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DESIGN AND ANALYSIS OF VENTILATED SINGLE DISC BRAKE ROTOR

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A B S T R A C T

The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc (or rotor), usually made of cast iron or ceramic composites (including carbon, Kevlar and silica), is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. 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 This thesis consists of modeling and analysis of both solid and vented type rotor disc brakes. The main objective of the project is to conduct thermal analysis and static analysis on the both rotors to study the heat and temperature distribution and stresses on disc brake rotor. The results were compared for better rotor and both results provide better understanding on the thermal characteristic of disc brake rotor and assist the automotive industry in developing optimum and effective disc brake rotor. Modeling is done in SOLID WORKS and analysis is done in ANSYS

Key words: Disc brake, Solid works, Ansys Workbench, etc.

I INTRODUCTION

A brake is a device which inhibits motion. Its opposite component is a clutch. The rest of this article is dedicated to various types of vehicular brakes.Most commonly brakes use friction to convert knetic energy into heat, though other methods of energy conversion may be employed. For example regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Other methods convert kinetic energy into potential energy in such stored forms as pressurized air or pressurized oil. Still other braking methods even transform kinetic energy into different forms, for example by transferring the energy to a rotating flywheel.Brakes are generally applied to rotating axles or wheels, but may may also take other forms such as the surface of a moving fluid (flaps deployed into water or air). Some vehicles use a combination of braking mechansims, such as drag racing cars with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps raised into the air during landing.

TYPES OF BRAKES

Brakes may be broadly described as using friction, pumping, or electromagnetics. One brake may use several principles: for example, a pump may pass fluid through an orifice to create friction.Frictional brakes are most common and can be divided broadly into "shoe" or "pad" brakes, using an explicit wear surface, and hydrodynamic brakes, such as parachutes, which use friction in a working fluid and do not explicitly wear. Typically the term "friction brake" is used to mean pad/shoe brakes and excludes hydrodynamic brakes, even though hydrodynamic brakes use friction.Friction (pad/shoe) brakes are often rotating devices with a stationary pad and a rotating wear surface. Common configurations include shoes that contract to rub on the outside of a rotating drum, such as a band brake; a rotating drum with shoes that expand to rub the inside of a drum, commonly called a "drum brake", although other drum configurations are possible; and pads that pinch a rotating disc, commonly called a "disc brake". Other brake configurations are used, but less often. For example, PCC trolley brakes include a flat shoe which is clamped to the rail with an electromagnet; the Murphy brake pinches a rotating drum, and the Ausco Lambert disc brake uses a hollow disc (two parallel discs with a structural bridge) with shoes that sit between the disc surfaces and expand laterally.

CHARACTERISTICS

Brakes are often described according to several characteristics including:

- **Peak force -** The peak force is the maximum decelerating effect that can be obtained. The peak force is often greater than the traction limit of the tires, in which case the brake can cause a wheel skid.

- **Continuous power dissipation -** Brakes typically get hot in use, and fail when the temperature gets too high. The greatest amount of power (energy per unit time) that can be dissipated through the brake without failure is the continuous power dissipation. Continuous power dissipation often depends on e.g., the temperature and speed of ambient cooling air.
- **Fade -** As a brake heats, it may become less effective, called brake fade. Some designs are inherently prone to fade, while other designs are relatively immune. Further, use considerations, such as cooling, often have a big effect on fade.
- **Smoothness -** A brake that is grabby, pulses, has chatter, or otherwise exerts varying brake force may lead to skids. For example, railroad wheels have little traction, and friction brakes without an anti-skid mechanism often lead to skids, which increases maintenance costs and leads to a "thump thump" feeling for riders inside.
- **Power -** Brakes are often described as "powerful" when a small human application force leads to a braking force that is higher than typical for other brakes in the same class. This notion of "powerful" does not relate to continuous power dissipation, and may be confusing in that a brake may be "powerful" and brake strongly with a gentle brake application, yet have lower (worse) peak force than a less "powerful" brake.
- **Durability -** Friction brakes have wear surfaces that must be renewed periodically. Wear surfaces include the brake shoes or pads, and also the brake disc or drum. There may be tradeoffs, for example a wear surface that generates high peak force may also wear quickly.
- **Weight** - Brakes are often "added weight" in that they serve no other function. Further, brakes are often mounted on wheels, and unsprung weight can significantly hurt traction in some circumstances. "Weight" may mean the brake itself, or may include additional support structure.
- **Noise -** Brakes usually create some minor noise when applied, but often create squeal or grinding noises that are quite loud.

