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Research Paper

FINITE ELEMENT ANALYSIS OF NORMAL AND VENTED DISC BRAKE ROTOR

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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 machine. The mechanical brakes are classified according to the direction of acting force, i.e.; Radial Brakes and Axial Brakes. In Radial Brakes force acting on the brake drum in the radial direction. where as in the Axial Brakes force acting on the brake drum in the axial direction that is disk brakes. The disc brake is a device for slowing or stopping the rotation of a wheel. Friction causes the disc and attached wheel to slow or stop. Brakes convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. This condition of failure is known as brake fade. Disc brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. In the present work actual disc brake rotor has no holes; design is changed by giving holes in the disc brake rotor for more heat dissipation. Modeling is to be done in cad software (solid works) and Analysis is to be done in ANSYS 13.0. Transient thermal, static structural and modal analysis is to be done on the disc brake rotor for TATA INDICA V2 car. The materials used are Cast Iron, Stainless steel and Aluminum metal matrix composites. Analysis is also done by changing the design of disc brake and best material is to be recommended for the purpose.

Keywords: Disc brake, Solid disk brake rotor, Vented disc brake rotor, Fem analysis, Aluminum metal matrix composite

INTRODUCTION

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. In the process of performing this function, the brakes absorb either kinetic energy of the moving member or the potential energy given up by objects being lowered by hoists, elevators etc. The energy absorbed by brakes is dissipated in the form of heat. This heat is dissipated in to the surrounding atmosphere.

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Classification of brakes (based on transformation of energy):

- Hydraulic brakes.
- Electric brakes.
- Mechanical brakes.

The mechanical brakes according to the direction of acting force may be sub divided into the following two groups:

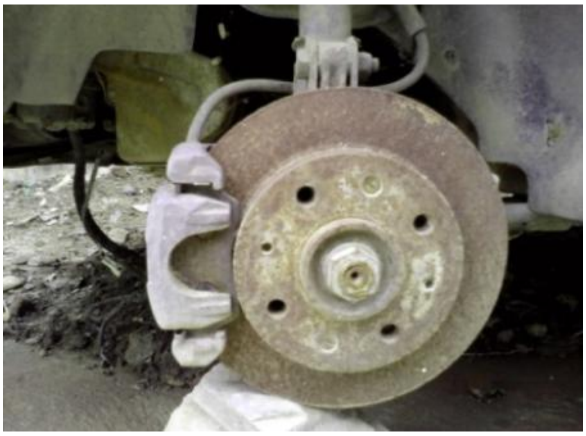
1. Radial brakes.
2. Axial brakes.

Radial Brake: In these brakes the force acting on the brake drum is in radial direction. The radial brake may be subdivided into external brakes and internal brakes.

Axial Brake: In these brakes the force acting on the brake drum is only in the axial direction, e.g., Disc brakes, Cone brakes.

Disc Brake: A disc brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of the vehicle, like the axle casing or the stub axle and is cast in two parts, each part containing a piston. In between each piston and the disc, there is a friction pad held in position by retaining pins, spring plates, etc., passages are drilled in the caliper for the fluid to enter or leave each housing. These passages are also connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston.

Figure 1: Schematic Diagram of Disc Brake



OBJECTIVE OF THE PROJECT

The present investigation is aimed to study:

- The given disc brake rotor for its stability and rigidity (for this Transient Thermal analysis, Modal and Structural analysis is carried out on a given disc brake rotor).
- Best combination of parameters of disc brake rotor like solid and vented rotor and there by a best material and rotor is suggested.
- Ventilated disc rotor for three different profiles like (circle, triangular, hexagon profiles) is compared for three different materials.

THEORETICAL CALCULATIONS OF DISC BRAKE

Specifications of Tata Indica V2 Car

- Overall weight of the car (M) = 1400 kg.
- Maximum speed (V) = 153 kmph = 42.5 m/s
- Average speed (V) = 75 kmph = 20.84 m/s

This model is run as a transient analysis because we want to study the heat distribution during braking from a maximum and average speed of 42.5 m/s and 20.84 m/s to a complete stop. We can easily calculate the time it takes to stop by first calculating the force it takes to stop the vehicle. We know that the vehicle is 1400 kg and we assume the coefficient of friction between asphalt and rubber is 0.72. To stop the vehicle in the shortest time, the maximum breaking force cannot be larger than the maximum friction force between the tires and the ground, which can be transmitted to the ground. This maximum friction force is calculated as follows.

