DESIGN AND ANALYSIS OF REINFORCED COMPOSITE MATRIX DISC BRAKE

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ABSTRACT: Each single system has been studied and developed in order to meet safety requirement. Instead of having air bag, good suspension systems, good handling and safe cornering, there is one most critical system in the vehicle which is brake systems. Without brake system in the vehicle will put a passenger in unsafe position. Therefore, it is must for all vehicles to have proper brake system. In this paper carbon ceramic matrix disc brake material and steel material use for calculating normal force, shear force and braking torque. And also calculating the brake distance of disc brake. The standard disc brake (Four) wheelers model using in Ansys and done the Static Structural analysis also calculate the deflection of the brake model. This is important to understand action force and friction force on the disc brake new material, how disc brake works more efficiently, which can help to reduce the accident that may happen in each day.

Keywords— *Disc Brake ,Static analysis, silicon –carbide, disc caliper, stainless steel.*

1. INTRODUCTION

Brakes are most important safety parts in the vehicles. Brakes function to slow and stop the rotation of the wheel. To stop the wheel, braking pads are forced mechanically against the rotor disc on both surfaces. The increases in travelling speeds as well as the growing weights of cars have made these improvements essential. An effective braking system is needed to accomplish this task with challenging term where material need to be lighter than before and performance of the brakes must be improved. Today's cars often use a combination of disc brakes and drum brakes. However, the effectiveness of braking system depends on the design itself and also the right selection of material. System that follow with some improvements. In order to understand the behaviors of braking system, there are three functions that must be complied for all the time

a) The braking system must be decelerate a vehicle in a controlled and repeatable fashion and when appropriate cause the vehicle to stop.

b) The braking should permit the vehicle to maintain a constant speed when traveling downhill.

c) The braking system must hold the vehicle stationary when on the flat or on a gradient.

2. STATEMENT OF PROBLEM

Brakes is such a crucial system in stopping the vehicle on all moving stages including braking during high speed, sharp cornering, traffic jam and downhill. All of those braking moments give a different value of temperature distribution and thermal stress.

This project concerns of the temperature distribution and constraint of the disc brake rotor. Most of the passenger cars today have disc brake rotors that are made of grey cast iron (Mackin, 2002). Grey cast iron is chosen for its relatively high thermal conductivity, high thermal diffusivity and low cost (Mackin, 2002). In this project, the author will investigate on the thermal issues of normal passenger vehicle disc brake rotor, High temperature during braking will caused to:

- Brake fade
- Premature wear
- Brake fluid vaporization
- Bearing failure
- Thermal cracks
- Thermally-excited vibration

Due to the application of brakes on the car disk brake rotor, heat generation takes place due to friction and this thermal flux has to be conducted and dispersed across the disk rotor cross section. The condition of braking is very much severe and thus the thermal analysis has to be carried out. The thermal loading as well as structure is axis-symmetric. Hence axis-symmetric analysis can be performed, but in this study we performed 3-D analysis, which is an exact representation for this thermal analysis.

3. BRAKE SYSTEMS

3. 1 PARTS OF DISC BRAKE

3. 1. 1 DISC CALIPERS

There are two types of disc calipers where further classified as floating and fixed caliper shows a type of floating caliper. This type of brake uses only a single piston to squeeze the brake pad against the rotor (BOSCH, 1992). The reactive force shifts the caliper housing and presses opposite side of braking pad against rotor. Referring to Figure the brake fluid pushes the piston when the brake is applied to the left of the piston and immediately pushes the inner pads and presses it against the rotor disc, the sliding caliper housing reacts by shifting towards right pushing the left pad against the disc. Floating Caliper Design (Source: BOSCH Automobile Handbook, 1992) Other type of disc calipers is a fixed caliper shows a type of fixed caliper. In these types of brakes, the caliper body is fixed and uses two or more pistons on each side of the rotor. The pistons are located in each half section of the fixed caliper.

