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ENHANCEMENT IN DESIGN AND THERMAL ANALYSIS OF DISC BRAKE ROTOR

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ABSTRACT
In automobile field, the contributions of composite materials are appreciable but cast iron is commonly used material for disc brake. Composite materials are less in weight and have more strength to weight ratio which can be chosen as an alternate material for disc brake. The objective of present work is Design and Analysis to evaluate the thermal analysis of enhanced disc brake rotor for three different materials, under severe braking conditions. This paper gives an idea about the enhancement design of a disc brake rotor used in Racing Cars. The materials used are Cast Iron, Aluminium, and Aluminium Composite. Actual disc brake rotor as no extrusions over the brake rotor. But in our design, by placing alternatively extrusions over the brake rotor which gives better results in heat dissipation. Modelling is done in Catia V5 and Thermal Analysis is done in FEA USING ANSYS

KEYWORDS: Disc Brake, Thermal Analysis, FEA USING ANSYS**.**

INTRODUCTION
DISC BRAKE
Brake is an integral part of an automotive, which is used to retard or stop the vehicle from its moving. From the safety aspect, the brake is an important and crucial component. So the brake rotor should be strong enough to withstand the thermal effect and dissipate the generated heat quickly. The materials for brake should be suitably selected. In general, commonly used material for disc brakes is cast iron, since its higher in its density which leads to more fuel consumption and emissions. So, we are preferred to use Composite materials as a disc brake rotor because of it’s a light weight and have good mechanical properties. In this present study Aluminum and aluminum composite are chosen as alternate material, and it has good mechanical properties compared to cast iron.

Components of Disc Brakes

A disc brake assembly mainly consists of:-
1. Brake Pedal: Force input to system from driver. Design gives a Mechanical Advantage.
2. Brake Pads: Provide friction force when in contact with rotor. Works to slow or stop vehicle.
3. Caliper: Holds pads and squeezes them against rotor.
4. Rotor: Spins with wheel. When used in Conjunction with brake pads, slows vehicle
5. Vents: Help us to provide heat dissipation when the brake is applied.

BRAKING REQUIREMENTS
1. Brakes should be a good anti wear resistant.
2. While braking the driver should have good control over the vehicle i.e. the vehicle should not skid.
3. Brakes of a vehicle should be strong so that it can stop a vehicle in minimum time.
4. Brakes should have good anti-fade characteristics.

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This work shows a heat generation and heat dissipation through a disc brake of a vehicle during emergency braking and the following release period. Brakes which slows the vehicle and thus transforms kinetic energy into heat energy which results in heating of the brake disc. If the disc overheats the brake pads which fades and it can melt in rare cases. Zaid, et al. (2009) a presented paper on investigation of disc brake by Finite element analysis. Manjunath and Suresh[1] presented a paper to study the analysis of thermo-mechanical behaviour of the brake disc during the braking. The thermal-structural analysis of disc brake is used to determine the deformation and the Von Mises stress in the disc for solid and ventilated disc with two different materials to investigate the performance of the rotor disc. A comparison between theoretical and analytical results are obtained from finite element model is done. The obtained values from the analysis
Which is less than their allowable values. Hence the suitable design and material of rotor disc is suggested and based on the performance, strength and rigidity.

N. Balasubramanyam [2] a transient analysis for the thermo-elastic contact problem of the disc brakes with heat generation is performed using the finite element analysis. To analyse the thermos-elastic phenomenon occurring in the disc brakes, heat conduction and elastic equations are solved. The numerical simulation for the thermo-elastic behaviour of disc brake is obtained in the repeated brake condition. The analytical results are presented for the distribution of heat flux and temperature on each friction surface between the contacting bodies.

Bouchetara M[3]The main purpose of this study is to analyze the thermos-mechanical behavior of the dry contact between the brake disc and pads during the braking phase. The simulation is based on computer code ANSYS. The modeling of transient temperature in the disc is actually used to identify the factor of geometric design of the disc to install the ventilation system in vehicles. The thermo-structural analysis is then used with coupling to determine the deformation established and the Von Mises stresses in the disc, the contact pressure in brake pads.

