Ahmedabad University

AUTOMOBILE ENGINEERING

DESIGN AND ANALYSIS OF DISC BRAKE & INTERNAL EXPANDING BRAKE

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| Monsoon – 2020, Project Report|

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Contributions

- **Rutvik Raval** – Design process of drum brake, thermal analysis of drum brake and report of drum brake
- **Rushil Patel** - Excel sheets for disc and drum brake
- **Dhruvil Patel** - Design process of disc brake and report of disc brake
- **Priyank Patel** - CAD Models of design disc and drum brake
- **Akash Prasad** - Simulations of disc and drum and some part in report

Executive Summary

Braking system is one of the crucial parts of any automobile. Its main function is to lower the speed of vehicle or stop it based on different driving conditions and requirements, by converting the kinetic energy of vehicle to heat energy and dissipating it into the atmosphere. This conversion happens due to the frictional force generated between the frictional lining and the rotor part of the brake when the brake pedal is pressed. There are two kinds of brakes i.e. disc brake and drum brake. Different vehicles have either of these or both of these kinds of brakes and it largely depends upon the how is the vehicle going to be used. Racing cars have disc brakes whilst normal passenger cars embed disc brakes for front wheels and drum brakes for rear wheels. In the present work, literature survey was done to understand the working of brake and visualize different parts of brake. The main focus of this work is designing the disc and drum brakes, making 3D models of these designs, simulating the calculations to validate design procedure. For the theoretical work of disc brake, *AUDI A3 (8V1,8VK) 2.0 TFSI* was selected and for drum brake *Hyundai Accent II (LC) 1.3*

1. Theory of Brakes

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction.

The brakes decelerate and stop a moving automobile by changing kinetic energy of the vehicle into thermal energy and releasing it into the atmosphere. It is the power of friction that changes kinetic energy into a thermal energy. Friction is the resistive force which is generated when two moving objects make contact.

Brakes are fitted to all four wheels of an automobile. The rotors or drum of the brakes rotate with the wheel, which are stopped with the power of friction. The strength of decelerating and stopping an automobile is called BRAKING FORCE.

When the driver steps on the brake pedal, the power is amplified by the brake booster and changed into hydraulic pressure by the master cylinder. The pressure reaches the brakes on the wheel via tubing filled with brake oil. The delivered pressure is about 30 times that of the stepping power.

There are various kinds of automobile brakes like,

1. Mechanical brakes
2. Hydraulic brake
3. Power brakes

Most of the automobiles equipped with mechanical brakes either disc brakes or drum brake based on their respective character or usage. On disc brakes, brake rotors are clamped by friction materials called as brake pads to stop an automobile. Drum brakes have brake drums which rotate with the wheels. Each drum has brake linings which are pressed on the drums from the inside to stop the wheel. Here we have designed and done analysis on disc and drum brakes.

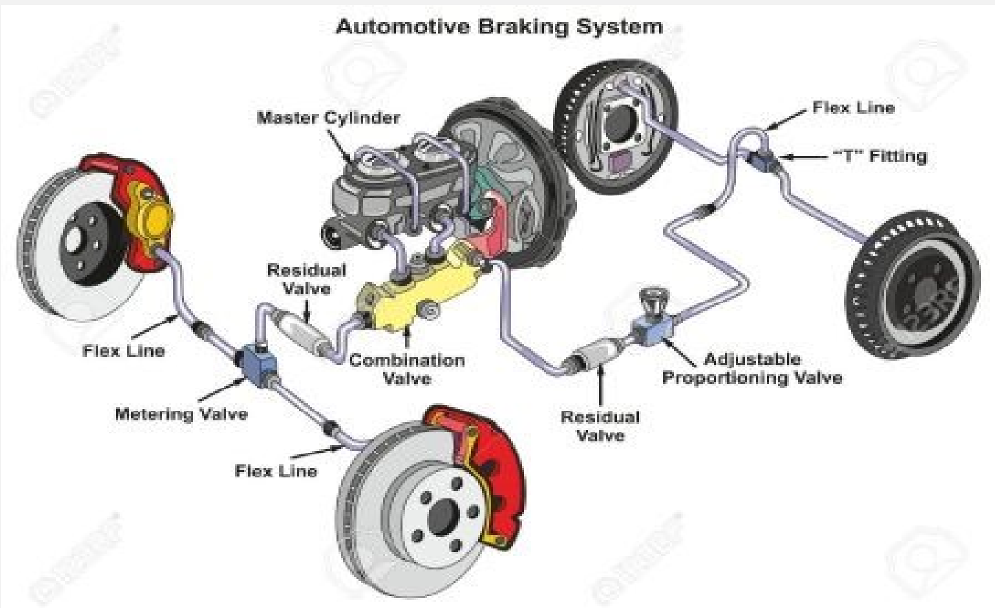

FIGURE 1 - BRAKING SYSTEM

1 Disc Brake

1.1 What is Disc Brake?

Brake rotors of disc brakes rotate with the wheels, and brake pads, which are fitted to the brake calipers and clamp on these rotors to stop or decelerate the wheels.

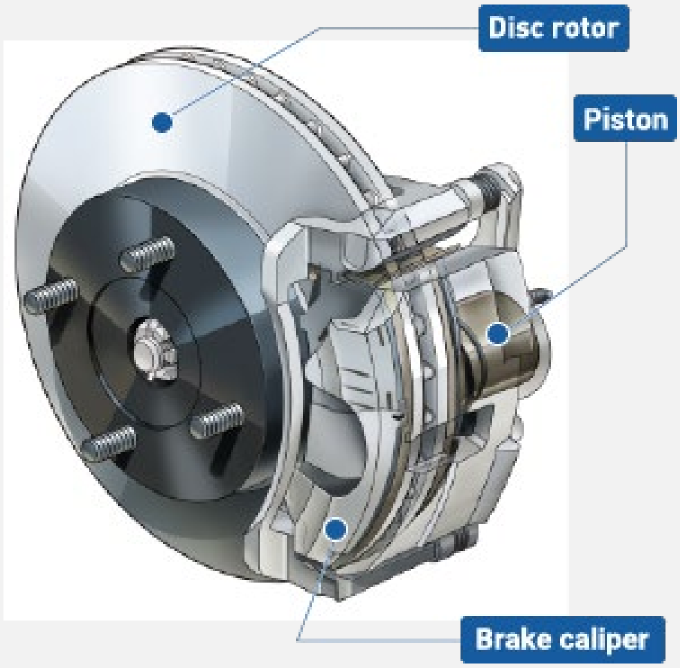

FIGURE 2 - MAIN COMPONENTS OF DISC BRAKE

The brake pads pushing against the rotors generate friction, which transforms kinetic energy into a thermal energy. This thermal energy generates heat, but since the main components are exposed to the atmosphere, this heat can be diffused efficiently. This heat-dissipating property reduces brake fade, which is the phenomenon where braking performance is influenced by the heat. Another advantage of disc brake is its resistance to water, which occurs when the water on the brakes significantly reduces braking force. When the vehicle is in motion, the rotor spins at high speeds and this rotational motion discharges the water from the rotors themselves, resulting in stable braking force.

There are two types of disc brakes. The "opposed piston type disc brake" has pistons on both sides of the disc rotor, while the "floating type disc brake" has a piston on only one side. Floating caliper type disc brakes are also called sliding pin type disc brakes.

1.2 Disc Brake Construction

The brake rotor (disc) which rotates with the wheel, is clamped by brake pads (friction material) fitted to the caliper from both sides with pressure from the piston(s) (pressure mechanism) and decelerates the disc rotation, thereby slowing down and stopping the vehicle.

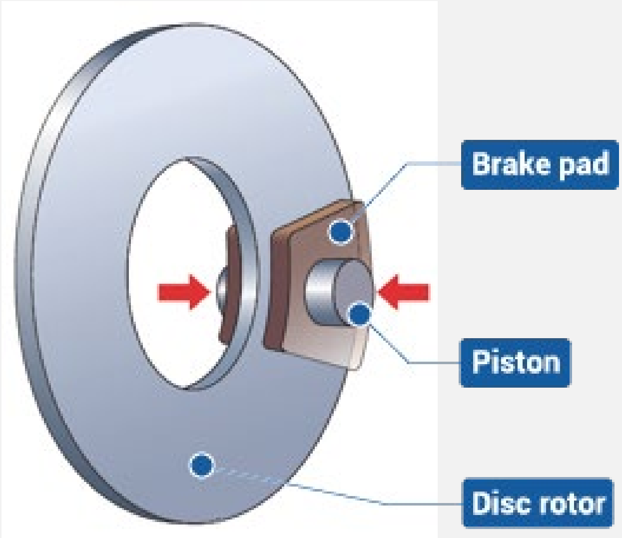

FIGURE 3 - SIMPLIFIED VIEW OF DISC BRAKE

1.3 How it works?

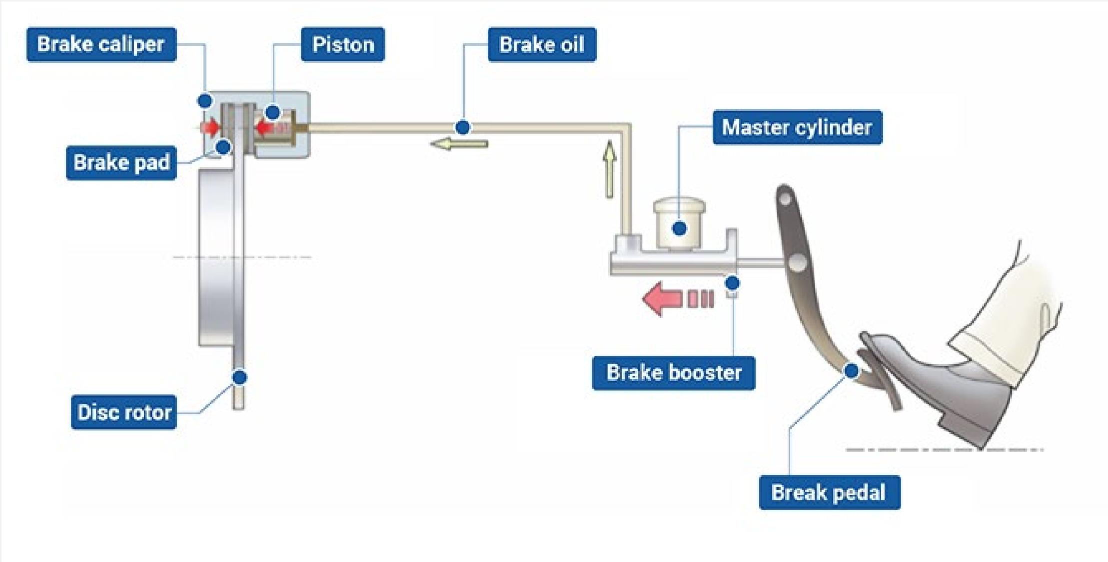

FIGURE 4 - MECHANISM OF DISC BRAKE

When the driver steps on the brake pedal, the power is amplified by the brake booster and changed into a hydraulic pressure by the master cylinder. The pressure reaches the brakes on the wheels via tubing filled with brake fluid. The delivered pressure pushes the pistons on the brakes of the four wheels. The pistons in turn press the brake pads, which are friction material, against the brake rotors which rotate with the wheels. The pads clamp on the rotors from both sides and decelerate the wheels, thereby slowing down and stopping the vehicle.