3. 1. 2 BRAKE PADS

Brake pads consist of steel carrier which the pad are bonded to the steel carrier. According to (Gerschler, 1980), organically bonded pads consist of metallic, ceramic or organic friction materials in a bonded mass such as rubber or synthetic resin. The bonded friction materials can withstand temperatures up to 750°c, with short term peaks-up to 950'~ where the friction coefficient is between 0.25 and 0.5. There is an advantage of brake pads, where most of them are poor to thermal conductivity which protects the hydraulic actuating elements from overheating.

3. 1. 3 BRAKE DISC / DISC BRAKE ROTOR

The heat generated on the surfaces of disc brake rotor when brake applied. Materials of disc brake rotor usually are made from cast iron, spheroidal- graphite cast iron or cast steel. It is chosen as a rotor material due to low cost of material and performs high thermal resistance. This type of material normally suit to normal passenger vehicle but not for high performance car. Once brake pads contacts to rotating rotor, there will be huge amount of heat generated to stop or slow down the vehicle. The rotor temperature can exceed 350° for normal cars and 1500° for race cars (Halderman, 1992).

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4. MATERIAL PROPERTIES, CONSIDERATIONS AND CALCULATIONS

Table 4. 1 MATERIAL PROPERTIES OF THE DISC:

Material Properties	*Silicon Carbide- Reinforced Carbon Composite matrix*	*Stainless Steel*
young's Modulus	250 GPa	193 GPa
Density	1.8 g/cm^3	7750 Kg/m^3
Poisson's Ratio	0.32	0.31
Ultimate Tensile Strength	185 MPa	580 MPa
Bulk Modulus	250 GPa	151 GPa
Shear Modulus	220 GPa	81 GPa
Compressive Strength	3000 MPa	250 MPa

5. CALCULATIONS:

5. 1 DIMENSIONS OF THE DISC PLATE:

Assumptions made for proceeding with the calculations:

Brake disc diameter	:	355 mm
Contact area diameter (Inner)	:	340 mm
Contact area diameter (Outer)	:	190 mm
Pressure applied on the disc during braking	:	P_{max}

Axle diameter	:	85 mm
Hole diameter for bolting	:	20 mm
Disc thickness	:	33 mm
Caliper pad thickness	:	12 mm
Coefficient between disc and pad (Dry friction coefficient, **μ**)	:	0.5
Vehicle Curb Weight	:	20000 N
Axle weight distribution ratio (γ)	:	0.3
Initial velocity	:	112.5 m/s
Final velocity	:	0 m/s
Percentage of kinetic energy absorbed by the disc	:	0.9

Vehicle load on the disc (F_V) = Total load of the vehicle * Axle weight ratio

= 20000 N * 0.3

= 6000 N

Area of contact (A) = Area of segment from Outer radius – Area of segment from Inner radius

= 17463.931-1042.13 mm^2

= 16421.801 mm^2

P_{max} = Force on the disc/ Area of the contact

(1.5*20000)/A

= 1.82632 N/mm^2

i) *Tangential Load acting on the disc due to brake pressure:*

Normal load on the disc (F_N) = (P_{max}/2) * Area of the brake pad

= (1.82632/2)* 16421.801

= 14995.7318 N

Tangential Load (F_T) = Normal load * Coefficient of friction

= 14995.7318 * 0.5

= 7497.8659 N

Total load on disc while braking (F_S) = $F_N + F_T + F_V$

= 14995.7318+7497.8659+ 6000

= 28493.5977 N

ii) *Brake torque acting on the disc brake*:

Brake torque on the disc = Total load on the disc * Radius of the rotor disc

= (28493.5977 N) * 0.1675 N-m

= 4772.6776 N-m

iii) *Braking distance:*

Distance covered by the

Vehicle during braking = x

Work done during braking = Total load on the disc * Braking distance

.... (Eq.1)

Kinetic energy released

During braking = (mass of the vehicle *Velocity of the vehicle^2) / 2

…. (Eq.2)

Since,

Work done during braking = Kinetic energy released during braking

$F_S * x = (mv^2) / 2$

$28493.5977 \text{ N} * x = (20000 * [(\pi*355*4000)/60]^2) / 2$

Braking distance of the vehicle (x) = 31.5 m

6. MODELLING OF COMPOSITE BRAKE DISC

6. 1 GENERAL MODELING PROCESS FOR EACH PART

- Plan the part
- Create the base feature
- Create the remaining features
- Analyze the part

- Modify the features as necessary
- Assembly modelling

Assemblies can be created from parts, either combined individually or grouped in subassemblies. The CATIA V5 builds these individual parts and sub assemblies into an assembly in a hierarchical manner according to relationships defined cy constrains.

