanisms within pressure chambers. The implications of this research are relevant for optimizing the performance and longevity of pressure chambers in engineering systems.

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NOMENCLATURE

Symbol	Meaning
A_S	Surface Area [m^2]
d	Diameter of Cylinder
L	Length
Lc	Characteristic Length
ΔT	Temperature difference (degree Celsius)
E	Young's Modulus (N/m^2)
Ra	Rayleigh Number
Pr	Prandtl Number
Nu	Nusselt Number
Gr	Grashoff Number
h	Convective Heat Transfer Coefficient [w/m^2k]
Cp	Specific Heat [$KJkg^{-1}k^{-1}$]
Q	Heat Transfer Rate [W]

Greek Symbols

ρ = Density of Air [kg/m^3]

δ = Dimple Depth [m]

$\propto=$ thermal expansion coefficient $\left[\frac{1}{\text{degree celsus.}}\right]$

$\sigma =$ Hoop's Stress (MPa)

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Chapter 1

INTRODUCTION

1.1 Background Concept

Understanding the thermal behavior of gases within confined environments is crucial for diverse applications, ranging from industrial processes to aerospace technologies. This research delves into the intricate dynamics of nitrogen, a commonly employed inert gas, within a high-pressure chamber. The study seeks to unravel the nuanced interplay of pressure, time, and initial conditions that govern the temperature variation of nitrogen, aiming to provide insights that can enhance process efficiency, safety, and design protocols.

Nitrogen, recognized for its inert nature and wide applicability, serves as an essential component in numerous industrial processes, particularly those requiring controlled atmospheres. The behavior of nitrogen under high pressure conditions is critical for optimizing systems that involve pressurized gases. Moreover, the study of temperature dynamics within a pressure chamber contributes to our fundamental understanding of heat transfer phenomena and aids in the refinement of engineering models.

The outcomes of this research not only contribute to the fundamental understanding of nitrogen behavior under high-pressure conditions but also hold practical implications for industries reliant on precise temperature control within pressure vessels. We aim to offer a holistic perspective on the temperature dynamics of nitrogen, thereby facilitating informed decision-making in diverse technological applications.

1.2 Sponsored Organization

The Defence Research and Development Organization (DRDO) is the premier agency of the Government of India, responsible for the development of technology for use by the Indian Armed Forces.

DRDO has a wide range of capabilities, and its laboratories and establishments work on various projects, including:

- Missiles and weapon systems
- Aerospace and aeronautical systems

- Armaments and ammunition
- Electronics and communication systems
- Vehicles and engineering systems
- Information systems and sensors
- Materials and metallurgy
- Life sciences and tribology
- Social sciences and agriculture

Research & Development Establishment (Engineers) is one of the many laboratories and establishments under the Defence Research and Development Organization (DRDO) of India. R&DE(E) is in Pune, Maharashtra, and is specifically dedicated to the research and development of engineer-related aspects of various Defence systems. The primary objective of the project is to design a chamber of different materials.

1.3 Problem Statement

This project delves into enhancing efficiency by strategically managing time, material, and thickness of the Chamber used in Aircraft. The use of Nitrogen in various applications such as Aerospace & Aircraft, Automotive & Transportation Equipment becomes less effective after it reaches a certain temperature, hence it is vital that we know the time required for nitrogen to reach that temperature due to effect of external conditions. By doing so we can schedule the operation of the system and plan the maintenance and replacement activities if required when needed.

1.4 Objectives

1. Optimizing Thermal Management: The objective may be to develop effective thermal management strategies to control and stabilize the fluid temperature, ensuring it remains within desired limits.
2. Optimization of Chamber Thickness according to stresses acting on the chamber
3. Material Optimization: Choosing materials with good insulation, high strength, low weight, low thermal expansion properties may be the goal. It can help in maintaining a steady temperature in the chamber.

1.5 Research areas

1. Material Properties: Fluids can exhibit changes in viscosity, density, and thermal conductivity with temperature changes, affecting their behavior and performance within the chamber.
2. Insulation: Effective insulation of the chamber minimizes heat exchange with the environment, reducing temperature fluctuations.
3. Materials and types of chambers
4. Fluid Dynamics: Investigating fluid behavior within chambers under high pressure aids in studying convection patterns, and heat transfer mechanisms.

Chapter 2

LITERATURE REVIEW

2.1 Introduction to Pressure Chamber

Nitrogen gas plays a vital role in various industrial applications, including refrigeration systems and inert atmospheres within pressure chambers. Understanding the temperature variation of confined nitrogen over time is crucial for maintaining optimal pressure conditions, ensuring efficient heat transfer, and guaranteeing the stability of stored materials. This literature review examines existing research on the temperature variation of nitrogen inside pressure chambers. We will analyze the key factors influencing this variation, explore relevant theoretical frameworks, and discuss established experimental methods for measurement. The insights gained from this review will inform our research on analyzing and potentially mitigating temperature fluctuations in nitrogen-filled pressure chambers.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
1	The transfer of heat by natural convection between bodies and their enclosures	R. 0. WARRINGTON, JR. and R. E. POWE	This research aims to experimentally explore natural convection heat transfer among isothermal inner bodies (spherical, cylindrical, and cubical) within a cubical enclosure. Objectives include comparing results, analyzing temperature distributions, assessing the impact of enclosure shape on Nusselt numbers, and correlating heat transfer data.	Create a controlled environment, vary Rayleigh numbers and inner body sizes. Record temperature distributions, compare with existing data, and analyze heat transfer correlations, emphasizing enclosure shape impact on Nusselt numbers.	The research in this paper focuses on the calculations related to Rayleigh number, Nusselt number and Grashoff number and its relation according to our calculation.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
2	A general methodology for investigating flow instabilities in complex geometries: application to natural convection in enclosures	E. Gadoina , P. Le Que´re´ a,* and O. Daubeb	Develop and validate a methodology to study natural convection instabilities in complex cavities. Validate tools with a differentially heated cavity, assess their efficacy in partitioned configurations , and explore reducing Navier–Stokes equations.	Utilizing Vanka's multigrid method, we address boundary layers at rising Rayleigh numbers. Solving a linear problem, we employ a correction scheme for efficiency. Linear operators are directly defined on coarse grids, enhancing applicability.	The article focuses on the understanding of natural convection and its relation with Rayleigh number.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
3	Experimental Investigation of Tool Geometry on Mechanical Properties of Friction Stir Welding of AA2014 aluminum alloy.	A. Somi Reddy	Assess Friction Stir Welding (FSW) suitability for AA 2014-T6. Examine FSW parameters on mechanical properties. Optimize conditions for defect-free welds. Evaluate mechanical and microstructural features. Compare different tool profiles for enhanced weld quality.	Apply Friction Stir Welding to AA 2014-T6, varying parameters. Assess defect-free welds under optimal conditions, comparing mechanical and microstructural characteristics.	The study helps us understand the properties of AA2014 alloy and got to know about its application.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
4	A review of simple formulae for elastic hoop stresses in cylindrical and spherical pressure vessels: what can be used when	G.B. Sinclair, J.E. Helms	Evaluate the applicability of classical hoop stress formulae traditionally used in thin-walled pressure vessels to thicker structures and external pressure conditions. Provide insights for design procedures to enhance their utility in structural analysis.	Review classical hoop stress formulae, analyze historical development, verify widespread acceptance, examine limitations, introduce Lamé formulae, investigate upper limits, and explore design facilitation using ASME code guidelines.	From this paper we understood the application of Hoops law and got the formulae required for our problem statement (Determination of thickness)

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
5	Numerical Analysis of Grashof Number, Reynolds Number and Inclination Effects on Mixed Convection Heat Transfer in Rectangular Channels	A. Ozsunar, S. Baskaya and M. Sivrioglu	To investigate mixed convection in rectangular channels computationally, analyzing Prandtl number, inclination angles, Reynolds numbers, and Grashof numbers' impact on instability onset. Validate results with literature and experiments.	Employ finite volume CFD to model rectangular channels, varying Prandtl, inclination, Reynolds, and modified Grashof numbers. Analyze local Nusselt numbers, validate with literature and experiments, and investigate instability onset.	In this research paper we understood the parameters which were required to be known for calculations of Nusslet, Grashoff, Prandtl number, etc.

