Performance Test of Multiplate Clutch and Analyses

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Abstract - This project consists of a performance test of Multi-plate clutch carried out by varying the parameters one by one while keeping others constant. This will show the change in torque transmitted by the clutch due to parameter change. This will help us generate a curve showcasing the relation between the torque and the respective parameter under variation. These curves can be useful in future design procedures as they give a brief idea how the torque changes. Further, we will do structural analyses on these clutches with different radii to get an idea of their structural behavior under loads.

***Key Words*: Multiplate Clutch, Solid edge, Ansys , Static Analysis**

1. INTRODUCTION

Clutch is the mechanism used to link or unlink the engine from rest of the transmission elements. It is situated between the gearbox and engine. When the clutch is engaged, the power transmission takes place from the driving shaft to the driven shaft i.e., the power transmission from the engine to the wheels takes place. When the clutch is disengaged, the power transmission from the engine to the wheels does not take place even though the engine is running because the driven shaft gets disconnected from the driving shaft which is connected to the engine.

1.1 Functions of a clutch:

- To start and run the engine at a required high speed to generate sufficient power necessary to move the vehicle from a stationary point.
- For smooth gear shifts without damaging the gear teeth.
- To engage and disengage the transmission from the engine to the other parts in the transmission.
- To absorb the shock and allow the engine to take up the load of the vehicle.

1.2 Requirements of a clutch:

- The clutch should be dynamically balanced, even in the case of high speeds.
- The size of the clutch should be minimal so that it will occupy less space.
- It should be operational for a long period of time and trouble free.
- It should be positioned in such a way that it should be easy to inspect, repair and inspect.
- It should be capable to dissipate a large amount of heat generated during its operation.

1.3 Main parts of a clutch:

- A driving member – It comprises of a flywheel, connected to the engine crankshaft.
- A driven member – It consists of a disc called clutch plate which carries friction materials on both sides.
- An operating member – It consists of a pedal which can be applied to delink the driving and the driven plates.

1.4 Friction material:

The material used for friction lining in a clutch is called friction material or friction lining material. The friction material should possess high coefficient of friction in operational conditions and also have high resistance to wear effects such as scoring and galling. It must be capable to withstand high temperatures and should not be affected by moisture and oil. Some of the materials used for friction lining are leather, cork, asbestos, fabric, grey cast iron, SF-BU, steel and bronze.

1.5 Co-efficient of friction:

- It is the ratio of frictional force resisting the motion of two contact forces to the normal force pressing the two surfaces together. It is represented as (μ).

- The mathematical form being, μ = F/N where, F represents frictional force and N represents normal force

1.6 Applications: The graphs generated from our work will not only help understand the behavior of clutch but also help in future design procedures in selecting the suitable values for parameters according to the requirement.

1.7 Future Scope:

- Further detailed graphs can be generated using more and more values with less interval. All these accompanied by highly accurate calculations can provide much more detailed and accurate graphs.
- Furthermore, we have done our work using only uniform pressure theory which means future work can be done using uniform wear theory widening its spectrum of application.

2 MATERIALS USED

We have selected three materials for the analysis and they are gray cast iron, aluminum alloy and copper alloy. The material properties are given below:

Properties	**Gray cast iron**	**Aluminum alloy**	**Copper alloy**
Young's modulus	120GPa	110Gpa	71Gpa
Shear modulus	44-45Gpa	41.04Gpa	26.69Gpa
Density	7200 kg/m3	2770 kg/m3	8300 kg/m3
Poisson's ratio	0.29	0.33	0.34

3 Research Gap:

- Clutch plate is one of the main components in the automobile, helps in effective power transmission
- Thus the parameters affecting the power transmission plays a vital role in design of the clutch plate so we are analyzing how the parameters affect the power transmission such that the design is safe and effective.

4 Objectives:

- To generate graphs of variation in torque transmitted by varying different parameters one by one (keeping others constant).
- To create 3d models of the clutch plate for different radii.
- Study the structural behavior of clutch plates under applied loads.

5 Methodology:

- Parameters affecting the torque transmitted will be recognized.
- Torque will be calculated for all the different values of parameters changed one by one (keeping others constant).
- Different 3d-models will be created for all the radii values of the clutch.
- Analyses will be carried on all the models to study its structural behavior under forces.
- Analyses reports and graphs will be reported.

6 3D Models of Plate

3d models for the clutch plate for different inner diameter have been created using solid edge software.

