Static Structural Analysis of Single Plate Friction Clutch

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Abstract— This experimental study of CAES (Compressed Air Energy Storage) System dives into the usage, advantages, disadvantages and properties of energy generation using the CAES. The Compressed Air Energy Storage (CAES) System represents a promising avenue for advancing energy generation. This abstract explores recent developments in CAES technology, highlighting improvements in efficiency, scalability, and environmental impact. The integration of advanced materials and smart control systems has enhanced the overall performance of CAES, enabling better grid integration and increased renewable energy utilization. The abstract also discusses challenges and potential future directions in optimizing CAES as a reliable and sustainable energy storage system. Environmental considerations, particularly regarding air quality and noise pollution, have driven research into advanced compression and expansion techniques, as well as the exploration of alternative storage media. Additionally, life cycle assessments and techno-economic analyses have become integral to the development process, ensuring that CAES systems are not only efficient but also sustainable. This abstract also discusses the salt caverns replaced with metal air receiving tanks which meets almost all the properties of these salt caverns and decreases the initial cost of finding these salt caverns which are out of reach. Salt caverns are found far from the power stations and may induce additional economical characteristics for transmission of electricity to the CAES system.

Indexed Terms- Compressed air Energy Storage, Salt Caverns, economical characteristics, alternative storage media, air receiving tanks.

I. INTRODUCTION

A clutch is a device used in the transmission system of a vehicle to engage and disengage the transmission system from the engine. Thus, the clutch is located between the engine and the transmission system. In a vehicle, the clutch is always in the engaged position. The clutch is disengaged when starting the engine, when shifting gears, when stopping the vehicle and when idling the engine. It is disengaged by operating the clutch pedal i.e., by pressing the pedal towards the floor of the vehicle. The clutch is engaged when the vehicle must move and is kept in the engaged position when the vehicle is moving. The clutch also permits the gradual taking up of the load, when properly operated; it prevents jerky motion of the vehicle and thus avoids putting undue strain on the remaining parts of the power transmission

1.1 Single plate friction clutch:

The parts of a single plate clutch can be seen below. It has only one clutch plate, mounted on the splines of the clutch shaft. This is the most used type. The flywheel is mounted on the crankshaft and rotates with it. The pressure plate is fixed on the flywheel through the pressure plate is fixed on the flywheel through the clutch springs. The plate rotates freely on the clutch shaft. It can also be moved axially along the clutch shaft. The axial movement of the pressure plate is affected by pressing the clutch pedal. The end of the clutch shaft rests and rotates freely in the pilot bearing housed at the center of the flywheel. The splined portion of the clutch shaft carries the clutch plate whose details are shown in the figure. The clutch plate consists of two sets of facings of friction material mounted on steel cushion springs. The waves of the cushion springs compress slightly as the clutch engages and thus provide some cushioning effect. The base disc and the spring retainer plate are slotted for inserting the torsion springs. These torsion springs contact the hub flange that fits between the spring retainer plate and the disc. The principle of this device is that the driven plate is not rigidly connected to the\ hub of the driven shaft but left free rotationally thereon and is connected through several small spring's blocks. As such, these torsion springs serve to transmit the twisting force applied to the facings, to the splined hub. The spring action serves to reduce tensional vibrations and shocks between the engine and the transmission during clutch operation. By this arrangement, certain tensional vibrations of the crankshaft that have given rise to noise in the gear box are damped out and noise is eliminated.

serve to transmit the twisting force applied to the facings, to the splined hub. The spring action serves to reduce tensional vibrations and shocks between the engine and the transmission during clutch operation. When the clutch gets engaged, the facings and the plates rotate with respect to the hub to the limit of the compression of the torsion springs or to the limit of the springs stops. When the clutch is engaged, the pressure on the facing compresses the cushion springs sufficiently to cause the unit to decrease in thickness by 1.0 to 1.5 mm. This construction helps clutch engagement to be smooth and chatter less.

