Static and thermal analysis of disc brake with Brake pad

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***Abstract*— The most important component in an automobile vehicle is a brake system. Now a days, due to increasing demands of the customers towards effective braking conditions and stability of the vehicle with respect to the speed has a designer challenge. In this work, an alternative material has been proposed for the brake pad and rotor to achieve effective braking conditions and stability of the vehicle by increasing coefficient of friction and good wear resistance. Two different materials, S2 Glass Fibre and Carbon fibre are selected as the pad materials and Aluminium alloy and Gray Cast iron is selected for the rotor material. Static and thermal analysis was performed on solid disc and ventilated discs for different pad materials and rotor materials using ANSYS 15. Different pad profiles with pure, single slot and double slot has been studied by varying material properties of pad . Based on the stresses and deformations obtained for different configurations, carbon fibre pure pad material is selected as the optimum material for the design as it is having high wear resistance, good thermal conductivity and good anti fade resistance. Based on the heat dissipation capacity of the brake system, Aluminium alloy is chosen as the best optimum material to dissipate heat to the surroundings.**

***Keywords*— Carbon fiber, S2Glassfiber, Gray Cast iron, Aluminium Alloy, static properties, thermal properties**

I. INTRODUCTION

In general, there are three main functions of a brake system, i.e., to control a vehicle's speed when driving downhill, to minimize a vehicle's speed when necessary and to keep a vehicle stationary when in parking. At present, most passenger vehicles are fitted with disc braking systems. The elements disc brake system are floating caliper design typically consists of a caliper, two pads, two guide pins, a disc, a piston, a carrier bracket. The major requirements of the caliper is to press Pads against the disc and it should ideally achieve as uniform interface pressure as possible. It is known that uniform pad wear, brake temperature, and friction coefficient could play vital role in braking action. In addition, to this it also reduces the life of the braking pads. This will cause the customers dissatisfaction and they often required to go to the garage more frequently to replace these brake pads. As the brake disc, usually made up of cast iron or ceramic composites is connected to the wheel or the axle. To stop the rotation of wheel, friction material in the form of brake pads is forced hydrolytically, mechanically, pneumatically or electromagnetically against both sides of the disc. The friction causes the disc and attached wheel to slow or stop. As soon as the brake applied friction causes which leads to convert into frictional heat. When large amount of heat is generated brakes can't perform satisfactory work [1].

Therefore, for the effective braking conditions suitable materials has to be considered in design stage itself, for the disc and brake pad based on strength, wear resistance and heat dissipation capacity of the vehicle.

II. MATERIALS

A. Aluminiuma alloy

Aluminium alloy is a most abundantly used light weight metal. It is soft and durable. Aluminium alloy is widely used in several engineering applications. It is non-magnetic and does not easily ignite. Aluminium has several important properties such as conductivity, low density, strength, durability, versatility, workability, corrosion resistance and recyclability.

B. Gray cast iron

Gray Cast Iron is a type of cast iron that has a graphitic microstructure. It is named after the gray colour of the fracture it forms, which is due to the presence of graphite. It is the most common cast iron and the most widely used cast material based on weight. A typical chemical composition to obtain a graphitic microstructure is 2.5 to 4.0% carbon and 1 to 3%silicon. The main advantages of Gray cast iron are easy to mould and acquire any desired shape. It has High compressive strength and damping capacity, resists corrosion after application of protective coating, It acts as a tool lubricant due to the presence of graphite, and It has relatively low prices compared to all other materials.

C. Carbon fiber

Carbon fiber possesses high strength and hig modulus, good thermal and electrical conductivity and possesses superior wear resistance compared to all the fibers. It is widely used for aerospace, nuclear engineering, automotive, marine and engineering components such as bearings, gears, cams, fan blades and automobile bodies.

D. S 2 Glass fiber

These are Magnesium alumina silicate glasses which are used for textile substrates or reinforcement in composite structural applications which require high strength, modulus, and stability under extreme temperature and corrosive environments. The main advantages of S2 Glass fiber are, Cost per weight or volume is less and better fibre toughness and enhanced stiffness and acts as a Chemical or galvanic resistant.