1.3.1 Components

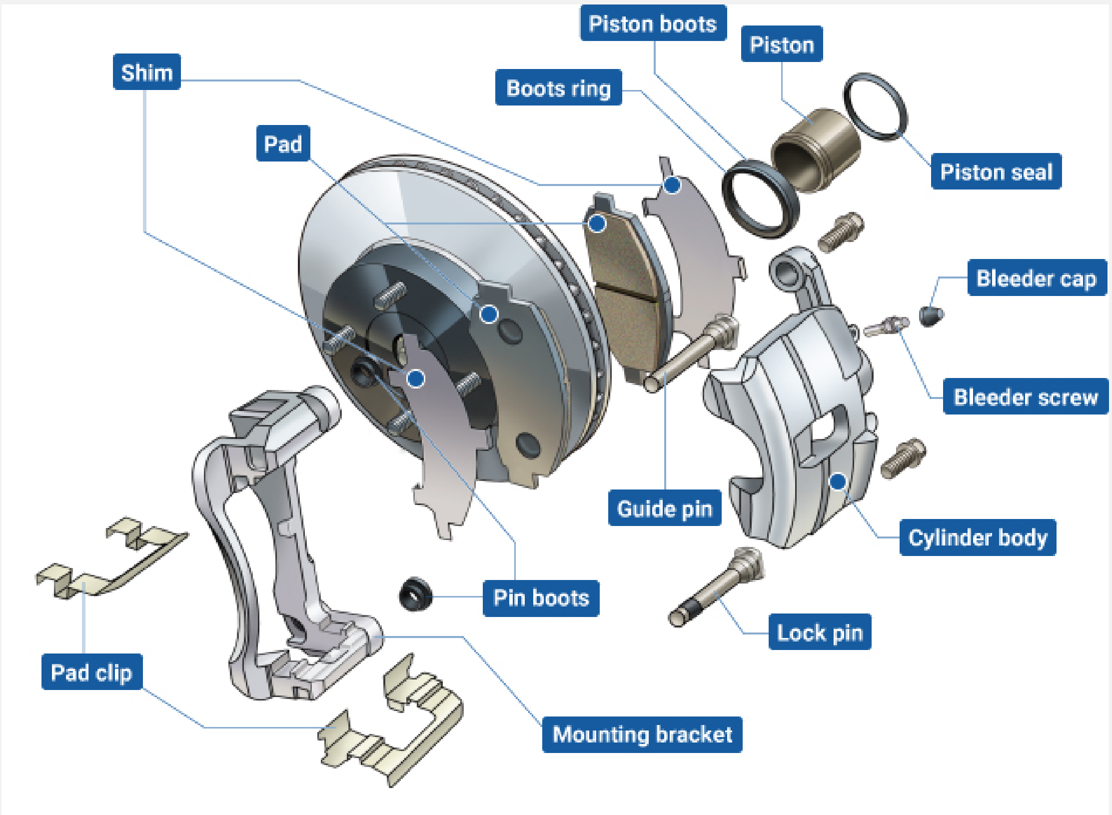

FIGURE 5 - COMPONENTS OF DISC BRAKE

1.4 Advantages and Disadvantages

- One of the biggest advantages is that disc brakes can generate and transfer greater amounts of heat to the atmosphere; because most of the friction area of a rotor is exposed to air, cooling is far more rapid than for a drum brake. This faster cooling makes them better suited for high-performance driving or heavy-duty vehicles and reduces the brake fade.

- During its use, disc brakes can remove dust particles trapped by themselves. In addition to dust particles, the fine particles generated by the surface of the brake lining will also be wasted on their own.

- Because of their shape, rotors tend to scrape off water more effectively. After being driven through water, disc brakes operate at peak performance almost immediately. Due to their design, disc brakes are self-adjusting and do not require periodic maintenance or rely on a self-adjusting mechanism that is prone to sticking. Disc brakes are also easier to service than drum brakes.

❖ Probably the most apparent disadvantage is that disc brakes are much more prone to noise. Their design tends to create squeals and squeaks, which can be very annoying.

❖ Another issue is that the rotors warp easier than in drum brake systems. Since the brake pads are pressing on each side of the rotor, thickness variations are very small which can cause brake pedal pulsations, requiring resurfacing or replacement. The last disadvantage is that since disc brakes are not self-energizing, they need higher clamping forces, which requires a power booster. This also makes it harder to use them as effective parking brakes.

❖ The disc brakes are ineffective when used as a parking brake. This happens because the brake pads have difficulty in retaining a smooth rotor surface. The disc brake system is only effective to reduce the vehicle's speed, but it is not as effective as drum brakes capable to self-energized to remain stationary while parked.

1.5 Design and Simulation

AUDI A3 (8V1, 8VK) 2.0 TFSI	
Model Year	2016 -
Performance	140KW / 190HP
Capacity	1984 CC
Cylinder	4
Brake System	Hydraulic
Drive Type	Front Wheel Drive
Engine Type	Petrol Engine

FIGURE 6 - DISC BRAKE MODEL CONSIDERATION

Before proceeding with the design of the disc brake, it is of utmost important to first understand the brake requirements, following mentioned are a few of them:

i. Brakes must be strong enough to stop the vehicle within a minimum distance in an emergency.

ii. Brakes must have good antifade characteristics i.e., their effectiveness should not decrease with constant application.
iii. They should have well anti wear properties.
iv. The material should be selected such that it is able to withstand high temperatures and heat.

Disc brake is always designed based on the **Uniform Pressure Theory** because brakes are mainly designed at maximum pressure and maximum automobile speed.

1.5.1 Sample Calculation

Mass of vehicle = 1340 kg
Maximum velocity of vehicle = 33.33 m/s
Wheel diameter = 0.62 m
Force on brake pedal by driver = 2000 N
Standard piston cylinder size = 1.12 in

Friction pad coefficient = 0.4
Select ratio = 1.320
Minimum inner diameter of rotor = 0.217 m
Minimum factor of safety for disc rotor = 1.2

1. $$\boldsymbol{Kinetic\ energy\ (KE) = \frac{MV^2}{2} = 1340(33.33)^2 = 744295.6\,J}$$

2. $$Maximum\ Friction\ force\ (f) = \mu Mg = 0.4 * 1340 * 9.8 = 9192.4\ N$$

3. $$Deceleration\ (a) = \frac{f}{M} = \frac{9192.4}{1340} = 6.86\ m/s2$$

4. $$Time\ taken\ to\ stop\ the\ vehicle\ (t) = \frac{V}{a} = \frac{33.33}{6.86} = 4.86\ s$$

5. $$Stopping\ distance\ (SD) = Vt = 33.33 * 4.86 = 161.94\ m$$

6. $$Braking\ force\ (F_t) = \frac{KE}{SD} = \frac{744295.6}{161.94} = 4596.2\ N$$

7. Piston diameter, Piston pressure, Outer & Inner diameter of the rotor, Actual factor of safety for disk rotor are calculated by **solver** function in excel.

8. $$Torque\ generated\ by\ caliper\ on\ rotor\ (T) = \frac{P_a f \pi (D_o^2 - D_i^2) d}{4} = 1293.320\ Nm$$

9. $$Effective\ rotor\ radius = \frac{Dr_o}{2} - \frac{D_c}{2} = \frac{0.290}{2} - \frac{0.028448}{2}$$

10. $$= 0.131\ m$$

11. $$Braking\ torque\ (T_b) = \frac{T_w D}{Dr_o} = \frac{356.2055\ *\ 0.62}{0.290} = 761.543\ Nm$$

12. $$Clamping\ force\ (C) = \frac{T_b}{2\mu R_e} = \frac{761.543}{2 \times 0.4 \times 0.131} = 7279.076\ N$$

13. $$N = \frac{VD}{\pi} = 17.12\ rps$$

14. $$Angular\ velocity\ (w) = 2\pi N = 6163.2\ deg/sec$$

$$Heat\ generated = kinetic\ energy = m_d * C_p * (t_f - t_i)$$

15. $$t_f = 478.617\ °C$$

16. $$Power = \frac{KE}{t}$$

17. $$Contact\ area\ of\ piston = \pi/4 * [Dr_o^2 - (Dr_o - D_c)^2]$$

18. $$Area\ (A) = 2 \times contact\ area\ of\ piston$$

19. $$Heat\ flux = \frac{Power \times A}{t} = 191.892\ K_w/m^2$$

1.5.1.1 Nomenclature

- *M = mass of vehicle*
- *μ = friction coefficient*
- *g = acceleration of gravity*
- *R = radius of tire*
- *P_a = pressure generated in caliper*
- *D_{ro} = rotor outer diameter*
- *D_c = caliper diameter*
- *m_d = mass of disc*
- *C_p = specific heat*
- *t_f = temperature increase in disc rotor*
- *t_i = initial temperature in disc rotor*

