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Thermo-Mechanical Analysis, Material Selection, and Testing of Cylinder Liners Using Matlab and Ansys for Performance Optimization

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This paper discusses the failure modes, thermal and mechanical properties, material designation and assessment, and testing of cylinder liners, modeled and analyzed with computational software such as ANSYS and MATLAB. The performance analysis of two materials namely Cast Iron as well as Aluminum Alloy (Al 6061) under different thermal and mechanical loading conditions is also reviewed. Procedures delivering useful ANSYS simulation results include stress, temperature distribution and deformation analysis of cylinder liner material. While, in the data processing and material optimization additionally, MATLAB is used for data processing as well as further processing. The investigation leads to the conclusion that while possessing the higher maximum stress (21.7 MPa and larger) and strain energy (11.514 mJ and larger), Cast Iron has lower Factor of safety and larger material failure for Aluminum Alloy (Al 6061) with Factors of safety equals 15 and smaller stress concentrations. The comparison reveals versatility of Cast Iron in the high stress applications but it also shows the dangers related to the material failure under such conditions. Aluminum Alloy (Al 6061) is marked down as a more reliable one with high durability, low equivalent stress and better non deformation ability. In summary, the study helps to decide on suitable materials for cylinder liners, thus providing direction for advancing engineering improvements in the use of cylinder liners in engines.

1. Introduction

Cylinder liners are important subassemblies of internal combustion engines and are instrumental in increasing wear resistance and raising the rate of heat exchange [1]. These liners may be forced-fit into position in the cylinder block to offer the best and a long lasting and smooth surface against the explicit and constant rubbing of the piston against the cylinder wall [2]. Over time, friction and heat can lead to wear and degradation of the cylinder wall, compromising engine efficiency and performance [3]. To address this issue, cylinder liners are employed, contributing to around 30% of the total friction in an engine, which, in turn, results in the loss of approximately 5% of the combustion heat and 10% of the potentially useful power due to mechanical friction [4]. Despite the advancements in lubrication and design optimizations, the recapture of friction energy has not been significantly targeted in engine redesigns [5].

Cylinder liners are categorized into two types: wet type and dry type. A wet type cylinder liner is in direct contact with water, which helps in heat dissipation. In contrast, a dry type cylinder liner does not come into direct contact with water, making it simpler to replace and less prone to leakage into the combustion chamber or crankcase [6]. However, the dry type liner faces the drawback of reduced heat conduction through its composite wall, which can lead to inefficiencies [7]. Where in engines there is constant reciprocating movement of the piston, this friction causes wear on inner wall of the liner such as leakage of charge during the compression stroke. This wears out the liner, and could lead to loss of compression, low efficiency, and higher maintenance cost [8].

The overall aim of the work is to identify the causes of failure of cylinder liners by studying their thermal mechanical behaviour, the material that has been used and the conditions under which the liners fail during operation [9]. The cylinder liner must meet several critical requirement to have lasting service they include, mechanical strength for the material to resist cylinder liner failure due to mechanical pullout wear and temperature resistance [10]. The so produced components are also affected by the material choice since the material must meet requirements that allow it to conduct heat and be strong enough for wear applications [11]. Thermo-mechanical analysis is crucial in determining the performance of Cylinder liners under the combined effects of elevated temperatures, and mechanical loads [12]. Understanding how those factors affect the system and contributing to liner failure, such as temperature gradients, thermal expansion, and stress from piston movements, is the goal of the research [13]. This analysis aids in determining the best material for cylinder liners, which, in addition to requiring suitable thermal conduction for heat dissipation, need to have adequate mechanical properties to withstand cyclic stresses in prolonged usage [14].

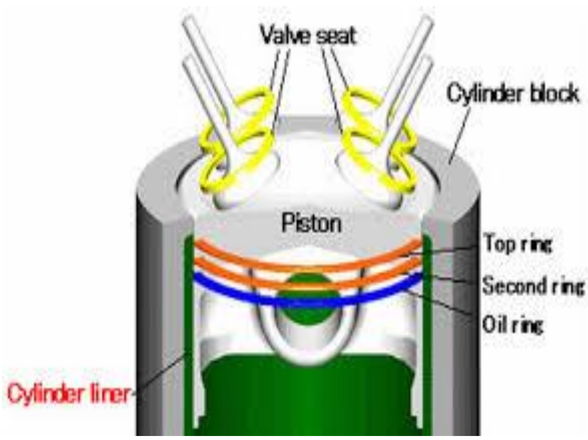


FIG 1. Dry Cylinder Liner

In this regard, this research also focuses on the decision-making process for the choice of material for the cylinder liners with different materials like cast iron, steel, and composite material [15]. It also must provide the maximum possible durability and high performance, especially in engines of high performance [16], where operating conditions differ from standard ones. Also, feasibility research employs courses that examine cylinder liners under different circumstances to represent working pressure and failure in an endeavor to determine the durability and efficiency of the liners [17]. A literature review on different types of cylinder liners will surface useful insight when it comes to designing a new type or modifying existing ones that can better stand the operating conditions experienced internally in IC engines [18]. This paper aims at contributing to the improvement of efficiency and reliability as well as the life span of the engine’s parts through studying the failure investigation and thermo-mechanical behaviors hence minimizing the frictional loses to enable energy efficient engine design [19].