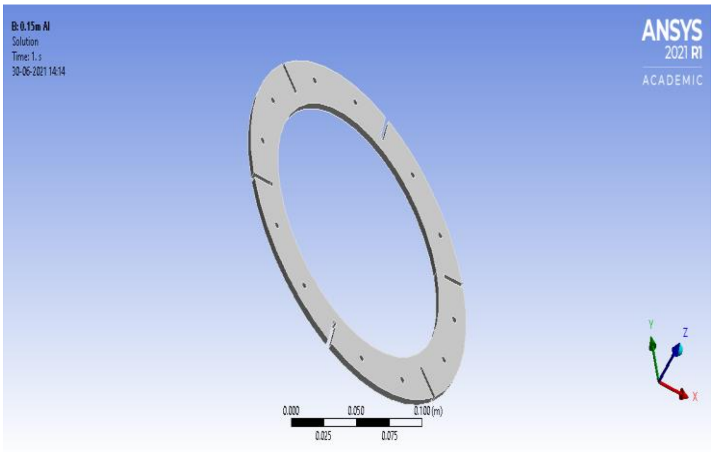


Fig-1: 3d model for Inner diameter (0.15m)

To analyzing the clutch plate the Ansys work bench is required. So, after completion of the 3d model, it is imported into the Ansys workbench.

Steps for the analysis of the clutch plate

- Workbench→toolbox→ component system→ engineering data→create standalone system
- Engineering data→engineering data sources→material selection
- Analysis system→ static structural→engineering data→geometry→import geometry
- Model→edit
- Geometry→material→assignment→select material
- Mesh→insert→method→sizing→select model→ apply
- Element size→define size→mesh→generate mesh
- Static structural→insert→fixed support
- Static structural→insert→pressure
- Fixed support→geometry→select one side of model→apply
- Pressure→geometry→select other side of model→apply
- Solution→inert→deformation→total deformation
- Solution→insert→deformation→directional deformation
- Solution→insert→strain→equivalent
- Solution→insert→stress→equivalent (von mises)
- Solve
- Images→image to file→save results

After importing the model into Ansys work bench, the material is selected for the clutch. As mentioned, three different materials are selected, they are:

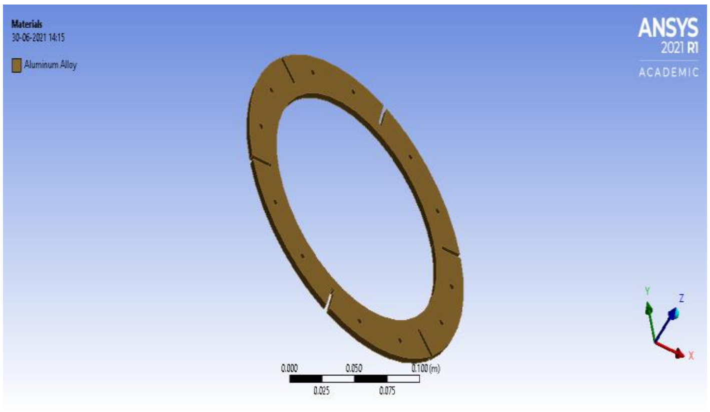


Fig-2: Material (aluminium alloy)

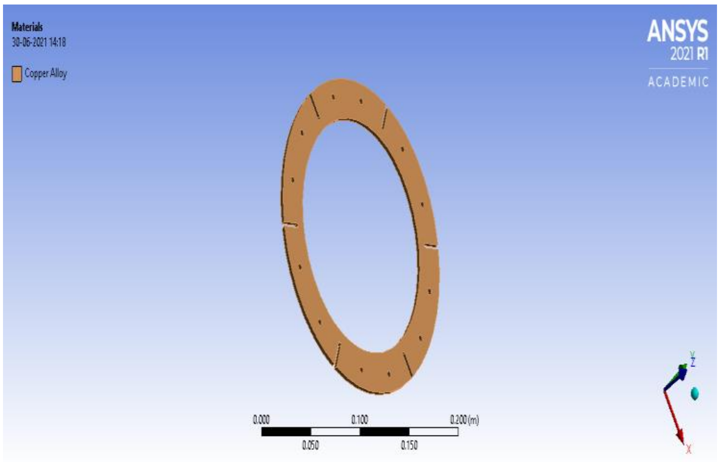


Fig-3: Material (copper alloy)