The single plate clutch in the engaged from as well as in the disengaged from can be seen in Fig. Due to the clutch spring force, the clutch plate is gripped between the flywheel and the pressure plate. Due to friction between the flywheel and clutch plate and the pressure plate, the clutch plate revolves. The clutch shaft which carries the plate also revolves. Clutch shaft is connected to the transmission. Thus, the engine power is transmitted from the crankshaft to the transmission unit.

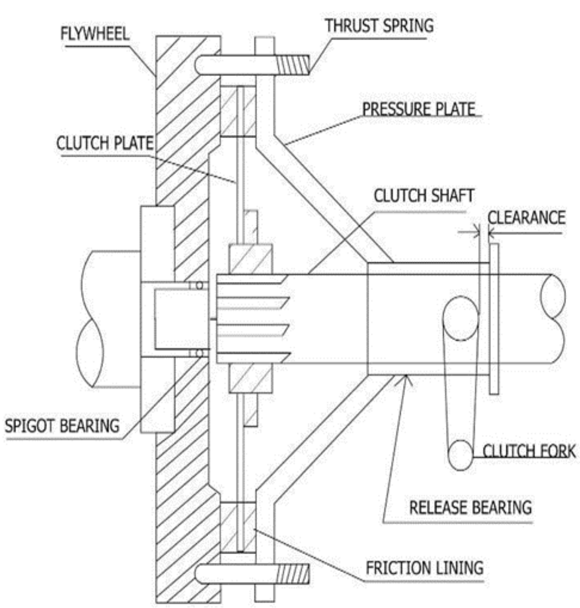


Fig.1 schematic diagram of

A friction plate, often referred to as a clutch plate or friction disc, is a crucial component in a clutch assembly used in vehicles with manual transmissions. Its primary function is to transmit power from the engine to the transmission, allowing the driver to engage or disengage the engine's power from the wheels, thereby controlling the vehicle's speed and movement. Friction plates are typically made from a high-friction material, such as organic compounds, ceramic, or a combination of materials. These materials are chosen for their ability to withstand heat and provide a strong grip on the flywheel and pressure plate. Over time, the friction material on the clutch plate can wear down due to the constant engagement and disengagement of the clutch. This wear can lead to a decrease in the clutch's effectiveness and eventually require replacement.

Desired properties of friction plate:
Material: The primary property of a friction plate is the friction material itself. This material is carefully chosen for its ability to provide a high coefficient of friction, which allows for a strong grip on the flywheel and pressure plate. Ex. Kevlar, ceramic, asbestos, composite materials.

Heat Resistance: Friction plates must be able to withstand the heat generated during engagement and disengagement. Heat resistance is crucial to prevent premature wear and ensure consistent performance. Ceramic and Kevlar materials excel in this regard.

Wear Resistance: The friction material should have good wear resistance to withstand constant friction and prevent excessive wear and tear. High-quality friction materials can last for a significant mileage before needing replacement.

Smooth Engagement: Friction plates should provide smooth and gradual engagement and disengagement to prevent jerky or abrupt shifts. This property contributes to driving comfort and vehicle control.

Sufficient Friction: Friction plates need to provide enough friction to transmit power effectively from the engine to the transmission. This property ensures that the vehicle accelerates, decelerates, and operates smoothly.

Durability: The durability of a friction plate is essential to ensure a long service life. Quality manufacturing processes and materials contribute to overall durability.

Torque Capacity: Friction plates are rated for their torque capacity, indicating the maximum amount of torque thecan handle without slipping or failing. This property is crucial for selecting the right friction plate for a specific application.

Dampening Capability: Some friction plates are designed with dampening properties to reduce noise, vibration, and harshness (NVH) levels during clutch engagement.

1.4ADVANTAGES OF COMPOSITE MATERIALS:

- Composite materials are corrosion resistance.
- Composites can be modeled into complex shapes and structures.
- It can withstand fatigue loads.
- These are electrically non-conductive.
- The maintenance is less when compared to traditional materials.

