Thermal and Structural Analysis using FEA on Pillar Vans Type Ventilated Disc Brake Rotor

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Abstract— Safety aspect in automotive engineering has been considered as a number one priority in development of new vehicle. Each single system has been studied and developed in order to meet safety requirement. Instead of having good suspension systems, Air bags, 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. For the purpose of safety and increased life cycle of the disc brakes this paper deals with the design modification of a disc break so as to produce better thermal and structural performance.

Key words: Disc Brake, FEA, Suspension Systems

I. INTRODUCTION

The brakes are one of the most important aspects of a vehicle since it fulfills all the stopping functions and requirements. A brake is a device by means of which artificial frictional resistance is applied to moving machine member, in order to stop the motion of a machine. Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. During the braking phase, the frictional heat generated at the interface disc - pads can lead to high temperatures. This phenomenon is even more important that the tangential stress as well as the relative sliding speeds in contact is important. As trivial as brakes may appear to be, many issues surround their heating characteristics when it comes to their development, including material choice, contact region properties, development of hot spots, associated physical geometry, and thermo-elastic deformations.

A. Component of Disc Brake:

1) Calliper
2) Brake pads
3) Brake Pad Materials:
- Asbestos
- Non-Asbestos Organics
- Semi-Metallic
- Low Steel
- Carbon
4) Piston and cylinder
5) Disc brake rotor

B. Disc brake rotor:

The disc brake rotor is the disc component against which the brake pads are applied. The ventilated type rotor consists of holes, slots and cooling fins to ensure good cooling.

Many high performance brakes have holes drilled through them for a heat dissipation purpose which is known as cross-drilling. Slotted Discs are mostly preferred in racing cars, within which shallow channels are machined thus, helping in removing dust, gas and water. Some disc are both drilled and slotted. In the wet condition the slotted and drilled rotor have a positive effect.

Material of disc rotor:

1) Nickel Chrome Steel.
2) Aluminum Alloy.
3) Cast Iron.
4) Carbon Reinforced polymer.
5) Titanium Alloy.

II. DISC BRAKE ROTOR FAILURE MODES

The various types of disc brake failures are explained in the following sections.

- Thermo-mechanical distortion
- Cracking

Problems in disc brake by applying brake, shoo pad is grip the disc of disc brake due to that stopping of their rotation and converting kinetic energy in to heat energy due to rapidly apply brake there is thermal expansion of disc. Due to thermal Expiation of disc brake jamming of disc in brake shoo.

Static analysis is used to determine the displacements, stresses, strains and forces in structures or components due to the loads that do not include significant inertia and damping effects. Steady loading in response conditions are assumed. The kind of loading that can be applied in a static analysis include externally applied forces and pressures, steady state Inertia forces such as gravity or rotational velocity imposed (non zero) displacements, temperatures (for thermal strain).

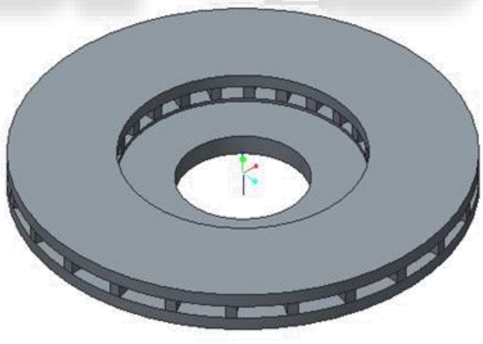

Fig. 1: Model of Disc Brake Rotor

III. MATERIAL PROPERTIES

A. Cast Iron:

Cast iron usually refers to grey cast iron, but identifies a large group of ferrous alloys, which solidify with a eutectic. Iron accounts for more than 95%, while the main alloying elements are carbon and silicon. The amount of carbon in cast iron is the range 2.1-4%, as ferrous alloys with less are denoted carbon steel by definition. Cast irons contain appreciable amounts of silicon, normally 1-3%, and consequently these alloys should be considered ternary Fe-C-Si alloys. Here graphite is present in the form of flakes. Disc brake discs are commonly manufactured out of a material called grey cast iron.

Properties of Outline Row 5: cast iron validation

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	6600	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	1.5E-07	K^-1		
5	Reference Temperature	22	C		
6	Isotropic Elasticity				
7	Derive from	Young's M...			
8	Young's Modulus	1.1E+11	Pa		
9	Poisson's Ratio	0.25			
10	Bulk Modulus	7.3333E+10	Pa		
11	Shear Modulus	4.4E+10	Pa		
12	Isotropic Thermal Conductivity	50	W m^-1 ...		
13	Specific Heat	380	J kg^-1 C...		