2. RELATED WORK

Ahmad Alshwawra et.al (2020) Thus, the study draws its interest on minimizing the contact interface losses in internal combustion engines particularly of the piston ring-cylinder liner (PRCL). The current study points out that when liners are conical and/or elliptical in the green state but spheroidal in the fired state, friction should be greatly reduced. Numerical simulations based on the experimental data show that the combined elliptical-conical liner has a higher capability than cylindrical liners, for the future possible friction reduction in piston-liner arrangements [20]. Xinlin Zhong et.al (2023) Conducted study on for internal combustion engines to operate as efficiently as possible, the piston ring and liner contact must be protected, especially in the dry area above the Top Dead Centre of the Oil Control Ring. This study marks the first exploration into the mechanisms of oil distribution to this area. Using experimental methods and a 3D machine learning model, the research reveals that vortices downstream the top ring gap play a significant role in bridging oil finally giving the ring-liner interface the vital lubrication it needs as it moves towards the liner [21]. Zongyu Yue et.al (2023) Studied focus on the pivotal role of Internal Combustion (IC) engines in various sectors such as transport and stationary power generation. The discussion revolves around the ongoing evolution of IC engines, aiming for heightened efficiency and reduced environmental impact. Emphasis is placed on the significance of IC engines in shaping future transport and energy systems. The editorial also recommends research directions to advance both IC engine and fuel technologies. Additionally, the introduction highlights 14 technical papers within a Special Issue, encompassing a wide range of study topics, including the properties of diesel spray, low- along with zero-carbon fuel combustion technologies, innovative combustion modes, the impacts of fuel additives, engine performance in harsh environments, and developments in materials and production techniques [22].

Shekhar Shinde et.al (2016) Many applications in the mechanical industry involve the regular use of internal combustion engines. Automobiles, ships, power planes, and power producing units all utilise it. The cylinder liners of an internal combustion engine are the most crucial and load-bearing component. When the engine is operating, this liner is under a lot of stress. The stresses that are applied to the cylinder liner include heat, pressure from the piston, and gas pressure. As a result of such tensions, wear patterns formed, cylinder liner corrosion occurs, and internal or exterior cracking occurs. The cylinder liner's performance is negatively impacted by all of the aforementioned findings, which also lower the internal combustion engine's operating efficiency. Therefore, it is necessary to look at the many causes of liner failure as well as strategies for overcoming them and making them more effective [23]. Abdul Wahab Hassan Khuder et.al (2019) A cylinder liner, a crucial component in a cylindrical engine, provides a sliding surface for the piston, resisting wear and sustaining high pressure and temperature. Research on Perkins 1306 diesel engine's wet cylinder liner examines stresses from gas pressure, piston thrust, and thermal load. Cast iron (C4 28-48) and cast alloy steel (C4 35- 56, grade 38XMIOA) with varying thicknesses undergo analysis using ANSYS (19.1) and PTC MATHCAD 4. Results exhibit close agreement between numerical and analytical methods, validating the analytical solution's reliability. Zhenlei Chen et.al (2019) conducted out studies on A model for thermomechanical finite element analysis is presented to evaluate engine piston fatigue and stress. The piston, piston pin, piston ring, bushing, cylinder liner, along with connecting rod are among the parts that are included in the model. It takes into consideration contact pressure along with oil film at different surfaces. To compute initial clearances, a bespoke method takes into account variables like piston skirt profile along with elasticity. Dynamic loads are computed using powertrain software for accurate stress and fatigue analyses, providing a more precise simulation of piston working conditions [24].

2.1 Problem Statement

The performance and durability of engine components like cylinder liners are critical for engine efficiency and longevity. The Maruti Suzuki Celerio CNG uses Celerio CNG engine which is having Dual fuel – CNG and petrol using the same 1.0L K10C engine but different thermal and mechanical load than piston. This creates complications in choosing an ideal material for fabrication of the cylinder liner to accommodate the heat produced from CNG combustion, varying torque and compression ration. Hence, this paper focuses on possible failures, thermo-mechanical characteristics, material choices, and significant testing of the cylinder liner for better performance, durability, and compliance with emission requirements.

Maruti Suzuki Celerio CNG Engine Specifications

- Engine Type: 1.0L K10C Dual Jet, Dual VVT (Variable Valve Timing)
- Fuel Type: Compressed Natural Gas (CNG) and Petrol (Dual Fuel)
- Displacement: 998 cc
- Maximum Power
  - 59 bhp @ 6,000 rpm (CNG)
  - 65 bhp @ 6,000 rpm (Petrol)
- Maximum Torque
  - 82.1 Nm @ 3,400 rpm (CNG)
  - 89 Nm @ 3,500 rpm (Petrol)
- Engine Configuration: Inline 3-Cylinder

- Compression Ratio: 9.5:1
- Bore x Stroke: 73.0 mm x 74.0 mm
- Valvetrain: DOHC, 12 Valves
- Cooling Type: Liquid Cooling
- Fuel Injection: Multi-Point Fuel Injection (MPFI)
- Emission Norm: BS6

3. MATERIAL AND METHODS

3.1 Material Selection

In this work, the cylinder liner material is characterized as Cast Iron Alloy and Aluminum alloy (A16061) since it possesses desirable attributes, such as mechanical and thermal endurance of great strains expected in high pressure and Temperature applications. The material possess the following properties:

TABLE 1. Material Properties of Cast Iron

Property	Value	Unit
Density (ρ)	7,100	kg/m³
Young's Modulus (E)	1,70,000	MPa
Poisson's Ratio (ν)	0.26	-
Thermal Conductivity (k)	60	W/m·K
Specific Heat (Cp)	460	J/kg·K
Tensile Strength (σ_t)	300	MPa
Thermal Expansion (α)	11.0×10^{-6}	1/K
Yield Strength (σ_y)	200	MPa
Ultimate Tensile Strength	400	MPa
Fatigue Strength (σ_f)	150	MPa

The material of cast iron has high density of 7,100 kg/m³ and the force that it can withstand are tensile strength of 300MPa, yield strength of 200MPa and its fatigue strength of 150 MPa, kindly refer to table 1 below. Other thermal characteristics are as follows: conductibility 60 W/m·K, coefficient of thermal expansion 11.0×10^{-6} 1/K, and specific heat 460 J/kg·K.