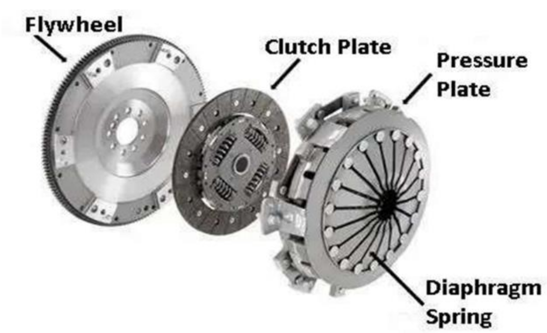


Fig. 2 Clutch plate Assembly

3.1 MATERIAL SELECTION:

Kevlar: Kevlar is incredibly strong and has a high tensile strength-to-weight ratio. It is approximately five times stronger than steel of the same weight, making it one of the strongest commercially available fibers. Despite its remarkable strength, Kevlar is relatively lightweight, which makes it an excellent choice for applications where weight is a critical factor. Kevlar has excellent heat resistance properties. It can withstand high temperatures without significant degradation, which makes it suitable for applications where exposure to heat is a concern

. Epoxy E-glass: The commonly used fibers are carbon, glass, etc. The main advantage of glass fibers is low cost. It has high strength, high chemical resistance and good insulating properties. The disadvantages are low modulus of elasticity, poor adhesion to polymer, low fatigue strength and high density which increase spring weight and size. The types of glass fibers are C-glass, Sglass and E-glass. The E-glass fiber is a high-quality glass, which is used as standard reinforcement fiber for all the present systems complying with mechanical property requirements. Thus, E-glass fiber was found appropriate for this application.

Ceramic: ceramic materials are a class of inorganic, non-metallic materials known for their remarkable combination of properties, which include hardness, high-temperature resistance, electrical insulation, and chemical inertness. Ceramics are exceptionally hard materials, often ranking among the hardest substances known. This property makes them highly resistant to wear and abrasion.

Epoxy carbon: Epoxy carbon typically refers to a composite material made by combining epoxy resin with carbon fibers. This combination results in a high-strength, lightweight material with a variety of applications. Epoxy resin is a thermosetting polymer that serves as the matrix or binder in the composite. It provides adhesion and structural integrity. Carbon fibers are the reinforcement 14 component. They are known for their exceptional strength-to-weight ratio, stiffness, and resistance to corrosion.

S.No	Material	Tensile yield strength (Mpa)	Young's modulus (Gpa)	Poisson's ratio	Density (kg/m^3)
1	Kevlar	3240	71	0.36	1470
2	Ceramic	1138	325	0.22	2130
3	Epoxy E-glass	1000	276	0.34	1900
4	Epoxy carbon	1570	260	0.29	1650

Table 1. Properties of different materials

II. MATERIALS AND METHODOLOGY

MODELING:

CLUTCH DESIGN: Specifications of friction clutch Outer diameter of the plate: 184mm. Inner diameter of the plate: 125mm. Depth of the groove: 1mm. Thickness of the plate: 4mm.