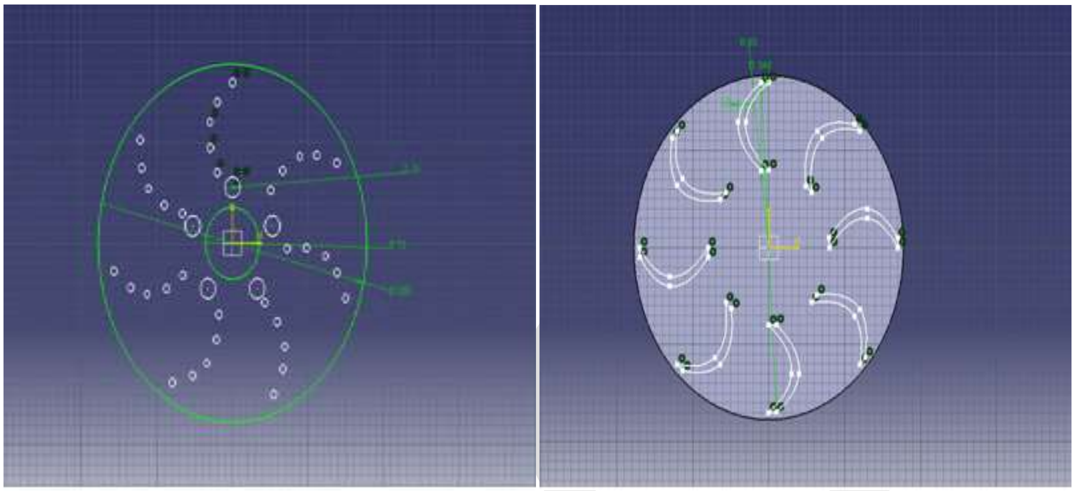

Fig 6.1 2-D View Of Disc Rotor(Composite And Solid Rotor) And 2-D View Of Disc Rotor (Vented Rotor)

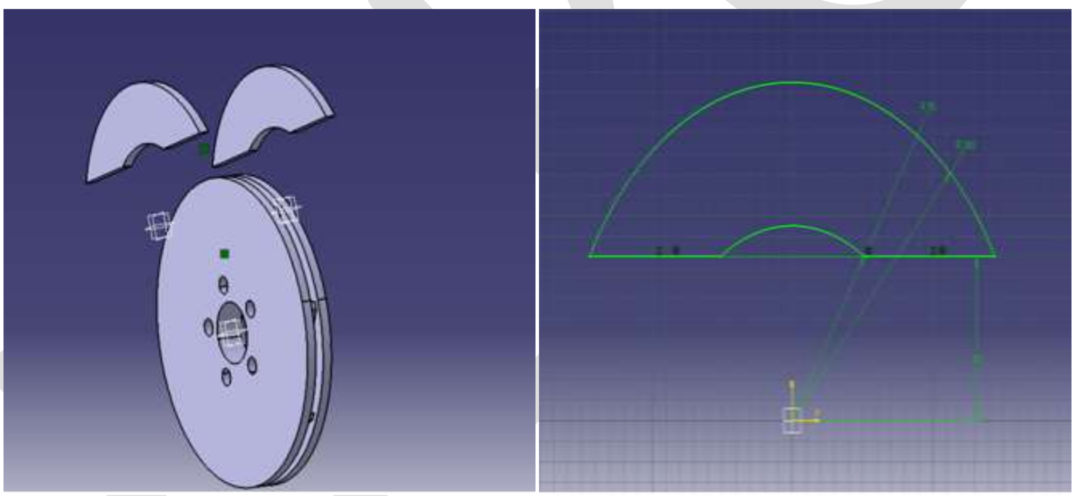

Fig 6.2 Exploded View Of Rotor Disc Assembly And 2-Dimensional View Of Friction Pad