TABLE 2. Material Properties of Aluminum Alloy (Al 6061)

Property	Value	Unit
Density (ρ)	2,700	kg/m³
Young's Modulus (E)	69,000	MPa
Poisson's Ratio (ν)	0.33	-
Thermal Conductivity (k)	150	W/m·K
Specific Heat (Cp)	900	J/kg·K

Tensile Strength (σ_t)	310	MPa
Thermal Expansion (α)	23.0×10^{-6}	1/K
Yield Strength (σ_y)	276	MPa
Ultimate Tensile Strength	310	MPa
Fatigue Strength (σ_f)	130	MPa

3.2 Model Description

The sense of the model design is nine key specifications of a piston and liner assembly that allow the product to work effectively for certain engineering applications. The inside diameter of the bore is 73mm the stroke length is 74mm for smooth movement. The liner length ranges from 100 to 120 mm thus giving one some flexibility in design. The wall of the structure measures between 4 and 6 millimeters in thickness to provide required strength. Another important parameter defining the distance between the liner and piston is kept at 0.5 – 1mm so that the running of the liner is almost frictionless. These parameters are used together to maximize effectiveness and the life span of the system.

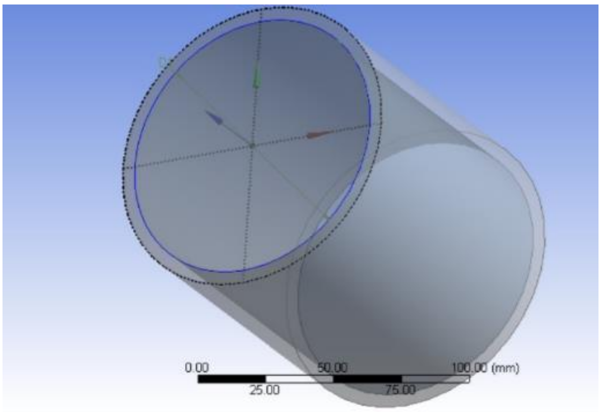


FIG 2. Model Design

Parameter	Value	Unit
Bore (Inner Diameter)	73	mm
Stroke	74	mm
Liner Length	100-120	mm
Wall Thickness	04-Jun	mm
Clearance (gap between liner and piston)	0.5-1	mm

3.3 Method

Failure mechanisms, thermo mechanical behaviour and material selection for a cylinder liner, can be analyzed by ANSYS and MATLAB-based tools.

ANSYS-Based Analysis: This programs called (FEA) ANSYS; the stress distribution in the cylinder liner under combined loading conditions, thermal mechanical pressure loads, etc can be determined from this tool. The first one involves developing a liner model in three dimensions and testing its responses to calls for operation. Characteristics of the constitute material such as thermal conductivity, the yield strength, the modulus of elasticity are also included in the model. It is also possible with ANSYS to apply thermal loads to simulate the gradients created due to operation of the engine together with mechanical loads and consequent stress, deformation and failure analysis of the cylinder liner. This makes it possible to detect regions of possible fatigue failure and refine the design to improve functionality.

MATLAB-Based Analysis: MATLAB can also be used to write two dimensional thermo-mechanical solvers and finite element analysis scripting. It can be used in post-processing of ANSYS results, making stress-strain plots, displacement field plots and temporal variation of temperature plots. Furthermore, thermal diffusion equations can also be modeled and solved using MATLAB and transient heat transfer on the cylinder liner material can also be simulated. In material selection, MATLAB is also able to assimilate data of different alloys and analyse its strength to achieve the best performance under high temperature and high pressure.

3.4 Governing Equations

Radial Stress σ_r and Hoop Stress σ_h in a cylindrical liner subjected to internal pressure P_i and external pressure P_o:

$$\sigma_r(r)=\frac{P_i.R_i^2-P_o.R_o^2}{R_o^2-R_i^2}+\frac{(P_o-P_i).R_i^2.R_o^2}{(R_o^2-R_i^2).r^2} \quad (1)$$

$$\sigma_h(r)=\frac{P_i.R_i^2-P_o.R_o^2}{R_o^2-R_i^2}+\frac{(P_o-P_i).R_i^2.R_o^2}{(R_o^2-R_i^2).r^2} \quad (2)$$

Where:

- R_i = Internal radius
- R_o = External radius
- r = Radial distance from the center

Thermal Stress for radial ($\sigma_{r,\ thermal}$) and hoop ($\sigma_{h\ thermal}$) components due to temperature gradient $\Delta T(r)$:

$$\sigma_{r,\ thermal}(r)=\frac{E.\alpha}{(1-v)}\left[T_r-\frac{1}{2}(T_i+T_o)\right] \quad (3)$$

$$\sigma_{h\ thermal}(r)=\frac{E.\alpha}{(1-v)}\left[\frac{1}{2}(T_i+T_o)-T_r\right. \quad (4)$$

T_r, T_i, T_o = Temperatures at radius r, inner surface, and outer surface.