Fig. 2: Material Properties of Cast Iron

Properties of Outline Row 3: stainless steel validation

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7100	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	1.2E-07	K^-1		
5	Reference Temperature	22	C		
6	Isotropic Elasticity				
7	Derive from	Young's M...			
8	Young's Modulus	2.1E+11	Pa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.75E+11	Pa		
11	Shear Modulus	8.0769E+10	Pa		
12	Isotropic Thermal Conductivity	36	W m^-1 ...		
13	Specific Heat	320	J kg^-1 C...		

Fig. 3: Material Properties of Stainless Steel

In the finite element analysis, the basic concept is to analyze the structure, which is an assemblage of discrete pieces called elements, which are connected together at a finite number of points called Nodes. A network of these elements is known as Mesh. As shown in fig.

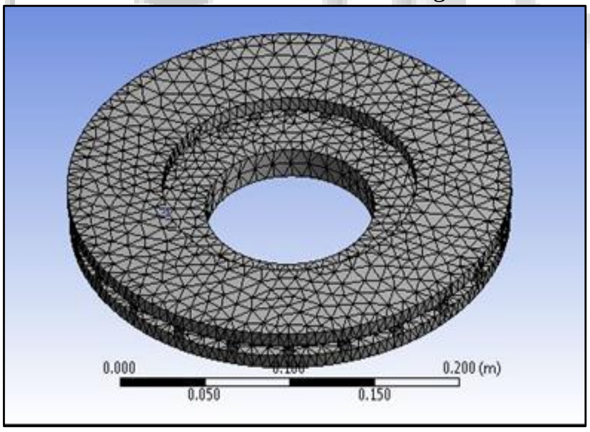

Fig. 4: Meshed Model

IV. THERMAL ANALYSIS

A. Heat Convection:

Energy is carried away from the surface by convection that is motion of the air removes the heated air near the surface and replaces it with cooler air. The finding by Sheridan (1988) suggested that 90% of the heat generated during braking is transferred by convection to the ambient air.

$$Q_{conv} = h_{As} (T_s - T_\infty) \qquad (1)$$

B. Static and structural analysis:

A static analysis calculates the effects of steady loading condition on a structure, while ignoring inertia and damping efforts 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 wind and seismic loads commonly defined in many building codes).

C. Dimensions of disc brake:

The dimensions of brake disc used for thermal and static structural analysis are shown in fig.
Outer diameter = 262 mm
Inner diameter = 60 mm
Thickness = 24 mm
Air gap = 8 mm
No. of vans = 24

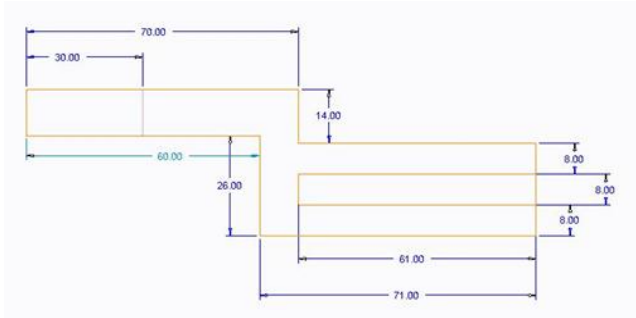

Fig. 5: Dimension of the Disc Brake Rotor

D. Input Parameters:

The input parameters are as follows:
1) Mass of the vehicle = 2500 kg
2) Initial velocity (u) = 27.78 m/s (100 kmph)
3) Vehicle speed at the end of the braking application (v) = 0 m/s
4) Brake rotor diameter = 0.262 m
5) Axle weight distribution 30% on each side (γ) = 0.3
6) Percentage of kinetic energy that disc absorbs (90%) k = 0.9
7) Acceleration due to gravity g = 9.81m/s2
8) Coefficient of friction for dry pavement μ = 0.7
9) Diameter of the drill holes = 8 mm
10) No. of holes = 24 on each face

1) Case 1:

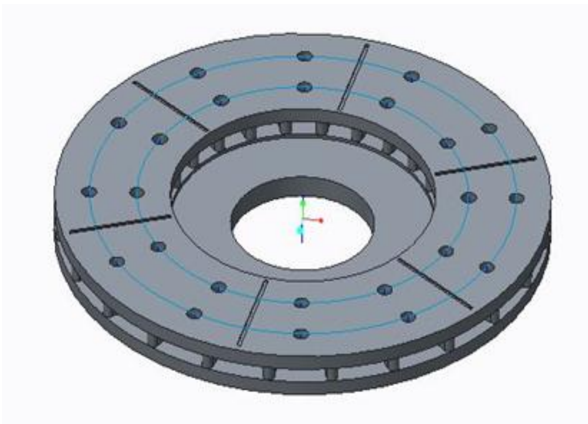

Fig. 6: Ventilated Type Drilled Disc Rotor with Face Groove

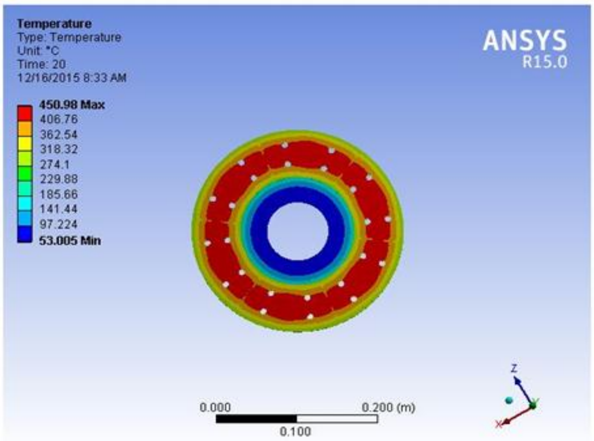

Fig. 7: Temperature Contours for Ventilated Type Drilled Disc Rotor of Cast Iron

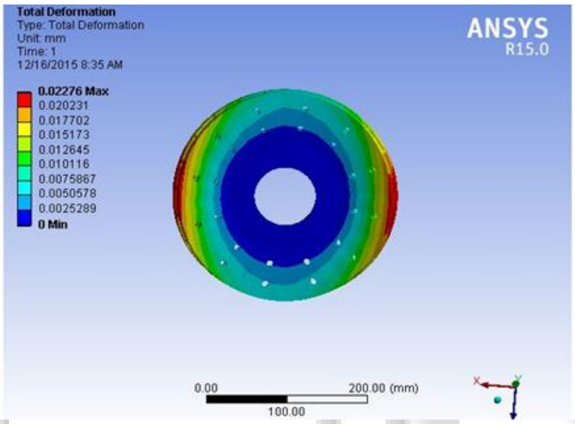

Fig. 8: Total Deflection of Ventilated Type Drilled Disc Rotor of Cast Iron

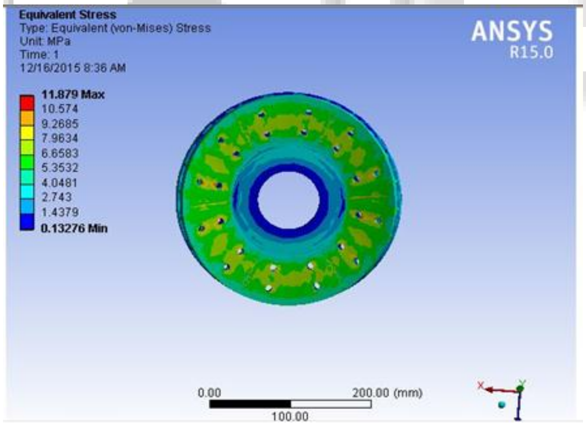

Fig. 9: Von Misses Stress on Ventilated Disc Rotor of Cast Iron

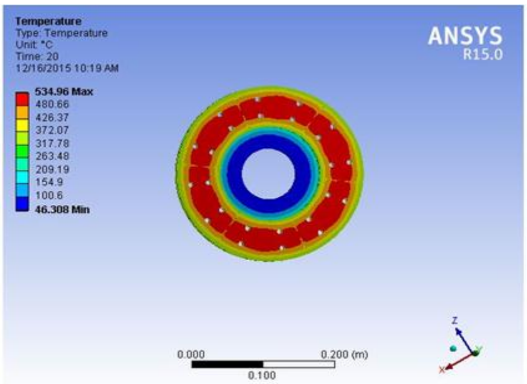

Fig. 10: Temperature Contours for Ventilated Type Drilled Disc Rotor of Stainless Steel

