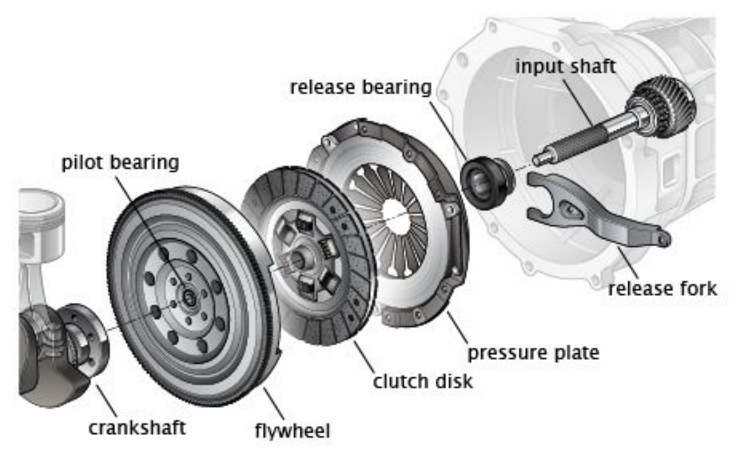
Static Structural Analysis of Single Friction Clutch Plate – Driven Plate using ANSYS APDL



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Introduction to Clutch System

Clutch is a mechanical device used in the transmission system of a vehicle especially from driving shaft to driven shaft. It engages and disengages the transmission system from the engine. Clutches are used whenever the transmission of power or motion must be controlled either in amount or over time.

Working Principle

The clutch works on the principles of friction, when two friction surfaces are bought in contact with each other and pressed they are united due to the friction between them. The friction between the two surfaces depends upon the **area of the surfaces**, the **pressure applied** upon them and **coefficient of friction** of the surface materials, The two surfaces can be separated and brought into contact when required.

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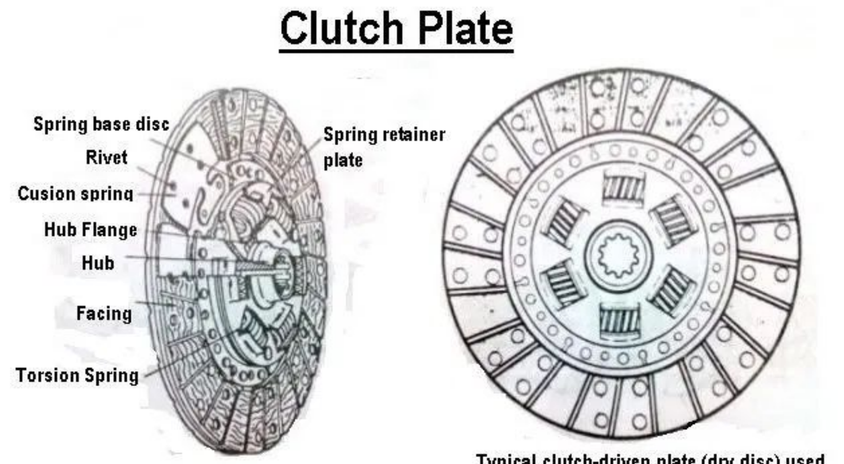
FOCUS OF THIS PROJECT:

Clutch Plate or Disc

The clutch plate is the driving member of the clutch and is gripped between the flywheel and the pressure plate. It is mounted on the clutch shaft through the splines. When it is gripped, rotates the clutch shaft and the power is transmitted from the engine to the transmission through the clutch.



Typical Clutch Plate or Disc

Typical clutch-driven plate (dry disc) used in car equipped with manual transmission or transaxle.