TABLE I

Material properties

Material	**Properties**					
	K W/mk	**E Gpa**	**μ**	**Specific heatJ/kgk**	**ρ Kg/m^3**	**Ultimate Strength Mpa**
Aluminium alloy	250	69	0.33	910	2712	3100
Gray cast iron	54	125	0.25	586	7100	2400
Carbon fiber	900	226	0.27	---	1800	2550
S 2 Glass fiber	1.45	87	0.28	737	2460	4890

III. Modelling and Analysis

Solid Works is a modern computer aided design (CAD) program. It enables designers to create a mathematically correct solid model of an object that can be stored in a database. When the mathematical model of a part or assembly is associated with the properties of the materials used, we get a solid model that can be used to simulate and predict the behaviour of the part or model with finite element and other simulation software. The same solid model can be used to manufacture the object and also contains the information necessary to inspect and assemble the product.

By using solid works software, disk brake assembly with brake pad has been designed with standard dimensions of Maruti gen car, which is widely used by middle class persons of India in Indian roads. Two types of disks namely solid and ventilated disks has been designed using solid works software. Three types of pad profiles namely pure, single slot and double slot has been designed using solid works software and assembled together and imported to ansys15 work bench for analysing the behaviour of assembly by varying material properties under different pressures.

A. Modelling

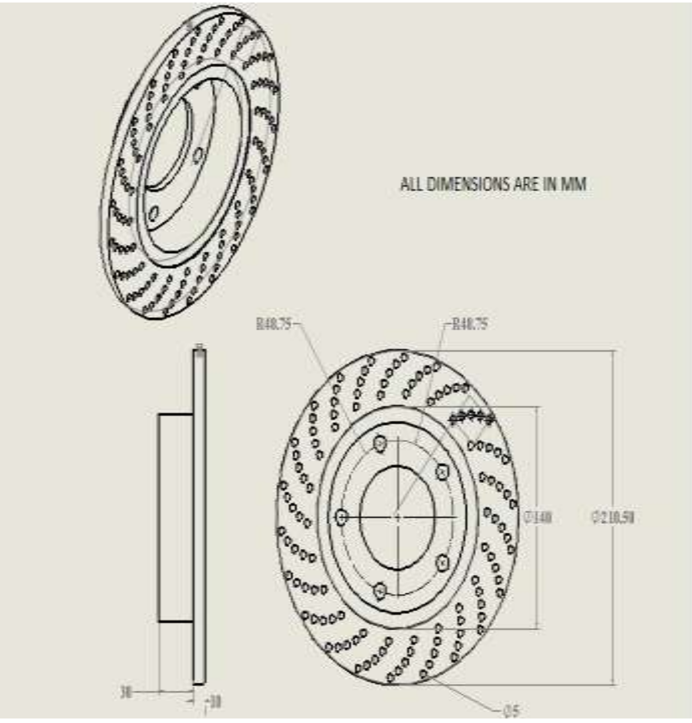


Fig 1. Dimensions of ventilated disk brake

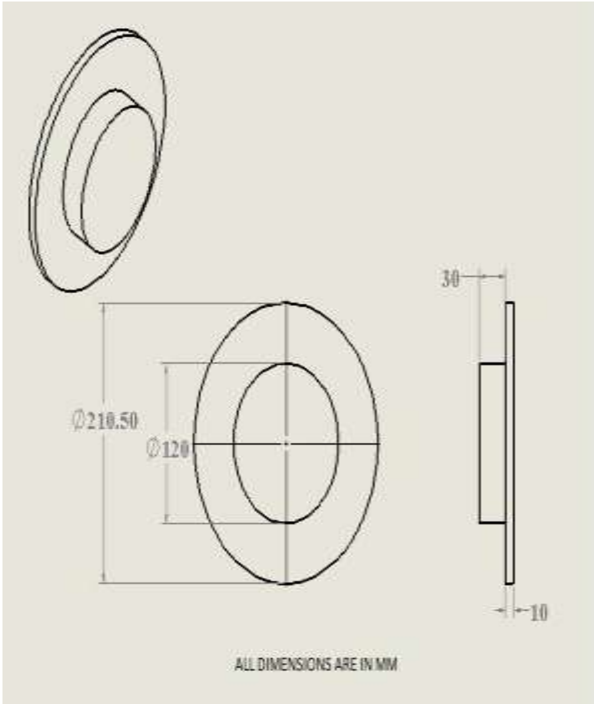


Fig 3 .Dimensions of Solid disk brake

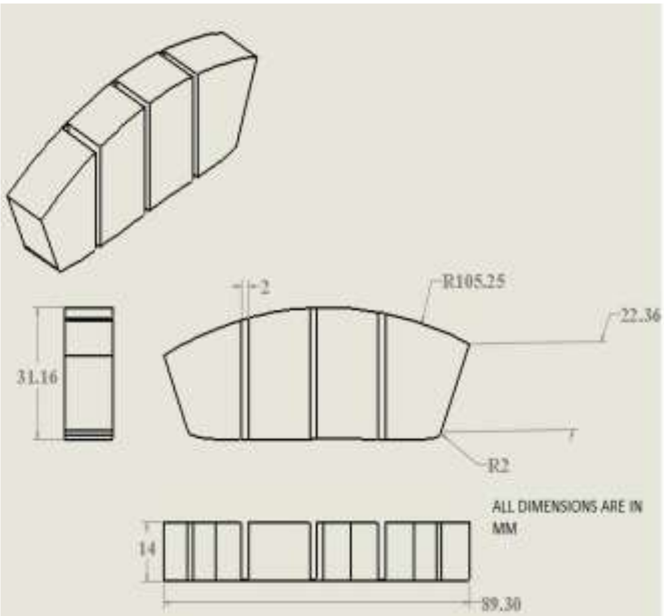


Fig 2. Dimensions of brake pad

B. Solid works disk brake and pad assembly

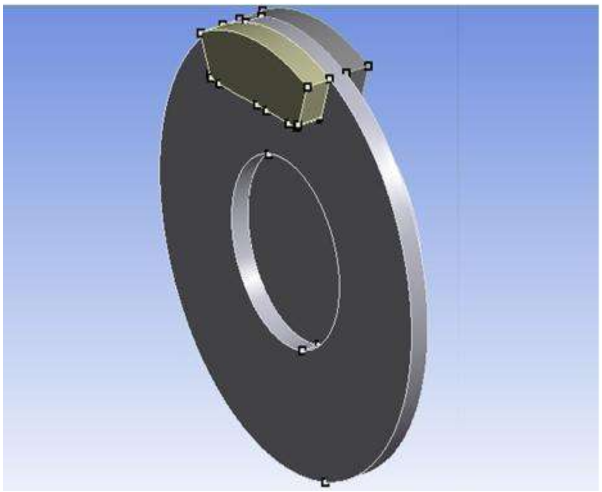


Fig 4. Solid disk brake and pad assembly

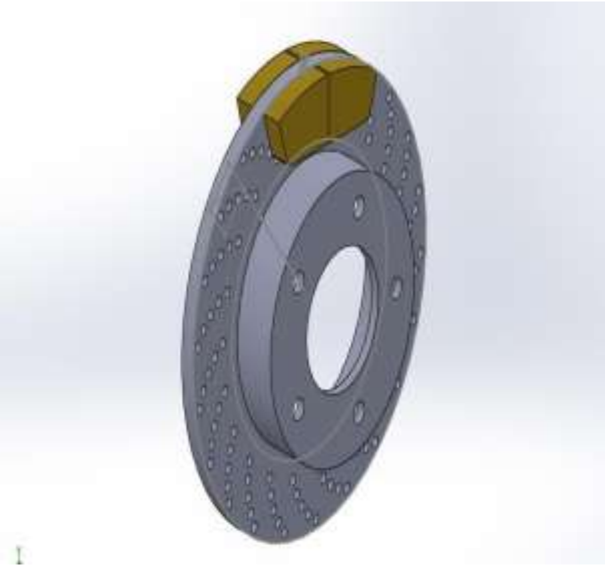


Fig 5.Ventilated disk brake pad assembly

C. Ansys workbench

ANSYS Workbench is the framework upon which the industry's broadest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user every step of the way. Even complex multi physics analyses can be performed with drag and-drop simplicity. The ANSYS Workbench platform automatically forms a connection to share the geometry for both the fluid and structural analyses, minimizing data storage and making it easy to study the effects of geometry changes on both analyses. In addition, a connection is formed to automatically transfer pressure loads from the fluid analysis to the structural analysis.