7. ANALYSIS OF COMPOSITE BRAKE DISC

7.1.1 STRUCTURAL STATIC ANALYSIS:

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects such as those caused by time varying loads. A static analysis can, however include steady inertia loads (such as gravity and rotational velocity), and time varying loads that can be approximated as static equivalent loads (such as static equivalent wind and seismic loads.

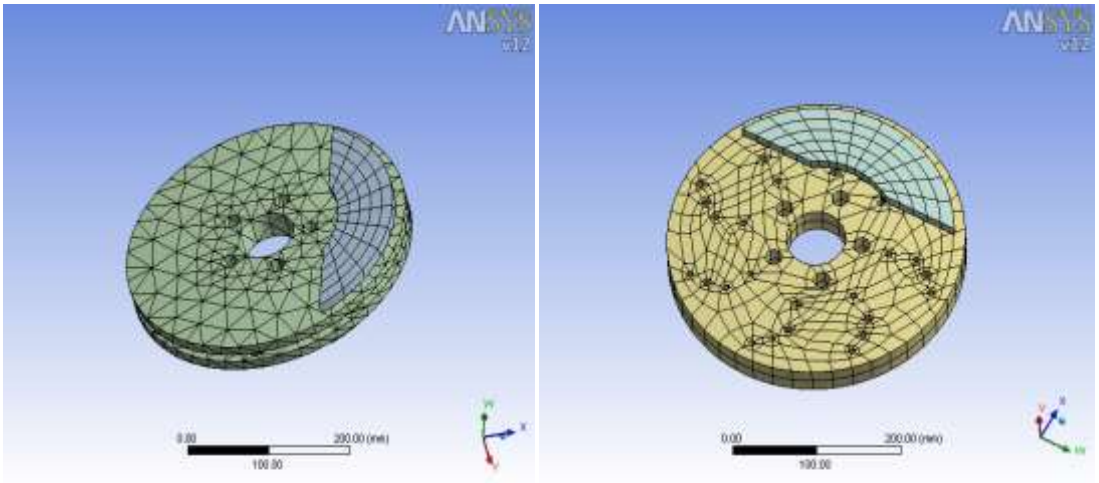

Fig 7.1 Meshed Model Of The Vented Disc Rotor And Meshed Model Of Solid Disc Rotor

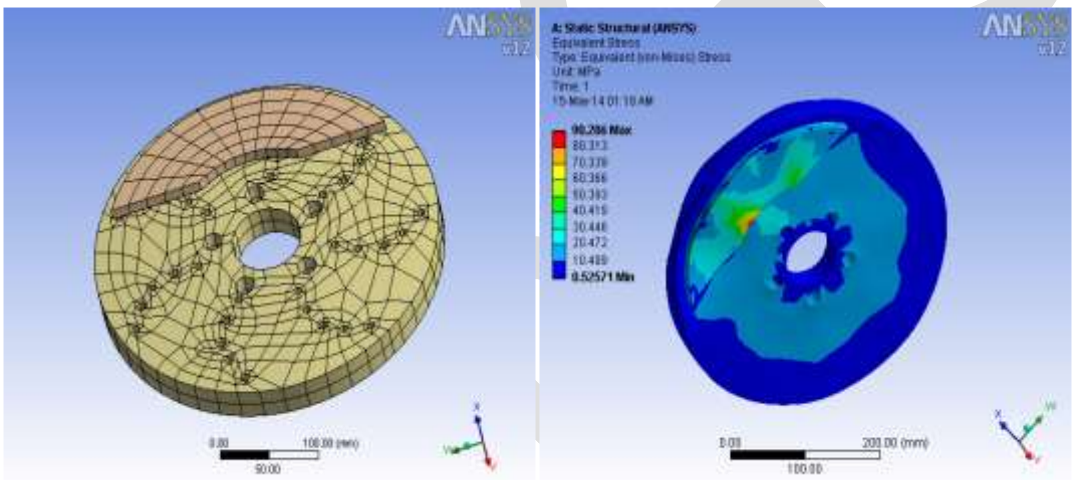

Fig 7.2 Meshed Model Of Composite Disc Rotor And Equivalent Sress Vented Disc Rotor