Sr No.	Page Title	Author	Problem Statement	Objective	Methodology	Key Findings
6	Equations for the Calculation of the Thermo-physical Properties of Stainless Steel	Kenneth C. MILLS, Yuchu SU, Zushu LI and Robert F. BROOKS	In stainless steel studies, current equations lack precision for diverse alloys (3-series, 4-series, 6-series) and microstructure-dependent thermophysical properties. This study aims to fill this gap for accurate modeling and product quality enhancement.	Establish accurate equations for diverse stainless-steel alloys (3-series, 4-series, 6-series), considering Fe, Cr, and Ni properties. Address microstructure effects and estimate liquidus temperatures for comprehensive thermophysical insights.	Review literature, collect experimental data on 3-series, 4-series, and 6-series stainless steels, analyze Fe, Cr, Ni similarities, consider microstructure effects, formulate precise equations, validate, calculate property values, estimate liquidus temperatures.	In this paper we interpreted Youngs modulus, thermophysical and thermodynamic properties of stainless steel such as thermal conductivity thermal diffusivity, thermal expansion coefficient.

Sr No.	Paper Title	Author	Problem Statement	Objective	Methodology	Key findings
7	Thermal energy storage inside the chamber with a brick wall using the phase change process of paraffinic materials: A numerical simulation	M. Javidan, M. Asgari, M. Gholinia , M. Nozari , A. Asgari , D.D. Ganji	This study addresses the efficiency of phase change materials (PCMs) for building energy supply. It investigates the impact of PCM layer thickness on thermal energy storage and temperature reduction.	Investigate the melting process of phase change materials (PCMs) under constant heat flux, emphasizing the impact of varying PCM thickness on thermal energy storage and temperature reduction for building efficiency.	Employ numerical simulations to study PCM melting under constant heat flux. Investigate the impact of variable PCM thickness on temperature reduction, buoyancy effects, and optimize for tropical building efficiency.	From this paper we got familiar with the parameters that are required for heat transfer by conduction and radiation, also we evaluated how to plot temperature vs time graph.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
8	Real-Time Determination of Convective Heat Transfer Coefficient Via Thermoelectric Modules	Nataporn Korprasertsak, Thananchai Leephakpreeda	This paper introduces a method for real-time determination of convective heat transfer coefficients.	Employing thermoelectric modules in cooling/heating processes, real-time convective heat transfer coefficients are determined using Seebeck effect and energy balance principles. Validation includes wind tunnel experiments and outdoor copper plate exposure.	The research in this paper focuses on the calculations related to calculations of convection and time for convection.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
9	Time-varying heat transfer coefficients between tube-shaped casting and metal mold	Tae-Gyu Kim, Zin-Hyoung Lee	The study aimed to analyze time-varying heat transfer coefficients (h(t)) between a tube-shaped casting and metal molds. Objectives included experimental investigation of h(t) for various alloys and understanding abnormal heat transfer phenomena during solidification.	Employed one-dimensional heat flow analysis for casting-mold interaction. Utilized the sequential function specification method to solve the nonlinear inverse heat conduction problem. Conducted casting experiments with diverse alloys, employing formulas for heat transfer coefficients.	The article focuses on the understanding of natural convection and its relation with Rayleigh number and analysis of time required for convection with respect to our problem.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
10	Design and Analysis of a High-Pressure Apparatus	K. C. Rolle, J. N. Crisp, A. N. Palazotto	Objectives include enhancing Bridgman's piston-displacement device through finite element techniques for precise measurements, refining analysis, and improving accuracy in pressure-volume-temperature relations.	Enhanced Bridgman's high-pressure apparatus for lubricants equilibrium phase diagrams using finite element techniques. Refined measurements were incorporated into expressions for precise pressure-volume-temperature relations at extreme conditions.	The study helps us to understand the provided structure with respective volumes and analyze for stress and temperature concentrations.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
11	Stress analysis using Solidworks simulation.	Yazeed Mohammed Ahmed Almashani, Abdullah Ahmed Alamri, Muhab Mohammed Faraj Al-Ghassani, Mithun V Kulkarni	The study aims to demonstrate the effectiveness of SolidWorks Simulation in predicting component behavior. Objectives include creating 3D models, assigning materials, applying loads, and comparing simulation results with hand calculations for bending-related stress analysis and stress concentration problems.	Utilized SolidWorks Simulation for stress analysis by creating a 3D model, assigning material properties, defining boundary conditions, meshing, and setting up analyses. Compared results with hand calculations, showcasing less than 1% variation.	This paper helped us to better understand the concept of stress analysis and simulation using solidworks.

Sr no.	Paper Title	Author	Objectives	Methodology	Key findings
12	Heat transfer in steam boiler furnaces	Blokh, A G	This volume aims to elucidate modern concepts in heat transfer within furnaces firing coal, gas, and fuel oil. Objectives include providing practical data for operational efficiency, addressing radiative properties, and serving as a valuable reference and design guide for thermal and industrial engineers.	This volume utilizes practical data for heat transfer calculations in furnaces firing coal, gas, and fuel oil. Covers radiative properties, effects on gases, ash particles, soot, and coke, and combustion conditions.	From this research paper we understood that Solving problems of heat transfer calculation are especially important for assuring operational efficiency and reliability.

Sr No.	Page Title	Author	Objective	Methodology	Key Findings
13	Thermoelastic and texture behavior of aluminum at high pressure and high temperature investigated by *in situ* neutron diffraction	Duanwei He; Yusheng Zhao; L. L. Daemen; J. Qian; K. Lokshin; T. D. Shen; J. Zhang; A. C. Lawson	Investigate aluminum behavior at high pressures and temperatures using in situ neutron diffraction with a Toroidal Anvil Press. Correct displacement effects, determine unit-cell dimensions, and compare results with previous experimental and theoretical data.	Utilized in situ time-of-flight neutron diffraction with Toroidal Anvil Press (TAP-98) to investigate aluminum behavior under high pressures and temperatures. Corrected diffraction center displacement and derived unit-cell dimensions, applying high-temperature Birch–Murnaghan equation of state. Validated results through comparison with previous experimental and theoretical data.	In this paper we interpreted behaviour of aluminium at high temperature and pressure, thermal diffusivity, and thermal expansion coefficient.

Sr No.	Paper Title	Author	Objective	Methodology	Key findings
14	Ideal Gas Behavior	Tenny KM, Cooper JS	Explore the Ideal Gas Law, including constituent laws. Analyze ideal gas limitations and investigate real gas behavior. Extend to mixtures and partial pressures, introducing alternative models.	The methodology involves explaining the principles behind the Ideal Gas Law and its constituent laws (Charles's, Boyle's, Gay-Lussac's). It outlines the role of the universal gas constant, considerations for ideal gases, and conditions for real gases' ideal behavior.	From this paper we understood the ideal gas equation and its relation with our problem.

Chapter 3
METHODOLOGY

3.1 Project Plan

Following flow chart explains the steps for experiment. The process flow mentioned above will be considered to meet the goal of research work.

Problem and Objectives

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Study Problem Statement And Collecting Relevant Data

↓

Design of Chamber

↓

Mathematical Calculations

↓

Geometry Creation

↓

Iterate and Refine

↓

Data Analysis and Reporting

↓

Experimental Verification (If permitted)

3.2 Problem and Objective

This project delves into enhancing efficiency by strategically managing time, material, and thickness of the Pressure Chamber used in Aircraft. The use of Nitrogen in various applications such as Aerospace & Aircraft, Automotive & Transportation Equipment becomes less effective after it reaches a certain temperature, hence it is vital that we know the time required for nitrogen to reach that temperature due to effect of external conditions. By doing so we can schedule the operation of the system and plan the maintenance and replacement activities if required when needed.

3.3 Study Problem Statement and Collecting Relevant Data

A well-defined problem statement is the foundation of any successful study. It clearly identifies the specific issue, question, or phenomenon you aim to investigate.

Once you have a clear problem statement, you can start gathering the information needed to answer your research questions. Choosing the appropriate data collection methods is crucial for obtaining reliable and valid findings. Here is data which we are using for calculations:

A Chamber of material 1) Aluminium; 2) Titanium; contains Nitrogen Pressurized to 350 bars. The Chamber is of capacity(volume) 1) 0.4 litres; 2) 0.5 litres; 3) 0.6 litres and the geometry is cylinder with hemisphere at each end, Length/Diameter ratio is ½. The Chamber is contained within a cubic enclosure of volume 1 m^3, the surface of enclosure is maintained at 100 °C by external means (unknown). The rest of enclosure contains air at room condition (T=25 °C, P= Patm). Determine a) The Heat Transfer from enclosure to Nitrogen inside chamber; b) Time Required to reach 100 °C for 1) Air Inside the Enclosure; 2) Inner and outer Surface of Chamber; 3) Nitrogen, Also Design Pressure Chamber

3.4 Design of Chamber

The specific design of your chamber will depend heavily on its intended purpose and the unique requirements of project. We are designing chamber used in Aircraft which is filled with Pressurized Nitrogen. Nitrogen gas is useful in preventing oxidative damage in Aircraft

3.5 Geometry Creation

Geometry creation involves defining the boundaries and obstacles within the flow domain. This can be done using Computer-Aided Design (CAD) software or by importing existing geometries. Accurate representation of the physical boundaries and flow passages is crucial for obtaining reliable results. Complex geometries and multi-component systems require special techniques for handling the geometry creation process. The geometry we required for our analysis was created in SolidWorks and Design Modeler.