1.6 3D Model

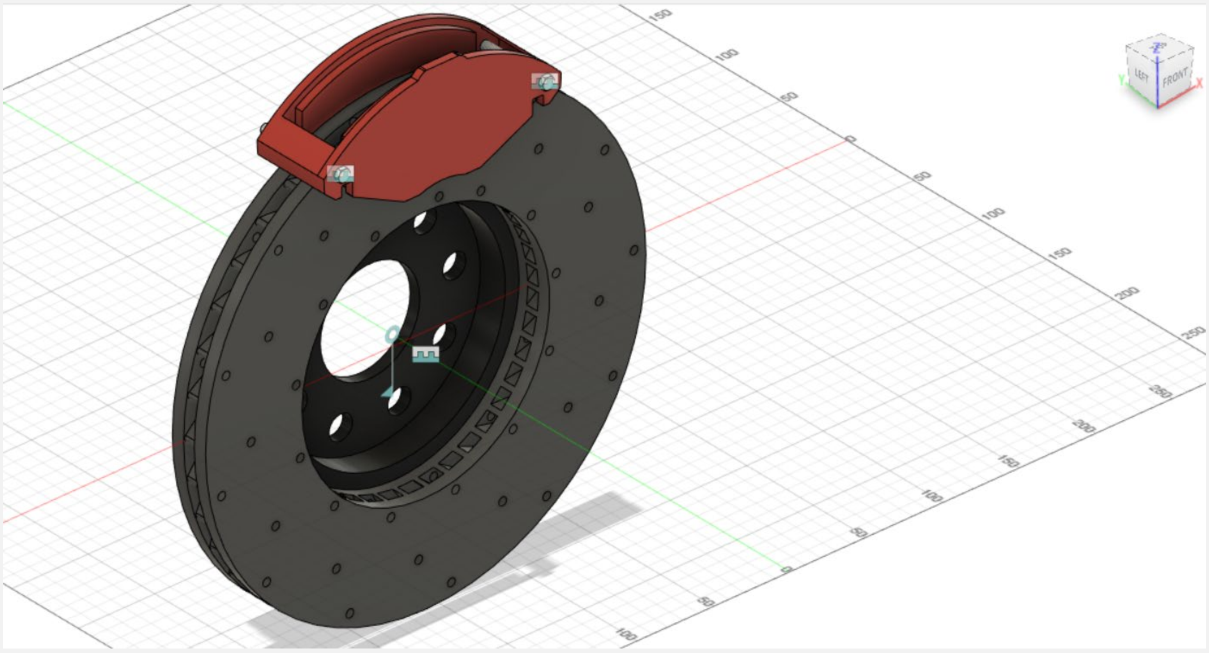

Figure 7 - 3D Assembly

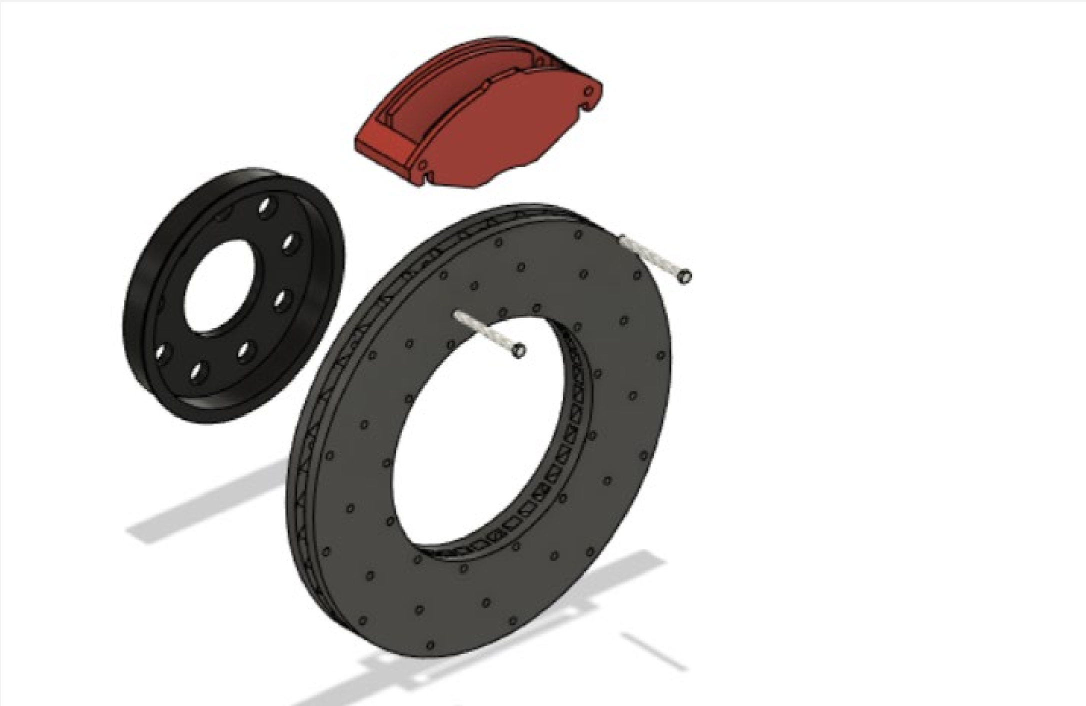

Figure 8 - 3D Exploded

1.7 Simulation

Simulations of disc brake were done in Solidworks with clamping force on each face and temperature obtained in the calculations (section Sample Calculation).