Swapnil R BhaskarD.P [4],In this paper carbon ceramic matrix disc brake material use for calculating piston force, normal force and shear force. And also calculating the brake distance of disc brake. The disc brake two wheelers model using in ANSYS and done the Thermal analysis and Modal analysis also calculate the Heat flux, Temperature distribution of disc brake model. This work is to understand action force and friction force on the disc brake.

In the present study provides us an enhanced design of a disc brake rotor is considered for analysis. Flange width of 10mm made of Cast Iron, Aluminum and Aluminum composite is considered. A Steady State Thermal Analysis is performed to obtain the Nodal Temperature Distribution across the disc brake rotor. An attempt is made to improve the heat dissipation for disc brake rotor, which yields a low temperature variation across the rotor disc and thus increase the efficiency of a disc brake rotor.

MATERIAL SELECTION

Gray Cast Iron is a material that is most extensively used material in engineering applications. Gray Cast iron has high thermal conductivity. Cast iron possesses carbon in the form of graphite flakes in a matrix that comprises of pearlite, ferrite or a combination of the two. The other alternative materials selected are

Aluminum is a most abundantly used light weight metal. It is soft and durable. Aluminum has several important properties such as conductivity, low density, strength, durability, versatility, workability, corrosion resistance and recyclability. Composite materials act as exceptional fire resistors when compared to other light weight alloys. Aluminum composite is a good corrosion resistant material.

Table.1 Material Properties

PROPERTIES	MATERIALS		
	Cast Iron	Al	Al Composite
Thermal Conductivity	54	250	181.65
Specific Heat	586	910	836
Density	7100	2712	2765.2

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Young's Modulus	$125 * 10^9$	$69 * 10^9$	$98.5 * 10^9$
Poisson's Ratio	0.25	0.33	0.33
Coefficient of Linear Expansion	$9.9 * 10^{-6}$	$23 * 10^{-6}$	$17.5 * 10^{-6}$

DESIGN AND MESHING OF DISC BRAKE ROTOR:

An enhanced CAD model of Disc brake rotor was made in 3D modelling software CATIA, after performing the model was imported to a HYPERMESH Software to perform meshing operation. Here we consider a ¼ part of the model is considered symmetrically to perform TETRA MESH, the element type used is solid 90. The further work is carried out by importing the component to the ANSYS software. A Steady State Thermal Analysis is carried out in ANSYS software.

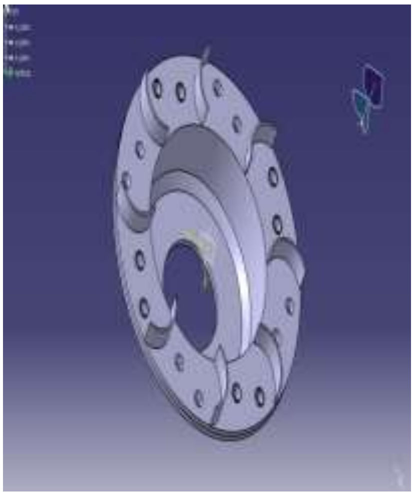

Fig.1 Rotor provided with vanes

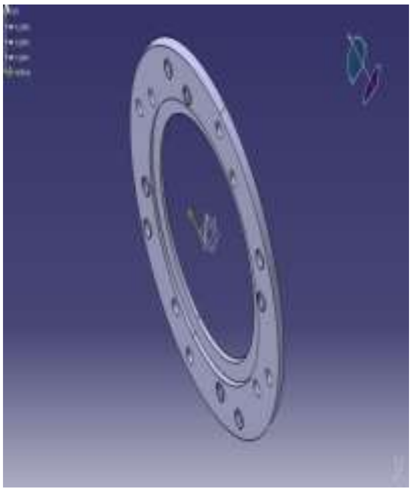

Fig.2 Flange with 10mm width

The above (Fig.1) base and upper component are joined together .This improved design would just look like a double rotor drilled disc brake. The above (Fig.2) is the base component of double rotor disc. This is basically a

Drilled disc rotor. There are cylindrical extrusions which are added to the usual drilled rotor. These extrusions are alternately added for proper air flow between the vanes. This helps us to improve the better flow of air through disc rotor when the brakes are applied suddenly. In addition to this a thin cylindrical extrusions are made to the inner side of the disc rotor which may act as a fin for better heat dissipation.