The ANSYS Workbench interface is arranged into two primary areas: The toolbox and the project Schematic. The toolbox contains the system templates that you can use to build a project. The project Schematic is the area if the interface where you will manage your project. The new project schematic view shows an overall view of the entire simulation project.

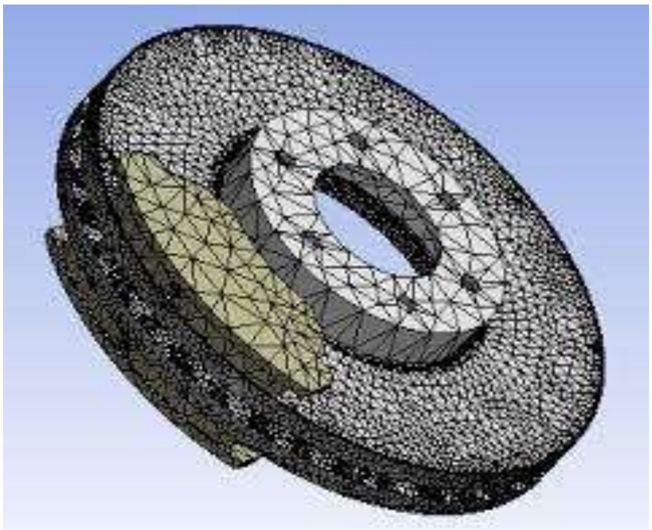


Fig 6. Meshing generation of disk brake pad assembly

The static and thermal analysis was performed on disk brake with pad assembly by varying different pressures ranging from 0.5MPa to 2 Mpa. Best configuration of pad material and disk rotor has been selected based on stresses and deformation and heat dissipation capacity.

IV. RESULTS AND DISCUSSIONS

A. STAIC ANALYSIS

1) Solid Aluminium alloy disk and S 2 glass fiber pad

Here the analysis was done on aluminium disc brake with various brake pad profiles (solid, single slotted, three slotted) made of S2 glass fiber.

1.1 Behaviour of solid disk brake pad assembly at Pressure 2 MPa

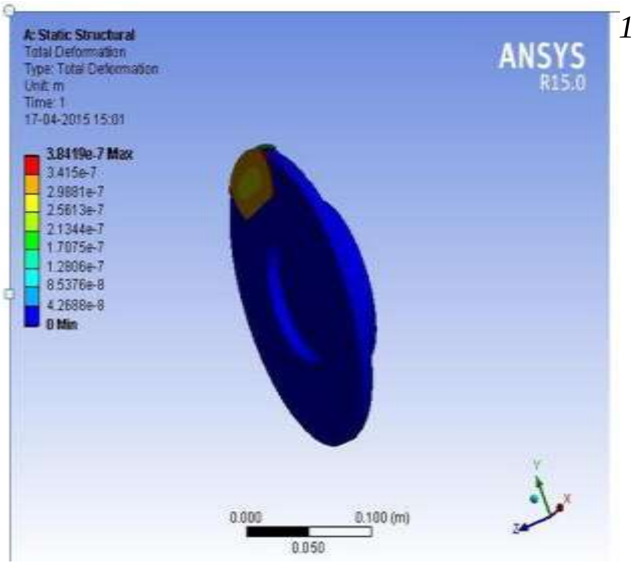
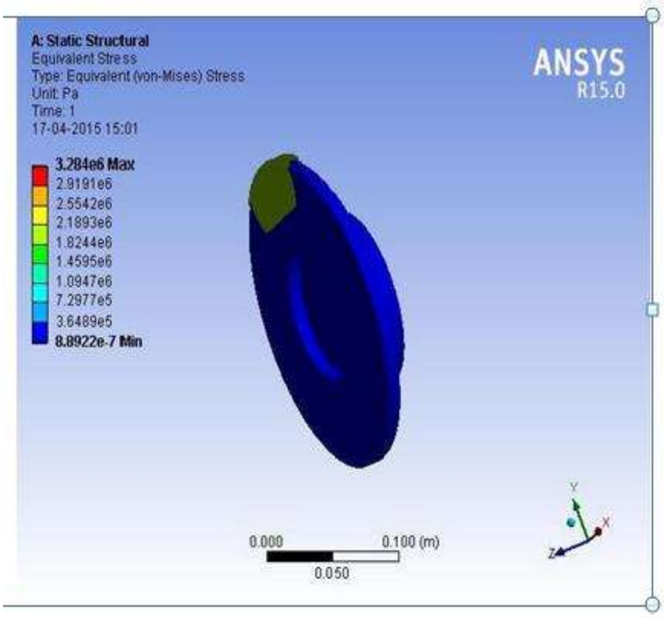