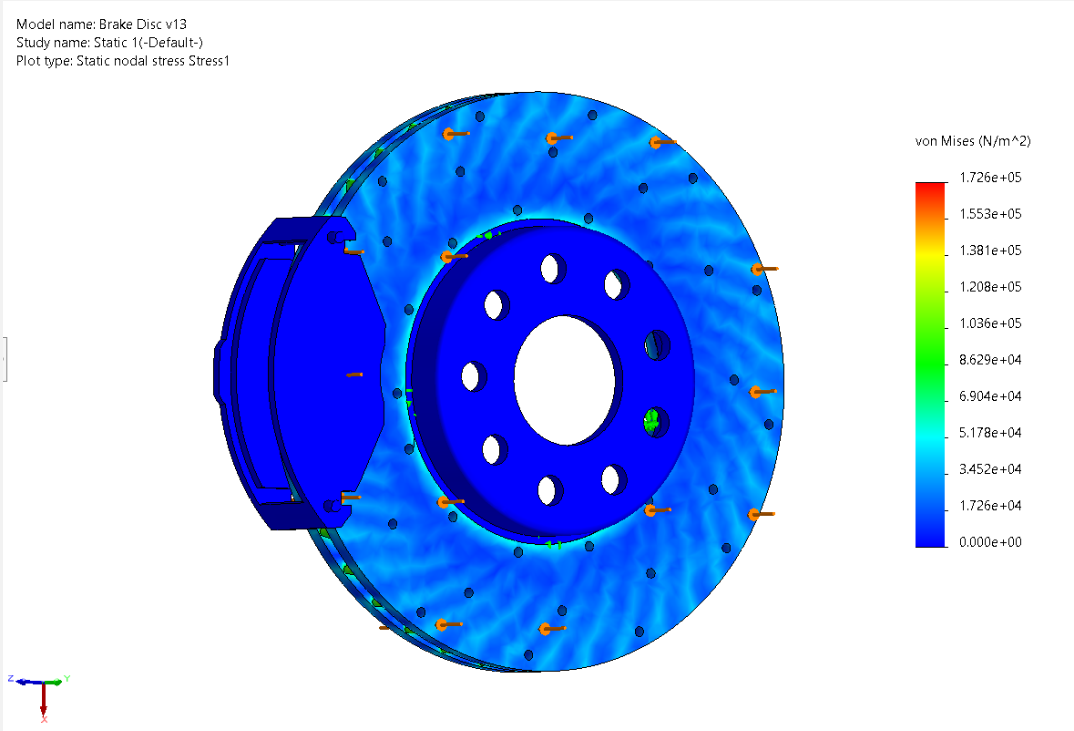

FIGURE 9 - STRESS DUE TO CLAMPING FORCE

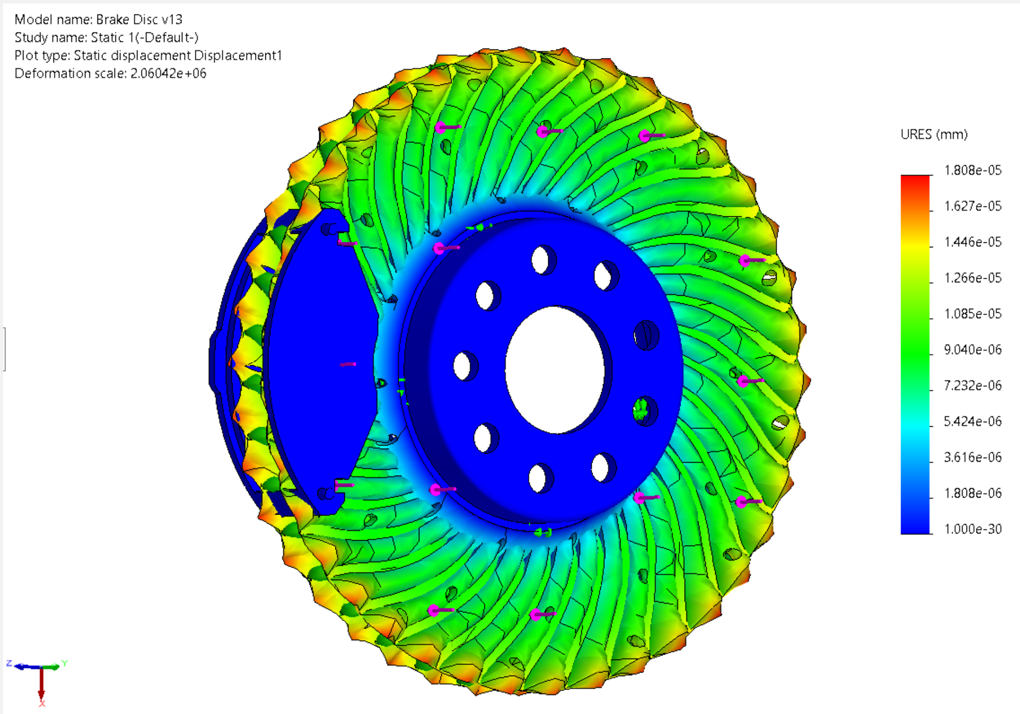

FIGURE 10 - DISPLACEMENT DUE TO CLAMPING FORCE

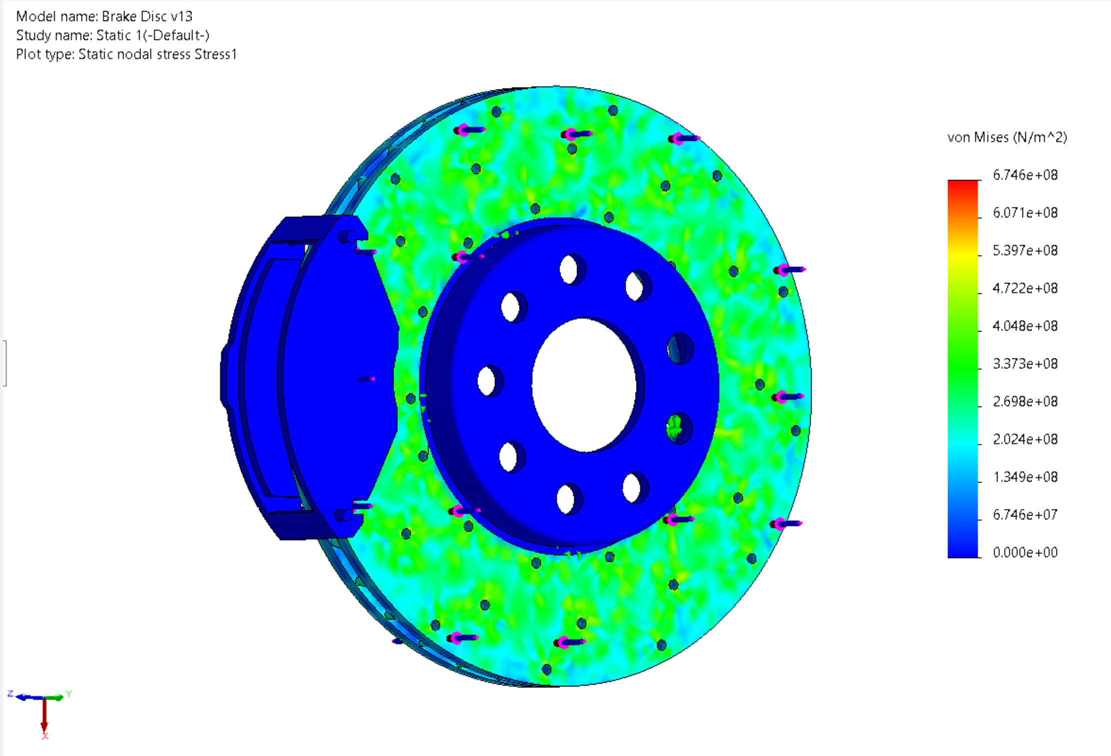

FIGURE 11 - STRESS DUE TO COMBINED EFFECT OF CLAMPING FORCE AND TEMPERATURE RISE

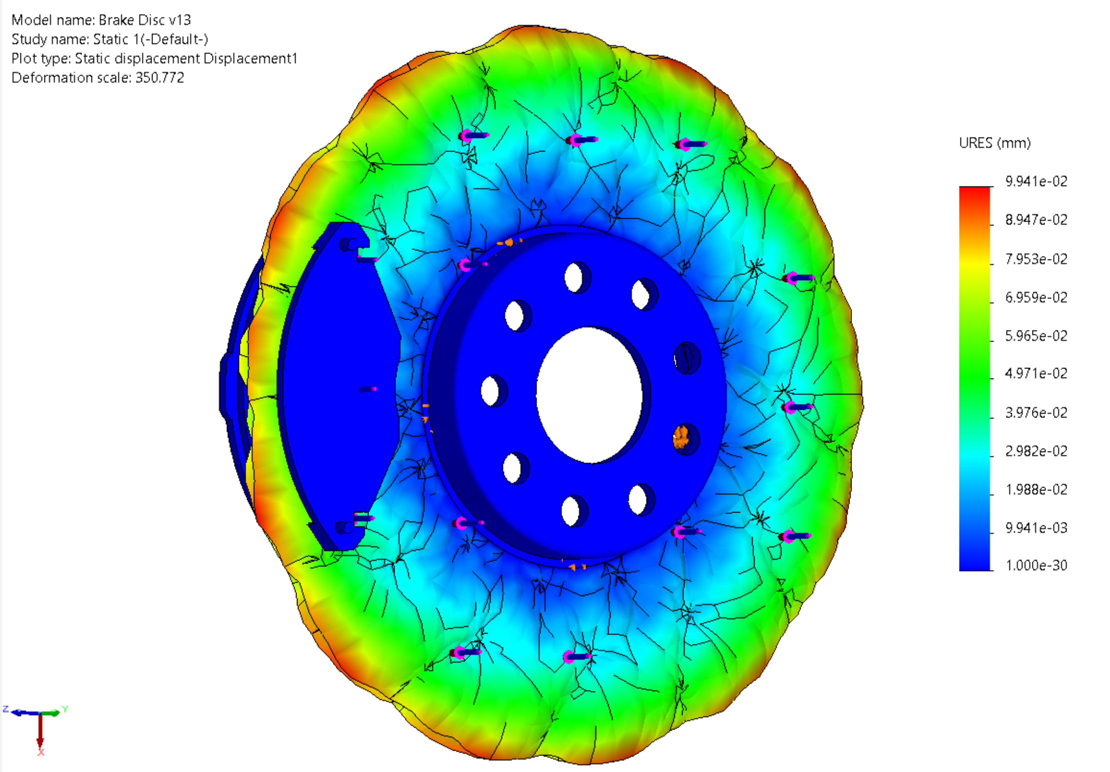

FIGURE 12 - DISPLACEMENT DUE TO COMBINED EFFECT OF CLAMPING FORCE AND TEMPERATURE RISE

2 INTERNAL EXPANDING(DRUM) BRAKE

2.1 Background and Principle

Drum Brakes are the modern brakes which are highly uses in the various automobiles. Drum brake uses the friction caused by a pair of shoes or pads that press outer side against a rotating cylinder-shaped part is called Drum brake.

Working Principle of Drum Brake:

When the force is applied to the brake pedals, due to hydraulic system that force is transfer to two curved brake shoes in each drum brakes. That brake shoes have friction material on the outer side which is also called brake liners. They are forced by hydraulic against the inner surface of the rotating cylinder type part which is called Drum. In the result of the friction between inner surface of drum and brake liner caused the vehicle slow down or stop.

2.2 Components

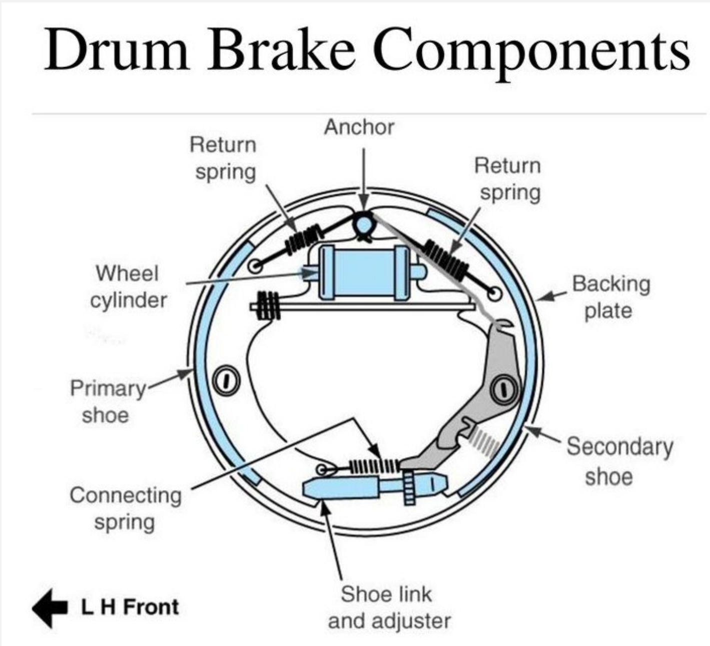

FIGURE 13 - DRUM BRAKE COMPONENTS

- **Wheel Cylinder:** It pushes the brake shoes on the outer side for friction when the brake paddle is pressed. It uses hydraulics to press piston outwards for braking.

- **Brake Lining:** Brake liner is connected with the brake shoes. So when the brake shoes is pressed outwards then it transfer to the brake lining. It has friction material on the outer side which comes in the contact with drum to slow down the vehicle.

- **Drum Brake:** Drum brake is rotating part in the vehicle. It rotates with wheel and when the brake is applied, the brake liner comes in a contact with drum which creates friction in order to slow down a vehicle.

- **Return Spring:** It is used for when the brake paddle is release then return spring pull the brake shoes at inner direction which disconnect the contact of brake liner and drum brakes.

2.3 Design and Calculation

Hyundai Accent II (LC) 1.3	
Model Year	2000-2005
Performance	55KW / 75HP
Capacity	1341 CC
Cylinder	4
Brake System	Hydraulic
Drive Type	Front Wheel Drive
Engine Type	Petrol Engine

FIGURE 14 - DRUM BRAKE MODEL CONSIDERATION

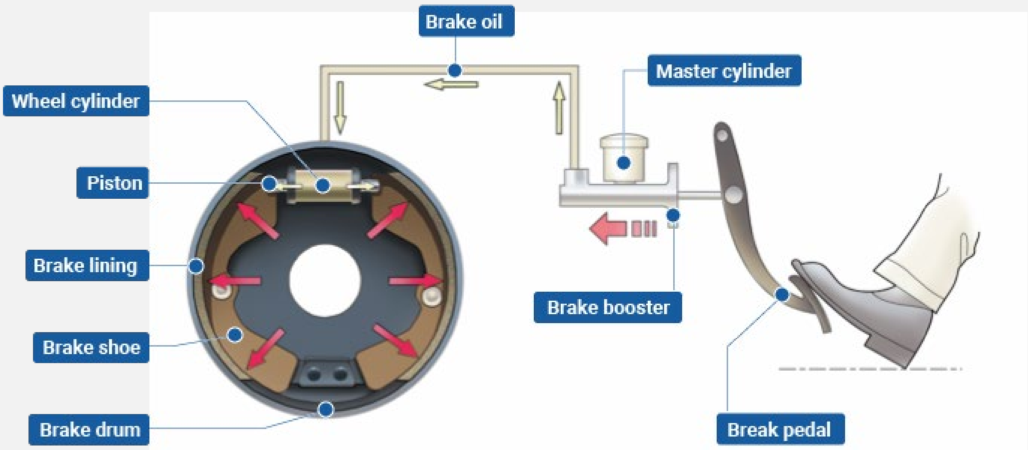

FIGURE 15 - WORKING OF DRUM BRAKE

i. Kinetic Energy $KE = \frac{1}{2}MV^2$ = 666533.34 joule

ii. Maximum Friction Force F = $\mu * M * g$ = 8232 N

iii. Deceleration = $\frac{F}{M}$ = 6.86 m/s²

iv. Time taken to stop distance $t = \frac{V}{a}$ = 4.86 sec

v. Stopping Distance $SD = V * t$ = 161.94 m

vi. Braking Force = $\frac{KE}{SD}$ = 4116 N

vii. Braking Torque on each wheel $T_w = F_t * R$ = 308.7 N-m

viii. Piston Diameter d(p) = 2 * $\sqrt{\frac{Fs}{\pi * p}}$ = 38.10 mm

ix. Width of Shoe (w) = $\frac{T}{2*\mu*Pmax*r^2*\sin(\frac{\emptyset_0}{2})}$ = 29.96 mm

x. To prevent self-locking Radius

$$R > \frac{4*\mu*r*\sin(\frac{\emptyset_0}{2})}{(\emptyset_0+\sin(\emptyset_0))(\sin(\alpha)+\mu*\cos(\alpha))} = R > 0.04$$

xi. Equal Friction Force at A & C = $F_s = \frac{P_{\max}*r*w*((\emptyset_0+\sin(\emptyset_0))}{4}$ = 1879.73 N

xii. Activation Force = $\frac{P_{\max}*r*w*((\emptyset_0+\sin(\emptyset_0))}{2}$ = 3759.46 N

xiii. Distance from point A to opposite shoe side h_o (mm)

$h_0 = 2 * r * \sin\beta$ = 0.060 m

xiv. Distance from point A to Drum surface h_1 =

$$h_1(\emptyset_1, R) = r * \sin\left(\text{acos}\left(\frac{R * \cos\left(\beta(\emptyset_1).deg\right)}{r}\right)\right) - h_0(\emptyset_1, R)$$

= 0.005 m

xv. Moment due to friction at trailing end =

$$M_f = \frac{P_{max}}{2} * \mu * r * \omega\left[4r\sin\left(\frac{\emptyset_0}{2}\right) - R(\emptyset_0 + \sin(\emptyset_0)\ cos\alpha\right]$$

= 116.40 N-m

xvi. Moment due to Pressure at trailing end =

$$M_p = \frac{P_{max}}{2} * R * r * \omega[\emptyset_0 + \sin(\emptyset_0)\sin\alpha]$$