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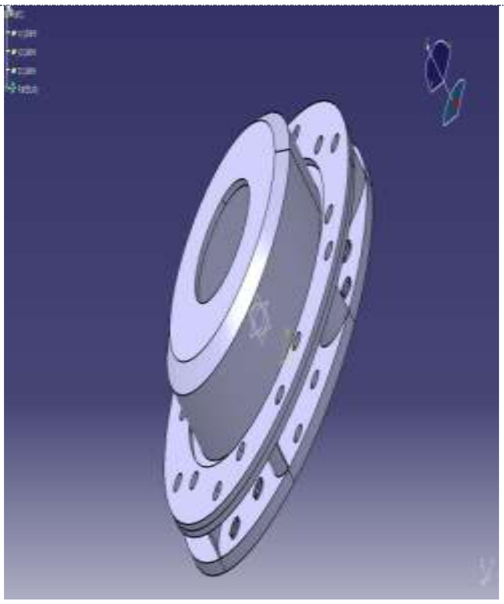

Fig.3 Final model (Assembly)

MESHING

Hyper Mesh is the software which is used to mesh any type of solid model. The optimal geometry tolerance parameter is determined by Hyper Mesh and is no longer user-controlled.

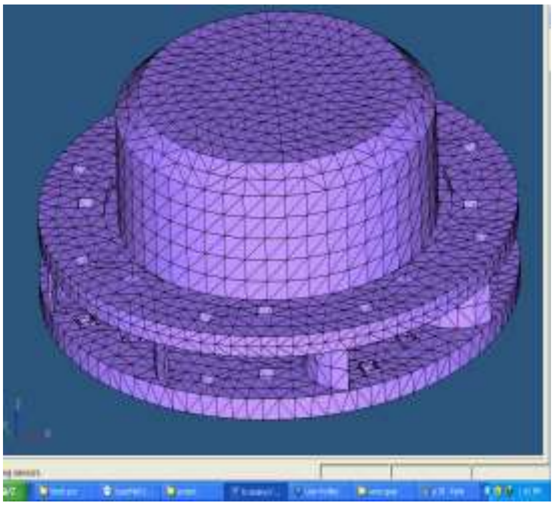

Fig.4 Meshing

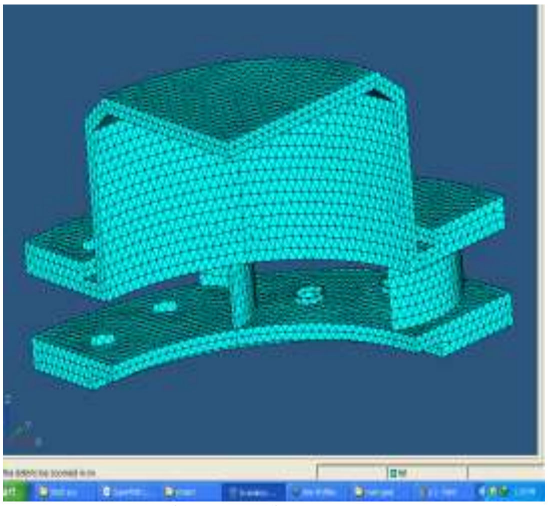

Fig.5 TETRAMESH for ¼ part of the Axi-Symmetry Model

From the above Fig.4 & Fig.5 Meshing as performed for final model of disc Brake rotor by importing the model in to the HYPERMESH software. Finally the Thermal analysis as done on the model by selecting the CI, Al & Al Composite Materials. Results are tabulated.

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ANALYSIS AND CALCULATIONS:

THERMAL ANALYSIS:

a) In thermal analysis, flange width of 10mm and three different materials such as Cast Iron, Aluminum, and Aluminum composite are considered respectively.
b) An improved model of disc brake rotor is created with flange width of 10mm.
c) In order to create the disc brake, lines are created as shown in the Figure.
d) The created model should obtain four sides in order to generate areas in ASYSY through lines as shown in Fig.6 (a&b).
e) In order to mesh the model, the element type considered for thermal analysis is solid 90.
f) The material properties such as Thermal conductivity, Specific heat and Density are defined in Table.1.
g) The boundary conditions such as heat flux, convection, heat flow and temperature are applied to the model.