DISC BRAKES

The disc brake or disk brake is a device for slowing or stopping the rotation of a wheel while it is in motion. A brake disc (or rotor in U.S. English) is usually made of cast iron or ceramic composites (including carbon, Kevlar and silica). This is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced

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mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes (both disc and drum) 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.

CERAMIC COMPOSITES

Ceramic discs are used occasionally in high-performance cars and heavy vehicles.

The first development of the modern ceramic brake was made by British Engineers working in the railway industry for TGV applications in 1988. The objective was to reduce weight, the number of brakes per axle, as well as provide stable friction from very high speeds and all temperatures. The result was a carbon fibre reinforced ceramic process which is now used in various forms for automotive, railway, and aircraft brake applications.

The requirement for a large section of ceramic composite material having very high heat tolerance and mechanical strength often relegates ceramic discs to exotic vehicles where the cost is not prohibitive to the application, and industrial use where the ceramic disc's light weight and low maintenance properties justify the cost relative to alternatives. Composite brakes can withstand temperatures that would make steel discs bendable.

DISC DAMAGE MODES

Discs are usually damaged in one of four ways: warping, scarring, cracking, or excessive rusting. Service shops will sometimes respond to any disc problem by changing out the discs entirely, This is done mainly where the cost of a new disc may actually be lower than the cost of labour to resurface the original disc. Mechanically this is unnecessary unless the discs have reached manufacturer's minimum

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recommended thickness, which would make it unsafe to use them, or vane rusting is severe (ventilated discs only). Most leading vehicle manufacturers recommend brake disc skimming (US: rotor turning) as a solution for lateral run-out, vibration issues and brake noises. The machining process is performed in a brake lathe, which removes a very thin layer off the disc surface to clean off minor damage and restore uniform thickness. Machining the disc as necessary will maximise the mileage out of the current discs on the vehicle.

LITERATURE REVIEW

Braking is a process which converts a vehicle's kinetic energy into mechanical energy which must be dissipated in the form of heat. During the braking phase, the frictional heat generated at the interface of the disc and pads can lead to high temperatures. The frictional heat generated on the rotor surface can influence excessive temperature rise which, in turn, leads to undesirable effects such as thermal elastic instability (TEI), premature wear, brake fluid vaporization (BFV) and thermally excited vibrations (TEV).In this project, solid and ventilated type disc brake rotor of a vehicle, taken an investigation into the usage of various materials is done so as to improve the braking efficiency and provide greater stability to the vehicle. Modelling of the disc brake rotor is done using CATIA V5R18, which facilitates collaborative engineering across various disciplines. The thermal and structural analysis of disc brake rotor is done using ANSYS 14.5, which is a dedicated finite element package used for determining the temperature distribution, variation of the stresses and deformation across the disc brake profile. A comparison is made between three different materials used for both solid and ventilated type disc brakes and the best material for making disc brake and type of disc brake have been suggested based on the magnitude of Vonmises stresses, temperature distribution and deformation.

METHODOLOGY

INTRODUCTION TO SOLID WORKS

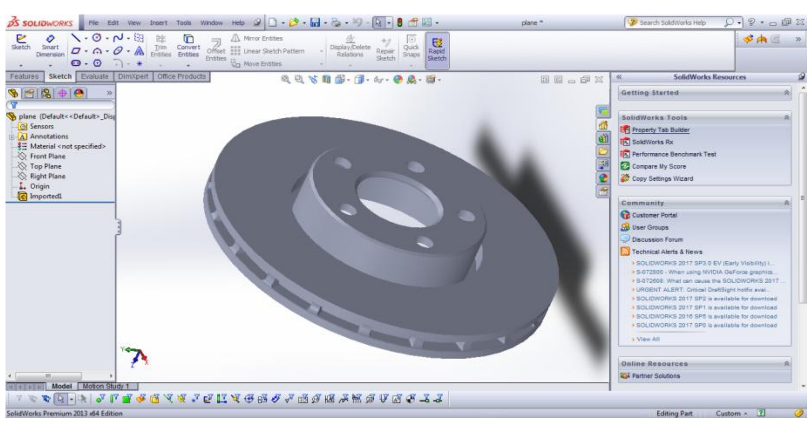
SolidWorks (stylized as **SOLIDWORKS**) is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes.

According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Also according to the company, fiscal year 2011–12 revenue for SolidWorks totalled $483 million.