= 310.88 N-m

2.4 3D Model

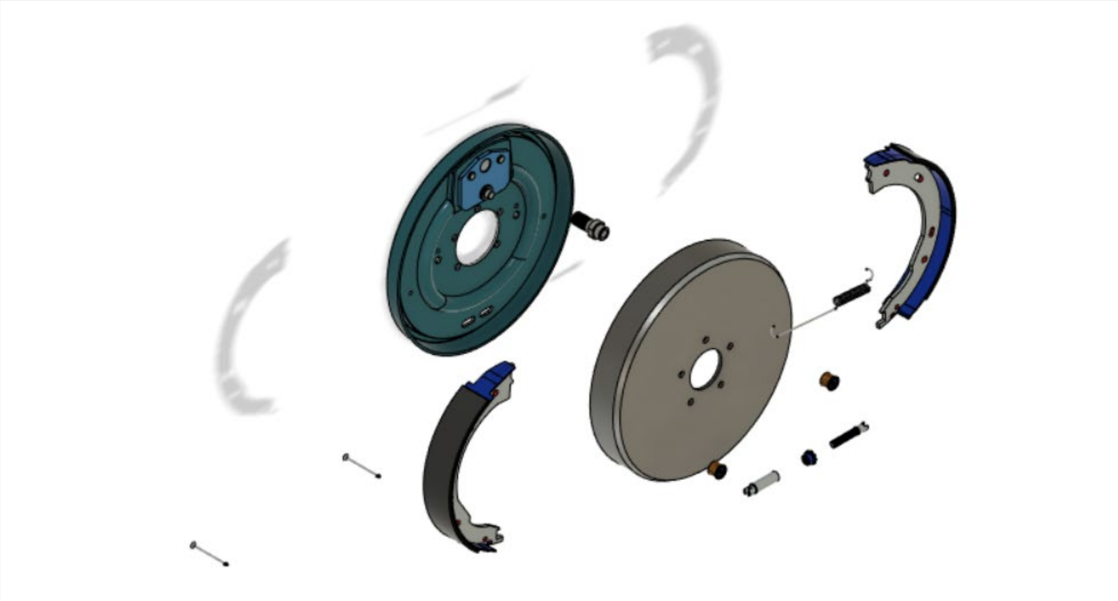

FIGURE 16 - EXPLODED VIEW OF DRUM BRAKE

2.5 Simulation

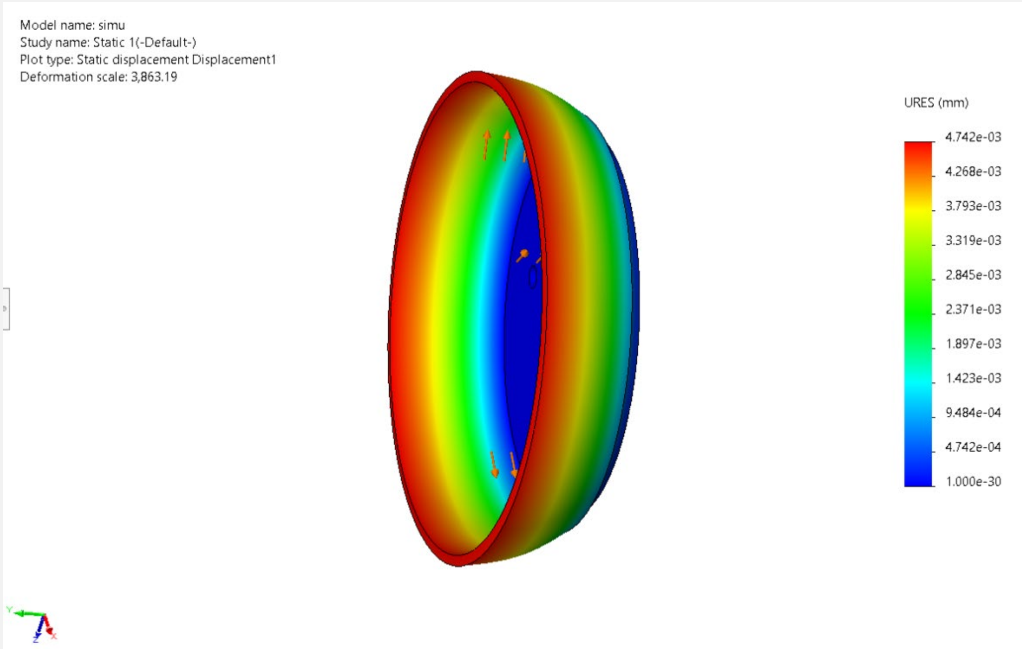

Figure 17 - Displacement Analysis

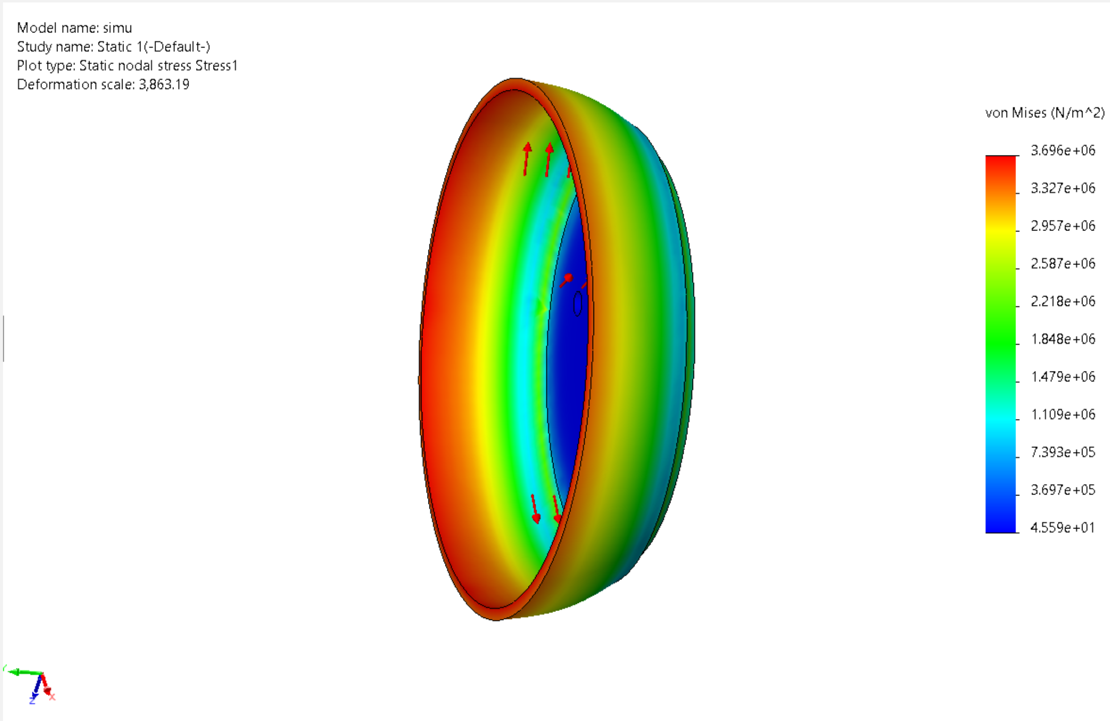

Figure 18 - Static Stress Analysis

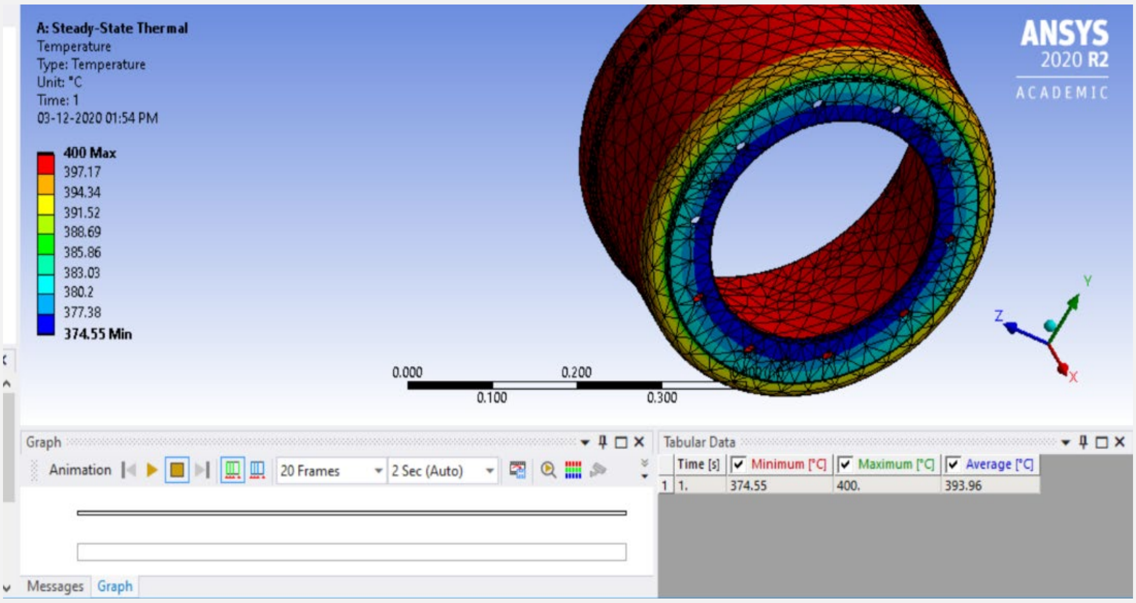

FIGURE 19 - THERMAL ANALYSIS OF DRUM

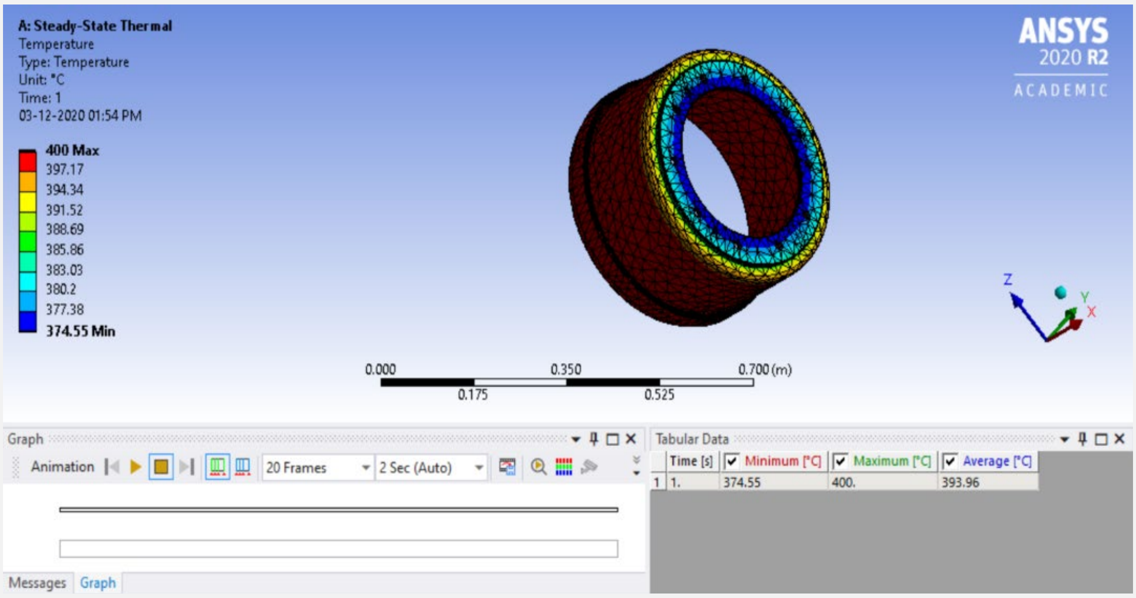

FIGURE 20 - THERMAL ANALYSIS OF DRUM

According to some research, the typical range of temperature of drum brakes is 300^0 C to 500^0 C. So, we assume the temperature of drum brake is 400^0 C in thermal analysis.