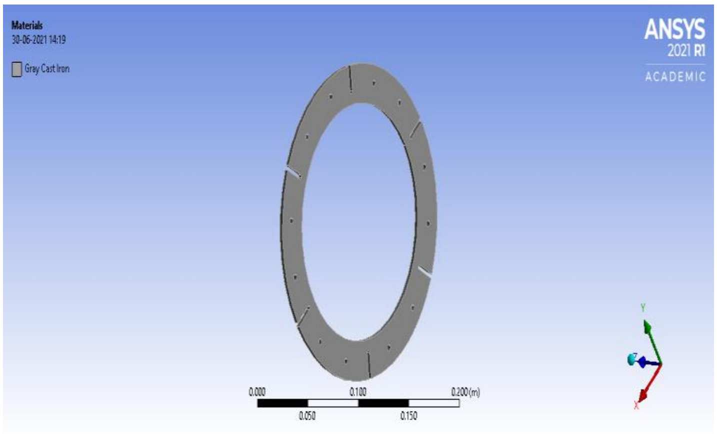


Fig-4: Material (grey cast iron)

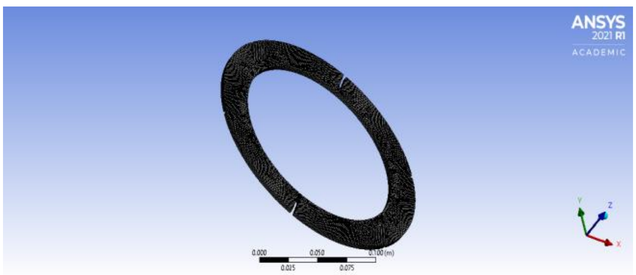


Fig-5: Meshing of the model

After the meshing is done, one side of the plate is fixed

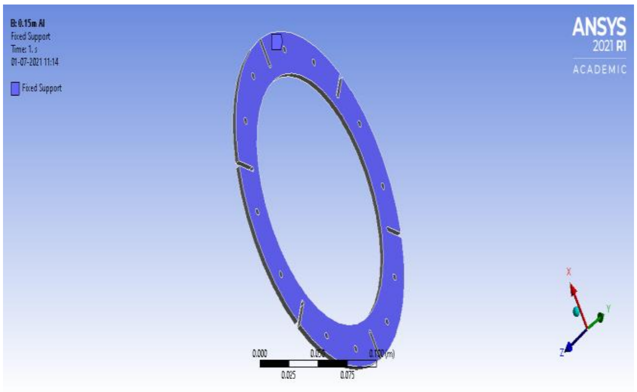


Fig-6: Fixed support

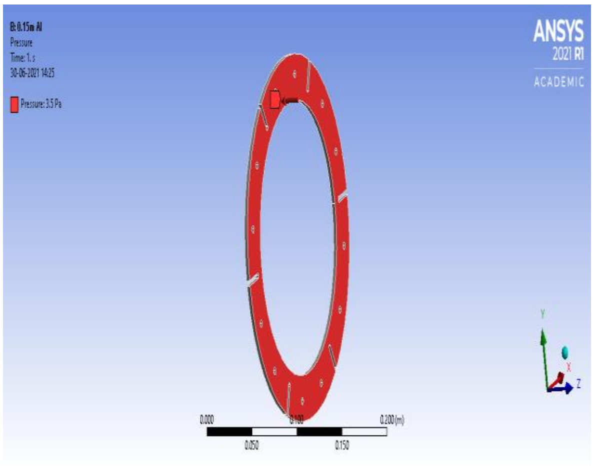


Fig-7: Pressure 3.5 Pa

After applying pressure, the model is solved for results

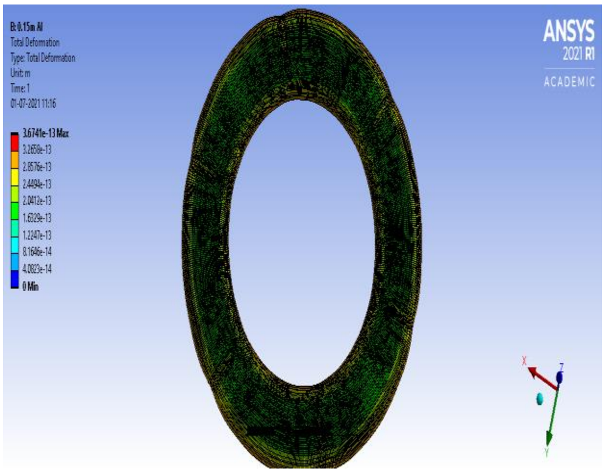


Fig-8: Total deformation

Fig-9: Equivalent elastic strain

Fig-10: Equivalent stress

Similarly, the analysis is performed for the all the five different plates for three different pressure and for three different materials. totally analysis has been done for the forty-five plates, the results are tabulated and graphs are plotted.