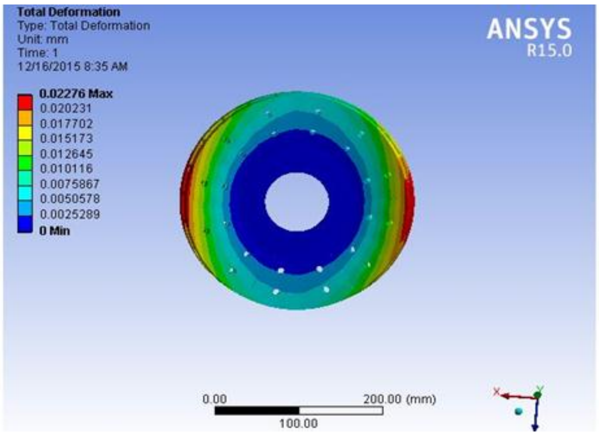

Fig. 11: Total Deflection of Ventilated Type Drilled Disc Rotor of Stainless Steel

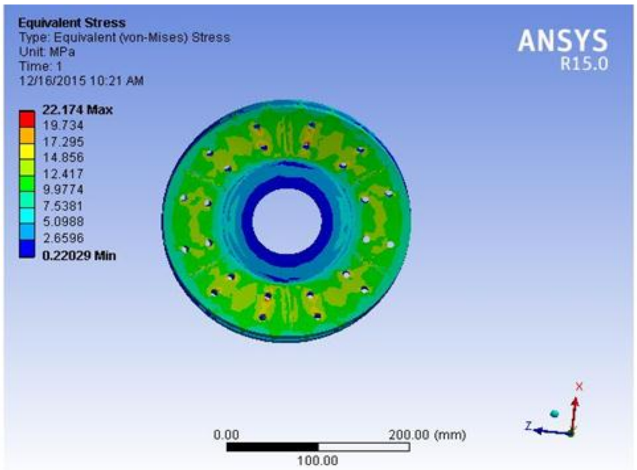

Fig. 12: Von Misses Stress on Ventilated Disc Rotor of Stainless Steel

2) Case 2:

Now for the different model which is dimensionally different from previous model, same condition is applied.

Flange width = 9 mm each face

Air gap = 6 mm

Vent = pillared type as shown in fig 13.