3.6 Data Analysis and Reporting

Reporting is the process of presenting information derived from data analysis in a structured. Data analysis is the process of inspecting, cleaning, transforming, and modelling data to discover useful information, draw conclusions.

Chapter 4
DESIGN CALCULATIONS OF CHAMBER & HEAT TRANSFER RATE

4.1 Procedure for calculation

Step 1: Calculation of dimensions (length and diameter) of the chamber based on the capacity(volume)

Step 2: Calculation of surface Area

Step 3: Calculation of characteristic length of the virtual sphere (assumed)

Step 4: Calculation of thickness with the help of thermal stress (hoop's stress)

Step 5: Calculation of convective heat transfer coefficient(h) by using concepts of Rayleigh, Prandtl &Nusselt numbers for ambient Air and pressurized Nitrogen

Step 6: Calculation of Heat transfer Rate

Step 7: Calculation of time required to reach 100 degrees centigrade (equilibrium state)

Step 8: Plotting Temperature vs Time graph

4.2 Material Selection

Selecting the right material for a design is crucial in aircraft, impacting factors like:

1. **Performance:** Does the material meet the required strength, durability, weight, thermal conductivity, etc.
2. **Manufacturability:** Can the material be easily shaped, formed, and joined using the desired techniques.
3. **Sustainability:** Does the material have a low environmental impact throughout its lifecycle, considering factors like recyclability and energy consumption during production. Aircraft requires a delicate balance between various factors

Primary materials which can be used in Aircraft

- **Aluminum alloys**: Widely used due to their excellent strength-to-weight ratio, formability, and recyclability. However, their susceptibility to corrosion requires additional treatments.

- **Titanium alloys:** Offer high strength, low weight, and excellent corrosion resistance, but are more expensive and have complex processing requirements.

- **Composites:** Increasingly used in primary structures and secondary components due to their superior strength-to-weight ratio, design flexibility, and excellent fatigue resistance. Examples include carbon fiber-reinforced polymers (CFRP) and glass fiber-reinforced polymers (GFRP).

4.3 Material Selected for analysis as per desired application

Aluminum 6262-T9

Mechanical properties	
Young's modulus	68.9 GPa
Poisson's ratio	0.33
Yield strength (elastic limit)	379 MPa
Tensile strength	400 MPa
Elongation	10-14% strain
Density	2720 kg/m^3
Thermal Conductivity	171 W/m-K
Cost	Rs 510/kg

Titanium α-β Annealed grade 9

Ti-3Al-2.5V

Mechanical properties	
Young's modulus	530 MPa
Poisson's ratio	0.3
Yield strength (elastic limit)	345 MPa
Tensile strength	620 MPa
Elongation	20 % strain
Density	4480 kg/m^3
Thermal conductivity	8.30 W/mK
Cost	Rs.4000/KG

Stainless steel 15-5 PH

Mechanical properties	
Young's modulus	196 GPa
Poisson's ratio	0.3
Yield strength (elastic limit)	1275 MPa
Tensile strength	1380 MPa
Elongation	10 % strain
Density	7780 kg/m^3
Thermal conductivity	17.8 W/mK
Cost	Rs 380/kg

4.4 Design of Chamber

Given Volume = [Volume of Hemisphere] ×2+ [Volume of Cylinder]
= [Volume of Sphere] + [Volume of Cylinder]
$=\frac{\pi}{6}d^3 + \frac{\pi}{4}d^2 L$

- $0.4 \times 10^{-3} = \frac{\pi}{6}d^3 + \frac{\pi}{4}d^2$L

As $\frac{d}{L} = \frac{1}{2}$

$$\pi\left[\frac{d^3}{6} + \frac{d^3}{2}\right] = 0.4 \times 10^3$$

$$\frac{2\pi d^3}{3} = 0.4 \times 10^{-3}$$

$$d = \sqrt[3]{\frac{0.4 \times 10^{-3} \times 3}{2\pi}}$$

$$d = 0.0575m$$

$$\& \quad L = 2d = 2(0.0575) = 0.1151m$$

Similarly, L & d can be calculated for volumes 0.5 & 0.6 liters.

- $Volume = 0.5 \times 10^{-3}\ m^3$

$$d = \sqrt[3]{\frac{0.5 \times 10^3 \times 3}{2\pi}} = 0.0620m$$

$$L = 2d = 2(0.0620) = 0.1240m$$

- $Volume = 0.6 \times 10^{-3} m^3$

$$d = \sqrt[3]{\frac{0.6 \times 10\text{^}3 \times 3}{2\pi}}$$

$$t = 2d = 2(0.0620) = 0.1240m$$

- **Surface Area**

$$\text{As} = Area\ of\ Cylinder + Area\ of\ Sphere$$
$$= \pi dL + \pi d^2$$

$$\text{As} = \pi(0.0575)(0.1151) + \pi(0.0575)^2 = 0.0311m^2$$

Assuming the Geometry as Virtual sphere [For simplification of calculation]

$(\text{Volume})_{\text{Sphere}} = \frac{\pi de^3}{6}$

$$= \sqrt[3]{\frac{6(volume)total}{\pi}}$$

$$= \sqrt[3]{\frac{6 \times 0.4 \times 10^{-3}}{\pi}}$$

- $L_{c1} = d_{e1} = 0.0914m$
- $L_{c2} = d_{e2} = 0.0984m$
- $L_{c3} = d_{e3} = 0.1046m$

Sr. No.	Volume	Surface Area(mm^2)	Diameter(mm)	Height(mm)	Characteristic Length(mm)
1	0.4×10^{-3}	31100	57.5	115.1	91.4
2	0.5×10^{-3}	36200	62	124	98.4
3	0.6×10^{-3}	40900	65.9	131.8	104.6

4.5 Using Concept of Hoop's Stress to find thickness of the chamber

For calculating thickness using the concept of hoop's stress

$$\sigma_{\text{hoop}} = \frac{yield\ strength}{factor\ of\ safety} = \frac{Pr}{t}$$

$$where\ \ P = Internal\ \text{Pressure}$$

$$r = radius$$
$$t = thickness$$

1. For Aluminum

   i. Volume $= 0.4 \times 10^{-3} m^3$

   $$\frac{379 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.02875}{t}$$

   t_1=9.2925mm $\approx 10mm$

   ii. Volume = $0.5 \times 10^{-3} m^3$

   $$\frac{379 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.031}{t}$$

   t_2 =10.0197mm $\approx 11mm$

   iii. Volume = $0.6 \times 10^{-3} m^3$

   $$\frac{379 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.0329}{t}$$

   t_3 =11.6339mm$\approx 12mm$

2. For Titanium

   i. Volume= $0.4 \times 10^{-3} m^3$

   $$\frac{345 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.02875}{t}$$

   t_1 = 10.2833mm$\approx 11mm$

ii. Volume = 0.5$\times 10^{-3} m^3$

$$\frac{345 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.031}{t}$$

t_2= 11.0072mm $\approx 12mm$

iii. Volume = 0.6$\times 10^{-3} m^3$

$$\frac{345 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.0329}{t}$$

t_2= 12.6818mm $\approx 13mm$

3. For Stainless Steel: -

i. Volume= $0.4 \times 10^{-3} m^3$

$$\frac{1275 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.02875}{t}$$

t_1 = 1.76mm$\approx 2mm$

ii. Volume = 0.5$\times 10^{-3} m^3$

$$\frac{1275 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.031}{t}$$

t_2=2.9784mm$\approx 3mm$

iii. Volume = 0.6$\times 10^{-3} m^3$

$$\frac{1275 \times 10^6}{3.5} = \frac{350 \times 10^5 \times 0.0329}{t}$$

t_3= 3.1609mm$\approx 4mm$

Thickness (in mm)

Material	**Volume (in litres)**		
	0.4	**0.5**	**0.6**
Aluminum	10	11	12
Titanium	11	12	13
Stainless steel	2	3	4

4.6 Calculation of convective heat transfer(h) for Air and Nitrogen

- As it is natural convection calculating using Relation(empirical) between Nusselt number, Grashoff number & Prandtl number or using Rayleigh Number
- Characteristic Length (Lc)- Converting the whole geometry into equivalent sphere to calculate the "Lc" for sphere i.e. diameter