DS Solidworks Corp. has sold over 1.5 million licenses of SolidWorks worldwide. This includes a large proportion of educational licenses. The Sheffield Telegraph comments that Solidworks is the world's most popular CAD software. Its user base ranges from individuals to large corporations, and covers a very wide cross-section of manufacturing market segments. Commercial sales are made through an indirect channel, which includes dealers and partners throughout the world. In the United States, the first reseller of SolidWorks, in 1995, was Computer Aided Technology, Inc, headquartered in Chicago. Directly competitive products to SolidWorks include Solid Edge, and Autodesk Inventor. SolidWorks also partners with third party developers to add functionality in niche market applications like finite element analysis, circuit layout, tolerance checking, etc. SolidWorks has also licensed its 3D modeling capabilities to other CAD software vendors, notably ANVIL.

3D MODELS OF DISC BRAKE

CASE1: PLANE DISC BRAKE



CASE2: DISC BRAKE WITH DRILLED HOLES

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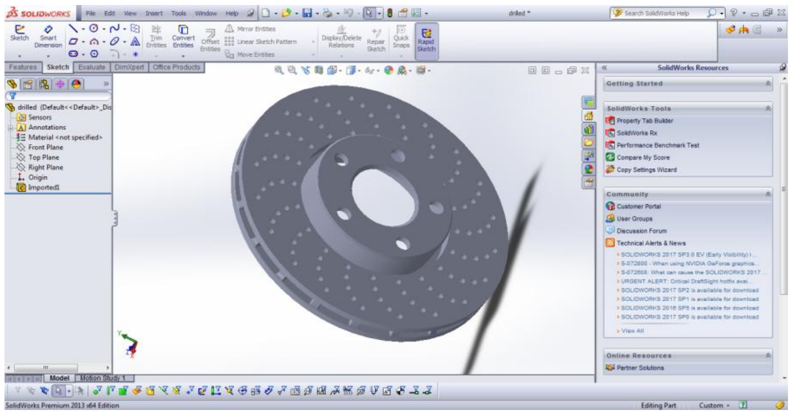

BRAKE DISTANCE (X)-

We know tangential braking force acting at the point of contact of the brake, and

Work done = FT.x....................................Equation A

Where, FT = FTRI+FTRO

X = Distance travelled by the vehicle (in meter) before it come to rest

We know kinetic energy of the vehicle.

kinetic energy = $(mv^2/2)$...............................Equation B

where, m = mass of vehicle

v = velocity of vehicle

In order to bring the vehicle to rest, the workdone against friction must be equal to the kinetic energy of the vehicle.

Therefore equating (Equation A) and (Equation B)

$FT.x = (mv^2/2)$

Assumption v = 100 kg/h = 27.77 m/s

M = 132 kg. (dry weight of vehicle)

So we get $x = mv^2/2\ FT$

$X = 132*(27.77)^2/(2*1000)$

X = 50.89 m

Heat generated (Q) = $M.C_P.\Delta T$ J/S

Flux (q) = Q/A W/m^2

Thermal gradient (K) = q/k K/m

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CARBON CERAMIC MATRIX-

Heat generated $Q = M.C_p.\Delta T$

Mass of disc = 0.5 kg

Specific heat capacity = 800 J/kg ^{0}c

Time taken to stop the vehicle = 5 sec

Developed temperature difference = 15 ^{0}c

Q = 0.5*800*15 = 6000 J

Area of disc = $\pi * (R^2-r^2) = \pi*(0.12^2 - 0.55^2)$

$= 0.03573\ m^2$

Heat flux = heat generated / second / area = 6000/5/0.03573 = 33.585 kw/m^2

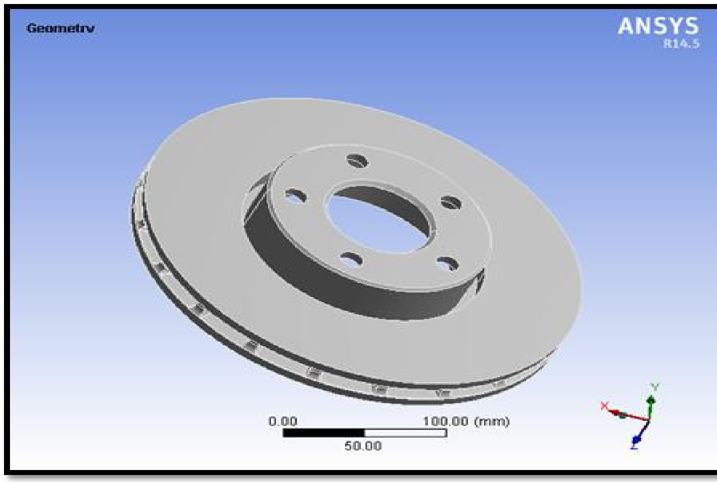
Thermal gradient = heat flux / thermal conductivity