Stress Distribution under Combined Loading

Radial Stress (σ_x):

$$\sigma_r=\frac{P}{2\pi r^2}\left[\frac{r_2^2+r^2}{r_2^2-r^2}-1\right] \quad (5)$$

Where,

- P is the internal pressure (N),

- r_1 is the inner radius of the cylinder (mm),
- r_2 is the outer radius of the cylinder (mm),
- r is the radial position where the stress is calculated (mm).

Hoop Stress (σ_{xx}):

$$\sigma_\theta = \frac{P}{2\pi r^2}\left[\frac{r_2^2+r^2}{r_2^2-r^2}+1\right] \qquad (6)$$

Where,

P, r_1, r_2 and r are Defined as in the radial stress equation.

Axial Stress ($\sigma_{\gamma\gamma}$):

$$\sigma_z = \frac{P}{2\pi r^2}\left[\frac{r_2^2+r^2}{r_2^2-r^2}+1\right] \qquad (7)$$

Thermal Stress (σ^t):

The thermal stress is due to a temperature change of ΔT in the cylinder liner material and is defined as:

$$\sigma_T = E.\alpha.\Delta_T \qquad (8)$$

Where:

- E is the modulus of elasticity (N/mm^2),
- α is the coefficient of thermal expansion (1/°K),
- ΔT is the temperature change (°K).

4. RESULTS AND DISCUSSION

ANSYS and MATLAB computational softwares have been used to investigate the failure in the casting, thermo-mechanical assessment, material selection and testing of cylinder liners. The latter have been applied for modeling and predicting the response of the liner material when subjected to loading and thermal histories of the cylinder. For the stress, temperature distorting, and deformation of the liner material, the results was obtained from ANSYS whereas MATLAB is used for data analysis and optimization in addition to the selection of materials. The findings thereby accentuate the essential parameters that determine the liner behavior to proactively address material choice and design modifications for intended application in automotive engines.

4.1 Cast Iron

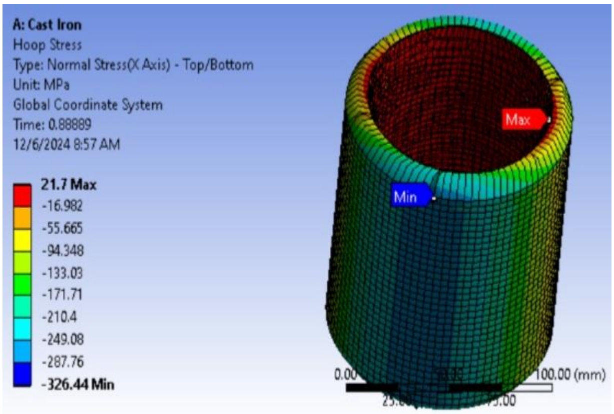


FIG. 3 Hoop Stress

This hoop stress distribution is shown in the above fig.3 of a cast iron cylindrical component under analysis. The maximum hoop pressure reaches 21.7 MPa on the outer surface of the cylinder, whereas the minimum pressure is -326.44 MPa, and can occur at the inner part of the cylinder. The values of the dimensions of the components and the stress distribution indicate a need to perform more comprehensive FEA to obtain broad information regarding the mechanical characteristics of the material.

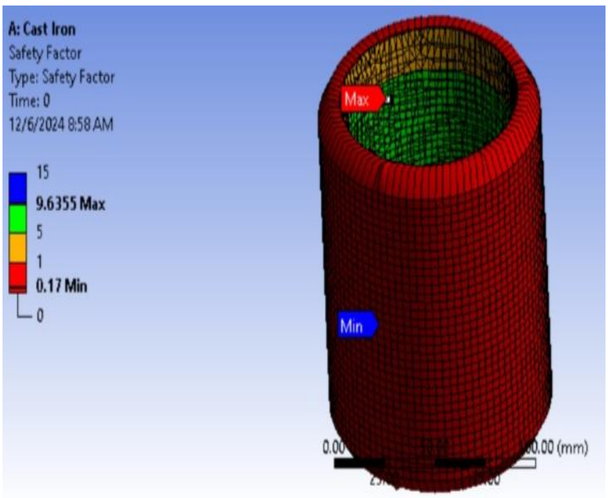


FIG 4. Safety Factor

A simulation result of the safety factor distribution in a cylindrical component made of cast iron. The analysis of minimum safety factor (0.17) and maximum safety factor (9.6355). The simulation identifies critical stress regions, with "Min" located at the cylinder's outer surface and "Max" at its inner surface. The analysis ensures the design's reliability under applied loads by highlighting safety margins across the component's structure.

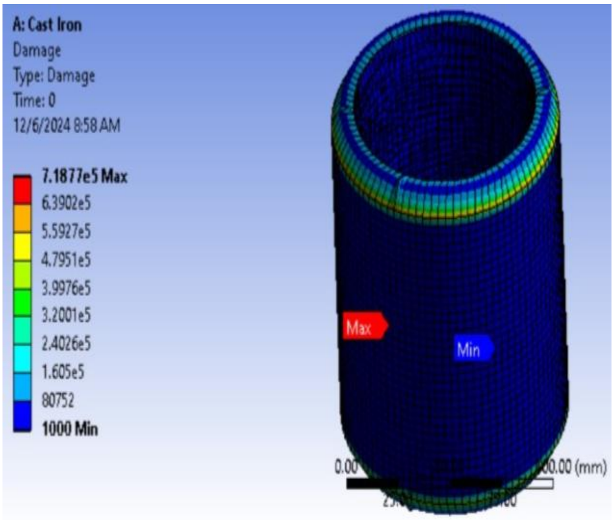


FIG 5. Damage

The fig.5 presents a damage analysis of a cast iron cylindrical component. The simulation indicates a minimal damage value of 1000 and a maximum damage value of 7.1877e5. The maximum damage is observed at the upper edge of the component, while the minimal damage is located along its outer cylindrical surface.