Main Parts of A Clutch:

The main parts of a clutch are classified into three groups
a) Driving members b) Driven members
c) Operating members

Driving member:

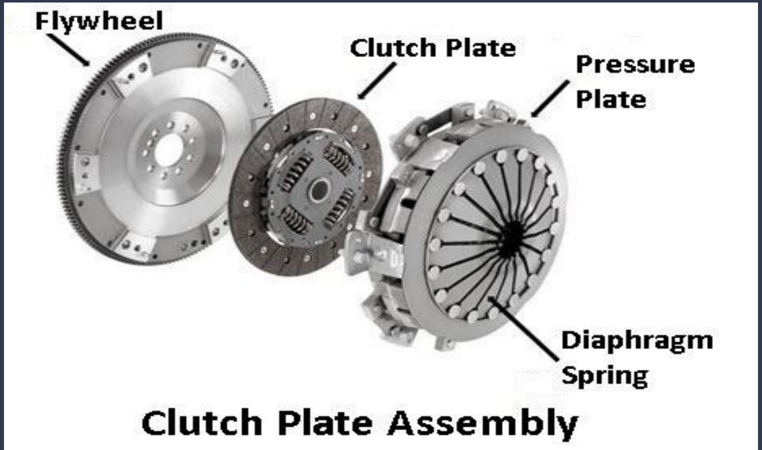
The driving member has a flywheel mounted on the crankshaft of the engine. The flywheel is fixed to a cover which supports a pressure plate or driving disc, pressure springs and releasing levers.

Driven member:

The driven member has a disc or plate, called the clutch plate. It is free to slide alongside on the splines of the clutch shaft. Driven member carries friction materials on both of its surface. When a driven member is held between the flywheel and the pressure plate, it helps to rotate the clutch shaft through the splines.

Operating member:

The operating members have a foot pedal, linkage, release or throw-out bearing, release leavers and the springs essential to ensure the proper operation of the clutch.

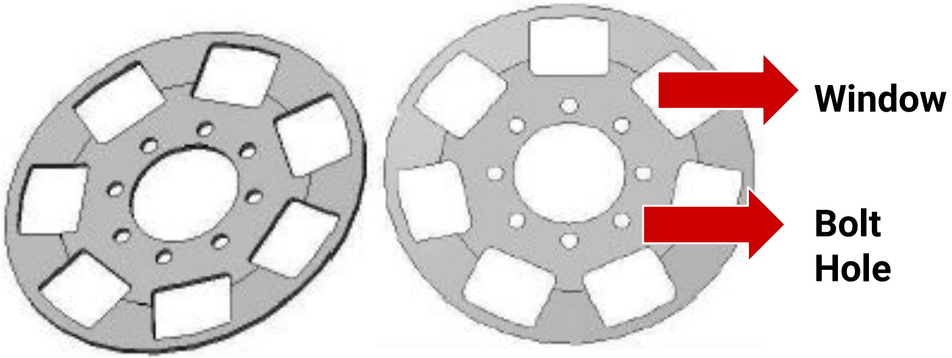


Side Plate of the Clutch:

Crack is formed on the side plate of the clutch. Side plate consists of various slots in which the damper springs are engaged. These slots are called the windows. The damper springs are used to absorb the torque during the engagement of the clutch. The crack is formed between these 2 windows.

The window acts as a stress raiser and I have done the structural analysis of the driven plate since it is more prone to failure.

Modified diagram of side plate:



Original Component Dimensions

The below clutch is an example of common dimensions of single clutch plate:

Clutch Disc 20-Spline 215mm / 22mm (Fiat 124 Spider Coupe, 131, Lancia Beta 1971) -

215mm surface, 20spline for input shafts with 22.0mm diameter

Own Dimensions of the Clutch Side Plate for Analysis

Since the side plate is smaller than the clutch disc the following are the dimensions I have taken for the analysis:

Outer Diameter: 110mm
Inner Diameter: 32mm
Plate Thickness: 3mm
No of Holes: 6
No of Windows/Rectangles: 6
Hole Diameter: 5mm
Rectangle dimensions: 23mm×17.66mm×3mm

Analysis was done with the help of research paper: STRUCTURAL ANALYSIS OF FRICTION CLUTCH PLATE BY CHANGING FILLET RADIUS SYAMBABU NUTALAPATI, Dr. D. AZAD, Dr. G. SWAMI NAIDU

Simplifications

It is solid circular plate with 6 windows and 6 holes for screws/ bolts.