Maximum Speed

Ff = «·*m*·*g* = (0.72) (1400) 9.81 = 9888.48 N

$a = f_f/m$ = 9888.48/1400 = 7.06 m/s^2

Time required stopping the vehicle

t = *v*/*a* = 42.5/7.06 = 6.01 s

K.E = ½*MV*^{2} = ½.1400.42.52 = 1264.37 KJ

If we assume all of that kinetic energy is transferred to thermal energy during Braking that lasts 6 seconds, we can calculate the heat power.

Heat Power = *K.E*/*t* = 1264.37/6 = 210.72 KW

Since we will analyze, about 60% of the mass of the vehicle will be on the front, the heat power is reduced.

Heat Power = 210.72*1000(0.60)/2 = 63218.75 watts

Heat Flux = *H.P*/*t*/*A*=63000/6/0.08186 = 128262 W/M^2

Average Speed

Ff = «·*m*·*g* = (0.72) (1400) 9.81 = 9888.48 N

$a = f_f/m$ = 9888.48/1400 = 7.06 m/s^2

Time required stopping the vehicle

t = *v*/*a* = 20.84/7.06 = 3 s

K.E = ½*MV*^{2} = ½.1400.20.842 = 304.01 KJ

If we assume all of that kinetic energy is transferred to thermal energy during braking that lasts 3 seconds, we can calculate the heat power.

Heat Power = *K.E*/*t* = 304.01/3 = 101.33 KW

Heat Power = 101.33*1000(0.60)/2 = 30401.39 watts

Heat Flux = H.P/t/A=30401/3/0.08186 = 123794 W/M^2

TRANSIENT THERMAL ANALYSIS OF DISC BRAKE ROTOR

Temperature Contours on Aluminium Metal Matrix Composite

Figure 2: Normal Disc Rotor

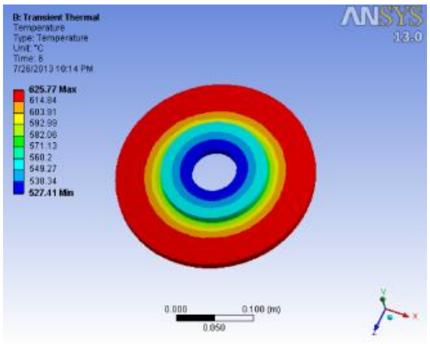


Figure 3: Vented Circular Rotor

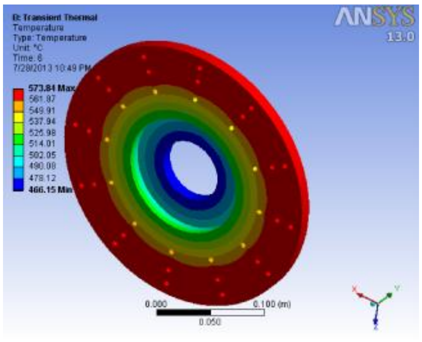


Figure 4: Vented Triangle Rotor

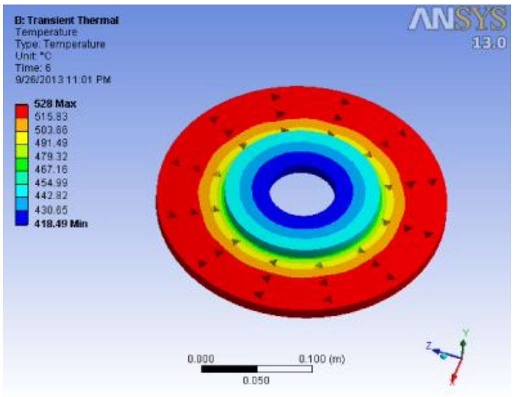
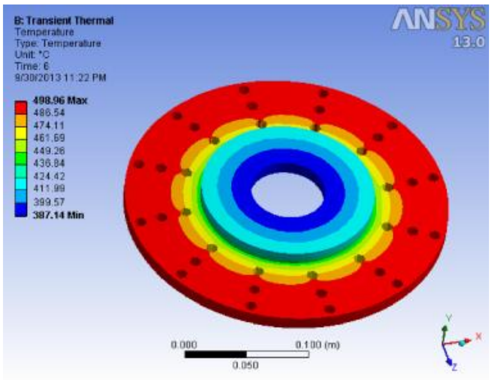


