Structural Analysis of Single Plate Friction Clutch

Mr.N.U. Kakde[1], Mr.Vaibhav Bankar[2], and Mr.Vishal Deshbhratar[3]
[1]*Asstt. Professor, Dr. Babasaheb Ambedkar College of Engg and Research, Nagpur*
[2]*HOD, ME, Vidarbha Institute of Technology, Nagpur*
[3] *Asstt. Professor, ITM, Nagpur*

***Abstract* - In design of the friction clutches of automobiles, knowledge on the thermo-elasticity a priori is very informative in the initial design stage. Especially, the precise prediction technique of maximum structural stress should be requested in design of mechanical clutches for their durability and compactness. In this study, an efficient and reliable analysis technique for the design of the mechanical clutches by using computer modeling and numerical method is developed.**

This project work contains stress analysis of single plate clutch of the automobile, in which the stresses and forces developed in the clutch is tried to reduce with the help of software approach. In this project detail study of clutch is done than modeling of clutch is done in pro-e software and the analysis is to be done in Ansys software. Also, in this project efficient and reliable design of mechanical clutch is find out.

***Index Terms* - Clutch, Modeling, Structural analysis**

1.INTRODUCTION

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.

When the clutch is engaged, power flows from the engine to the driving wheels through the transmission system and the vehicle moves. When the clutch is disengaged, power is not transmitted to the driving wheels and the vehicle stops, while the engine is still running.

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 has to 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.

In a car the clutch is operated by the left-most pedal using a hydraulic or cable connection from the pedal to the clutch mechanism. Even though the clutch may physically be located very close to the pedal, such remote means of actuation (or a multi-jointed linkage) are necessary to eliminate the effect of slight engine movement, engine mountings being flexible by design. On most motorcycles, the clutch is operated by the clutch lever, located on the left handlebar. No pressure on the lever means that the clutch plates are engaged (driving), while pulling the lever back towards the rider will disengage the clutch plates, allowing the rider to shift gears.

Principle of operation of a clutch:

The clutch works on the principle of friction. The driving member of a clutch is the flywheel mounted on the crankshaft. The flywheel is a simple disc with a thick rim having a flat face, into which are screwed sis studs. These studs carry a thick plate called pressure plate, which is thus fixated to the flywheel as regards rotation. The pressure plate thus becomes the driven member. The pressure plate is, however, free to slide along the studs. The pressure plate is spring loaded and is mounted freely on the transmission shaft which is also called clutch shaft. The pressure plate can be moved axially towards the flywheel. Friction surfaces called clutch plates are there between the flywheel and the pressure plate. The hub of the clutch plate has internal splines, while the transmission shaft has matching external splines. Some clutches use one clutch plate while other use multiple clutch plates. The spring arrangement and the pressure plate are meant for pressing the clutch plate tightly against the smooth rear face of the flywheel. When the clutch is engaged, the friction disc (Clutch plate) is held tightly against the flywheel (by the clutch springs) so that if rotates with the flywheel. This rotary motion is carried through the hub of the friction disc and clutch shaft to transmission.

Clutch Types:
Clutches can be classified into following main types as follows,

1. Friction clutch
2. Diaphragm clutch
3. Hydraulic clutch
4. Magnetic clutch

The Plate or Disc clutches are further divided into two types,

1. Single Plate Friction Clutch
2. Multi-Plate Friction Clutch

2.SINGLE PLATE FRICTION CLUTCH

2.1 Introduction

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 commonly 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 effected by pressing the clutch pedal. The end of the clutch shaft rests and rotates freely in the pilot bearing housed at the centre of the flywheel.
The splined portion of the clutch shaft carries the clutch plate whose details are shown in the figure.