Fig 7. Total deformation of pure pad



F ig 8 .Vonmises stress distribution of pure pad

Similar results are formulated for single slot and double slot pad profiles for solid and ventilated disks for gray cast iron material.

1.2 Behaviour of ventilated Aluminium alloy disk brake and three slotted carbon fiber pad assembly at Pressure 2 MPa

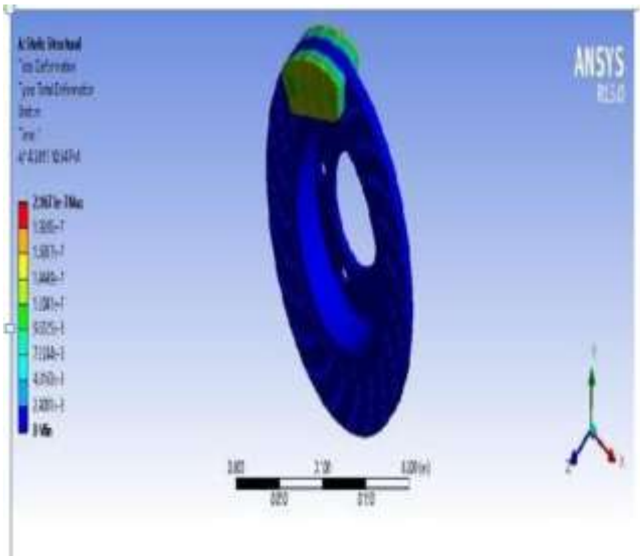


Fig9.Total deformation of three slotted carbon fiber pad

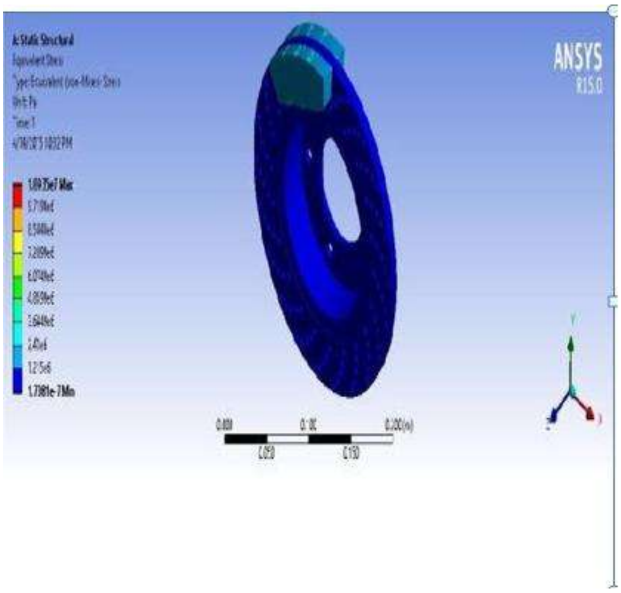


Fig 10.Vonmises stress distribution of three slotted carbon fiber pad

Similar results are drawn for gray cast iron disk rotor material by varying pad profiles and material properties.