Rayleigh (Ra) $= \frac{g\beta(Ts-T\quad)Lc^3}{\vartheta\alpha}$

1] For Air: -

For Lc_1

$$g = 9.81\frac{m}{s^2}$$

$$\beta = \frac{1}{T(film)} = \frac{1}{\left[\frac{373+298}{2}\right]}$$

$$\vartheta(air) = 1.516 \times 10^{-5}\,\frac{m^2}{s}$$

$$\propto = 18.4 \times 10^{-6}\,\frac{m^2}{s}$$

$$Ra = \frac{9.81 \times 1 \times (100-25) \times (0.0914)^3}{1.516 \times 10^{-5} \times 18.4 \times 10^{-6} \times 211.5}$$

$$Ra = 9.5222 \times 10^6$$

$$Pr = \frac{\mu Cp}{Kf} = \frac{\vartheta\rho Cp}{Kf}$$

$$Pr = \frac{1.516\ x\ 10^{-5} x\ 1.2\ x\ 1005}{0.024}$$

$$\therefore\ Pr = 0.7617$$

$$Nu = 2 + \frac{0.589Ra^{1/4}}{[1+\left(\frac{0.469}{Pr}\right)^{\frac{9}{16}}]^{4/9}}$$

$$Nu = 2 + \frac{0.589(9.5222\times10^{11})^{1/4}}{[1+\left(\frac{0.469}{0.7617}\right)^{\frac{9}{16}}]^{4/9}}$$

Nu = 25.4424

Nu = $\frac{hLc}{K}$

27.4424 = $\frac{h \times 0.0914}{0.024}$

h = 7.2058 W/m^{2}K

Characteristic length(mm)	**Rayleigh number**	**Prandtl number**	**Nusselt number**	**Convective heat Transfer coefficient(w/m^{2}k)**
91.4	9.5222×10^6	0.7617	25.4424	7.2058
98.4	11.8819x 10^6	0.7617	28.8902	7.5860
104.6	14.2724 x10^6	0.7617	30.1513	7.917

2] For Nitrogen: -

$\vartheta = 4.6276 \times 10^{-8}$ m^2/s

α = 6.2805 x 10^{-8} m^2/s

$\rho = 395.453$ kg/m^3

C_p = 1.04 KJ/KgK & C_v = 0.74 KJ/KgK

Using PV = MRT

$\rho = \frac{P}{RT} = \frac{350 \times 10^5}{0.297 \times 298}$

$\rho = 395.453$ kg/m^3

K = 0.02583 W/mK

μ = 1.83 x 10^{-5} N-s/m^2

$$Ra = \frac{g\beta(Ts - T\infty)Lc^3}{\vartheta\alpha}$$

$$Ra = \frac{9.81 \times 1\,(75)(0.0914)^3}{4.6276 \times 10^{-8} \times 211.5 \times 6.2805 \times 10^{-8}}$$

$Ra = 9.1392 \times 10^{11}$

$$Pr = \frac{\mu Cp}{k}$$

$Pr = 0.7368$

$$Nu = 2 + \frac{0.589Ra^{(\frac{1}{4})}}{[1+\left(\frac{0.469}{Pr}\right)^{\frac{9}{16}}]^{4/9}}$$

$$Nu = 2 + \frac{0.589(9.132\times10^{11})^{(\frac{1}{4})}}{[1+\left(\frac{0.469}{0.7368}\right)^{\frac{9}{16}}]^{4/9}}$$

$Nu = 448.2216$

$$Nu = \frac{h\,Lc}{K}$$

$$448.2216 = \frac{h \times 0.0914}{0.02583}$$

$h_1 = 126.6692$ W/m^{2}K

Characteristic length(mm)	**Rayleigh number**	**Prandtl number**	**Nusselt number**	**Convective heat Transfer coefficient(w/m^{2}k)**
91.4	9.1392×10^{11}	0.7368	448.2216	126.6692
98.4	1.1403×10^{12}	0.7368	473.6147	133.8454
104.6	1.3698×10^{12}	0.7368	495.7303	140.0953

4.7 Calculation of Heat transfer Rate

$$Q = \frac{\Delta T}{\frac{1}{h1A1}+\frac{r2-r1}{4\pi kr1r2}+\frac{1}{h2A2}}$$

- **Aluminum**

i. Volume = $0.4 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0311}+\frac{0.010}{4\pi \times 193 \times 0.03875 \times 0.02875}+\frac{1}{126.67 \times 0.0311}}$$

$$Q = 15.8763W$$

ii. Volume = $0.5 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0362}+\frac{0.011}{4\pi \times 193 \times 0.031 \times 0.042}+\frac{1}{126.67 \times 0.0362}}$$

$$Q = 18.4780W$$

iii. Volume = $0.6 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0409}+\frac{0.012}{4\pi \times 193 \times 0.03295 \times 0.04495}+\frac{1}{126.67 \times 0.0409}}$$

$$Q = 20.8795W$$

- **Titanium**

i. Volume = $0.4 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0311}+\frac{0.011}{4\pi \times 8.30 \times 0.03975 \times 0.02875}+\frac{1}{126.67 \times 0.0311}}$$

$$Q = 15.5611W$$

ii. Volume = $0.5 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0362} + \frac{0.012}{4\pi \times 8.30 \times 0.031 \times 0.043} + \frac{1}{126.67 \times 0.0362}}$$

$Q = 18.0791$W

iii. Volume = $0.6 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0409} + \frac{0.013}{4\pi \times 8.30 \times 0.03295 \times 0.04795} + \frac{1}{126.67 \times 0.0409}}$$

$Q = 20.3873W$

- **Stainless Steel**

i. Volume = $0.4 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0311} + \frac{0.002}{4\pi \times 17.8 \times 0.03075 \times 0.02875} + \frac{1}{126.67 \times 0.0311}}$$

$Q = 15.8626W$

ii. Volume = $0.5 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0362} + \frac{0.003}{4\pi \times 17.8 \times 0.031 \times 0.034} + \frac{1}{126.67 \times 0.0362}}$$

$Q = 18.4473W$

iii. Volume = $0.6 \times 10^{-3}\ m^3$

$$Q = \frac{75}{\frac{1}{7.20 \times 0.0409} + \frac{0.004}{4\pi \times 17.8 \times 0.03295 \times 0.03695} + \frac{1}{126.67 \times 0.0409}}$$

$Q = 20.8234W$

Material	Heat transfer rate(Q) (in watt) Volume (in litres)		
	0.4	**0.5**	**0.6**
Aluminum	15.8763	18.4781	20.8795
Titanium	15.5611	18.0791	20.3873
Stainless steel	15.8626	18.4473	20.8234

4.8 Calculation for Time

$$\int \frac{dQ}{dt} dt = \int mc \frac{dT}{dt}\, dt$$

$$Q \times t + C1 = mcT + C2$$

$$T(t) = \frac{Q}{mc} \times t + \frac{C1 - C2}{mc}$$

1. Aluminum

⇨ Mass calculations (sample)

$m = \rho \times V$

1) Nitrogen

⇨ $395.5 \times 0.4 \times 10^{-3} = 0.1582$ Kg

2) Chamber

$R_{outer} = R_{inner} +$ thickness = 0.02875+0.010 = 0.03875m

⇨ Volume = $(\text{volume})_{outer} - (\text{volume})_{inner}$

$= \frac{4}{3}\pi Ro^3 + \pi Ro^2 H - (0.4 \times 10^{-3})$

$= 0.00038668 m^3$

⇨ 2720×0.00038668 = 1.05176Kg

3) Air

⇨ Volume= $1-(0.4\times10^{-3}) = 0.9996 m^3$

⇨ 1.02×0.9996=1.0195Kg

Mass(kg) & specific heats (KJ/KgK)

Volume(m^3) =>	0.4×10^{-3}	0.5×10^{-3}	0.6×10^{-3}	Specific heat
Nitrogen	0.1582	0.1977	0.2373	740
Chamber	1.05176	1.3532	1.6783	890
Air	1.0195	1.0194	1.0193	718

For t_3, $mc = [0.1582 \times 740] + [0.8167 \times 880] + [1.0192 \times 718] = 1785.1354$