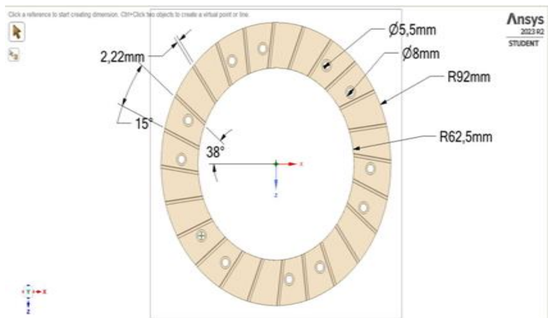


Fig. 3 Sketch of friction plate

3D Model: Design of friction plate is done by using ANSYS design modular

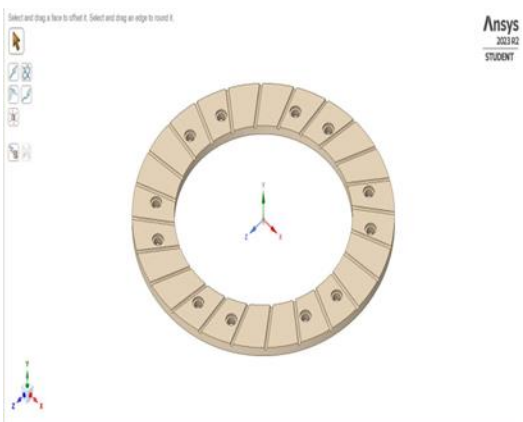


Fig. 4 Design of friction plate in Ansys design modular

DISCRETIZATION: “TETRAHEDRAL MESH” is used in this analysis. A tetrahedral mesh, often simply referred to as a "tetra mesh," is a type of mesh used in computer graphics, computer-aided design (CAD), and finite element analysis (FEA). It is a three-dimensional mesh consisting primarily of tetrahedral elements. A tetrahedron is a geometric shape with four triangular faces, four vertices, and six edges. In a tetrahedral mesh, these tetrahedra are used to discretize a three-dimensional space into smaller, finite elements. Each tetrahedron in the mesh is defined by its vertices, and the combination of these tetrahedra forms a mesh that can be used to represent the geometry of a 3D object or volume. Tetrahedral meshes are particularly useful for simulating and analyzing complex three-dimensional structures or volumes, as they can accurately represent irregular shapes and handle curved surfaces. They are commonly used in various engineering and scientific simulations, including structural analysis, fluid dynamics, and electromagnetic field simulations. The size of each element in tetra mesh is 2mm.

Details of "Mesh"

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	2, mm
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	260,25 mm
Average Surface Area	387,15 mm²
Minimum Edge Length	3,5136 mm

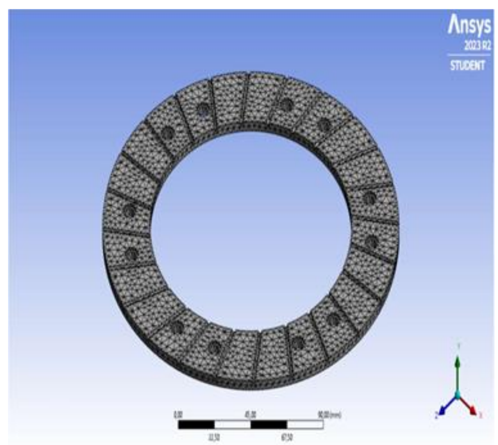


Fig. 4 Discretization of Friction plate

QUALITY OF MESH:

The mesh is a discretization of the geometry into smaller elements, and its quality refers to how well these elements capture the true geometry and physics of the problem.

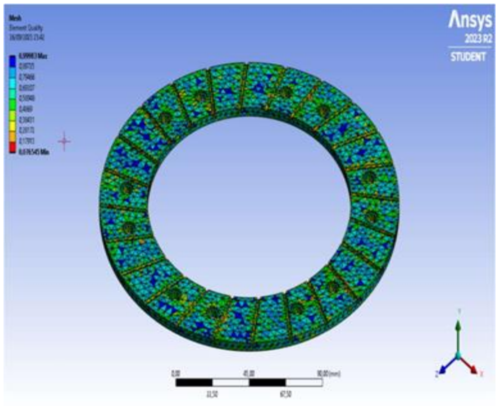


Fig.5 Mesh quality

BOUNDRY_CONDITIONS:

Fixed Support:A fixed support boundary condition for a clutch plate simulation means that you are constraining or "fixing" certain degrees of freedom at specific locations on the clutch plate to simulate a solid and immovable connection. This condition helps represent how the clutch plate interacts with its surroundings and can be an essential part of an accurate FEA analysis.