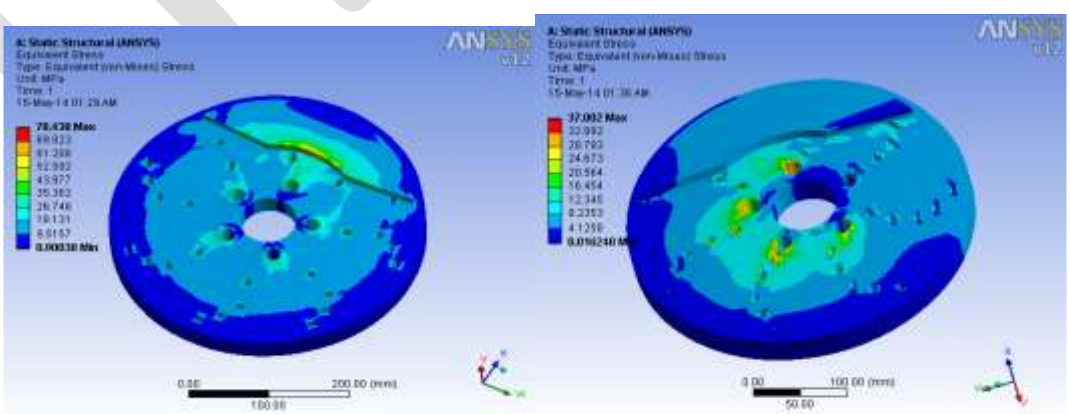

Fig 7.3 Equivalent Stress- Solid Disc Rotor And Equivalent Strain-Vented Disc Rotor

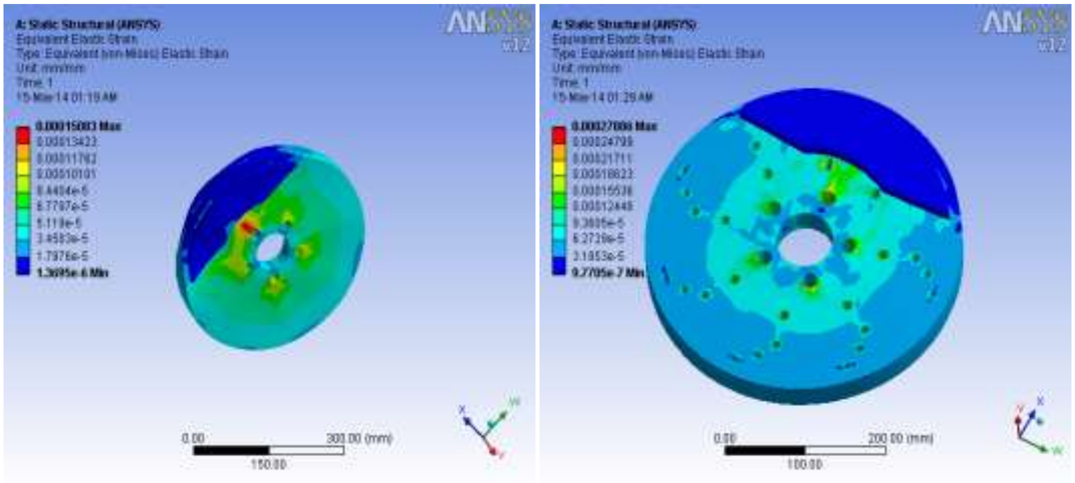

Fig 7.4 Equivalent Strain-Vented Disc Rotor And Equivalent Strain-Solid Disc Rotor