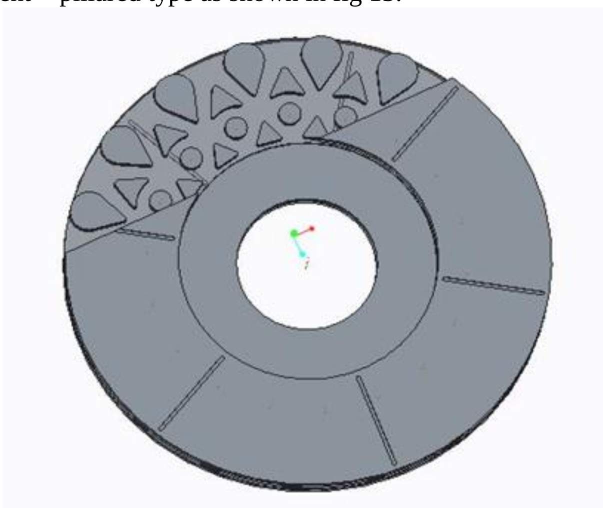

Fig. 13: Ventilated Type Disc Rotor with Pillared Vans

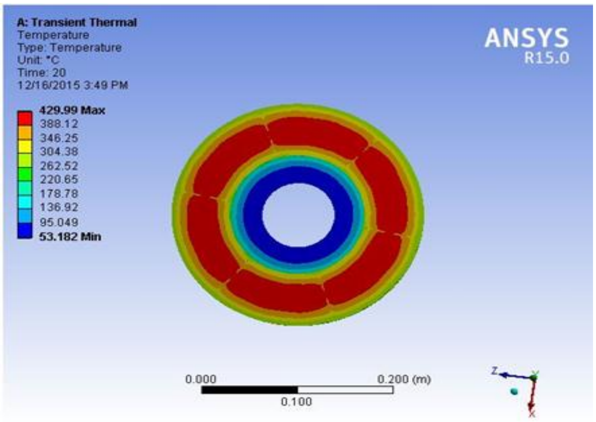

Fig. 14: Temperature Contours Pillared Type Ventilated Disc Rotor of Cast Iron

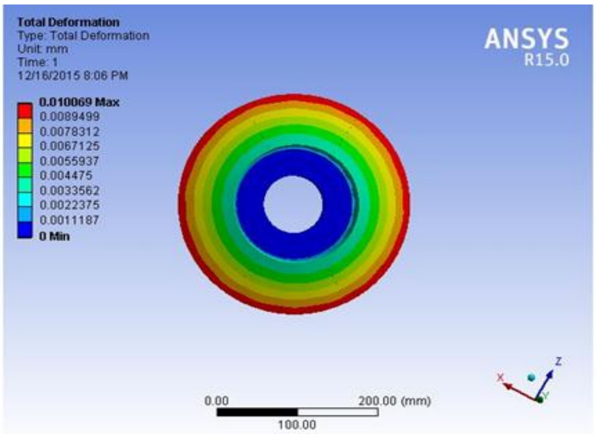

Fig. 15: Total Deflection of Pillared Type Ventilated Disc Rotor of Cast Iron

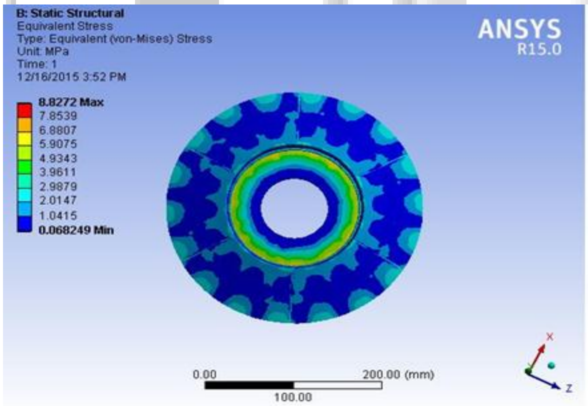

Fig. 16: Von Misses Stress on Pillared Type Ventilated Disc Rotor of Cast Iron

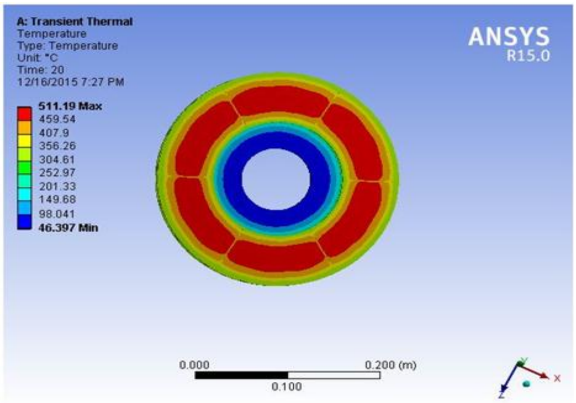

Fig. 17: Total Deflection of Pillared Type Ventilated Disc Rotor of Stainless Steel

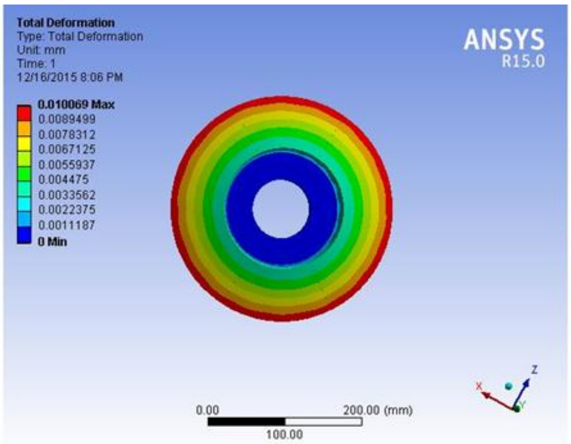

Fig. 18: Total Deflection of Pillared Type Ventilated Disc Rotor of Stainless Steel

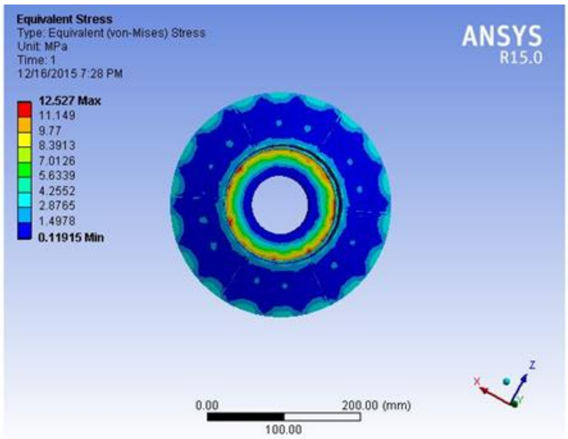

Fig. 19: Von Misses Stress on Pillared Type Ventilated Disc Rotor of Stainless Steel

V. CONCLUSION

By the transient thermal and static structural analysis of Disc brakes it is observed that from deformation point of view the stainless steel can provide better brake performance than others whereas from stress point of view cast iron provides better performance. The present study can provide a useful design tool and improve the brake performance of Disc brake system.

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