$= 33.585*10^3 /40$

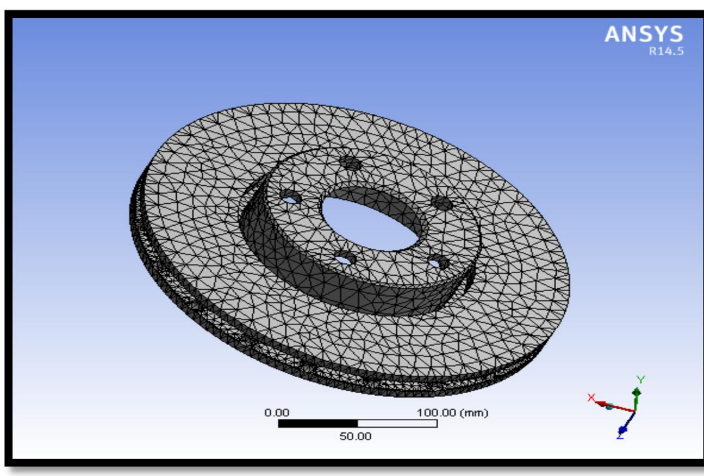
= 839.63 k/m

STRUCTURAL ANALYSIS OF DISC BRAKE

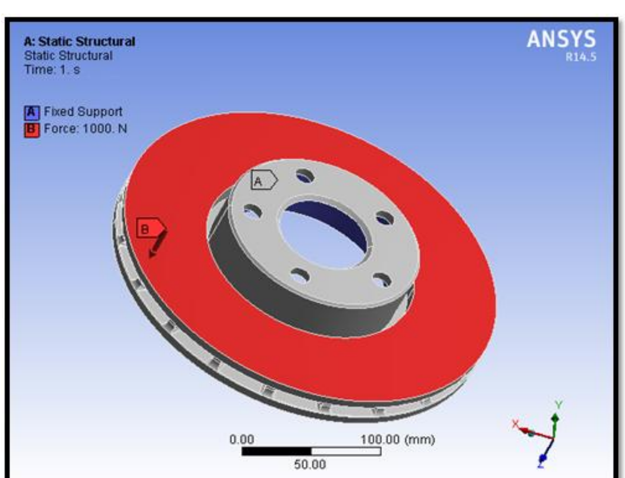
CASE 1-PALNE DISC BRAKE



Meshing



Boundary conditions



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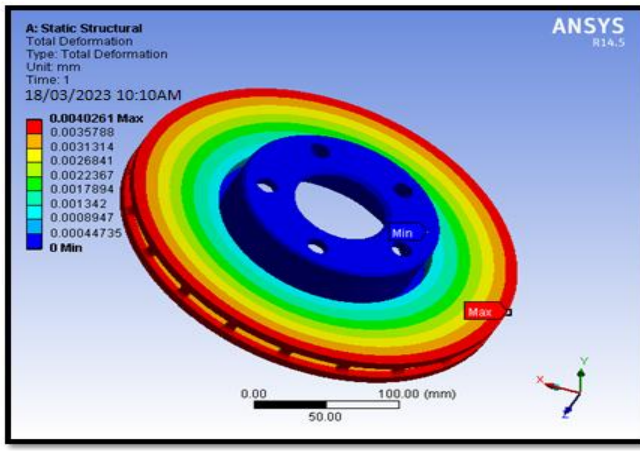
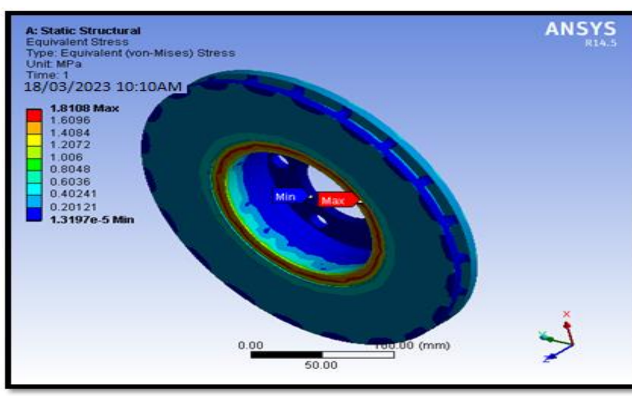
MATERIAL – ALUMINUM ALLOY