7 RESULTS

A static structural analysis calculates the effect of steady (or static) loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. After performing static structural analysis on the proposed CAD models of the clutch discs by varying the four parameters one by one (keeping others constant) we were able to obtain 3 key behaviors about the discs that are:

- Stress distribution
- Strain distribution
- Deformation

All our findings are showcased in the form of a table below:

PRESSURE=4.5 Pa									
INNER DIAMETER (m)	MATERIAL	TOTAL DEFORMATION (m)		EQUVALENT ELASTIC STRAIN (m/m)		EQUIVALENT STRESS (Pa)		DIRECTIONAL DEFORMATION (m)	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
0.15	AL	0	3.6741e-13	3.0620e-11	1.5716e-10	2.173	11.158	-1.9812e-13	1.9812e-13
	CU	0	2.4039e-13	1.8876e-11	1.0364e-10	2.076	11.401	-1.3253e-13	1.3253e-13
	GCI	0	2.2181e-13	2.3768e-11	9.0971e-11	2.614	10.007	-1.0537e-13	1.0537e-13
0.16	AL	0	3.6585e-13	3.0148e-11	1.5666e-10	2.140	11.123	-1.9694e-13	1.9693e-13
	CU	0	2.3931e-13	1.8581e-11	1.0330e-10	2.043	11.363	-1.3173e-13	1.3171e-13
	GCI	0	2.211e-13	2.3507e-11	9.076e-11	2.585	9.9837	-1.0482e-13	1.0481e-13
0.17	AL	0	3.5982e-13	2.9031e-11	1.5482e-10	2.061	10.992	-1.9191e-13	1.9195e-13
	CU	0	2.3523e-13	1.7849e-11	1.0203e-10	1.963	11.224	-1.283e-13	1.2835e-13
	GCI	0	2.1809e-13	2.2899e-11	8.9886e-11	2.518	9.8874	-1.022e-13	1.0229e-13
0.18	AL	0	3.4099e-13	2.8104e-11	1.4124e-10	1.995	10.028	-1.758e-13	1.7587e-13
	CU	0	2.2247e-13	1.726e-11	9.2908e-11	1.898	10.22	-1.174e-13	1.1747e-13
	GCI	0	2.0875e-13	2.2251e-11	8.2818e-11	2.447	9.1099	-9.420e-14	9.4205e-14
0.19	AL	0	3.0244e-13	2.8633e-11	1.1646e-10	2.004	8.269	-1.295e-13	1.2969e-13
	CU	0	1.9661e-13	1.7785e-11	7.6318e-11	1.956	8.395	-8.646e-14	8.6575e-14
	GCI	0	1.8858e-13	2.0744e-11	6.9662e-11	2.262	7.6628	-6.956e-14	6.9645e-14