By taking symmetry, I have simplified the modelling by dividing the entire model into 12 parts - **30 degree each.**

Procedure

I did an analysis using three commonly used materials to find the best material for varying mesh sizes namely 0.5mm, 1mm, 2mm and 3mm.

Using that material, I have done an analysis varying the fillet radius of the window to find out which for which radius the total deformation and principal stresses are the least.

Finite Element Model

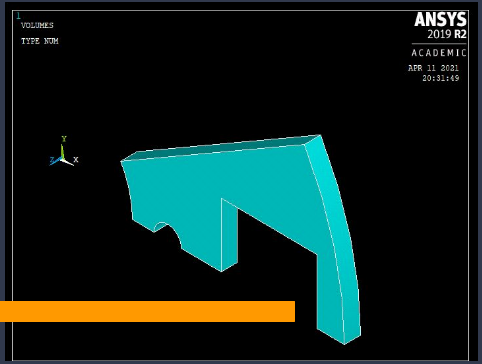
Preferences: Structural
Element type: Solid Brick 8 Node 185
Material Properties: Structured Steel, Gray Cast Iron, Sintered Iron - Linear, Isotropic
Modelling:

1. Partial Annulus Area: Rad 1 = 55mm, Theta 1 = 30, Rad 2 = 16mm
2. Solid Circle Semicircle Area (Bolt Area): WP X = 22.5, WP Y = 0, Rad = 2.5
3. Subtract Solid Circle Area from Annulus Area
4. Drew Half Window using 4 key points: (50,0), (50,11.5), (32.34,11.5), (32.34,0), created area and subtracted from annulus area
5. Extrude Final Area by 3 mm along normal

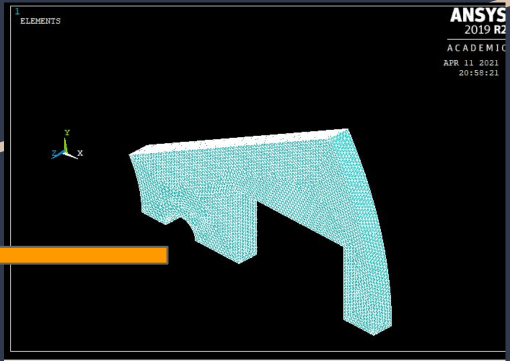
Meshing:
Size Control - Manual Size - Global - 0.5 mm
Tetrahedral Free Mesh of Volume
Loads:
Displacement: Symmetry Boundary Conditions on lower and top surface
Fixed BC (all dof) at circular area (due to presence of bolt) and Fixed support to shaft (all dof = 0)
Pressure on main surface = 0.31N/mm^2

Model after Meshing 0.5 mm

SOLID185 is used for the three-dimensional modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, stress stiffening, large deflection, and large strain capabilities.