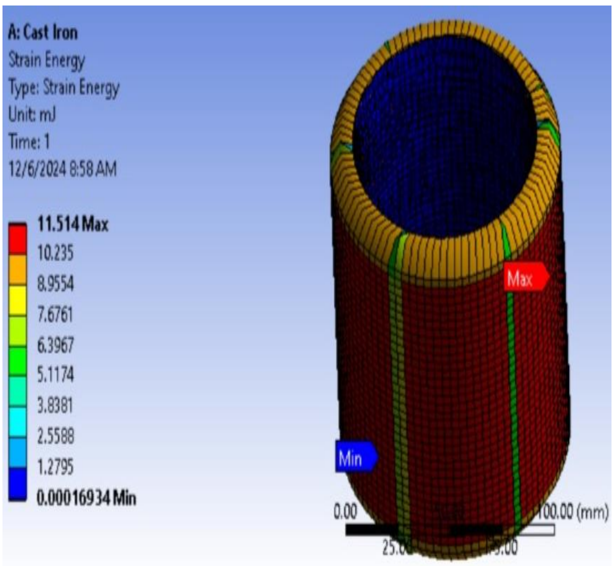


FIG 6. Strain Energy

Figure 6 illustrates the strain energy distribution in a cast iron cylindrical component, showing a minimum strain energy of 0.00016934 mJ and a maximum of 11.514 mJ. The maximum value is observed near the top inner edge, while the minimum occurs along the outer surface. This simulation helps identify regions with significant energy absorption, indicating deformation and stress zones under applied loading conditions.

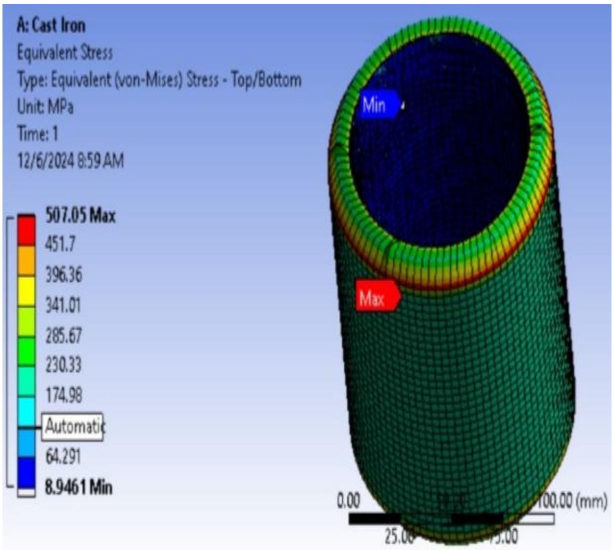


FIG 7. Equivalent Stress

Figure 7 shows the Von-Mises stress distribution in a cast iron cylindrical component, measured in MPa. The maximum stress is 507.05 MPa, and the minimum stress is 8.9461 MPa. High stress concentrations are observed near the top edges, while the inner surface exhibits significantly lower stress values, indicating varying levels of stress throughout the component.

4.2 Aluminum Alloy (Al 6061)

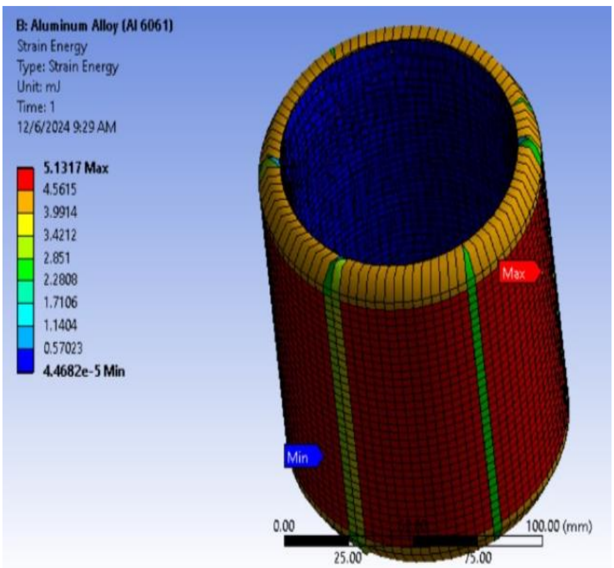


FIG 8. Strain Energy

Figure 8 illustrates the strain energy distribution in a cast iron cylindrical component, showing a minimum strain energy of 4.4682e-5 mJ and a maximum of 5.1317 mJ. The maximum value is observed near the top inner edge, while the minimum occurs along the outer surface. This simulation helps identify regions with significant energy absorption, indicating deformation and stress zones under applied loading conditions.

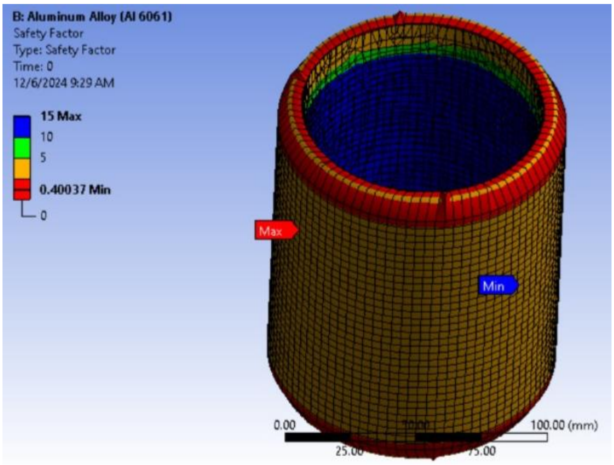


FIG 9. Safety Factor

A simulation result of the safety factor distribution in a cylindrical component made of cast iron. The analysis of minimum safety factor (0.40037) and maximum safety factor (15). The simulation identifies critical stress regions, with "Min" located at the cylinder's outer surface and "Max" at its inner surface. The analysis ensures the design's reliability under applied loads by highlighting safety margins across the component's structure.