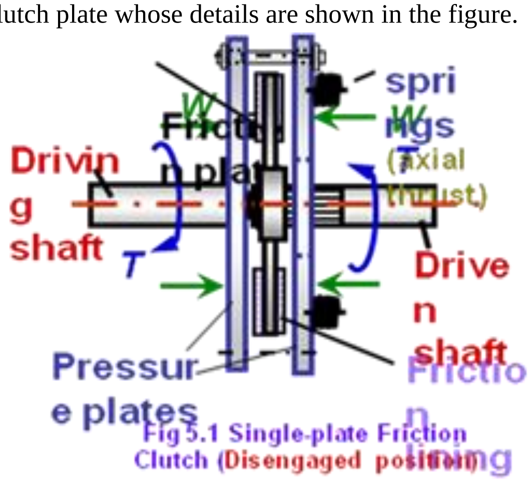


Fig 5.1 Single-plate Friction Clutch (Disengaged position)

The clutch plate consists of two sets of facings of friction material mounted on steel cushion springs. The facings and the waved cushion springs are riveted to a spring base disc and spring retainer plate. 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 a number of small springs 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.
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 chatterless.
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 caries the plate also revolves. Clutch shaft is connected to the transmission. Thus, the engine power is transmitted from the crankshaft to the transmission unit.
When the clutch pedal is pressed, the pressure plate is moved back against the clutch spring force. Thus, the clutch plate becomes free between the flywheel and the pressure plate. The flywheel remains rotating as long as the engine is running, whereas the clutch shaft speed reduces gradually and finally it stops rotating. As soon as the clutch pedal is pressed, the clutch is said to be disengaged, otherwise it remains in the engaged position due to the clutch spring force. To dissipate the heat generated by friction during the

operation of the clutch, the clutch housing and cover are provided with openings for ventilation.

2.2Use of single plate friction clutch

2.2.1 Clutch Plates in Heavy Vehicles:

In vehicles there are one or more friction discs that are joined together or pressed against a flywheel using springs. Clutch plates found in trucks and speed cars are made of ceramic. When the clutch pedal is depressed the spring pressure is released pushing or pulling the diaphragm of the pressure plate. Thus, the friction plate is released and allowed to rotate freely. The clutch plate is used to increase or decrease the speed of a vehicle. However, increasing the engine speed too high engages the clutch. This, in turn, causes excessive clutch plate wear. There are two types of clutches available- wet and dry. While the wet clutch is bathed in a cooling lubricating fluid, a dry clutch is not. A wet clutch gives good quality performance and lasts long due to the clean surfaces. But, they lose some energy to the liquid and can be slippery.

2.2.2 Clutch Plates in Automobiles and Motorcycles:

Clutch plate in a car is controlled by the left-most pedal. This makes use of hydraulics or a cable connection. The clutch may be physically located in close proximity to the pedal, but remote means of actuation are required to remove the effect of slight engine movement. If there is no pressure on the pedal, it means that the clutch plates are engaged. It gets disengaged once the clutch pedal is depressed. Cars can also function with manual transmission. In this there are cogs that have matching teeth to synchronize the speed. One can select gears with the help of these cogs. In motorcycles, the clutch is operated by the clutch lever. One can engage the clutch plate by applying no pressure on the lever. Pulling the lever back towards the rider disengages the clutch plates. Slipper clutch plates are often used by racing motorcycles to get rid of engine braking.

Theory:

There are two operating conditions applicable to clutch plates

- Uniform wear: It is applicable for practical clutch assemblies after period of operation
- Uniform pressure: It is applicable for new clutch plates.

3.STRUCTURAL ANALYSIS

3.1 Introduction

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behavior of structures. The subjects of structural analysis are engineering artifacts whose integrity is judged largely based upon their ability to withstand loads; they commonly include buildings, bridges, aircraft, and ships. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses. In practice, structural analysis can be viewed more abstractly as a method to drive the engineering design process or prove the soundness of a design without a dependence on directly testing it.

It consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation.

It includes the following methods,

1. Analytical Methods
2. Strength of materials methods (classical methods)
3. Elasticity methods
4. Finite element methods (FEM)

3.2 Finite Element Analysis (FEA)

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.