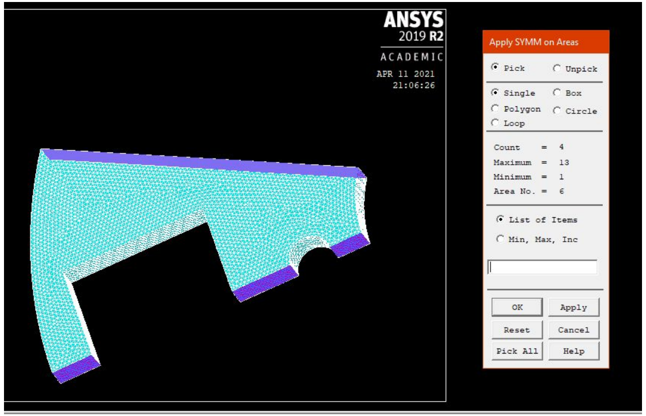


Window

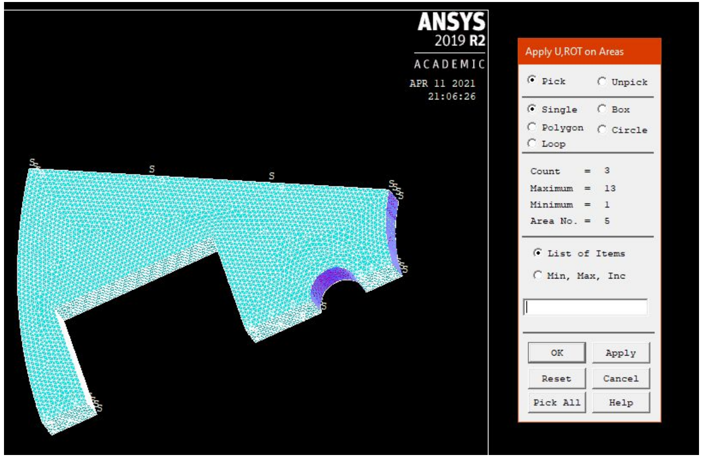


Bolt Circle

Symmetry Boundary Conditions



Fixed Boundary Conditions - All dof =0



Pressure - 0.31 N/mm^2

Taking P = 0.32MPa, W=Axial thrust, R1= Outer Radius (55mm), R2= Inner Radius (16mm)

P=intensity of pressure = P = (W)/ Π *r1²- r2²]

Substituting the values in P - W = 2.7 kN

2.7 KN= 2 Π(16 P max) *[55²- 16²]

P max = 0.68N/mm²

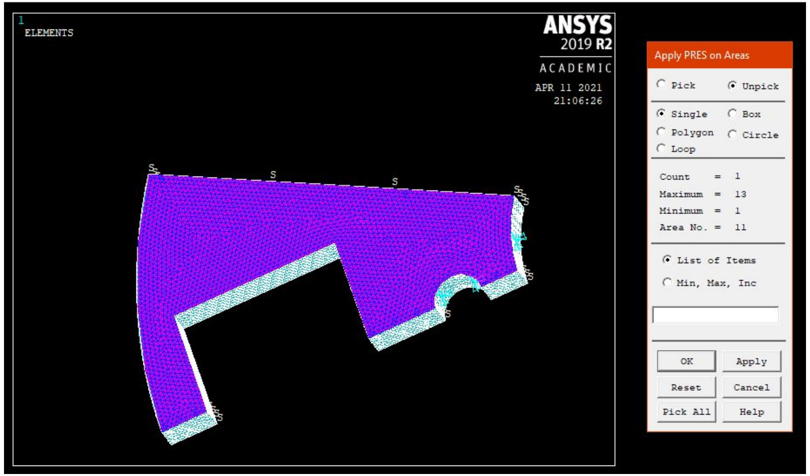
2.7 KN= 2 Π(55 P min) *[55²- 16²]

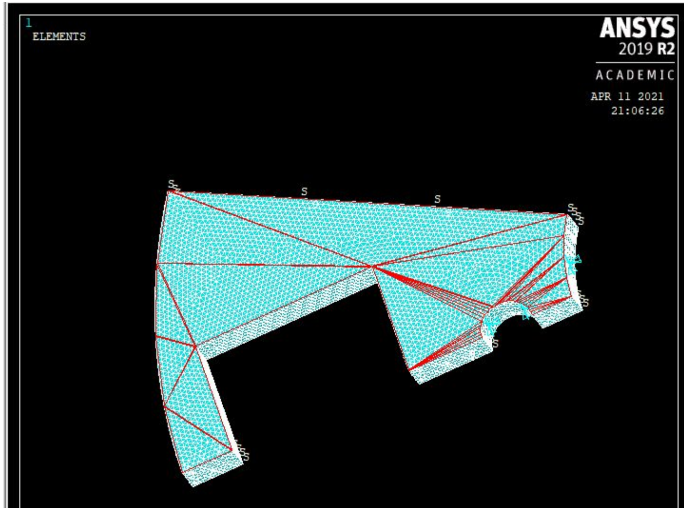
P min = 0.2 N/mm²

Pavg = Total Normal Force/ Area

Pavg = W/ Π *r1²- r2²]