PRESSURE=4.0 Pa									
INNER DIAMETER (m)	MATERIAL	TOTAL DEFORMATION (m)		EQUVALENT ELASTIC STRAIN (m/m)		EQUIVALENT STRESS (Pa)		DIRECTIONAL DEFORMATION (m)	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
0.15	AL	0	3.2658e-13	2.7217e-11	1.3969e-10	1.9319	9.9183	-1.761e-13	1.761e-13
	CU	0	2.1368e-13	1.6778e-11	9.2129e-11	1.8454	10.134	-1.178e-13	1.178e-13
	GCI	0	1.9717e-13	2.1127e-11	8.0863e-11	2.3239	8.8949	-9.366e-14	9.366e-14
0.16	AL	0	3.252e-13	2.6798e-11	1.3926e-10	1.9024	9.8872	-1.7506e-13	1.7505e-13
	CU	0	2.1272e-13	1.6516e-11	9.1823e-11	1.8163	10.1	-1.1709e-13	1.1708e-13
	GCI	0	1.9653e-13	2.0895e-11	8.0676e-11	2.2984	8.8744	-9.3171e-14	9.3165e-14
0.17	AL	0	3.1984e-13	2.5805e-11	1.3761e-10	1.8321	9.7706	-1.7059e-13	1.7062e-13
	CU	0	2.091e-13	1.5866e-11	9.0696e-11	1.7452	9.9766	-1.1406e-13	1.1409e-13
	GCI	0	1.9386e-13	2.0355e-11	7.9898e-11	2.239	8.7888	-9.0908e-14	9.0922e-14
0.18	AL	0	3.031e-13	2.4981e-11	1.2554e-10	1.7735	8.9137	-1.5633e-13	1.5633e-13
	CU	0	1.9775e-13	1.5342e-11	8.2585e-11	1.6876	9.0844	-1.0442e-13	1.0442e-13
	GCI	0	1.8556e-13	1.9779e-11	7.3616e-11	2.1757	8.0977	-8.3739e-14	8.3738e-14
0.19	AL	0	2.6883e-13	2.5452e-11	1.0352e-10	1.7821	7.3502	-1.1513e-13	1.1528e-13
	CU	0	1.7476e-13	1.5809e-11	6.7838e-11	1.739	7.4622	-7.686e-14	7.6959e-14
	GCI	0	1.6763e-13	1.8439e-11	6.1921e-11	2.0115	6.8114	-6.1833e-14	6.1907e-14

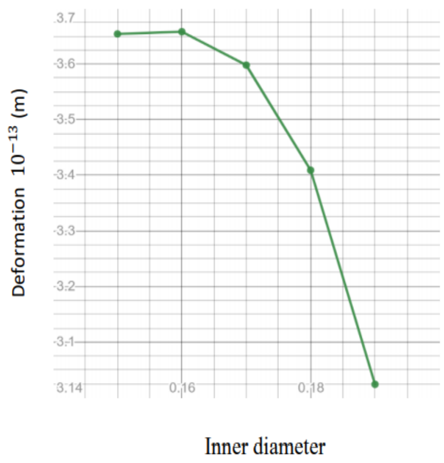
PRESSURE=3.5 Pa									
INNER DIAMETER (m)	MATERIAL	TOTAL DEFORMATION (m)		EQUVALENT ELASTIC STRAIN (m/m)		EQUIVALENT STRESS (Pa)		DIRECTIONAL DEFORMATION (m)	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
0.15	AL	0	2.8576e-13	2.3815e-11	1.2223e-10	1.6905	8.6785	-1.5409e-13	1.5409e-13
	CU	0	1.8697e-13	1.4681e-11	8.0613e-11	1.6147	8.8674	-1.0308e-13	1.0308e-13
	GCI	0	1.7252e-13	1.8486e-11	7.0755e-11	2.0334	7.783	-8.1953e-14	8.1952e-14
0.16	AL	0	2.8455e-13	2.3448e-11	1.2185e-10	1.6646	8.6513	-1.5318e-13	1.5317e-13
	CU	0	1.8613e-13	1.4452e-11	8.0345e-11	1.5893	8.8379	-1.0245e-13	1.0244e-13
	GCI	0	1.7196e-13	1.8283e-11	7.0591e-11	2.0111	7.7651	-8.1524e-14	8.1519e-14
0.17	AL	0	2.7986e-13	2.2579e-11	1.2041e-10	1.6031	8.5493	-1.4926e-13	1.4929e-13

	CU	0	1.8296e-13	1.3883e-11	7.9359e-11	1.5271	8.7295	-9.9806e-14	9.9825e-14
	GCI	0	1.6963e-13	1.7811e-11	6.9911e-11	1.9592	7.6902	-7.9545e-14	7.9557e-14
0.18	AL	0	2.6522e-13	2.1858e-11	1.0985e-10	1.5519	7.7995	-1.3679e-13	1.3679e-13
	CU	0	1.7303e-13	1.3424e-11	7.2262e-11	1.4767	7.9488	-9.1371e-14	9.1369e-14
	GCI	0	1.6236e-13	1.7307e-11	6.4414e-11	1.9037	7.0855	-7.3271e-14	7.3271e-14
0.19	AL	0	2.3523e-13	2.227e-11	9.0584e-11	1.5594	6.4315	-1.0074e-13	1.0087e-13
	CU	0	1.5292e-13	1.3833e-11	5.9358e-11	1.5216	6.5294	-6.7252e-14	6.7336e-14
	GCI	0	1.4667e-13	1.6134e-11	5.4181e-11	1.76	5.9599	-5.4104e-14	5.4169e-14