For t_2, $mc = [0.8167 \times 880] + [1.0192 \times 718] = 1668.0674$

For t_1, $mc = 1.0192 \times 718 = 732.001$

⇨ For volume $=0.4\times10^{-3} m^3$

$$T(t) = \frac{Q}{mc} \times t + \frac{C1 - C2}{mc}$$

Applying boundary condition; at t=0 T=25℃

$25 = \frac{C1-C2}{1785.1354}$ => C1-C2= 44628.385

Put C1-C2 in equation to find time to reach temperature = 100℃

$$100 = \frac{15.8763(t3)}{1785.1354} + \frac{39188.74}{1785.1354}$$

t_3=140.5503min

Similarly, for t_2, C1-C2= 41701.685 & t_2= 131.3331min

for t_1, C1-C2=18300.025 & t_1= 57.6331min

Volume(m^3)	t_1(min)	t_2(min)	t_3(min)
0.4×10^{-3}	57.6331	131.3331	140.5503
0.5×10^{-3}	49.5133	130.9853	140.8820
0.6×10^{-3}	43.8134	133.2374	141.9958

2. Stainless Steel: -

$T(t) = \frac{Q}{mC} \times t$ +(C_1-C_2)× $\frac{1}{mC}$

Mass(kg) & specific heats (KJ/KgK)

Volume(m^3) =>	**0.4×10^{-3}**	**0.5×10^{-3}**	**0.6×10^{-3}**	**Specific heat**
Nitrogen	0.1582	0.1977	0.2373	740
Chamber	0.4956	0.8944	1.372	420
Air	1.0195	1.0194	1.0193	718

By using, $T(t) = \frac{Q}{mC} \times t$ +(C_1-C_2)× $\frac{1}{mC}$

For T(t)=25°C, t = 0,

$$25 = \frac{15.8626}{732.001} \times 0 + \frac{C1-C2}{732.001}$$

C_1-C_2 = 18300.025

For T(t)=100°C,

$$100 = \frac{15.5611}{732.001} \times t + \frac{18300.025}{732.001}$$

t_1= 57.6829 min

For T(t)=25°C, t = 0,

$$25 = \frac{15.8626}{940.153} \times 0 + \frac{C1-C2}{940.153}$$

C_1-C_2 = 23503.825

For T(t)=100°C,

$$100 = \frac{15.8626}{940.153} \times t + \frac{23503.825}{940.153}$$

t_2= 74.0856min

For T(t)=25°C, t = 0,

$$25 = \frac{15.8626}{1057.221} \times 0 + \frac{C1-C2}{1057.221}$$

C_1-C_2 = 26425

For T(t)=100°C,

$$100 = \frac{15.8626}{1057.221} \times t + \frac{26425}{1057.221}$$

$t_3 = 83.3108\ min$

Volume(litres)	t_1 (min)	t_2(min)	t_3(min)
0.4	57.6829	74.0856	83.3108
0.5	49.5959	75.0500	84.9633
0.6	43.9323	78.5787	89.1198

3. Titanium: -

$T(t) = \frac{Q}{mC} \times t$ +(C_1-C_2)× $\frac{1}{mC}$

Mass(kg) & specific heats (KJ/KgK)

Volume(m^3) =>	0.4×10^{-3}	0.5×10^{-3}	0.6×10^{-3}	Specific heat
Nitrogen	0.1582	0.1977	0.2373	740
Chamber	1.9462	2.4788	3.0492	1040
Air	1.0195	1.0194	1.0193	718

By using, $T(t) = \frac{Q}{mC} \times t$ +(C_1-C_2)× $\frac{1}{mC}$

For T(t)=25°C, t = 0,

$$25 = \frac{15.5611}{732.001} \times 0 + \frac{C1-C2}{732.001}$$

C_1-C_2 =18300.025

For T(t)=100°C,

$$100 = \frac{15.5611}{732.001} \times t + \frac{18300.025}{732.001}$$

$t_1 = 58.8005\ min$

For T(t)=25°C, t = 0,

$$25 = \frac{15.5611}{2756.049} \times 0 + \frac{C1-C2}{2756.049}$$

C_1-C_2 =68901.225

For T(t)=100°C,

$$100 = \frac{15.5611}{2756.049} \times t + \frac{68901.225}{2756.049}$$

$t_2 = 221.3893\ min$

For T(t)=25°C, t = 0,

$$25 = \frac{15.5611}{2873.117} \times 0 + \frac{C1 - C2}{2873.117}$$

C_1-$C_2 = 71827.925$

For T(t)=100°C,

$$100 = \frac{15.5611}{2873.117} \times t + \frac{71827.925}{2873.117}$$

$t_3 = 230.7392\ min$

Volume(litres)	**t_1 (min)**	**t_2(min)**	**t_3(min)**
0.4	58.8005	221.3893	230.7932
0.5	50.6060	228.8472	238.9623
0.6	44.8721	239.3049	250.0715

Chapter 5
CONCEPT DESIGN

5.1 Introduction

In this section, we present the 3D models and snapshots generated using SolidWorks and Design Modeler software to illustrate the design aspects of the Chamber. These models provide a comprehensive visual representation of design considerations for the volumes.

5.2 Overview of SolidWorks Models

The SolidWorks models included in this section showcase various aspects of the Chamber design.

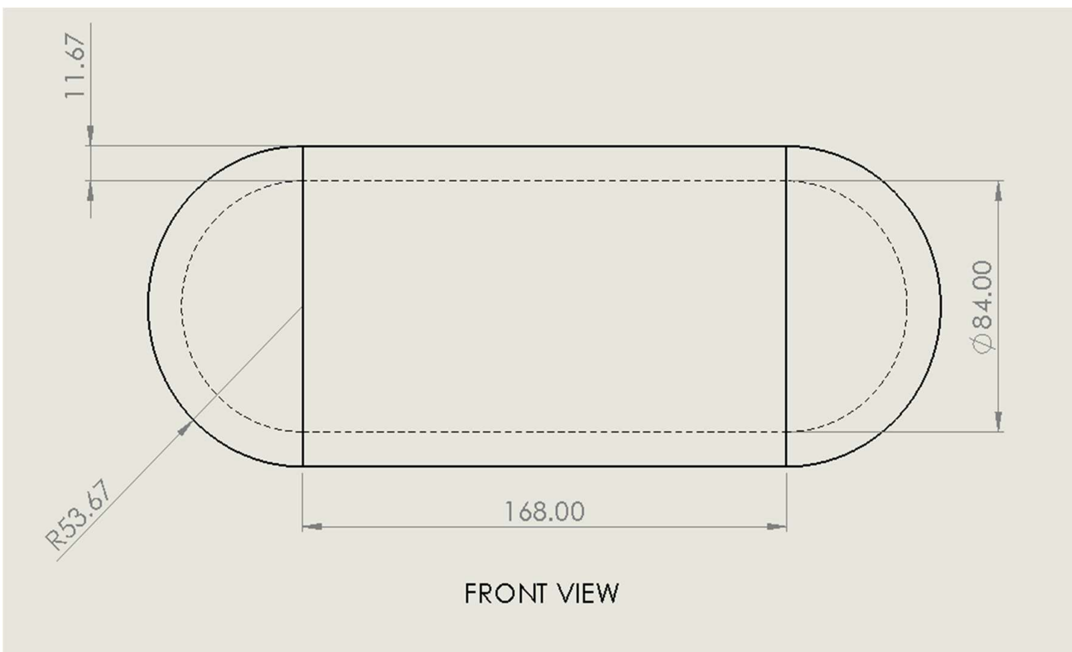

Fig.5.2.1 CAD Design Front view

Fig.5.2.2 Isometric View of Chamber

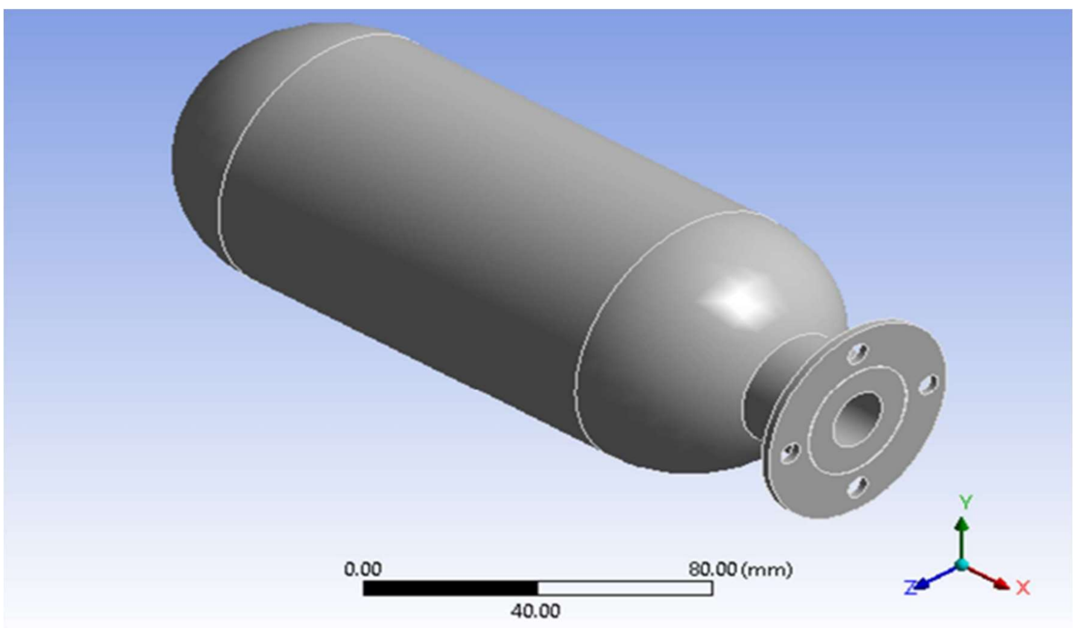

Fig.5.2.3 Isometric View of Chamber 16 mm diameter opening

Chapter 6
RESULTS

6.1 Introduction

ANSYS is a powerful engineering simulation software widely used for various analyses, including static structural, thermal, fluid flow, and electromagnetic simulations.