Pavg = 0.31 N/mm²





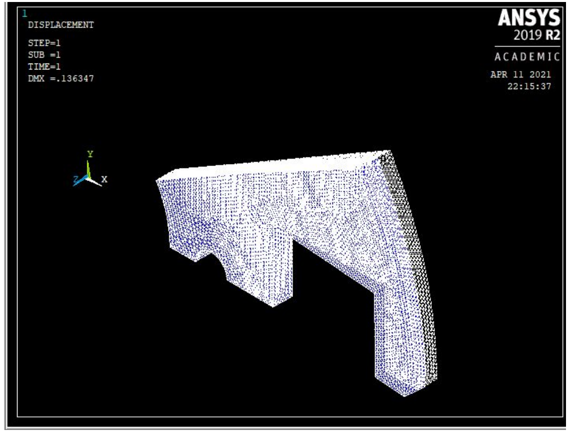
Analysis 1: Comparison of 3 commonly used clutch plate materials for standard fillet radius of window/slot (0mm) for varying mesh sizes

Properties	Sintered Iron - SI	Grey Cast Iron - GCI	Structural Steel- SS
Density	6200 kg/m^3	7200 kg/m^3	7850 kg/m^3
Young's Modulus	275.79 MPa	120 GPa	200 GPa
Poisson's Ratio	0.34	0.29	0.3

Material	Fillet Radius		Mesh Size - Element Edge Length (mm)				
			0.3	0.5	1	2	3
SS	0	TOTAL DEFORMATION	0.14274	0.136347	0.116807	0.061734	0.050642
GCI	0		-	0.227969	0.195481	0.10381	0.085015
SI	0		-	97.4848	82.9473	42.7019	35.043

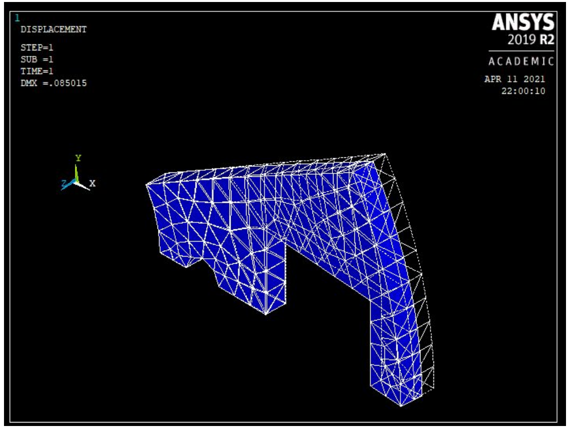
Result 1: With decreasing mesh size, the accuracy in the total deformation value improved. Mesh Size of 0.5 mm was selected for 2nd Analysis. Structural steel was found to be the best material with the least total deformation of 0.136347 mm. Mesh size 0.3mm could not be used for meshing since it was violating in the case of GCI and SI materials.