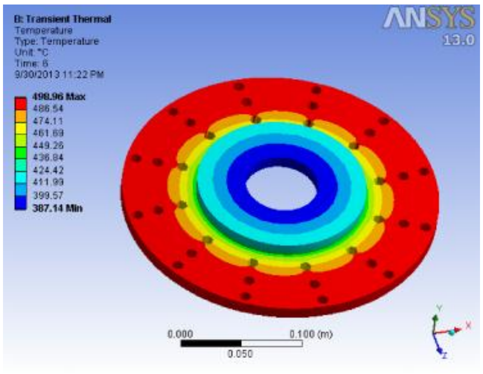
Figure 5: Vented Hexagon Rotor



STATIC STRUCTURAL ANALYSIS OF DISC BRAKE ROTOR

Equ-Von Miss Stress (Mpa) Distribution on the Rotor Disc

Figure 5: Vented Hexagon Rotor



Aluminium Metal Matrix Composite

Figure 6: Normal Disc Rotor

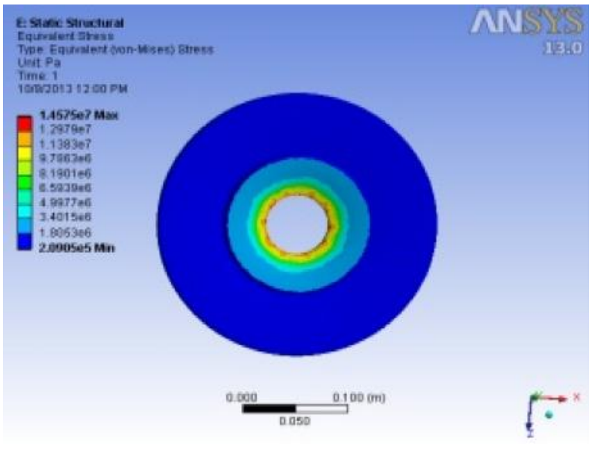


Figure 7: Vented Circular Rotor

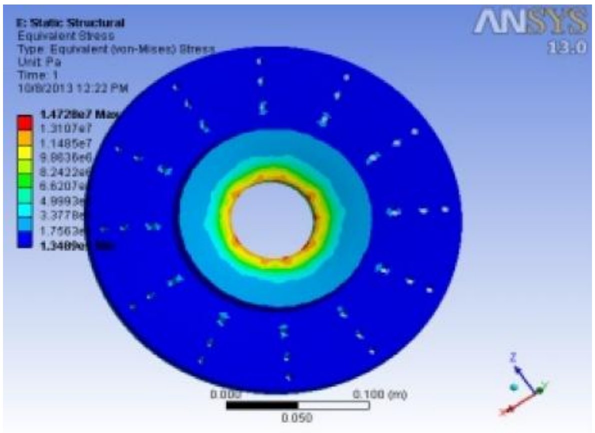


Figure 8: Vented Triangle Rotor

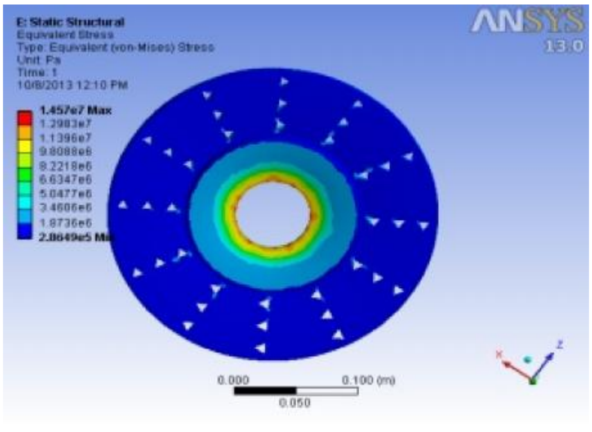