2.6 Advantages and Disadvantages

Advantages:

- Less expensive
- Weight savings, much smaller and lighter hydraulics cylinders as compared to calipers.
- Lower maintenance is required due to good corrosion resistance compared to disk
- Required less input force for braking.

Disadvantages:

- Chances of overheating of brake shoes
- During hard braking, the chances of increase in diameter of drum due thermal expansion
- Maintenance of drum brake is relatively more time consuming

3 Conclusion

From the above calculations and analysis, we can conclude that designing disc or drum brake for any automobile is an iterative process. For designing, we need to assume bunch of data. We also have to consider the material and its' mechanical properties so that it can withstand at least theoretical loads. Also, for the simulation part, it is advisable to use more sophisticated software such as Ansys workbench which allows to define the inputs accurately and concisely and is capable of providing more accurate graphical results so that we can change design accordingly. Also using Fusion 360 gives access to generative design feature in which we can tweak designs of discs. Although drum brakes are outdated in nature but it is still being used as parking brake in most of automobiles.

4 Works Cited

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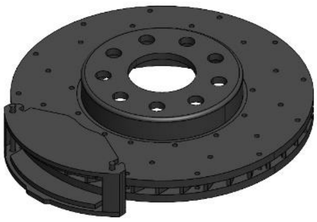


Simulation of Brake Disc v13

Date: 04 December 2020
Designer: Solidworks
Study name: Static 1
Analysis type: Static

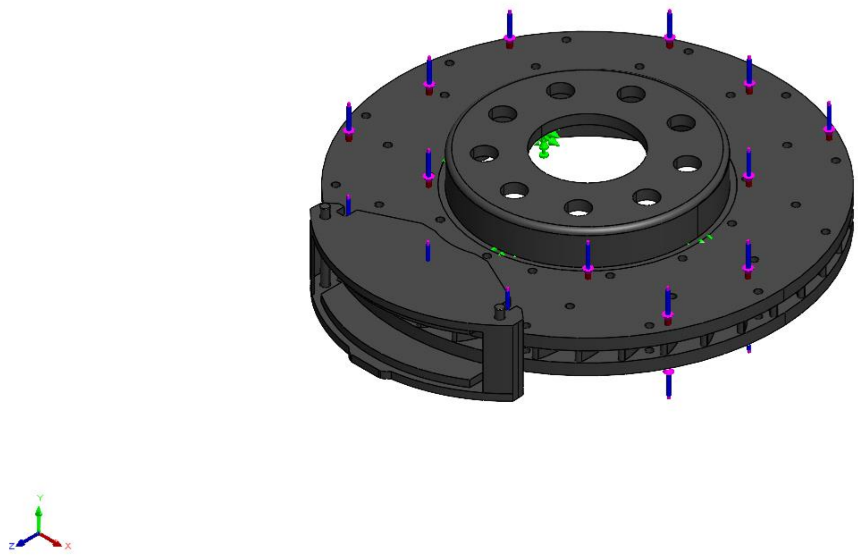
Table of Contents

Description

No Data

Assumptions

Model Information



Model name: Brake Disc v13
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
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Brake Disc v13.iges	Solid Body	**Mass:0.0121799 kg** **Volume:1.69165e-06 m^3** **Density:7,200 kg/m^3** **Weight:0.119363 N**	**C:\Users\Admin\AppData\Local\Temp\swx20660\IC~~\Component8.iges.SLDPRT** Dec 4 16:24:24 2020

Study Properties

Study name	Static 1
Analysis type	Static
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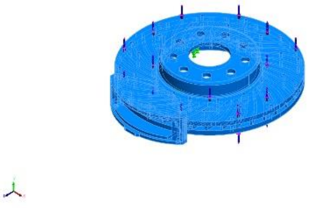
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (D:\Sem VII\Automobile Engineering\Project\Disc Brake)

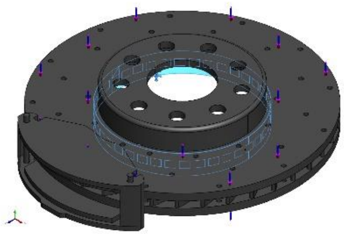
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

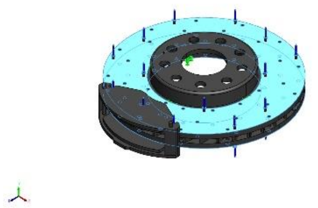
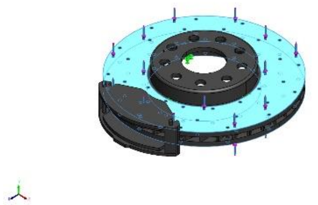
Model Reference	Properties	Components
	**Name:** Gray Cast Iron **Model type:** Linear Elastic Isotropic **Default failure criterion:** Mohr-Coulomb Stress **Tensile strength:** 1.51658e+08 N/m^2 **Compressive strength:** 5.72165e+08 N/m^2 **Elastic modulus:** 6.61781e+10 N/m^2 **Poisson's ratio:** 0.27 **Mass density:** 7,200 kg/m^3 **Shear modulus:** 5e+10 N/m^2 **Thermal expansion coefficient:** 1.2e-05 /Kelvin	SolidBody 1(Brake Disc v13.iges)(Brake Disc v13.iges-1/Component1.iges-1), SolidBody 1(Brake Disc v13.iges)(Brake Disc v13.iges-1/Component2.iges-1), SolidBody 1(Brake Disc v13.iges)(Brake Disc v13.iges-1/Component3.iges-1), SolidBody 1(Brake Disc v13.iges)(Brake Disc v13.iges-1/Component7.iges-1), SolidBody 1(Brake Disc v13.iges)(Brake Disc v13.iges-1/Component8.iges-1)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-2		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

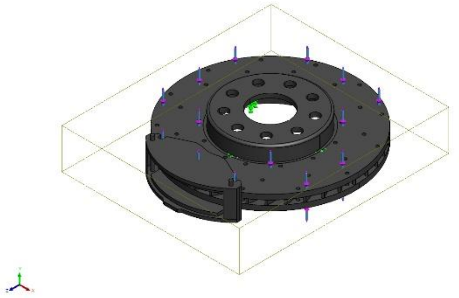
Components	X	Y	Z	Resultant
Reaction force(N)	-0.00714111	-0.013092	-0.0214891	0.0261568
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		**Entities:** 2 face(s) **Type:** Apply normal force **Value:** 909.875 N
Temperature-1		**Entities:** 2 face(s) **Temperature:** 478 Celsius

Connector Definitions

No Data

Contact Information

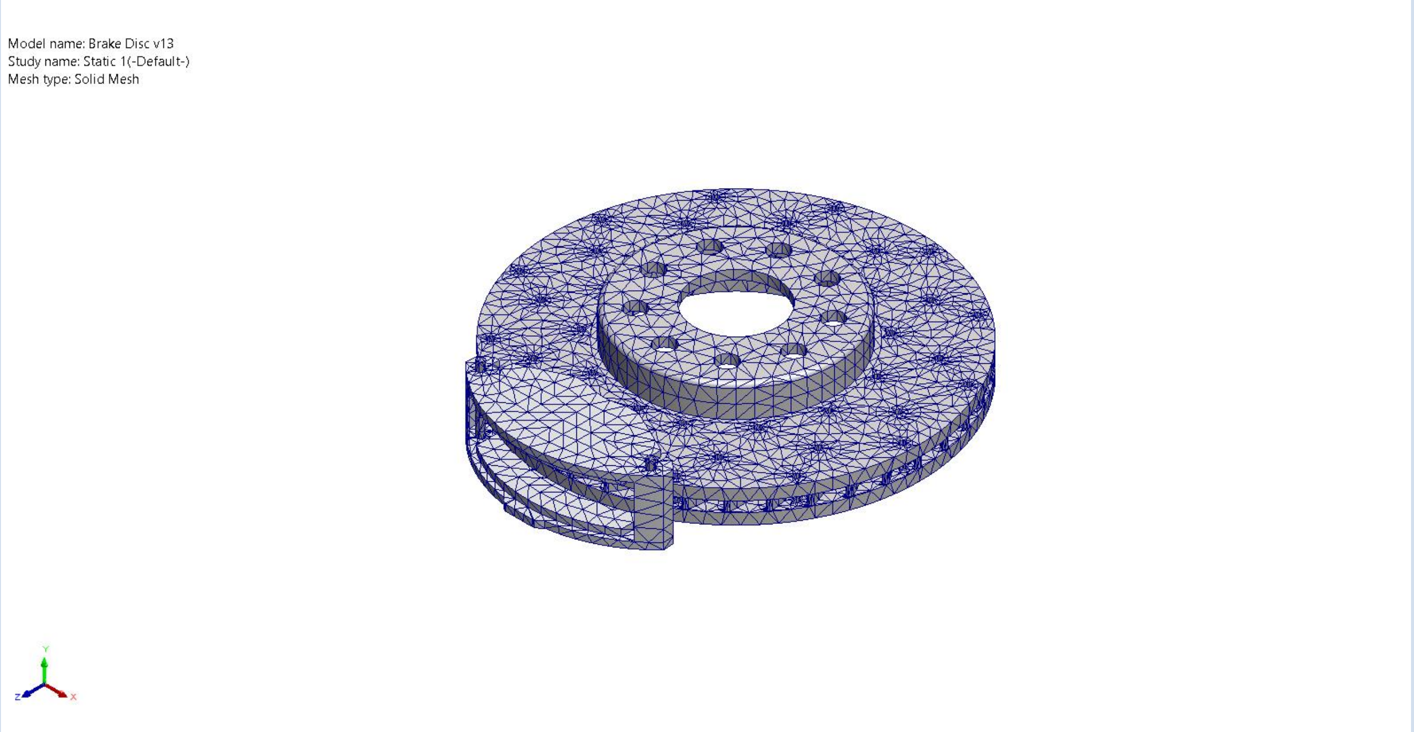
Contact	Contact Image	Contact Properties
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Incompatible mesh

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High quality mesh	16 Points
Element Size	10.1633 mm
Tolerance	0.508163 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off

Mesh information - Details

Total Nodes	59867
Total Elements	32212
Maximum Aspect Ratio	40.798
% of elements with Aspect Ratio < 3	70.2
Percentage of elements with Aspect Ratio > 10	0.475
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:36
Computer name:	ALTEREGO



Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.00714111	-0.013092	-0.0214891	0.0261568

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.0208234	0.00831065	-0.0313415	0.0385353