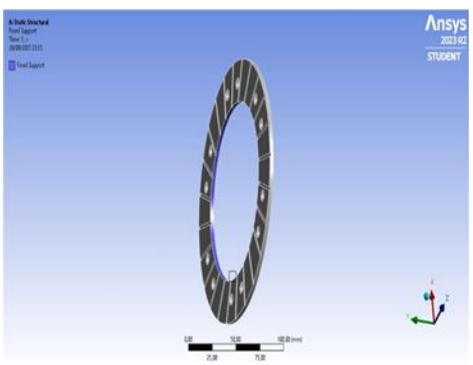


Fig. 6 Fixed support

Applied Pressure:

Pressure is applied on the opposite side of the friction lining. Here it indicates the pressure applied by the pressure plate. Pressure of 1Mpa is applied over the surface area

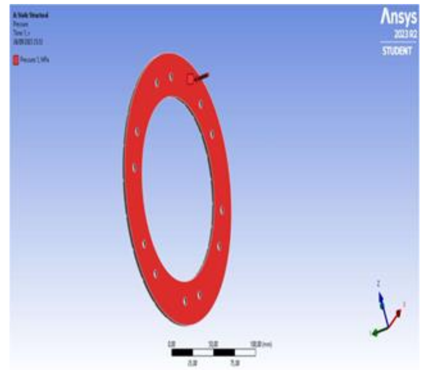


Fig. 7 Applied Pressure

TESTING AND ANALYSIS:

MATERIAL 1- KEVLAR:

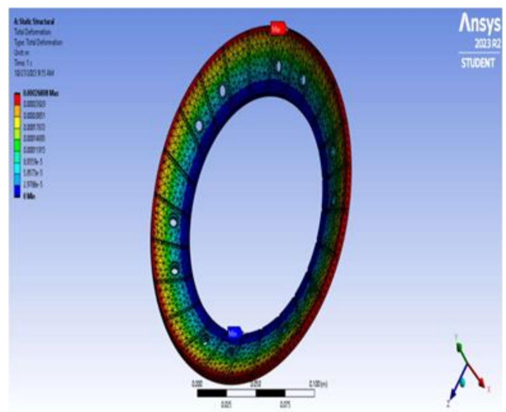


Fig. 8 Total Deformation 0.26808mm

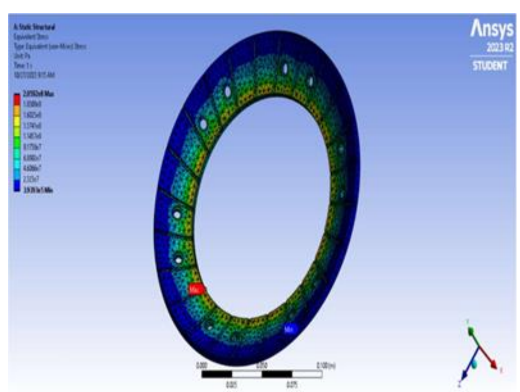


Fig. 9 Equivalent Stress 205.92Mpa

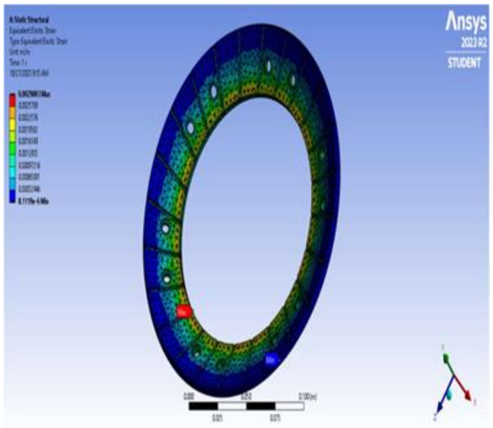


Fig. 10 Equivalent Strain 0.00029003

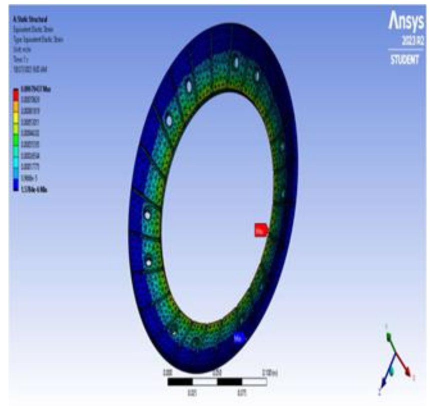


Fig. 13 Equivalent Strain 0.00079437

MATERIAL 2- CERAMIC:

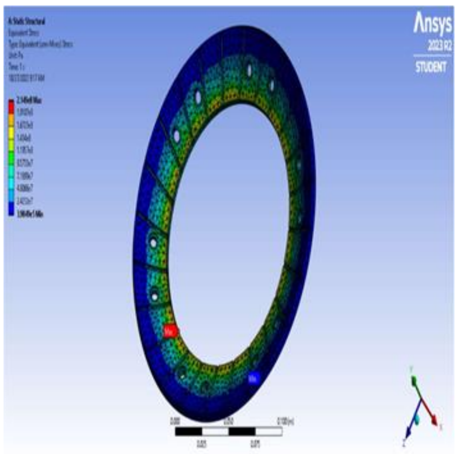


Fig. 11 Total Deformation 0.0654mm.

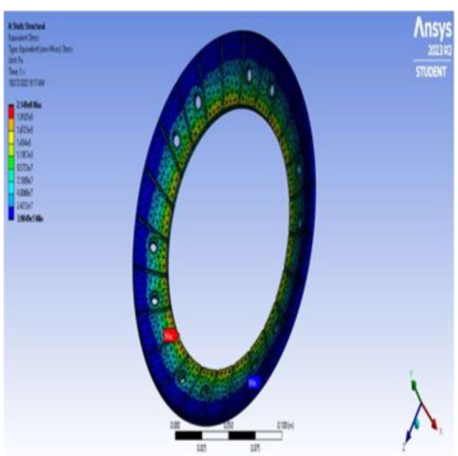


Fig. 12Equivalent Stress 258.17MPa

MATERIAL 3- EPOXY E-GLASS:

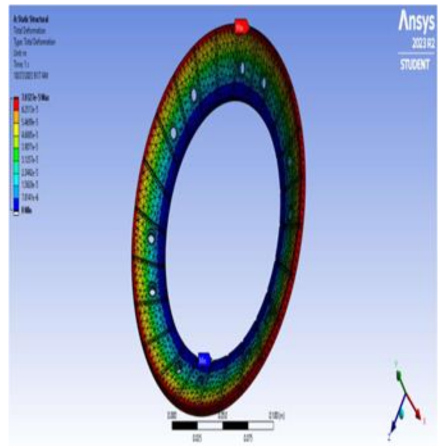


Fig. 14 Total Deformation 0.0703mm

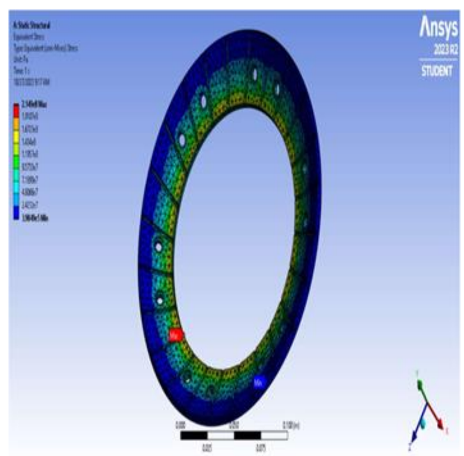


Fig. 15 Equivalent Stress 214.9MPa

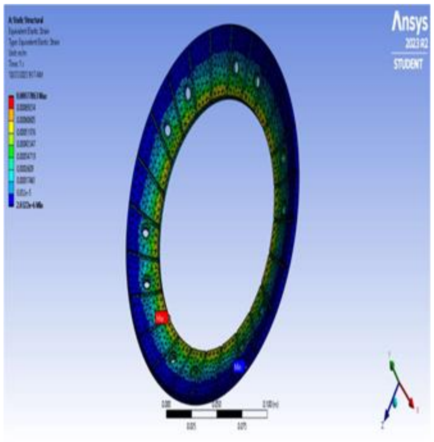


Fig. 16 Equivalent Strain 0.00077863

MATERIAL 4- EPOXY CARBON:

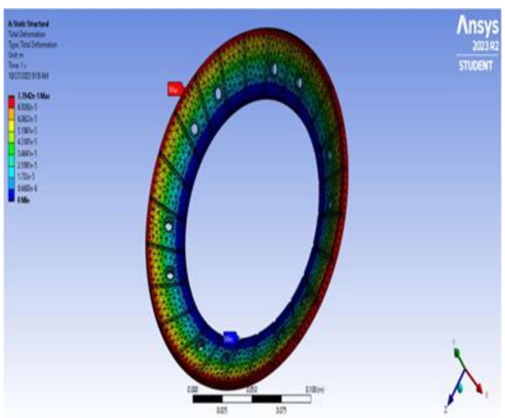


Fig. 17 Total Deformation 0.0779mm

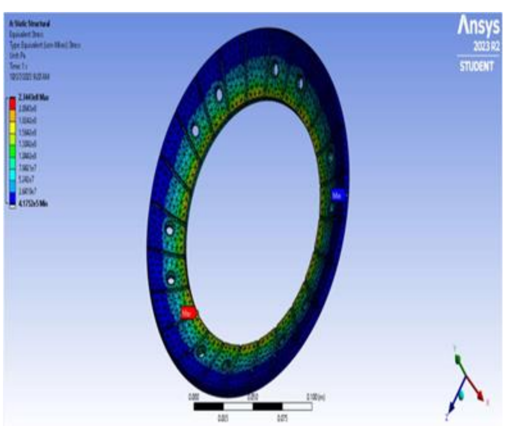
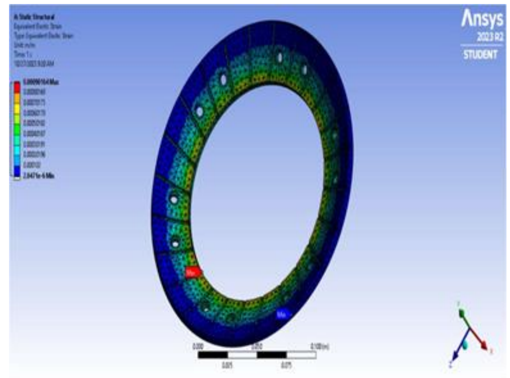


Fig. 18 Equivalent Stress 234.43MPa



III. RESULTS AND DISCUSSION

3.1 RESULTS

The results of four materials of clutch are shown in

S.NO	MATERIAL	TOTAL DEFORMATION (mm)	JIVALENT STRESS (MPa)	JIVALENT STRAIN
1	Kevlar	0.2680	205.92	0.0002900
2	Ceramic	0.0654	258.17	0.00079437
3	E-glass Epoxy	0.0703	214.9	0.00077863
4	Epoxy Carbon	0.0779	234.43	0.00090164

The clutch plate is analyzed in ANSYS WORKBENCH for four materials. The obtained results are compared. Better results are obtained for CERAMIC when compared to Kevlar, E-glass Epoxy, Epoxy Carbon

CONCLUSION

In this work, clutch plate of an automotive clutch assembly has been designed using differentmaterials and simulated using ANSYS software for comparison. Among those different lining materials Ceramic friction material was selected as the best lining material as compared to the above selected 4 materials because the Total Deformation is 0.0654 which is less than other materials and the Stress Developed is within the limit. The effect of same pressure intensity of 1 MPa for different materials was observed, clutch wear can be minimized by selecting suitable material. Good contact pressure also reduces wear during slippage time.

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