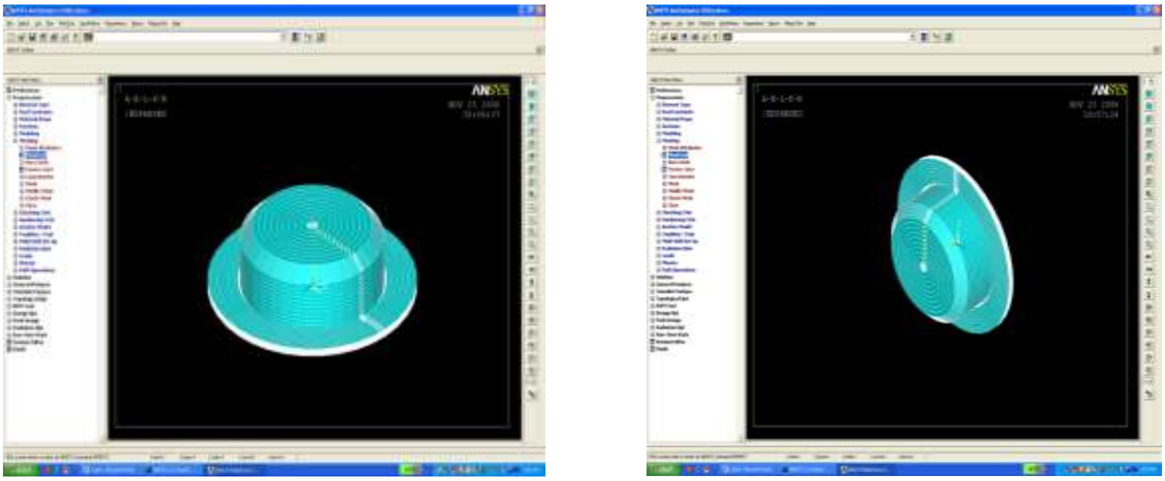

Fig.6 (a) and (b) are different views of Disc Brake Rotor

ASSUMPTIONS:

1. A vehicle moving with a velocity of 112 KMPH is considered.
2. Time taken to stop the vehicle is 4 sec.
3. The boundary conditions such as heat flux, convection, heat flow and temperature are applied to the model.

The calculations are as follows:

- Heat Flux Calculation for 10mm

Velocity of the vehicle = 70 mph = 112kmph
= 31.11m/s
Time for stopping the vehicle = 4 sec
Mass of the vehicle = 1800kg

- Kinetic Energy (K.E) = ½ * m * υ^2
= ½ * 1800 * 31.11^2
= 871048.89 J

For 10mm flange width, the heat generated by four wheels is obtained from the above calculation i.e. 217762.222 J.
The area of the rubbing faces:
Area = 2* Π * (0.2 – 0.1036) * 0.01
= 0.00605 m^2

- Heat Flux = Heat Generated / Time / twice the projected area

= 217762.222 / 4 / (2* 0.00605)
= 4499219.4 Watts / m^2

The analysis is done by taking the Brake Efficiency of 30% and hence the distribution of braking torque between the front and rear axle is 70:30.

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Thus,

- Heat Flux = 4499219.4 * 0.7
  = 3149453.62Watts / m^2

Convection values = 200
Heat flow = 0
Temperature = 200

h) Since the analysis is a steady state thermal analysis time duration of 4 seconds is applied to the model.