Free body moments

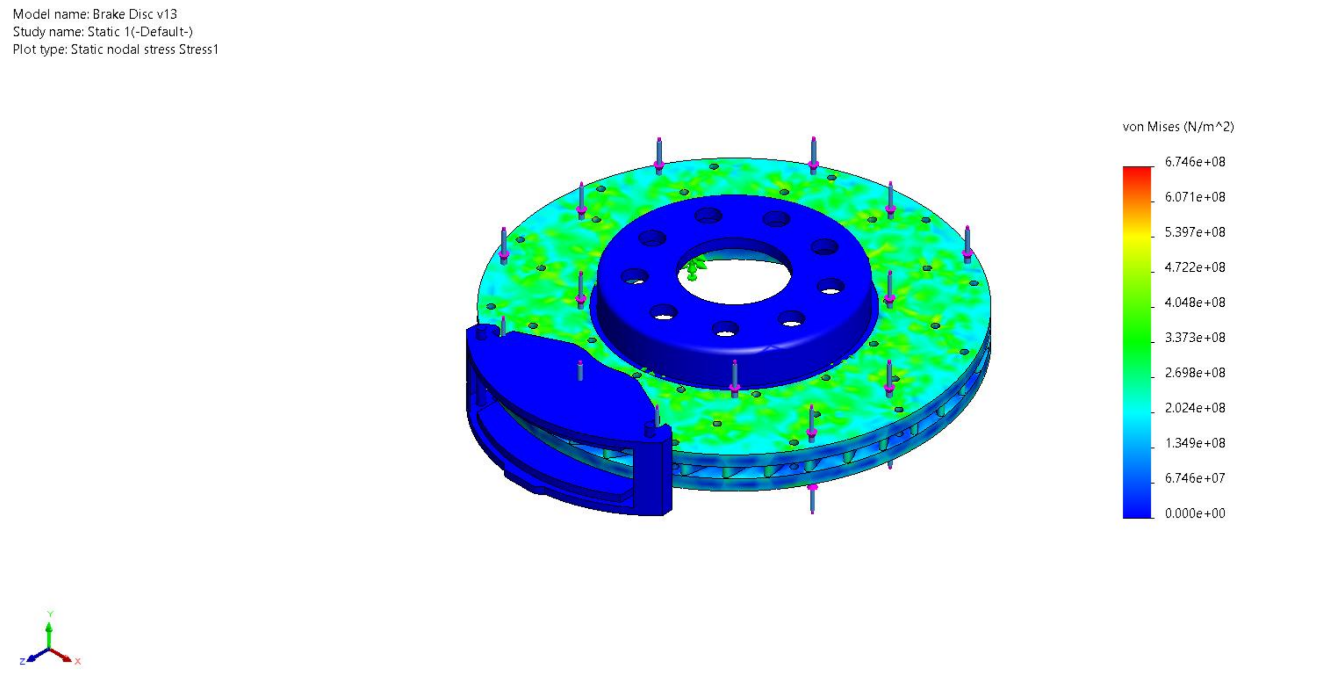
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

Beams

No Data

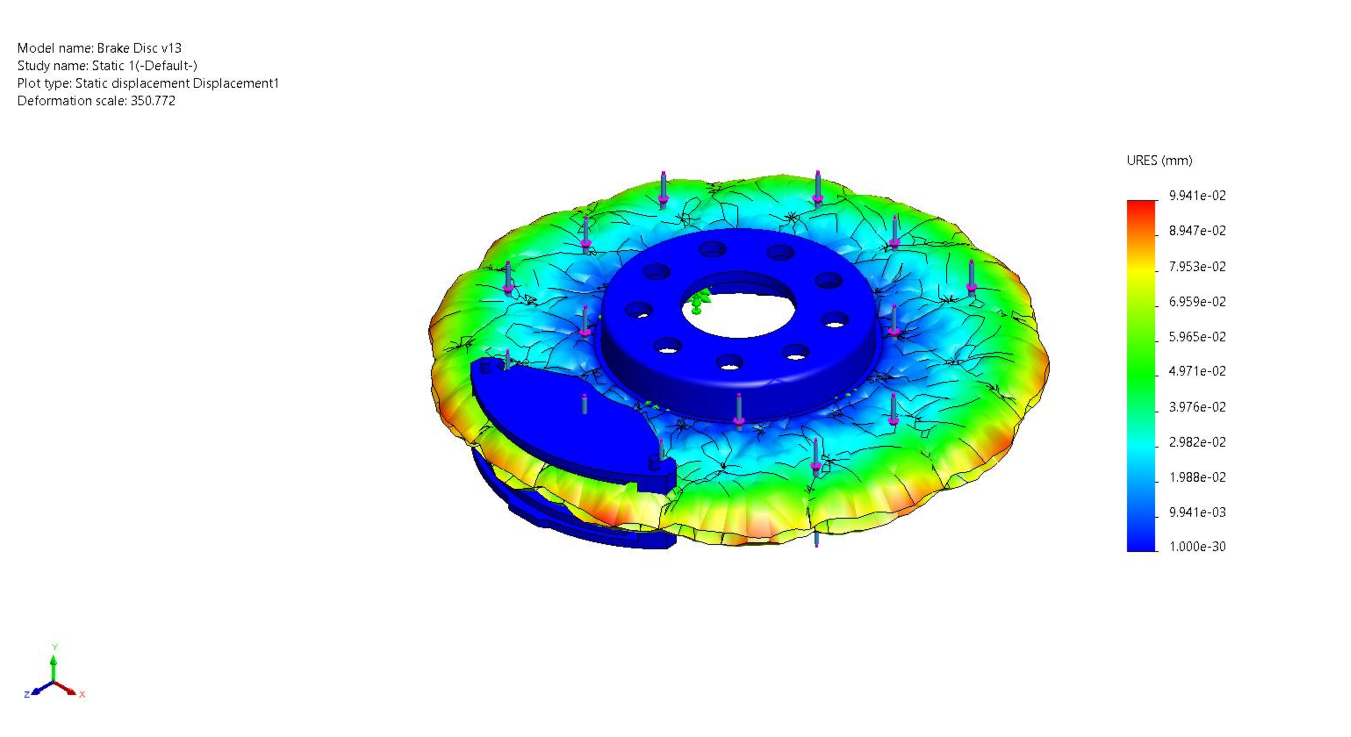
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000e+00N/m^2 Node: 49511	6.746e+08N/m^2 Node: 46303



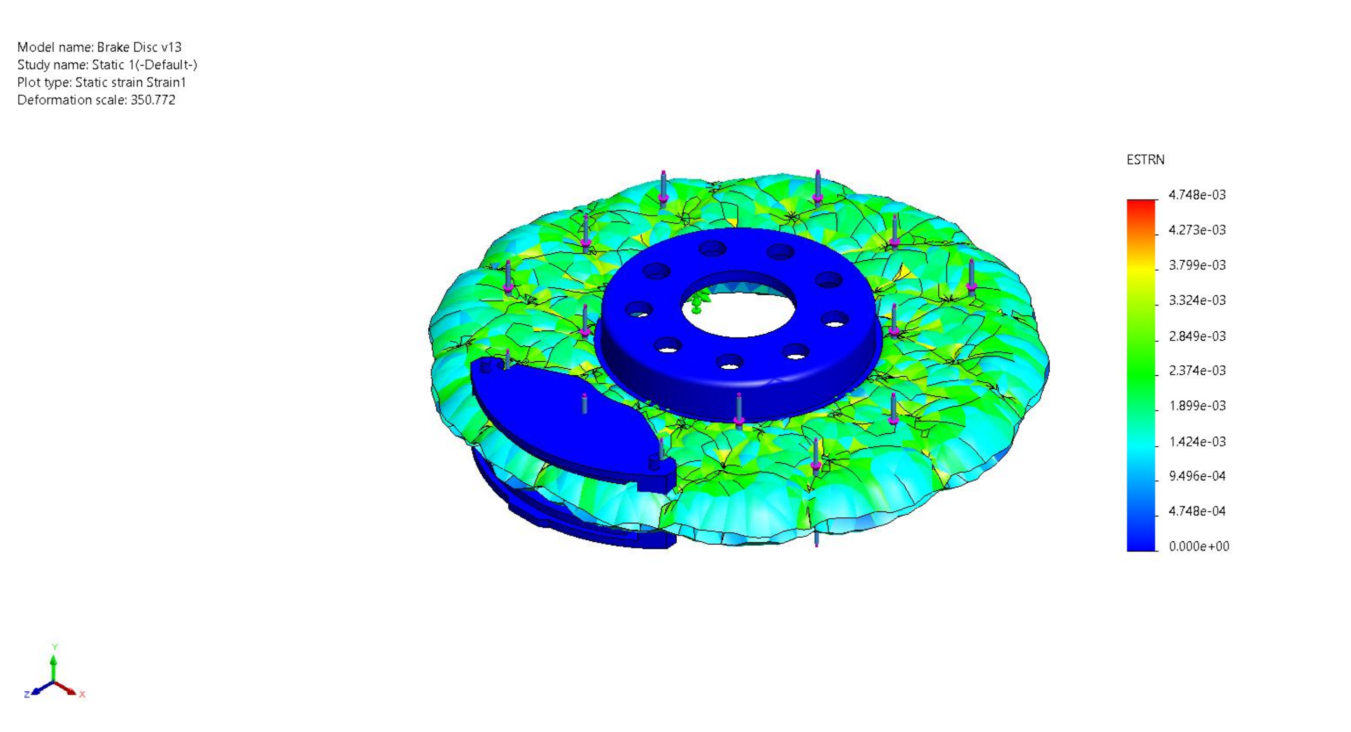
Brake Disc v13-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1395	9.941e-02mm Node: 2056



Brake Disc v13-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000e+00 Element: 27234	4.748e-03 Element: 7082



Brake Disc v13-Static 1-Strain-Strain1

Conclusion

Simulation of simu

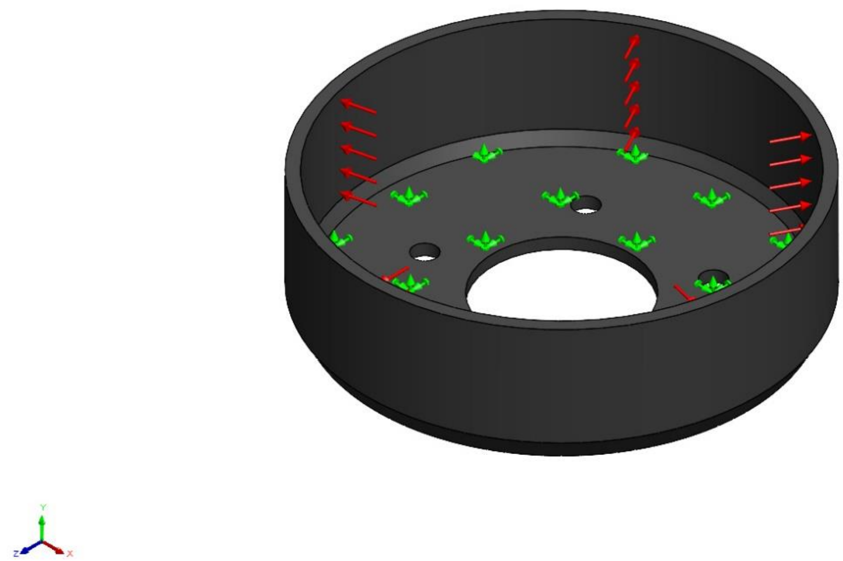
Date: 04 December 2020
Designer: Solidworks
Study name: Static 1
Analysis type: Static

Description
No Data

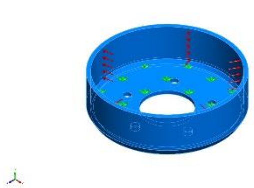
Table of Contents

Assumptions

Model Information



Model name: simu
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Component2DRUM180.iges 	Solid Body	**Mass:1.69697 kg** **Volume:0.000235714 m^3** **Density:7,199.3 kg/m^3** **Weight:16.6303 N**	**D:\Sem VII\Automobile Engineering\Project\drum sim\simu.SLDPRT** Dec 4 11:45:34 2020