In this section, we present the analysis and snapshots generated using Ansys Workbench software to illustrate the aspects of the chamber. This section presents the key findings and insights obtained from your analysis.

6.2 Overview of Ansys Models

The Ansys models included in this section showcase various aspects of the chamber, **Static structural analysis** is a type of engineering simulation used to predict the behavior of a structure under static loading conditions. In static structural analysis, total deformation refers to the overall change in the shape and size of a structure due to the application of static loads. Static structural analysis with equivalent stress is performed to evaluate the overall stress distribution and potential failure points within a structure subjected to static loads (loads that does not change over time).

Safety factor is a numerical value calculated to assess the reserve capacity of a structure or component to withstand applied loads without failure. It serves as an indicator of structural integrity and margin of safety under anticipated operating conditions.

Transient thermal analysis is performed for a variety of purposes, primarily to understand how a system or component responds to changes in temperature over time. Transient thermal reveals how long it takes for a system to reach a certain temperature

6.3 Boundary Condition

Boundary conditions for this study have been indicated in Fig.7.3.1. In the simulation setup, the fixed face which is B in our case of the object serves as a reference point for establishing boundary conditions in Ansys. The pressure applied inside the object is 350 bar defined as a boundary condition to simulate the external forces acting on the system. This pressure boundary condition helps model the behavior of the object under various loading conditions, allowing for the analysis of its structural response and performance. Additionally, other boundary conditions such as material properties.