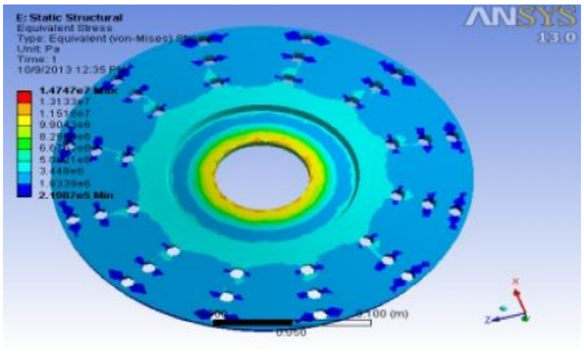
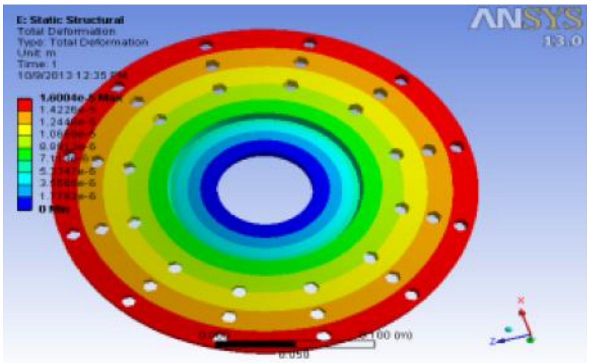


Figure 9: Vented Hexagon Rotor



Total Deformation (mm) Along the Rotor

Figure 10: Vented Hexagon Rotor



MODAL ANALYSIS OF DISC BRAKE ROTOR

Vented Hexagonal Profile

Aluminium Metal Matrix Composite

Figure 11: 1st Mode Shape at 2249 Hz

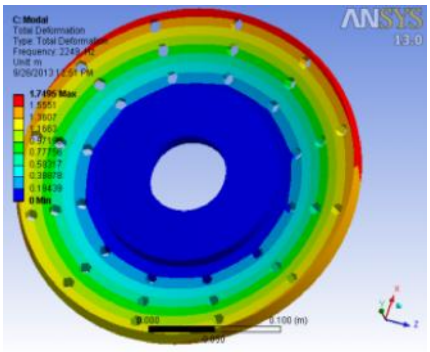


Figure 12: 2nd Mode Shape at 2266 Hz

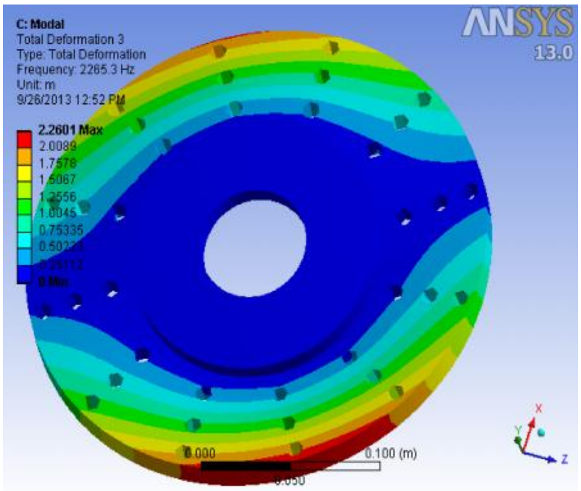
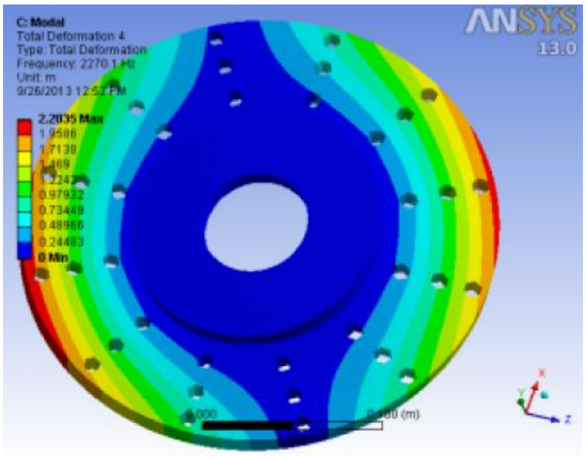