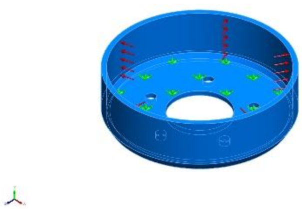
Study Properties

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (D:\Sem VII\Automobile Engineering\Project\drum sim)

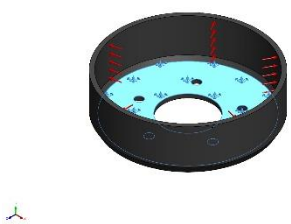
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

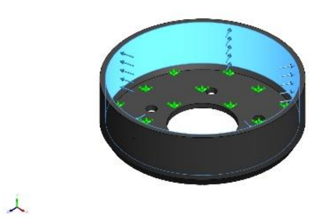
Model Reference	Properties	Components
	**Name:** Gray Cast Iron **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Tensile strength:** 1.51658e+08 N/m^2 **Compressive strength:** 5.72165e+08 N/m^2 **Elastic modulus:** 6.61781e+10 N/m^2 **Poisson's ratio:** 0.27 **Mass density:** 7,200 kg/m^3 **Shear modulus:** 5e+10 N/m^2 **Thermal expansion coefficient:** 1.2e-05 /Kelvin	SolidBody 1(Component2DRUM180.iges)(Component2DRUM180)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.069296	0.0708241	0.0659281	0.119015
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Pressure-1		**Entities:** 1 face(s) **Type:** Normal to selected face **Value:** 0.176122 **Units:** N/mm^2 (MPa) **Phase Angle:** 0 **Units:** deg

Connector Definitions
No Data

Contact Information
No Data

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High quality mesh	16 Points
Element Size	4.55879 mm
Tolerance	0.22794 mm
Mesh Quality	High

Mesh information - Details

Total Nodes	37644
Total Elements	20838
Maximum Aspect Ratio	4.0307
% of elements with Aspect Ratio < 3	99.8
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:09
Computer name:	ALTEREGO

Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.069296	0.0708241	0.0659281	0.119015

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.134135	-0.987145	0.246455	1.02625

Free body moments

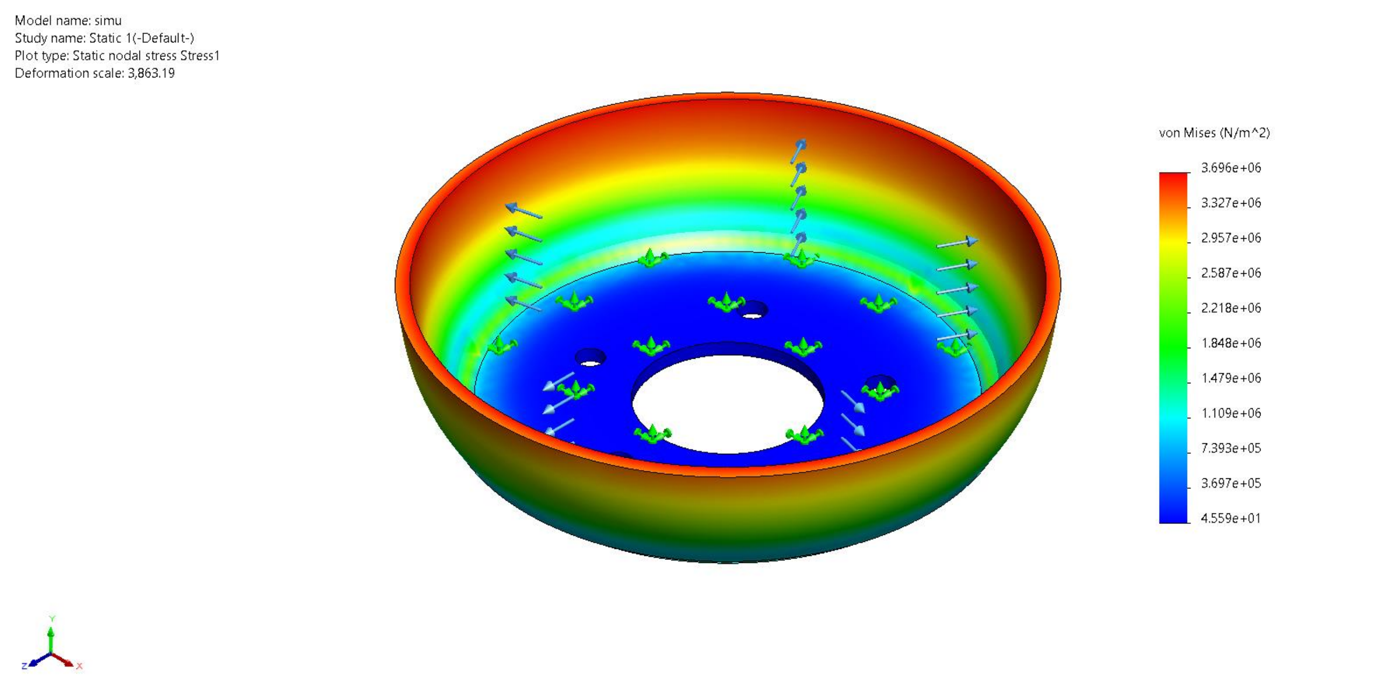
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

Beams

No Data

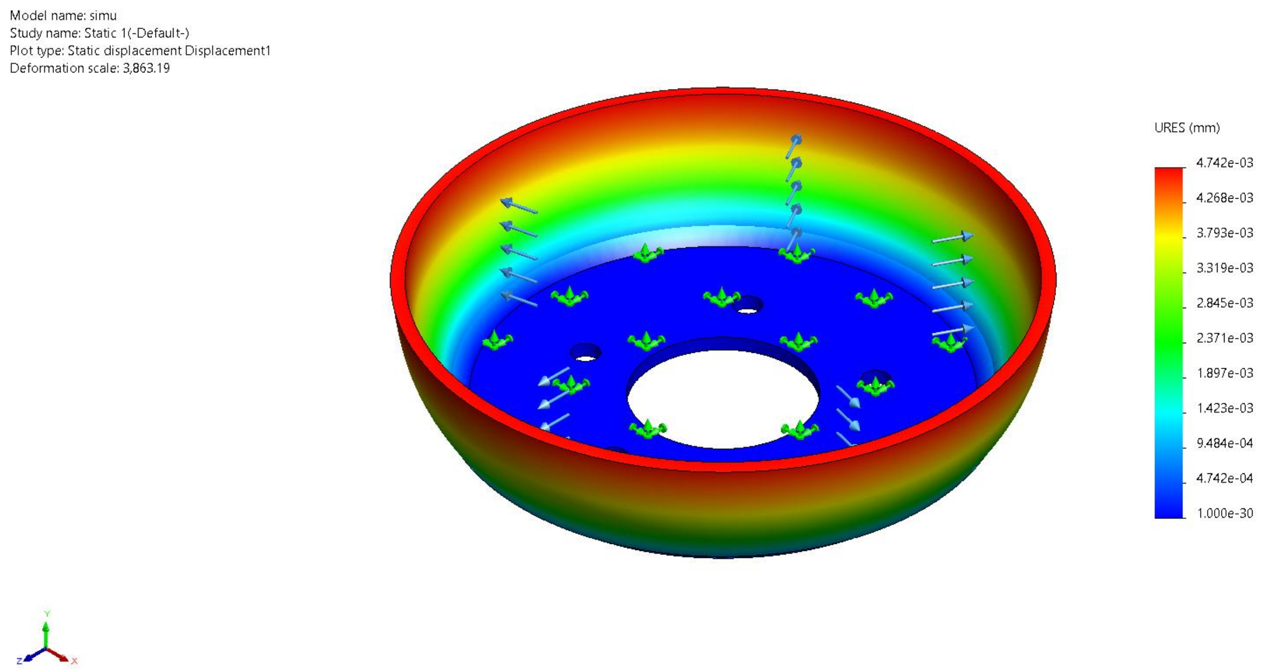
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.559e+01N/m^2 Node: 37334	3.696e+06N/m^2 Node: 1813



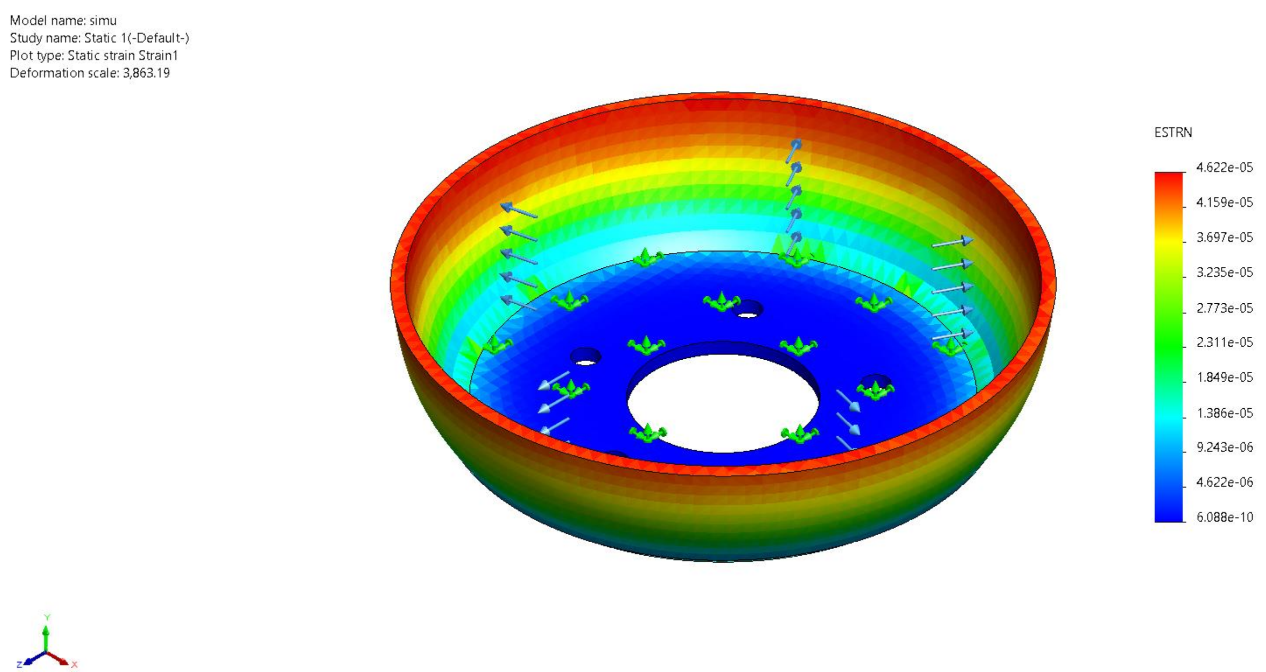
simu-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1	4.742e-03mm Node: 2256



simu-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.088e-10 Element: 7794	4.622e-05 Element: 19403



simu-Static 1-Strain-Strain1

Conclusion