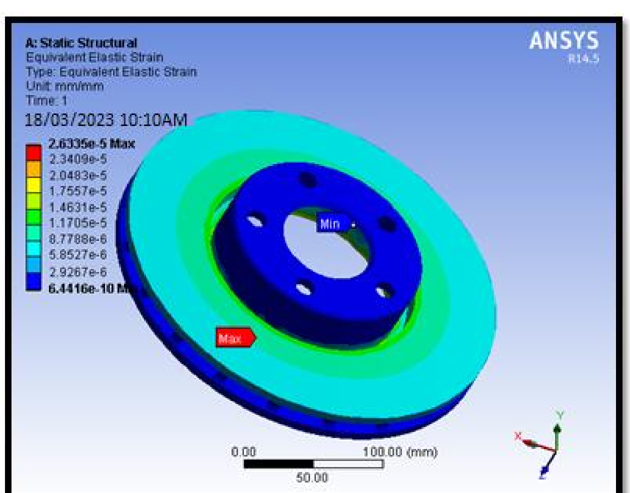
DEFORMATION



STRESS



STRAIN



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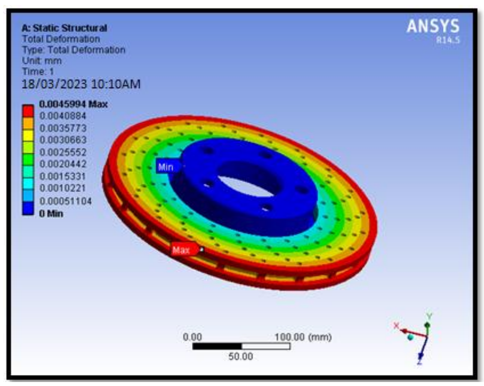
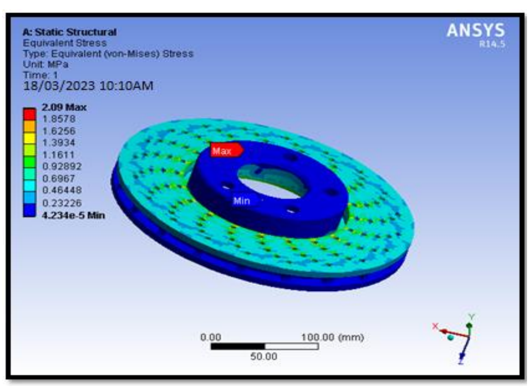
CASE 2: DISC BRAKE WITH DRILLED HOLES

MATERIAL – ALUMINUM ALLOY

DEFORMATION



STRESS



STRAIN

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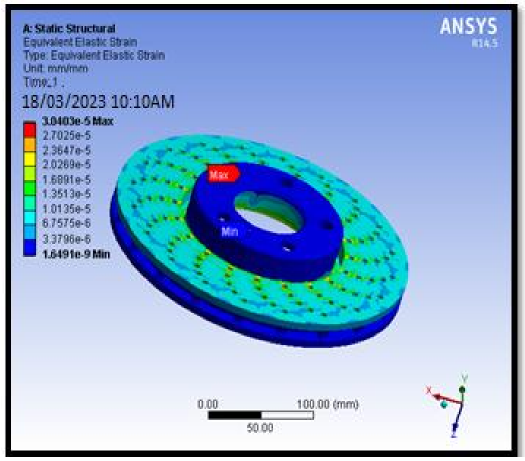

STATIC ANALYSIS RESULT TABLE

Models	Materials	Deformation(mm)	Stress(MPa)	Strain
Case:1	Aluminum alloy	0.0040261	1.8108	2.633E-5
	Cast iron	0.003371	2.0811	2.0247E-5
	Ceramic	0.00063348	1.7128	4.5178E-6
Case:2	Aluminum alloy	0.0045994	2.09	3.0403E-5
	Cast iron	0.0038578	2.6053	2.5322E-5
	Ceramic	0.00072215	1.8371	4.8451E-6

CONCLUSION

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.By observing the static analysis results the stress values are less for the ceramic material by the design model is case: 3 models i.e., disc brake with slots.By observing the fatigue analysis the safety factor more for ceramic material by the model is case: 3.By observing the dynamic analysis the stress values are less for ceramic material and stress

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values are increases by increasing the time and loads So it can be concluded the disc brake with slots model is better design for disc brake and ceramic material is the better material for disc brake.

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