TABLE II

Aluminium solid disc – S2 Glass fibre pure pad

Pressure (MPa)	Total deformation (10^{-7} m)	Von mises stress (MPa)
0.5	0.96	0.82
1	1.92	1.64
1.5	2.88	2.46
2	3.84	3.28

TABLE III

Aluminium solid disc – S2 Glass fibre single slotted pad

Pressure (MPa)	Total deformation (10^{-7} m)	Von mises stress (MPa)
0.5	1.36	2.89
1	2.72	5.78
1.5	4.08	8.67
2	5.45	11.57

TABLE IV

Aluminium solid disc – S2 Glass fibre three slotted pad

Pressure (MPa)	Total deformation (10^{-7} m)	Von mises stress (MPa)
0.5	1.36	2.89
1	2.72	5.78
1.5	4.08	8.67
2	5.45	11.57

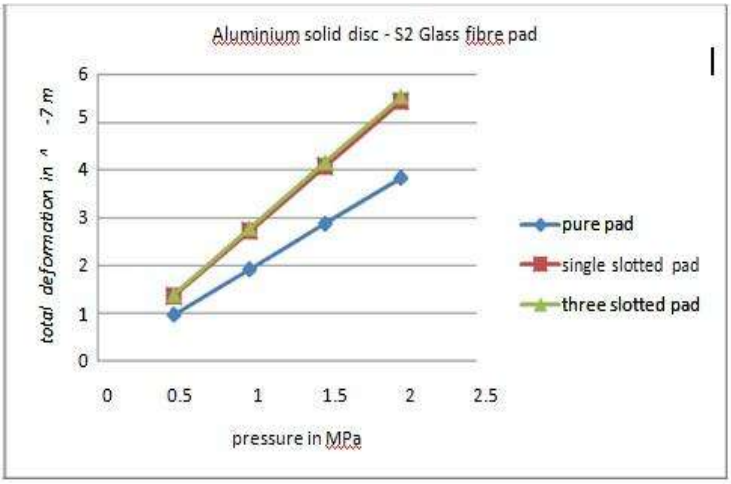


Fig 11. Alumiminum Alloy solid disk- S2 glass fiber pad

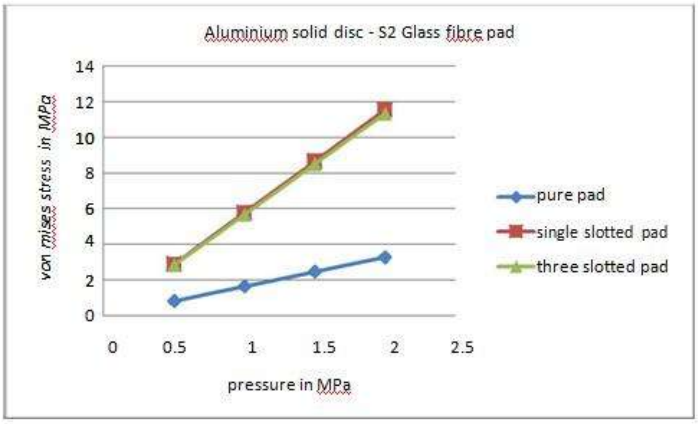


Fig12. Aluminium alloy solid disk- S 2 Glass fiber pad

From the above graphs, we obtained that **S2 Glass fibre** pure pad has less total deformation and von mises stresses when compared with single slotted and three slotted pads.

B. Gray cast iron ventilated disk rotor with carbon fiber pad

TABLE V

Pressure (MPa)	Total deformation (10^{-7}m)	Von mises stress (MPa)
0.5	0.39	1.5
1	0.78	3.01
1.5	1.17	4.51
2	1.57	6.01

Gray cast iron ventilated disc –carbon fibre pure pad

TABLE VI

Pressure (MPa)	Total deformation (10^{-7}m)	Von mises stress (MPa)
0.5	0.53	2.82
1	1.06	5.64
1.5	1.58	8.46
2	2.11	11.28