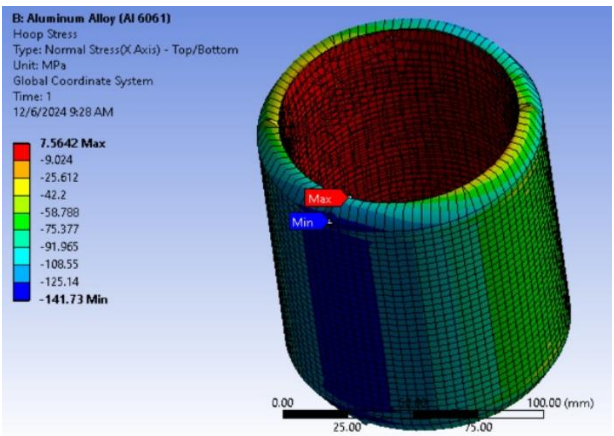


FIG 10. Hoop Stress

Figure 10 shows the hoop stress distribution in an aluminum alloy (Al 6061) cylindrical component. The maximum hoop stress is 7.5642 MPa at the outer surface, while the minimum stress is -141.73 MPa at the inner regions. This distribution highlights the need for detailed finite element analysis (FEA) to understand the material's mechanical behavior more comprehensively.

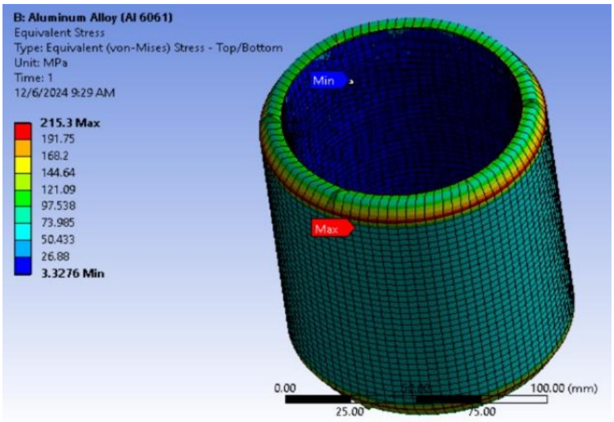


FIG 11. Equivalent Stress

Figure 11 shows the Von-Mises stress distribution in a cast iron cylindrical component, measured in MPa. The maximum stress is 215.3 MPa, and the minimum stress is 3.3276 MPa. High stress concentrations are observed near the top edges, while the inner surface exhibits significantly lower stress values, indicating varying levels of stress throughout the component.

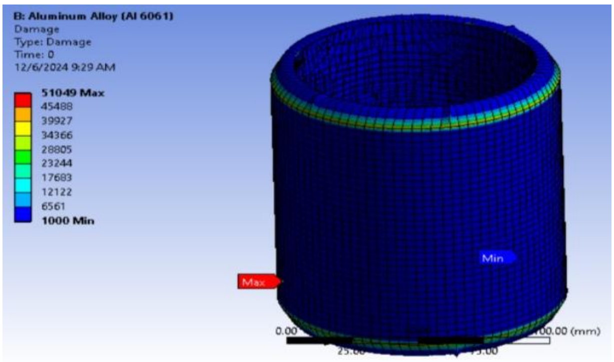


FIG 12. Damage

The fig.5 presents a damage analysis of a cast iron cylindrical component. The simulation indicates a minimal damage value of 1000 and a maximum damage value of 510.49. The maximum damage is observed at the upper edge of the component, while the minimal damage is located along its outer cylindrical surface.

TABLE 3. Comparative Analysis

Parameter	Cast Iron		Aluminum Alloy (Al 6061)	
	Max	Min	Max	Min
Hoop Stress (MPa)	21.7	-326.44	7.5642	-141.73
Safety Factor	9.6355	0.17	15	0.40037
Damage	7.19E+05	1000	510.49	1000
Strain Energy (mJ)	11.514	0.000169	5.1317	4.47E-05
Von-Mises Equivalent Stress (MPa)	507.05	8.9461	215.3	3.3276