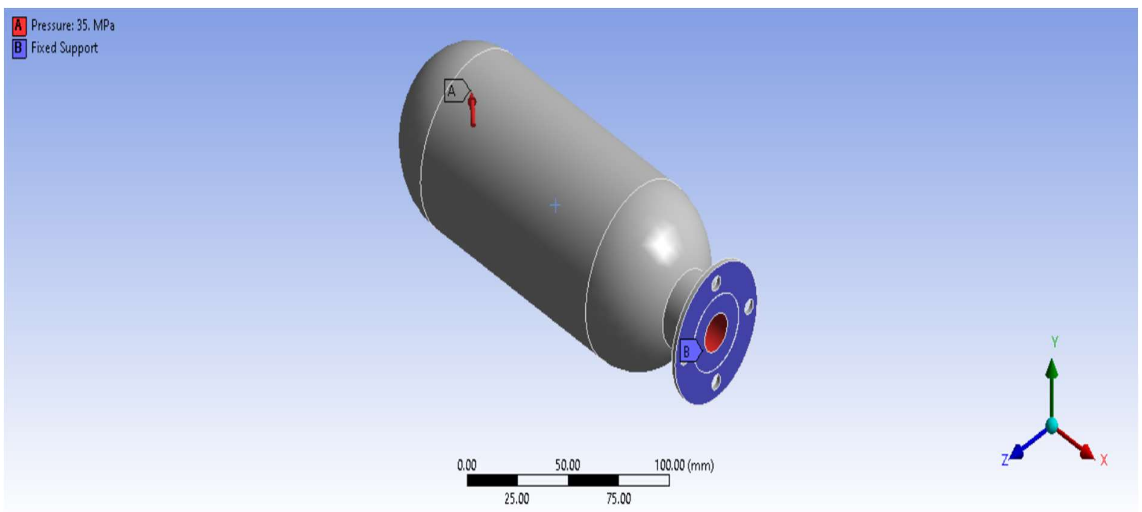

Fig.6.3.1 Boundary Conditions

6.4 Results for Total Deformation of different material

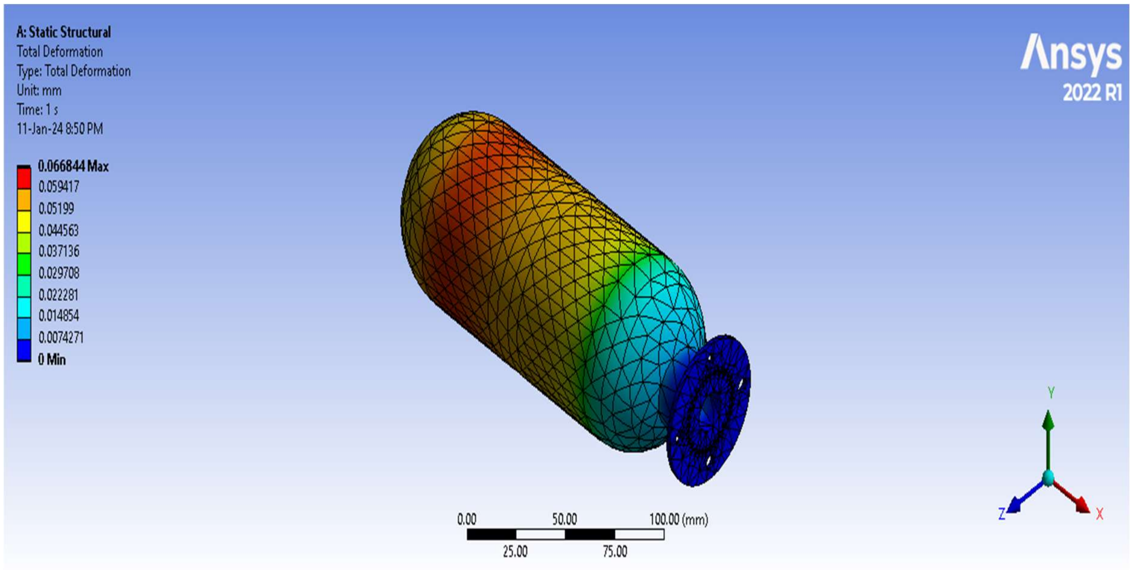

Fig.6.4.1 Total Deformation of aluminum

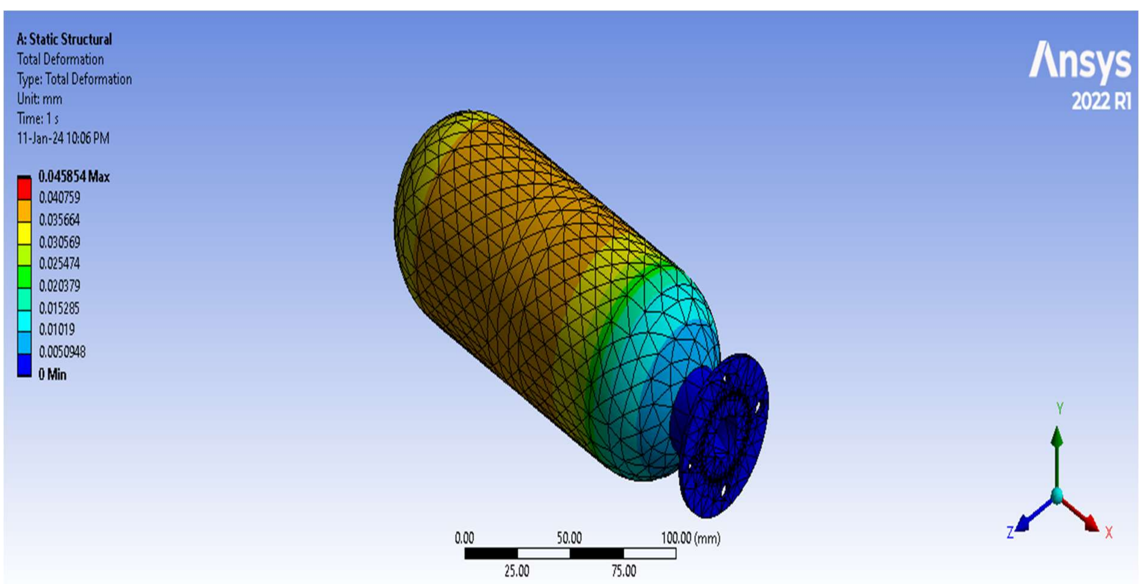

Fig.6.4.2 Total Deformation of Titanium

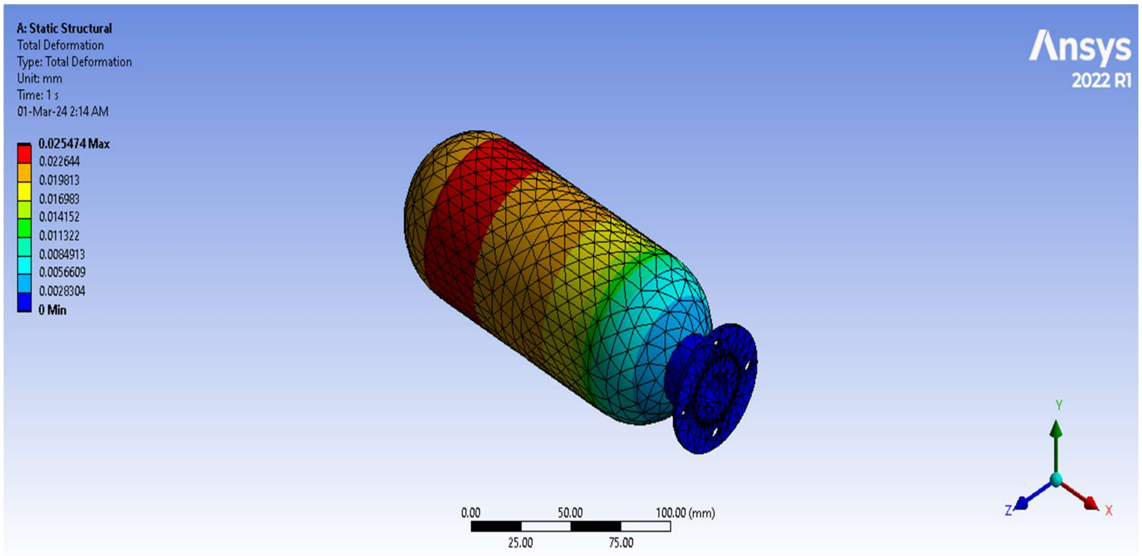

Fig.6.4.3 Total Deformation of Stainless Steel

The analysis revealed a maximum total deformation of aluminum is 0.066 millimeters (mm) at the free end of the of the Chamber (Figure 7.3.1), maximum total deformation of titanium is 0.04 millimeters (mm), maximum total deformation of 15-5 PH is 0.025. This deformation values are well within the acceptable limits for the intended application, according to dimensions of chamber

6.5 Results for Equivalent Stress of different material

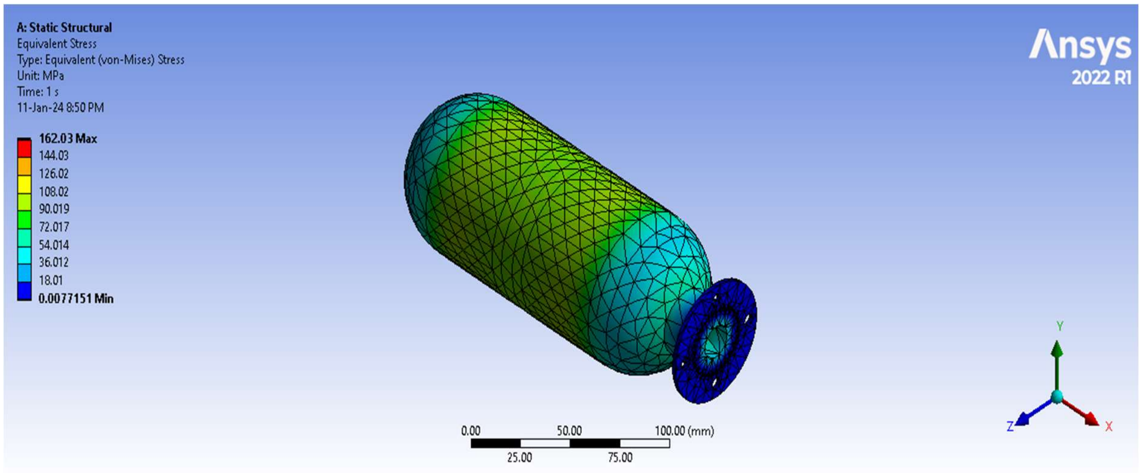

Fig.6.5.1 Equivalent Stress of aluminum

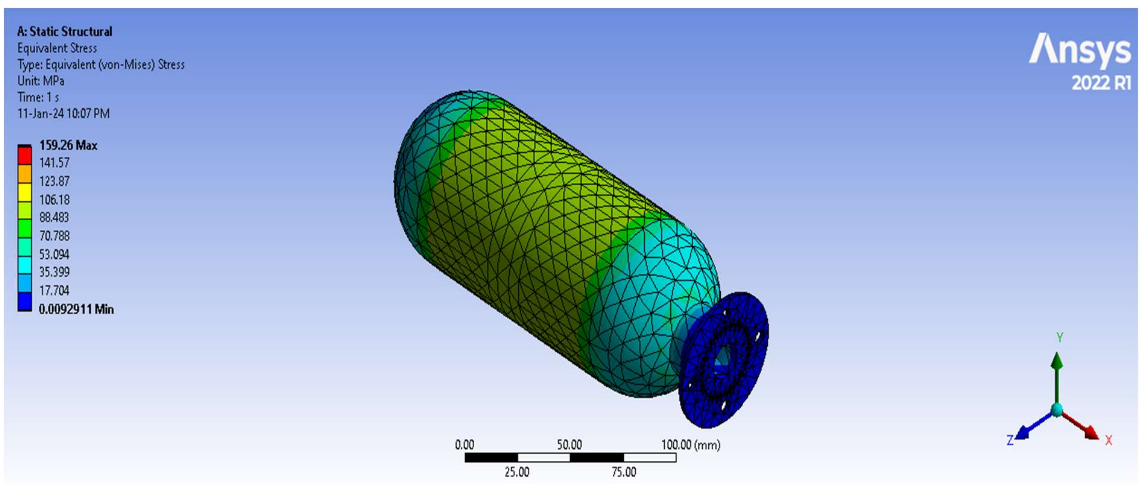

Fig.6.5.2 Equivalent Stress of Titanium

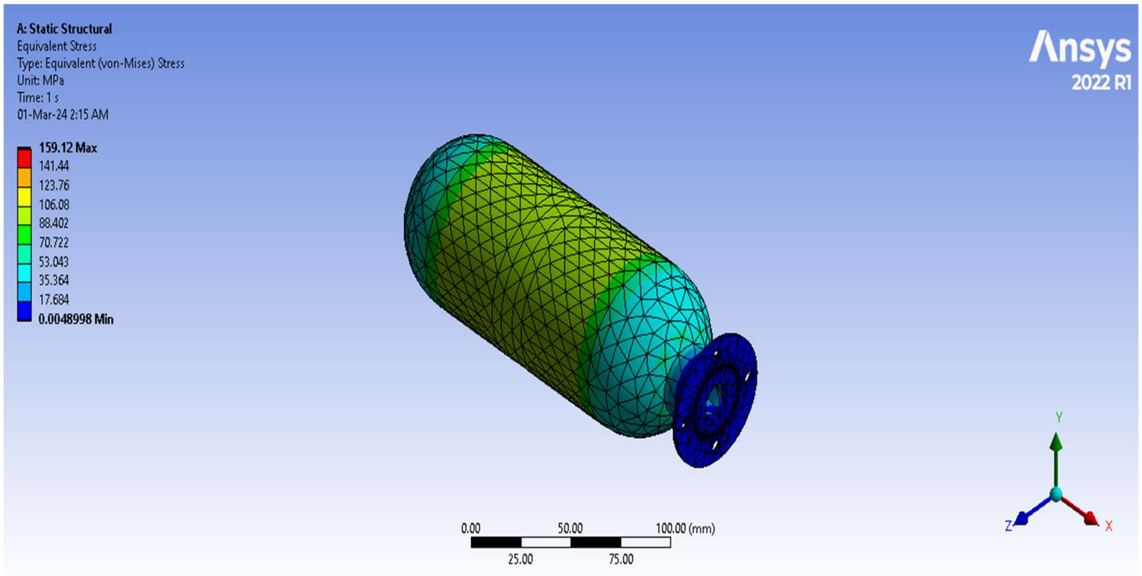

Fig.6.5.3 Equivalent Stress of Stainless Steel

Equivalent stress is calculated in various engineering analyses, particularly in static structural and dynamic structural simulations, to represent the combined effect of all normal and shear stresses acting at a point within a material.