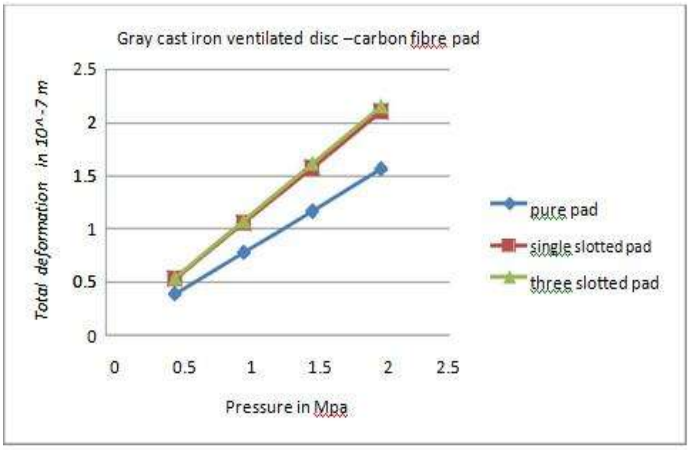
Gray cast iron ventilated disc –carbon fibre single slotted pad

TABLE VII

Pressure (MPa)	Total deformation (10^{-7}m)	Von mises stress (MPa)
0.5	0.54	2.73
1	1.08	5.47
1.5	1.62	8.2
2	2.16	10.93

Gray cast iron ventilated disc –carbon fibre three slotted pad

Fig 13. Gray cast iron ventilated disk with carbon fiber pad pressure vs total deformation



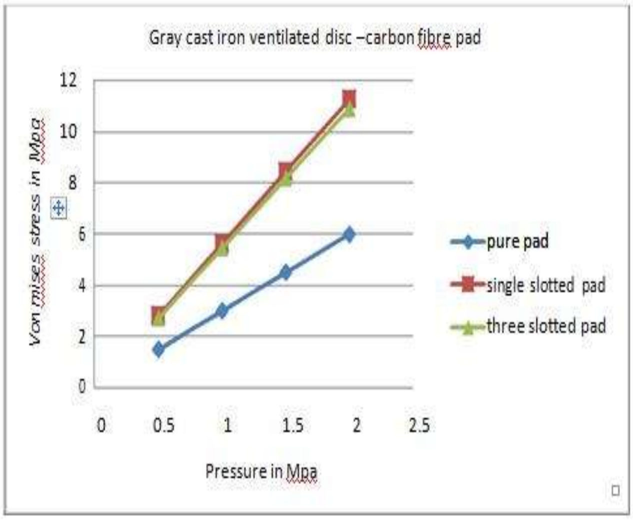


Fig14. Gray cast iron ventilated disk with carbon fiber pad pressure vs. vonmises stress

From the above graphs, we obtained that **Carbon fibre** pure pad has less total deformation and von mises stresses when compared with single slotted and three slotted pads

C. Thermal analysis

Calculations

Heat flux calculation:

Velocity of vehicle =1000kmph = 27.78 m/s

Time for stopping the vehicle =5 sec

Mass of the vehicle =1500kg

Kinetic energy (K.E.) $= \frac{1}{2} \times m \times v^2 = \frac{1}{2} \times 1500 \times 27.78^2$

$= 578796.3$ J

The above value is the total kinetic energy developed, when the vehicle is in motion.