The ANSYS CAE (Computer-Aided Engineering) software program was used in conjunction with 3D CAD (Computer-Aided Design) solid geometry to simulate the behavior of mechanical bodies under thermal/structural loading conditions.

For effective and efficient FEM analysis the Ansys software should have:

- Pre processor
- Solver
- Post processor

Pre Processors

All the tasks that take place before the numerical solution process are called preprocessing. The operation tube carried out in this stage is,

- Defining the geometry in computational form
- Definition of a mesh of nodes and elements to represent the geometry
- Definition of boundary conditions
- Application of boundary conditions
- Application of initial condition whenever necessary
- Definition of material and physical properties for groups of elements
- Application of controlled parameters for solver

Solver

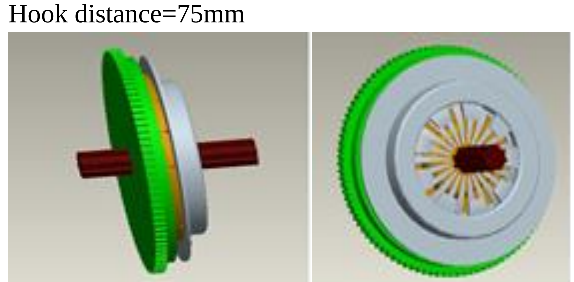
Solver defines the behavior of a structure under a given set of boundry conditions and solves the equations as well. The solver reads the data that has been definite by the pre-processor and then carries the necessary numerical operations.

Post Processor

Post processor is devoted to the display of the results, with typical picture containing, a section of computational mesh together with vector plots of stresses, contour plots of scalar variables such as intensity, or plots of the displaced shape of a structure when subject to load.

4.MODELING OF CLUTCH

4.1 Specification:
Model- TATA 475 IDITC
Maximum power - 51.5 Kw @4800rpm
Maximum torque- 124 Nm @ 2800rpm
Capacity-1405cc
Clutch kit:
1) Pressure plate:
Internal dia = 200mm
Pressure plate Outer diameter = 230mm
Rim diameter= 30mm
2) Clutch plate
Material: Structural steel
External diameter= 230mm
Width=9mm
3) Flywheel
External diameter= 260mm
No. of teeth=122
4) Spring;
Length=40mm
Outer diameter = 16mm
Inner diameter= 15mm
5) Release bearing;
Outer diameter=44mm
Inner diameter-30mm
Hook distance=75mm



5.RESULT BY SOFTWARE (ANSYS)

Table Properties of Structural steel

Table *"Structural Steel"* constant properties	
Name	Value
Compressive Ultimate Strength	0.0 Pa
Compressive Yield Strength	2.5×10^{8} Pa
Density	7,850.0 kg/m³
Ductility	0.2
Poisson's Ratio	0.3
Tensile Yield Strength	2.5×10^{8} Pa
Tensile Ultimate Strength	4.6×10^{8} Pa
Young's Modulus	2.0×10^{11} Pa
Thermal Expansion	1.2×10^{-5} 1/°C
Specific Heat	434.0 J/kg·°C
Relative Permeability	10,000.0
Resistivity	1.7×10^{-7} Ohm·m