The observed maximum equivalent stress for aluminum 162 MPa, for titanium 159 MPa, for Stainless Steel 159 MPa, indicating a significant margin of safety and low risk of failure. The stress concentration at inner walls of chamber.

6.6 Results for Factor of Safety of different material

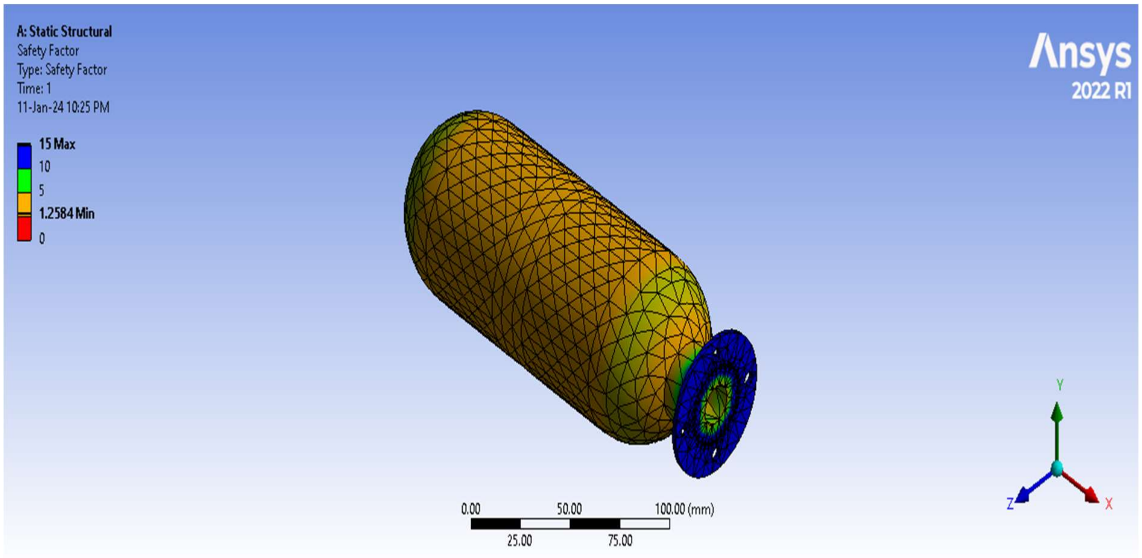

Fig.6.6.1 Factor of Safety of aluminum

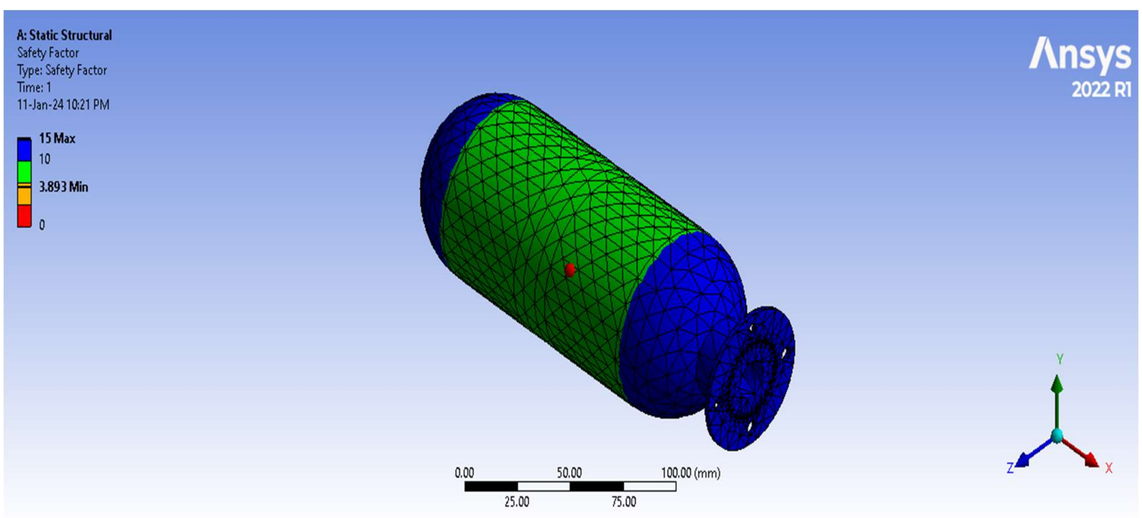

Fig.6.6.2 Factor of Safety of Titanium

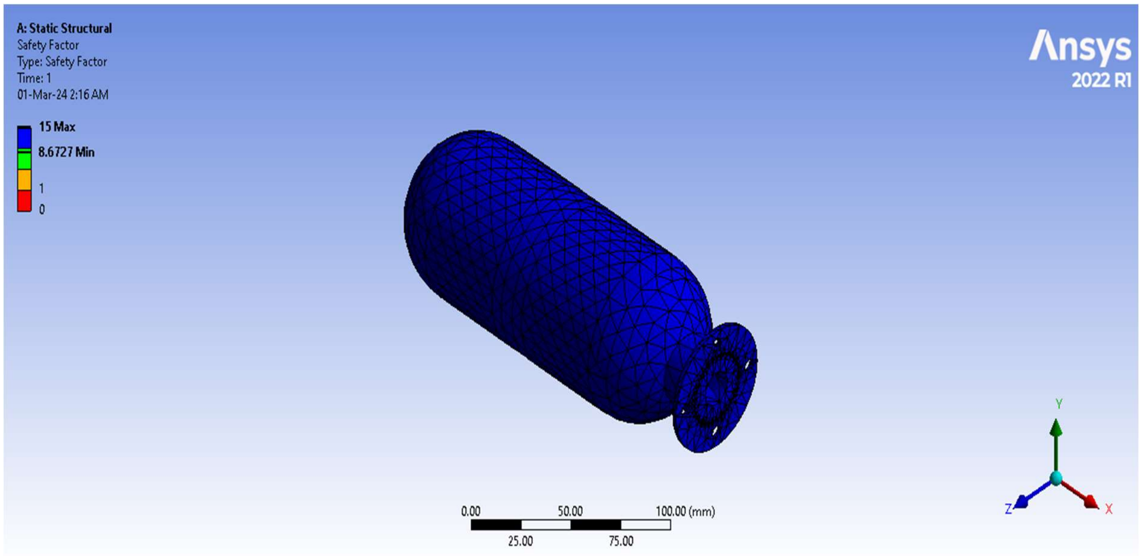

Fig.6.6.3 Factor of Safety of Stainless Steel

Material	**Total Deformation**	**Maximum Equivalent Stress (MPa)**	**Minimum Factor of Safety**
Aluminum 6262-T9	0.066	162	1.23
Titanium α-β Annealed grade 9	0.04	159	3.9
Stainless steel 15-5 PH	0.02	159	8.7

Sr.no.	**Parameter**	**Aluminum**	**Stainless steel**	**Titanium**	**Preferred**
1	**Thermal conductivity**	Highest	Intermediate	Lowest	Titanium
2	**Weight**	Lightest	Intermediate	Heaviest	Aluminum
3	**Factor of safety**	Barely safe	Overly safe	Standard	Stainless steel
4	**Deformation**	Highest	Medium	Lowest	Titanium
5	**Machinability**	High	Intermediate	Extremely low	Aluminum

Chapter 7

CONCLUSION

1. Dimensions of chamber i.e., Diameter, Length and thickness are calculated for different volumes along with characteristic length
2. Rayleigh Number (Ra), Prandtl Number (Pr) and Nusselt number (Nu) are calculated
3. The Convective heat transfer coefficient(h) is calculated for different materials for volumes of 0.4,0.5,0.6 litres.
4. Structural Analysis and Transient Thermal was performed using Ansys for to find if chamber can sustain pressure of pressure of 350 bars
   i. The Total Deformation was obtained for materials on Ansys the result where it was observed maximum deformation in Aluminium Alloy and minimum deformation was observed in Stainless Steel 15-5 PH
   ii. The Factor of Safety for all three materials was calculated and following conclusion was reached: Stainless Steel 15-5 PH > Ti-3Al-2.5V > Aluminium 6262-T9 Considering this criterion stainless steel is best suited material for design.
5. The Heat Transfer Rate was calculated(Q) and it was inferred that maximum heat transfer was through chamber made of material aluminum while minimum was observed for titanium, Hence Titanium is optimal while considering heat transfer as criteria
6. As aluminum is light in weight it will be preferred as opposed to titanium which is to heaver side
7. While considering economic aspects stainless steel will be preferred as it is cheaper and easier to machine (while manufacturing). Titanium being hard metal is difficult to machine while also being highly priced.

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