Total Kinetic Energy =Heat Generated

Hence , Heat generated = 578796.3 J

Heat Generated per wheel = 578796.3/4

= 144699.07 J

Area of the rubbing faces $= 2\times3.14(105.25^2 - 60^2)\times10^{-6}$

$= 0.047\ m^2$

Heat flux = Heat Generated/time/Twice the projected area
= 144699.07 /5/2 ×0.047

$= 307870.37\ w/m^2$

Thermal inputs to ansys workbench for analysing heat dissipation capacity:-

Ambient temperature = 28^0 C
Heat flux generated = 307.8 KW/m^2

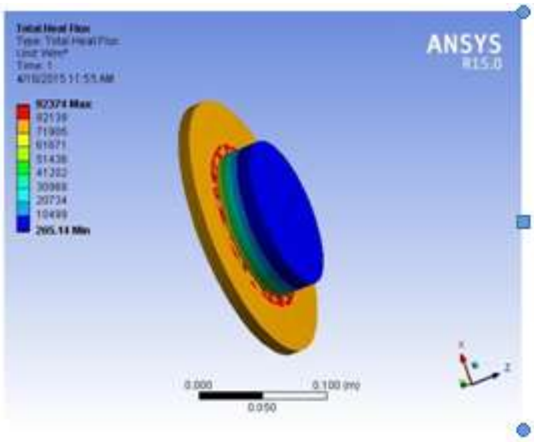


Fig 15. Total heat flux for solid disk gray cast iron

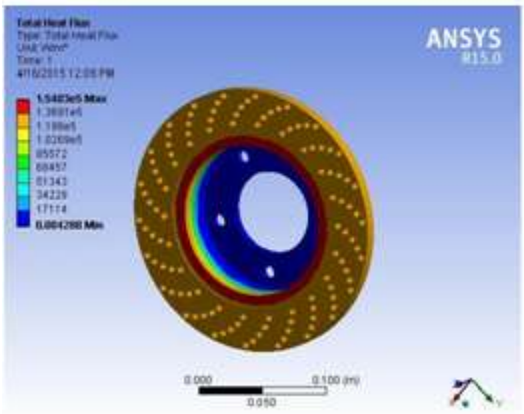
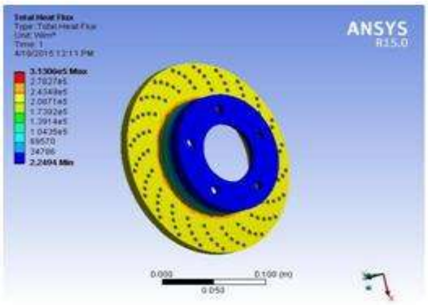


Fig 16.Total heat flux for ventilated disk gray cast iron

Fig 17.Total heat flux ventilated disk aluminium alloy



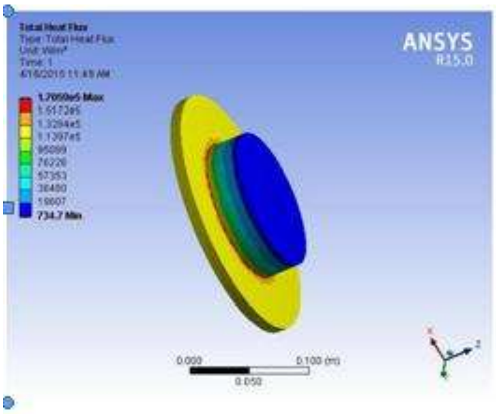


Fig 18. Total heat flux solid disk aluminium alloy

TABLE VIII

Material	Solid disk q(W)	Ventilated disk q(W)
Aluminium	1.7*10^5	3.13*10^5
Gray Cast iron	0.92*10^5	1.54*10^5

From the above table ventilated disc made of aluminium has a high heat flux.

V.CONCLUSION

In order to improve the braking efficiency and provide greater stability to the vehicle in the design stage, an investigation is carried out for implementing new types of brake pad materials.

1) In our present project, we have taken carbon fibre and S2 Glass fibre as the pad materials for the replacement of asbestos brake pad. Static analysis is performed on Carbon fibre and S2 Glass fibre pad materials with varying pad profiles (Pure, Single slot & Three slot) for solid disc and ventilated type of disc materials.
2) The materials for solid and ventilated disc are taken as Gray cast Iron and Aluminium materials.
3) From the above static analysis, the following conclusions are drawn
   a) Based on the deformation, **carbon fibre** brake pad of pure profile with solid and ventilated disc is taken as the best material for brake pad.
   b) Based on the von mises stress, **carbon fibre** brake pad of pure profile with solid and ventilated disc is taken as the best material for brake pad
4) Thermal analysis is performed on solid and ventilated discs made of Aluminium and Gray Cast Iron materials. From the above analysis we obtained that Ventilated disc made of Aluminium shows the best Heat Dissipation Effect. Finally we conclude that

   Ventilated Disc made of Aluminium Alloy is the best rotor to dissipate heat to the surroundings.

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