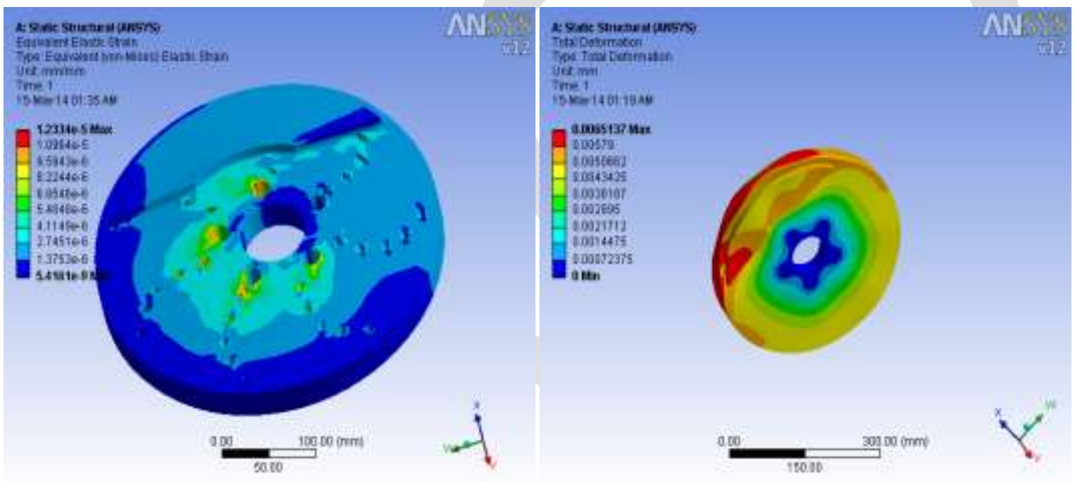

Fig 7.5 Equivalent Strain- Composite Disc Rotor And Total Deformation- Vented Disc Rotor

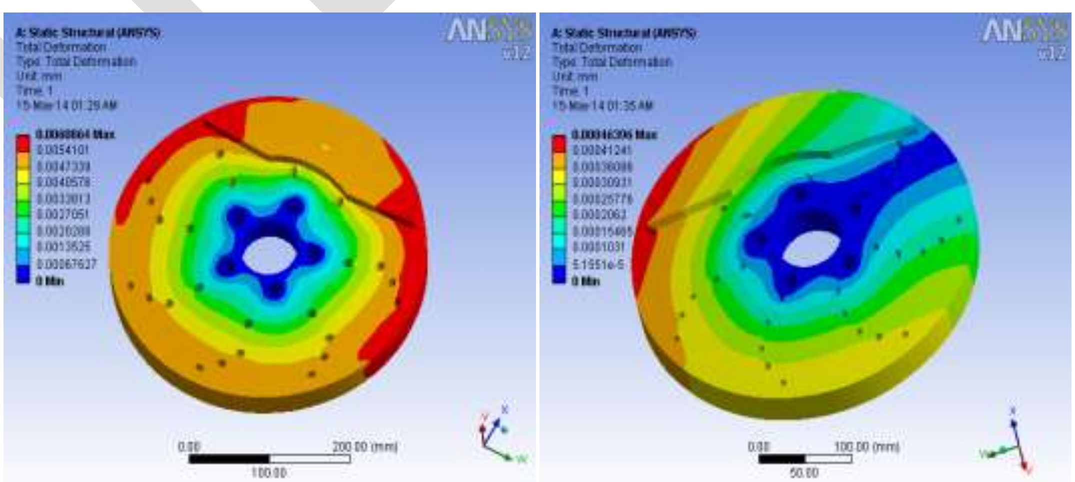

Fig 7.6 Equivalent Strain- Solid Disc Rotor And Equivalent Strain- Composite Disc Rotor

10. CONCLUSION

From the results obtained above, we can come to the conclusion that:

- Practical use of C-SiC composite material produces much effective braking compared to steel disc brakes.
- Deformation in steel is much higher than composite, which implies the deformation resistance of the composite structure than the steel material.
- Stress accumulated on the composite is much less, which proves the wear resistance, rigid & stable braking during high speeds.

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