The data from these tables as shown as a graph for better interpretation and interpolation

- **Varying inner diameter:**

- ✓ Total deformation

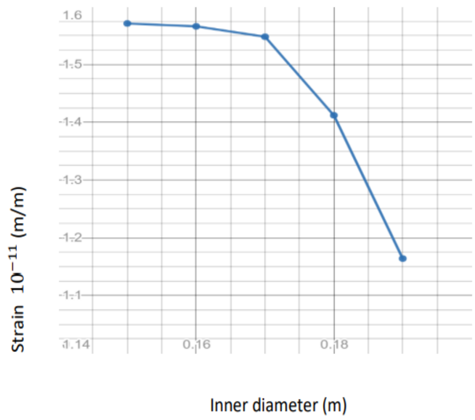


Scale:

X-axis: 1U=0.2m

Y-axis: 1U=0.1*10^{-13}m

- ✓ Strain

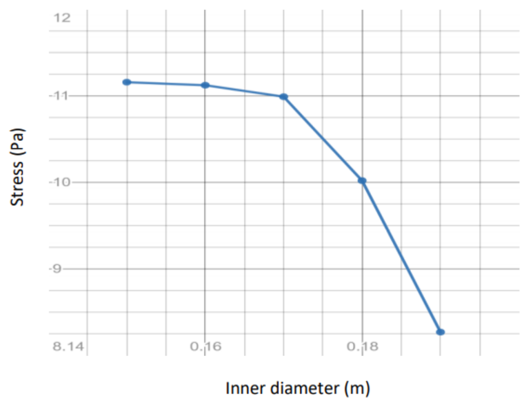


Scale:

X-axis: 1U=0.2m

Y-axis: 1U=0.1*10^{-11}m/m

- ✓ Stress



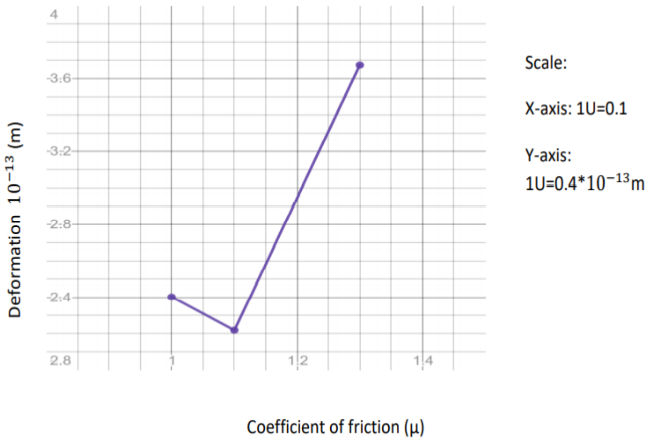
Scale:

X-axis: 1U=0.2m

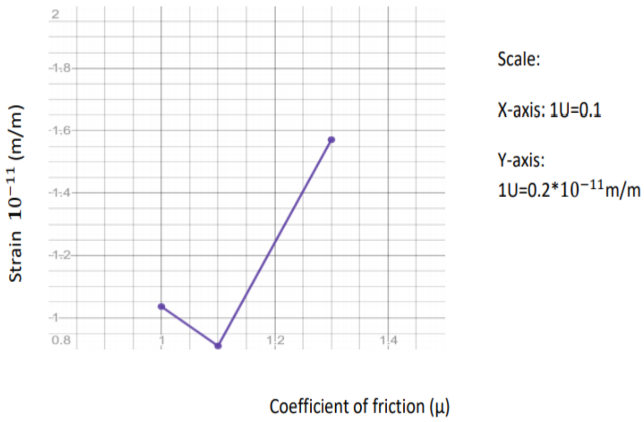
Y-axis: 1U=1Pa

- **Varying coefficient of friction/material:**

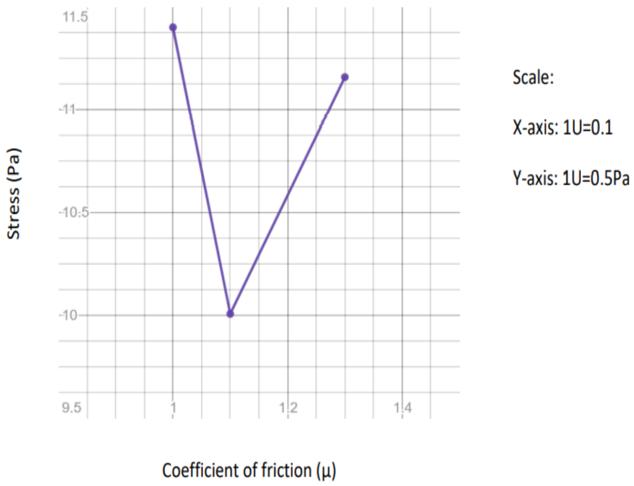
✓ Deformation



✓ Strain

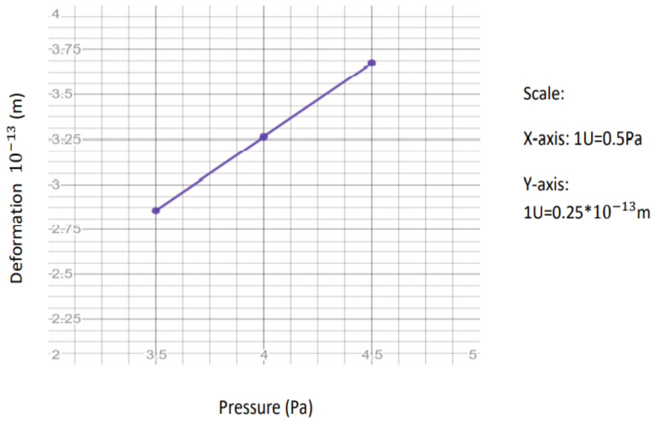


✓ Stress

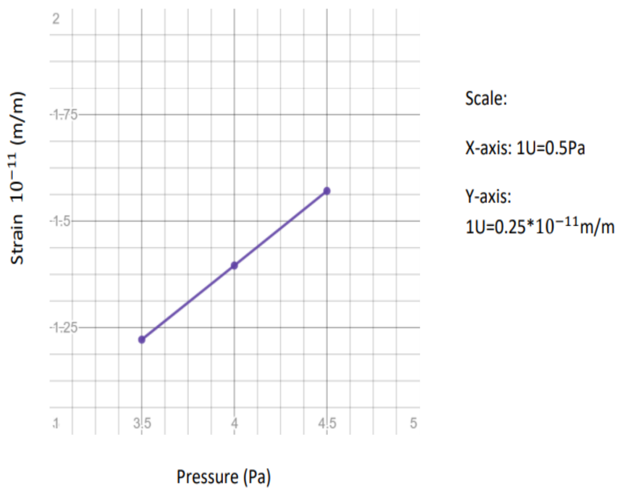


- **Varying Pressure:**

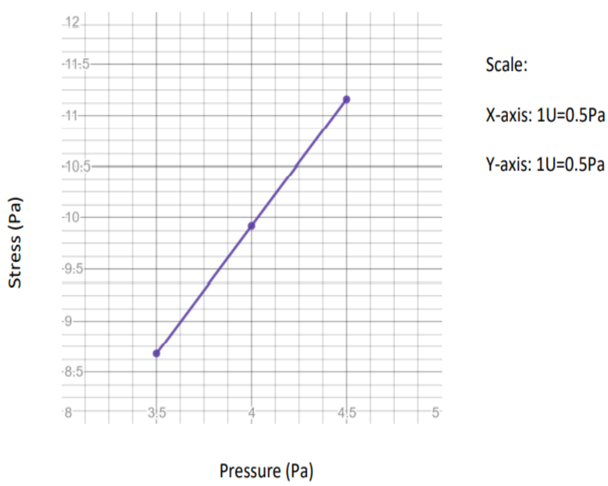
✓ Deformation



✓ Strain



✓ Stress



8 CONCLUSION

From the ANSYS Workbench structural analysis in FEM is a key to facilitate the assessment of structural analysis of clutch plate which provides relatively simpler method for analysing of material strength. Besides, the analysis shows that increase in tensile yield strength of material results in decrease in deformation and strain on the clutch disc.

And, the increase in pressure resulted in increase in both the deformation and strain on the clutch disc. On the other hand, increasing the inner diameter of clutch disc resulted in decrease of both the deformation and strain.

Thus, it can be concluded that clutch discs with thinner surface and higher tensile strength perform moderate at torque transmission but are safer.

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