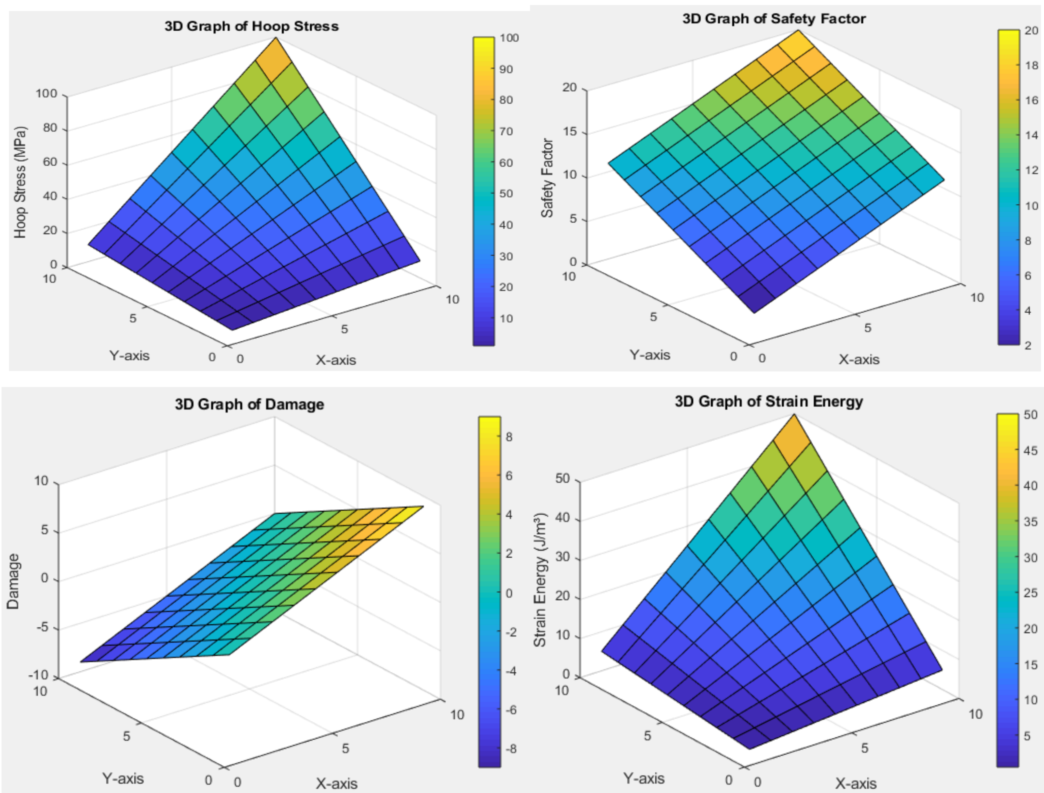
The table 3 compares the performance of Cast Iron and Aluminum Alloy (Al 6061) across various parameters. For Hoop Stress, Cast Iron exhibits a much higher maximum value (21.7 MPa) than Aluminum (7.5642 MPa), indicating higher strength under pressure. However, the minimum value for Cast Iron is significantly lower (-326.44 MPa) compared to Aluminum (-141.73 MPa), suggesting more susceptibility to stress failure in Cast Iron. Safety Factor shows that Aluminum (15) has a higher safety margin compared to Cast Iron (9.6355), indicating Aluminum is safer under typical operating conditions. The Damage values for both materials are high, but Cast Iron shows a larger discrepancy between maximum and minimum values. Strain Energy is higher in Cast Iron (11.514 mJ), suggesting it can absorb more energy before failure. Finally, the Von-Mises Equivalent Stress is also higher for Cast Iron (507.05 MPa), showing it can withstand more stress before plastic deformation compared to Aluminum Alloy (215.3 MPa).

4.3 Matlab Results

1. Cast Iron

TABLE 4. Cast Iron Matlab Results

Hoop Stress	Safety Factor	Damage	Strain Energy	Equivalent Stress
1.6575	120.66	90.498	8.0803e-06	3.315