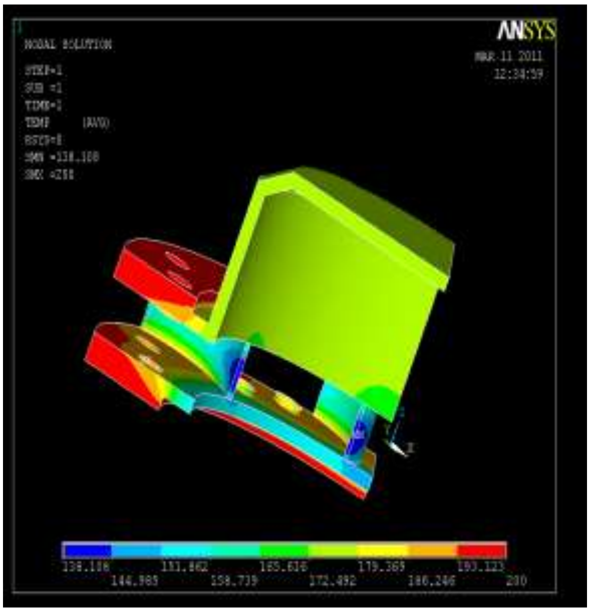
i) After applying the boundary conditions, the thermal analysis problem is resolved and the results are obtained.

j) The results are tabulated and compared.

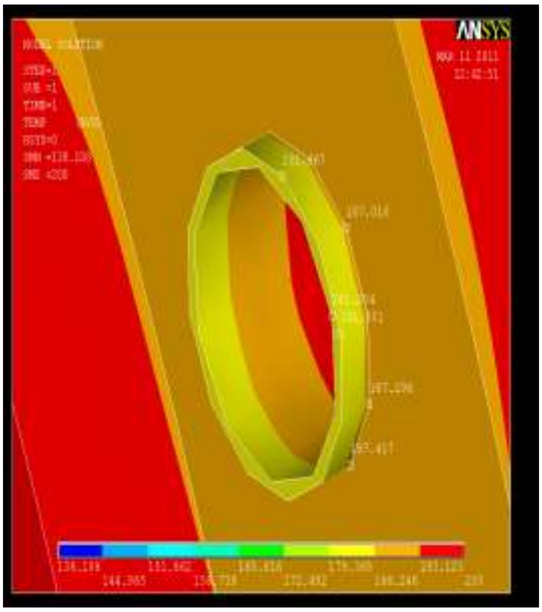
RESULTS AND CONCLUSIONS

The below images shows the Thermal Analysis and Nodal temperature distribution Cast iron material, Aluminium and Aluminium Composite Materials.

CAST IRON:

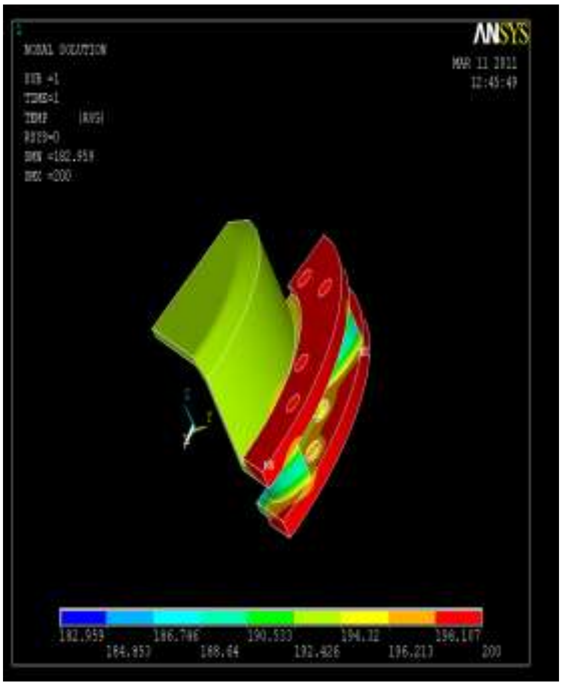


THERMAL ANALYSIS OF CAST IRON

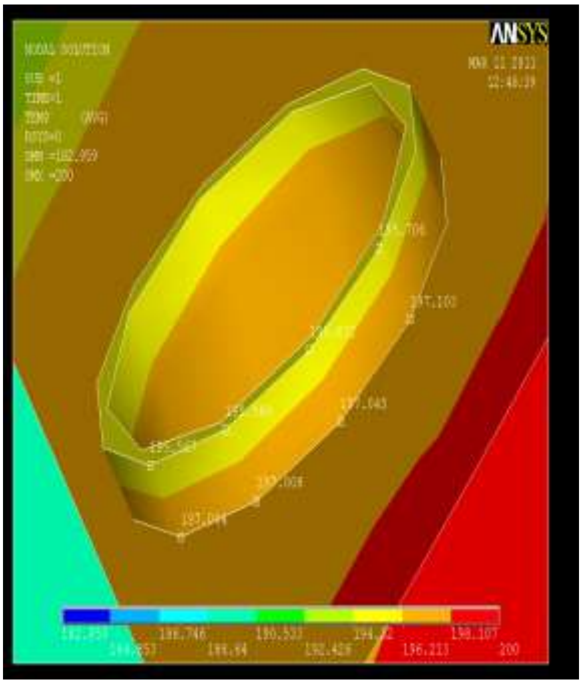


NODAL TEMPERATURE DISTRIBUTION OF CAST IRON

ALUMINUM



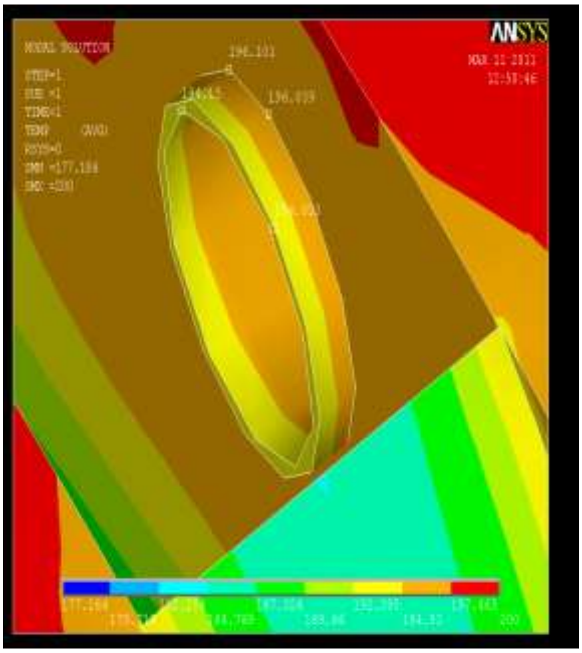
THERMAL ANALYSIS OF ALUMINUM



NODAL TEMPERATURE DISTRIBUTION OF ALUMINUM

ALUMINUM COMPOSITE:

THERMAL ANALYSIS OF AL COMPOSITE



NODAL TEMPERATURE DISTRIBUTION OF AL-COMPOSITE

Table.2 Results for 10 mm flange width

Nodal Temp.	MATERIALS		
	Cast Iron	Al	Al Composite
without extrusion	187.06 °C	197.04 °C	196.03 °C
with extrusion	181.46 °C	195.56 °C	194.46 °C
Temperature difference by adding extrusion	6 °C	2 °C	1.57 °C

The above tabulation shows of all the results of Nodal Temperature and thermal Analysis of with and without extrusions placed on the 10mm flange width made of Cast Iron, Aluminum and Aluminum composite. As it is evident from the table, Cast Iron of 10mm flange width, when compared to Aluminum and Aluminum composites has max heat transfer

REFERENCES

[1] M. T. V and D. S. P. M, "Structural and Thermal Analysis of Rotor Disc of Disc Brake," *International Journal of Innovative Research in Science, Engineering and Technology,* vol. 2, no. 12, pp. 7741-7749, 20138.
[2] B. N and P. G, "*Design and Analysis of Disc Brake Rotor for a Two wheeler*," *International Journal of Mechanical and Industrial Technology,* vol. 1, no. 1, pp. 7-12, 2014.
[3] B. M. Belhocine A, "*Temperature and Thermal Stresses of Vehicles Gray Cast Brake*," *Journal of Applied Research and Technology,* vol. 11, pp. 675-682, 2013.
[4] D. Swapnil R. Abhang, "*Design and Analysis of Disc Brake*," *International Journal of Engineering Trends and Technology,* vol. 8, pp. 165-, 2014.
[5] P. P. C. D. S. B. Jaju, "*A Review on Thermal and contact stress analysis of Disc braking system*," *International Journal of Engineering Research and General Science,* vol. 2, no. 1, pp. 78-84, 2014.
[6] Halderman J.D "*Automotive Brake Systems*", Prentice Hall, Inc, NJ, USA, 1996.