Model of Clutch

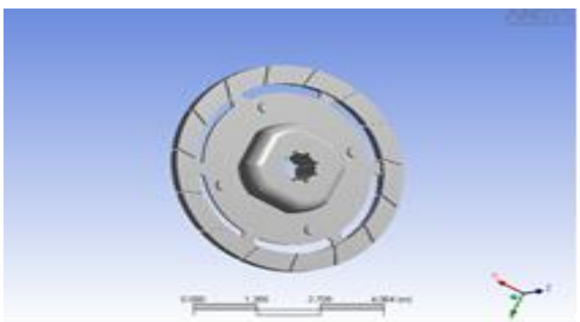


Fig Model of Clutch

5.2 Discretization

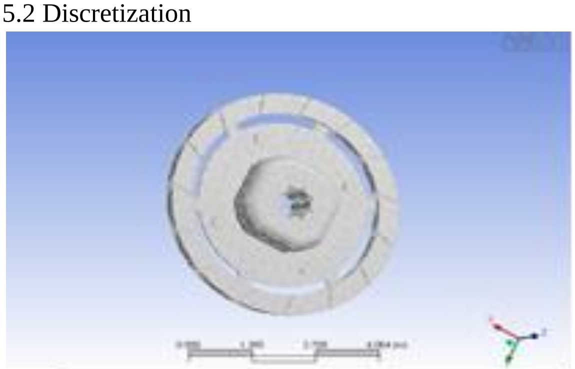


Fig Discretization

Mesh" contains 12196 nodes and 6591 elements.

5.3 Fixed Support

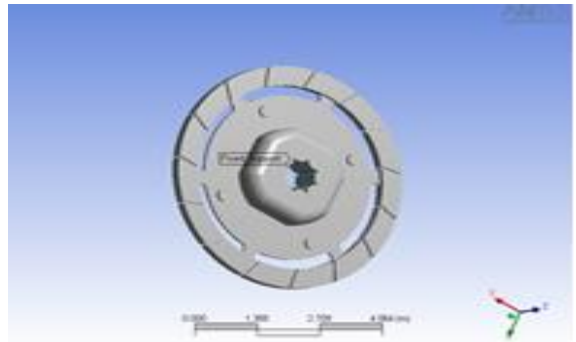


Fig Fixed Support

5.4 Moment

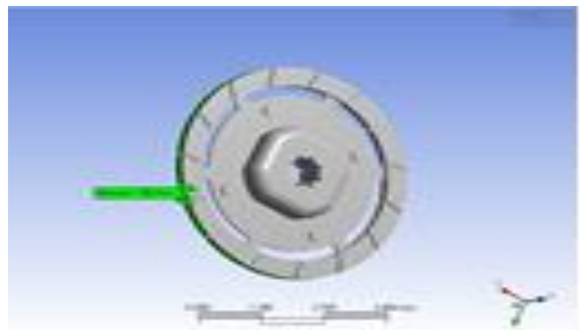


Fig Moment on Plate

Table 8.2 Structural Loading

Name	Type	Magnitude	Vector	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector
"Moment"	Surface Moment	100.0 N·m	[0.0 N·m x, 0.0 N·m y,100.0 N·m z]	N/A	N/A	N/A	N/A

Table 8.3 Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector
"Fixed Support"	Fixed Surface	5.78×10^{-7} N	[2.1×10^{-7} N x, -5.23×10^{-7} N y, 1.25×10^{-7} N z]	100.0 N·m	[-8.01×10^{-6} N·m x, 5.32×10^{-5} N·m y, -100.0 N·m z]