SS - 0.5 mm mesh size

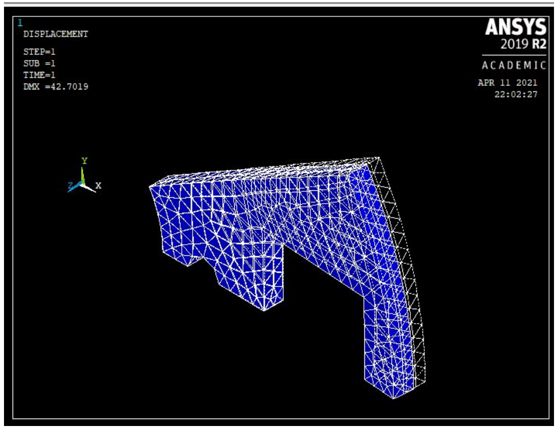


Sample Images of Total Deformation:

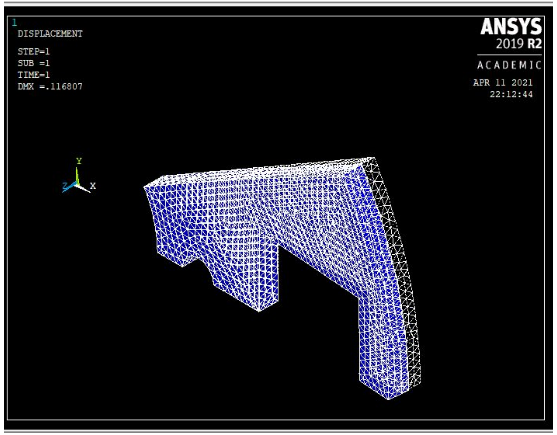
GCI - 3 mm mesh size



SI - 2 mm mesh size



SS - 1 mm mesh size

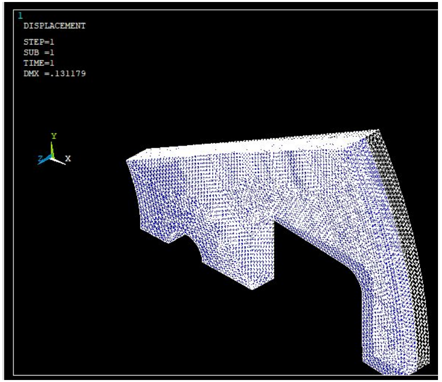


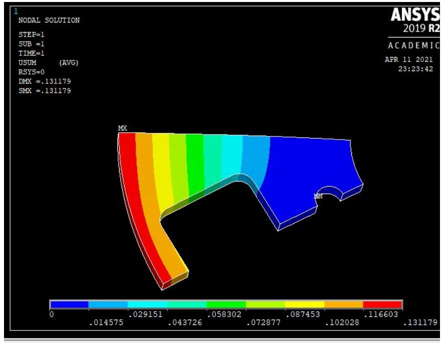
Analysis 2: Using mesh size of 0.5mm for structural steel side clutch plate of 30 deg, fillet radius of window was changed from 0 mm to 3mm in 0.5 mm increments

Fillet Radius	Total Deformation	Equivalent Stress	Maximum Principal Stress	Middle Principal Stress	Minimum Principal Stress
0	0.136347	194.71	219.94	86.227	65.056
0.5	0.135708	191.58	225.49	90.766	68.673
1	0.134778	171.02	226.01	91.361	69.107
1.5	0.133503	152.62	229.85	92.929	70.075
2	0.132657	147.04	226.21	91.8	69.138
2.5	0.131179	148.07	225.3	90.246	67.704
3	0.130213	151.74	232.7	93.984	70.650