Figure 13: 3rd Mode Shape at 2270 Hz



RESULTS

Table 1: Normal Rotor Disc

S. No.	Material	Max Temperature (°C)		Defor-mation (mm)	Von Misses Stress (MPa) Max
		Max Speed	Avg Speed		
1.	Castiron	658	644	0.01526	16
2.	Stainless Steel	700	686	0.00978	15
3.	Aluminium Metal Matrix Composite	625	612	0.0153	14.5

Table 2: Vented Circular Profile Rotor Disc

S. No.	Material	Max Temperature (°C)		Defor-mation (mm)	Von Misses Stress (MPa) Max
		Max Speed	Avg Speed		
1.	Castiron	608	593	0.0154	16
2.	Stainless Steel	650	634	0.0091	15
3.	Aluminium Metal Matrix Composite	573	560	0.0155	14

Table 3: Vented Triangular Profile Rotor Disc

S. No.	Material	Max Temperature (°C)		Defor-mation (mm)	Von Misses Stress (MPa) Max
		Max Speed	Avg Speed		
1.	Castiron	562	548	0.01602	16
2.	Stainless Steel	604	589	0.0102	16
3.	Aluminium Metal Matrix Composite	528	514	0.0159	14

Table 4: Vented Hexagon Profile Rotor Disc

S. No.	Material	Max Temperature (°C)		Defor-mation (mm)	Von Misses Stress (MPa) Max
		Max Speed	Avg Speed		
1.	Castiron	534	520	0.0162	17
2.	Stainless Steel	574	559	0.010	15.9
3.	Aluminium Metal Matrix Composite	498	485	0.016	14

Figure 14: Vented Hexagon Profile Rotor Disc Max Temperature Distribution

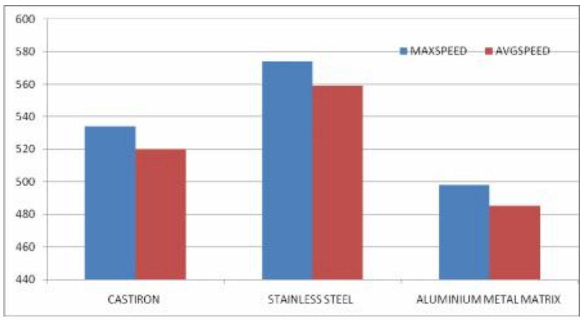
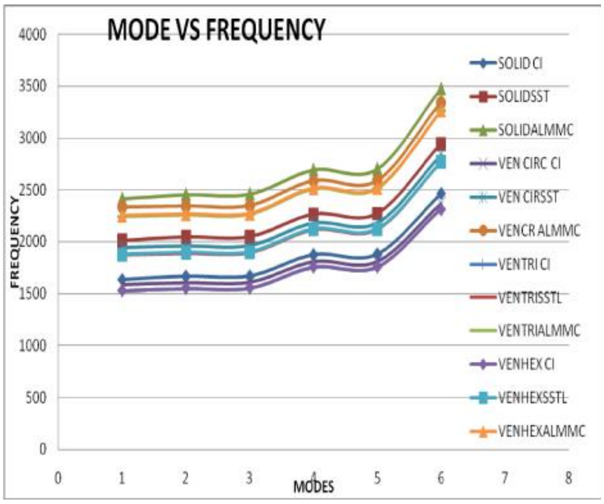


Figure 15: Modal Analysis Frequency



CONCLUSION

In this publication, we presented the finite element analysis of disc brake rotor; the modeling is based on the solid works and analysis is done by using ANSYS 13.0. By checking and comparing the results of materials in above tables and finalizing the results we can say that all the values obtained from the analysis are less than their allowable values. Hence the brake disc rotor design is safe based on the strength and rigidity criteria. Comparing the different results obtained from analysis it is concluded that disc brake rotor with vents with hexagonal profile and of material aluminum metal matrix composite is the best possible Combination for the present application. ALMMCs are more beneficial due to their light weight, better wear resistance and thermal conductivity. The use of ALMMCs also contributes to the increase of ac-celebration and reduces the braking distance; it also provides less noise and wear in the system The temperature in the ALMMCs disc brake rotors, leads to less heating in brake discs.

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