5.5 Equivalent stress

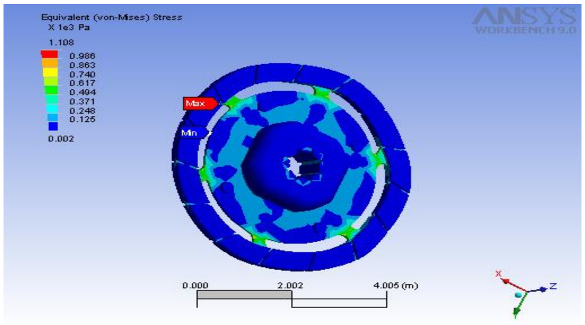


Fig Equivalent Stress

5.6 Total Deformation

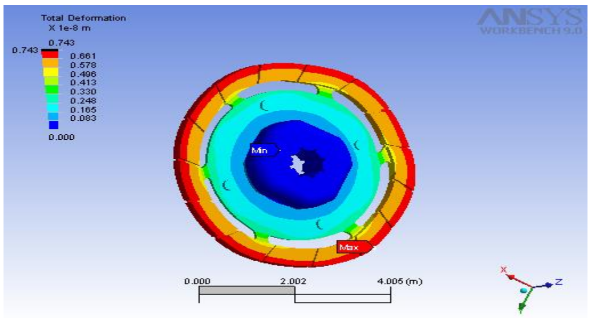


Fig Total Deformation

5.7 Maximum Shear stress

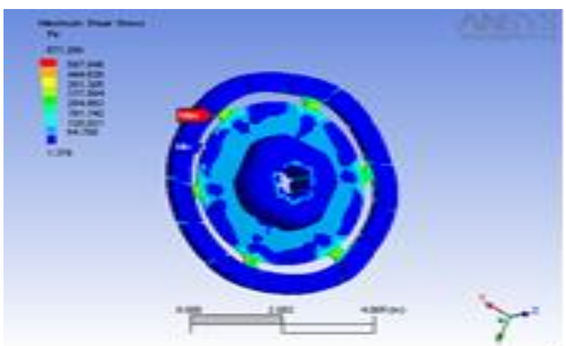


Fig Maximum ShearStress

5.8 Maximum Principal Stress

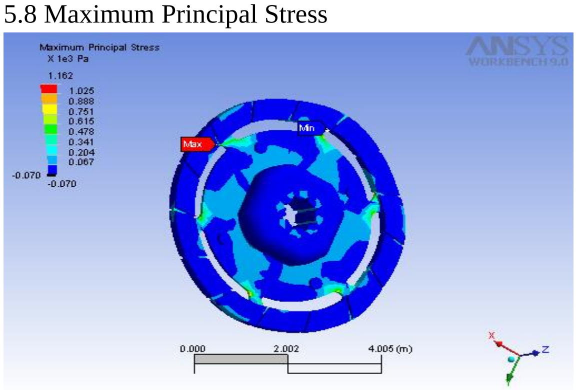


Fig Maximum Principle Stress

5.9 Directional Deformation

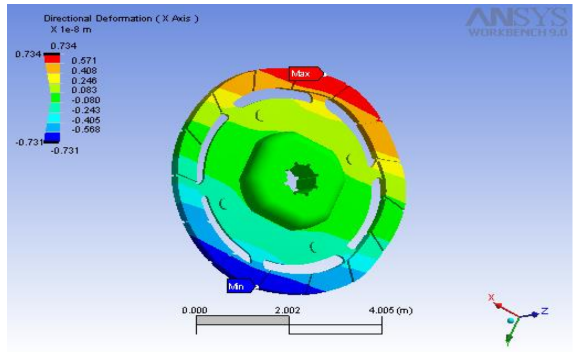


Fig Directional Deformation

Similar analysis has been done for Aluminum Alloy

Table No.8.4Properties of Aluminum Alloy

Table *"Aluminum Alloy"* Constant Properties	
Name	Value
Compressive Ultimate Strength	0.0 Pa
Compressive Yield Strength	2.8×10^{8} Pa
Density	2,770.0 kg/m³
Poisson's Ratio	0.33
Tensile Yield Strength	2.8×10^{8} Pa
Tensile Ultimate Strength	3.1×10^{8} Pa
Young's Modulus	7.1×10^{10} Pa
Thermal Expansion	2.3×10^{-5} 1/°C
Specific Heat	875.0 J/kg·°C
Relative Permeability	1.0
Resistivity	5.7×10^{-8} Ohm·m