For Mesh size 0.5 mm, Material Structural Steel, Fillet Radius of Window 2.5mm

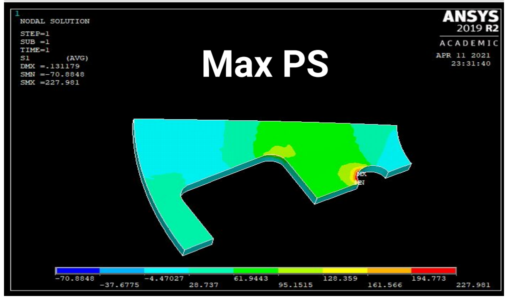
Total Deformation

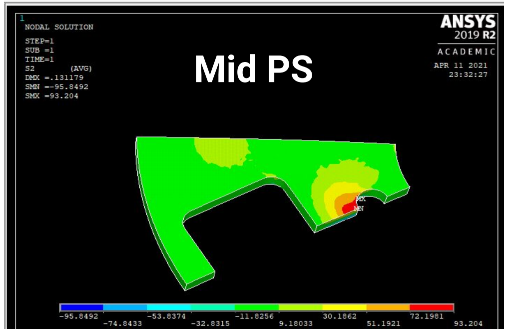


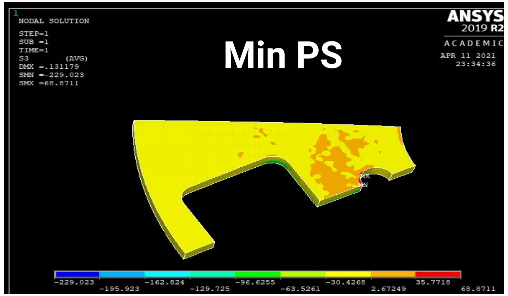


Displacement is maximum at the outer radius.

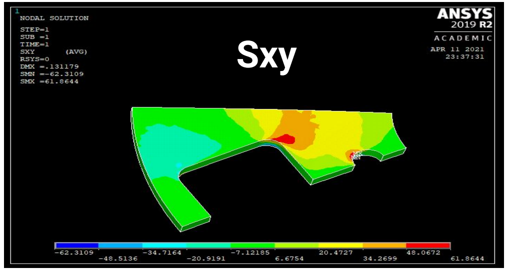
Principal Stress

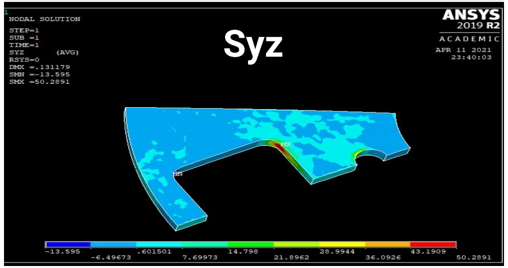


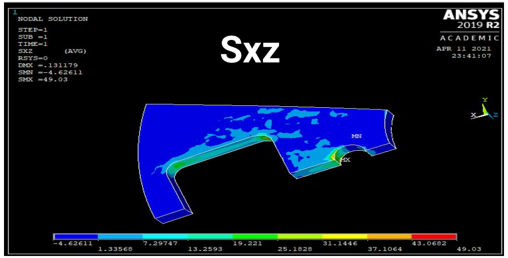




Shear Stress







Shear stress Sxy acts at the window fillet is maximum.

Result 2: Using mesh size of 0.5mm, for clutch plate of structural steel, 2.5 mm fillet radius for window was found to be optimal.

1. Without fillet radius for window, equivalent stress and total deformation was found to be 194.71N/mm2 and 0.136347mm.
2. With fillet radius for window of 2.5 mm, equivalent stress and total deformation was found to be 148.07 N/mm2 and 0.131179mm.

- Although for fillet radius 3 mm total deformation was lower than 2.5 mm, its equivalent stress is more at 151.74 N/mm2.
- Similarly for fillet radius 2 mm equivalent stress of 147.04 was lower than that of 2.5 mm of 148.07 N/mm2. However the total deformation was larger for 2mm fillet radius of 0.132657 mm.

Fillet Radius	Max Sx	Max Sy	Max Sz	Max Sxy	Max Syz	Max Sxz
2.5mm	188.11	139.34	86.768	57.850	50.289	48.849

Conclusion:

- For the dimensions taken, mesh size of 0.5mm was used for Finite element analysis of clutch plate made of structural steel and it is concluded that for fillet radius 2.5 mm is the best design for the clutch plate for the used dimensions. Stress concentration is more at the corners of the window and care has to be taken to make sure that stress value is within material limit to prevent failure.