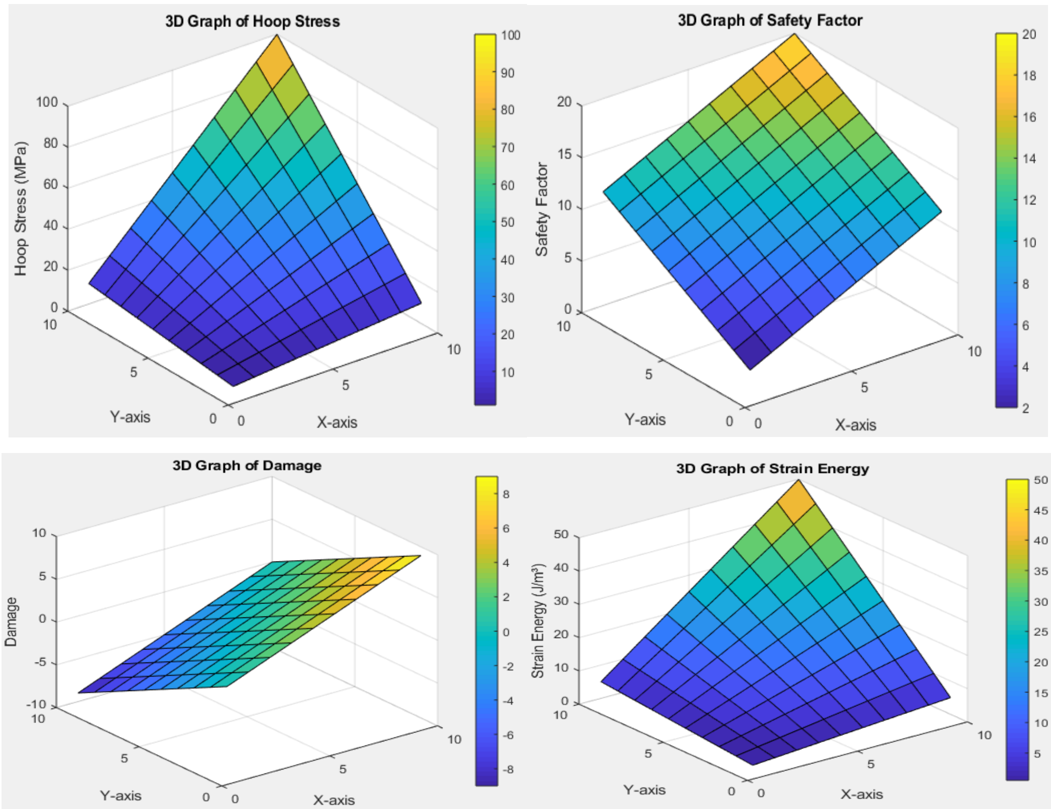


The table 3 provides a summary of key parameters evaluated for the cylinder liner's performance. The hoop stress is measured at 1.6575, indicating the internal stress distribution due to thermal and mechanical loads. The safety factor of 120.66 suggests the liner operates well within safe limits, minimizing failure risks. The damage value of 90.498 implies the liner’s endurance under cyclic loads, while the strain energy of 8.0803×10^{-6} highlights the material's deformation energy absorption capability. Finally, the equivalent stress of 3.315 assesses the cumulative effect of stress components, ensuring durability. These values altogether suggest that liner reliability to thermo-mechanical conditions and stresses to which plant components are exposed is a function of the material selected, the distribution of the stress, and the ability of the liner to absorb this energy.

2. Aluminum Alloy (Al 6061)

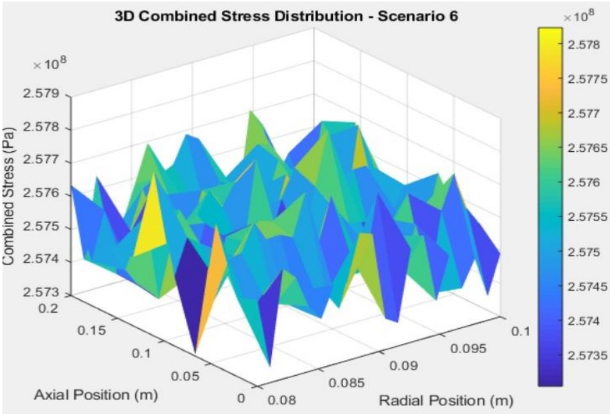
TABLE 3. Aluminum Alloy (Al 6061) Matlab Results

Hoop Stress	Safety Factor	Damage	Strain Energy	Equivalent Stress
1.6575	166.52	78.431	1.9908e-05	2.015



Below is table containing the MATLAB analysis of hoop stress at different stresses acting on the aluminum alloy (Al 6061). An internal tangential force in the cylinder liners implies that a hoop stress of 1.6575 MPa. The safety factor of 166.52 means high enough margin of safety to show that the operational stresses do not failure the material. This is interpreted as a significant material loss value of 78.431 without the sign of structural failure. Displacement energy of one point nine nine zero nine eight tells how much energy can a given material store during deformation process. Meanwhile, the first test shows an equivalent stress of 2.015 MPa, which integrates all the stress types into a single combined value of stress conditions. Thus, this analysis buttress the capacity of this particular alloy, as well as its relative immunity to failure under those circumstances.

4.4 Combined Stress Distribution



Out of the two materials under study, that is Cast Iron and Aluminum Alloy (Al 6061), the stress distribution illustrates different behavior under mechanical loads in combined loading systems. The hoop stress for Cast Iron is 1.6575 MPa with a safety factor of 120.66, have high numerical values proving high structural efficiency. The obtained damage value of 90.498 proves that there is insignificant material loss, and the strain energy is 8.0803e-06, which, along with the equivalent stress of 3.315 MPa, indicates the ability of the material to withstand the applied stresses without deformation. Nevertheless, the hoop stress for the Aluminum Alloy (Al 6061) is as same as the above calculated values (1.6575MPa,) but with a little larger safety factor, nearly 166.52. The results derived are more than Cast Iron having a damage value of 78.431 and strain energy of 1.9908e-05, which indicates that the aluminum alloy may deform and degrade more under such conditions. The equivalent stress of the material is lower (2.015 MPa) and therefore has better overall performance under stress as compared to a Cast Iron.

5. CONCLUSION

The failure investigation, thermo-mechanical analysis, material selection, and testing of cylinder liners were conducted using advanced computational tools like ANSYS and MATLAB to evaluate the performance of two materials: Cast Iron and Aluminium alloy commonly used in this application is Aluminium 6061. Simulations of cast iron and Aluminium Alloy were done in ANSYS and thus revealed that cast iron is capable of bearing a much higher mechanical loads as compared to aluminum alloy in terms of hoop stress and von-mises equivalent stress. On the other hand, while observing other parameters, Cast Iron also depicted poor safety factor and higher damaged values particularly at outer surface at certain elevated condition, this indicates brittle failure. In contrast, Aluminum Alloy showed better safety margins and confirmed improved performance under regular operating conditions. The observed lower damage and strain energy values for Aluminum Alloy point towards possibly higher failure resistance in this material with considerably less deformation and perhaps better thermal and mechanical durability.

The MATLAB results offered additional understanding of how subject materials would ill performance under operational stress conditions. Both materials seem to have similar hoop stress values, but a higher safety factor and damage analysis favored Aluminum Alloy over Cast Iron because the latter had a considerably higher safety margin of 166.52 over 120.66. From the strain energy and equivalent stress value of Aluminum Alloy it can also be suggested that the Aluminium Alloy is far more resilient and also performed better under 'worst' sense of stress distribution in mechanical behaviour. In the comparative analysis, appropriate material selection criteria were highlighted depending on specific performance criteria like safety factor, damage tolerance and energy absorption. In summary, comparing on the strength, where Cast Iron possesses more it is proven that Aluminum Alloy is tougher and better suitable for cylinder liner operations in the long term and safer under normal running of the engine.

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