5.10 Equivalent stress

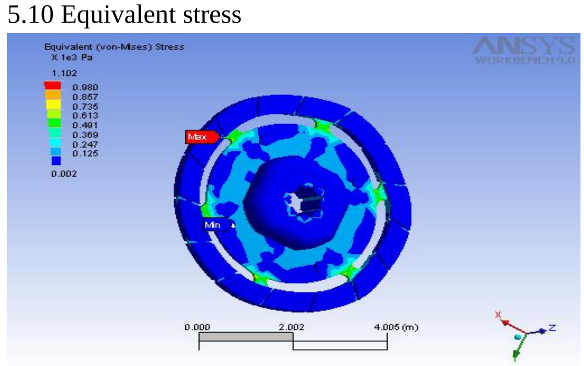


Fig Equivalent Stress

5.11 Total Deformation

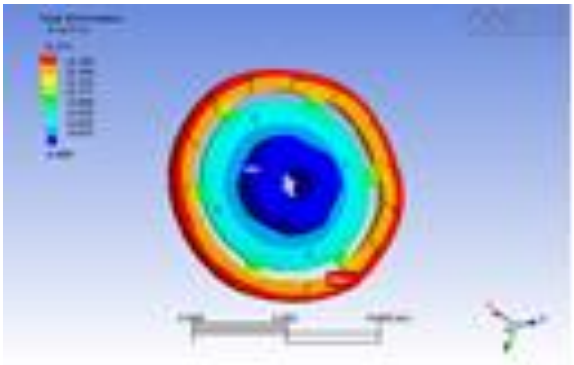


Fig Total Deformation

5.12 Maximum Shear stress

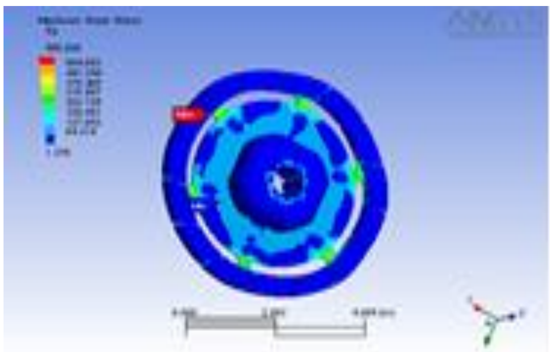


Fig Maximum Shear Stress

5.13 Maximum Principal Stress

Fig Maximum Principle Stress

5.14 Directional Deformation

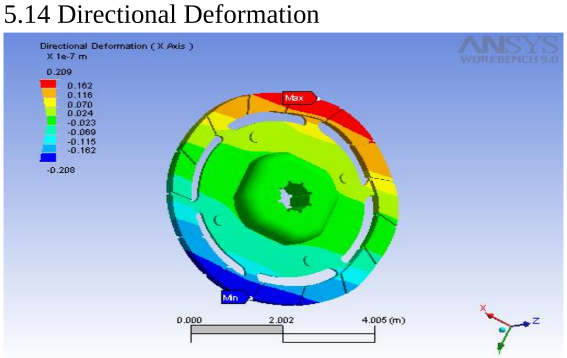


Fig Directional Deformation

FEM APPROACH
FEM model using Finite

6.CONCLUSION

After completion of the analysis in CAE software i.e. ANSYS 9.0 based on the values of Equivalent stresses for material loading conditions it is clearly seen that these are less than the allowable stresses for that particular material under applied conditions the part not going to yield and hence the design is safe. The result occurred are quiet favorable which was expected. The stresses as well as deformation clear the idea about what parameter should have been taken into account while defining the single plate friction clutch. The result observed carefully, the equivalent stress obtained for the structural steel is 1,108.44 MPa similarly for the Aluminum Alloy it is 1,101.65MPa.Similarly the shear stresses obtained for the structural steel is 571.269 MPa and for the Aluminum Alloy it is 566.92 MPa, which shows that the Aluminum Alloy is the more suitable one.

7.SCOPE FOR FUTURE WORK

In the present analysis, structural analysis of the Single plate clutch has been done using FEM approach. In this analysis Thermal Stresses and Effect due to vibration have not been included. The same can be analyzed in the future analysis.

The analysis is limited to the clutch plate it can be extended to other parts of the Clutch assembly like Flywheel and Pressure plate with the help of FEM approach.

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