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Design evaluation and optimization of a disc brake

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ABSTRACT

The braking system is a process that converts the kinetic energy of the vehicle in the mechanical energy that must be dissipated in the atmosphere in the form of heat. In general, a brake disk in cast iron or ceramic composites is connected to the wheel and/or of the axle. The friction materials in the form of brake pads are forced, so mechanical, hydraulic or pneumatic electromagnetically against both sides of the disk to stop the wheel. The present analysis transitional thermal "and the structural analysis of disk brake" deals with the production of heat in the different materials of disk brake with different vehicle speeds and heat dissipation by these materials and also the deformation and the stresses produced in these materials due to the increase in temperature is analyzed. A comparative study is made between these materials to suggest the best material for the brake disk to the aspect of the problem considered. Modeling of the disk brake has done with the help of PROE WILDFIRE 3.0 and the complete analysis is made using ANSYS 15.0.

Keywords: Brake disk, axle, Materials, Modeling, Ansys, PROE

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 kinetic 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 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 mechanisms, 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. Since kinetic energy increases quadratically with velocity ($K = mv^2 / 2$), an object traveling at 10 kilometers per second has 100 times as much energy as one traveling at 1 kilometer per second, and consequently the theoretical braking distance, when braking at the traction limit, is 100 times as long. In practice, fast vehicles usually have significant air drag, and energy lost to air drag rises quickly with speed.

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LITERATURE REVIEW

Disc-style brakes development and use began in England in the 1890s. The first caliper-type automobile disc brake was patented by Frederick William Lanchester in his Birmingham, UK factory in 1902 and used successfully on Lanchester cars. However, the limited choice of metals in this period, meant that he had to use copper as the braking medium acting on the disc. The poor state of the roads at this time, no more than dusty, rough tracks, meant that the copper wore quickly making the disc brake system non-viable (as recorded in The Lanchester Legacy). It took another half century for his innovation to be widely adopted.

Modern-style disc brakes first appeared on the low-volume Crosley Hotshot in 1949, although they had to be discontinued in 1950 due to design problems. Chrysler's Imperial also offered a type of disc brake from 1949 through 1953, though in this instance they were enclosed with dual internal-expanding, full-circle pressure plates. Reliable modern disc brakes were developed in the UK by Dunlop and first appeared in 1953 on the Jaguar C-Type racing car. The Citroën DS of 1955, with powered inboard front disc brakes, and the 1956 Triumph TR3 were the first European production cars to feature modern disc brakes. The first production car to feature disc brakes at all 4 corners was the Austin-Healey 100S in 1954. The first British company to market a production saloon fitted with disc brakes to all four wheels was Jensen Motors Ltd with the introduction of a Deluxe version of the Jensen 541 with Dunlop disc brakes. The next American production cars to be fitted with disc brakes were the 1963 Studebaker Avanti (optional on other Studebaker models), standard equipment on the 1965 Rambler Marlin (optional on other AMC models), and the 1965 Chevrolet Corvette Stingray (C2). The 1965 Ford Thunderbird came with front disc brakes as standard equipment.

ABOUT DISC BRAKE

The disc 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 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.

Disc brakes were most popular on sports cars when they were first introduced, since these vehicles are more demanding about brake performance. Discs have now become the more common form in most passenger vehicles, although many (particularly light weight vehicles) use drum brakes on the rear wheels to keep costs and weight down as well as to simplify the provisions for a parking brake. As the front brakes perform most of the braking effort, this can be a reasonable compromise.

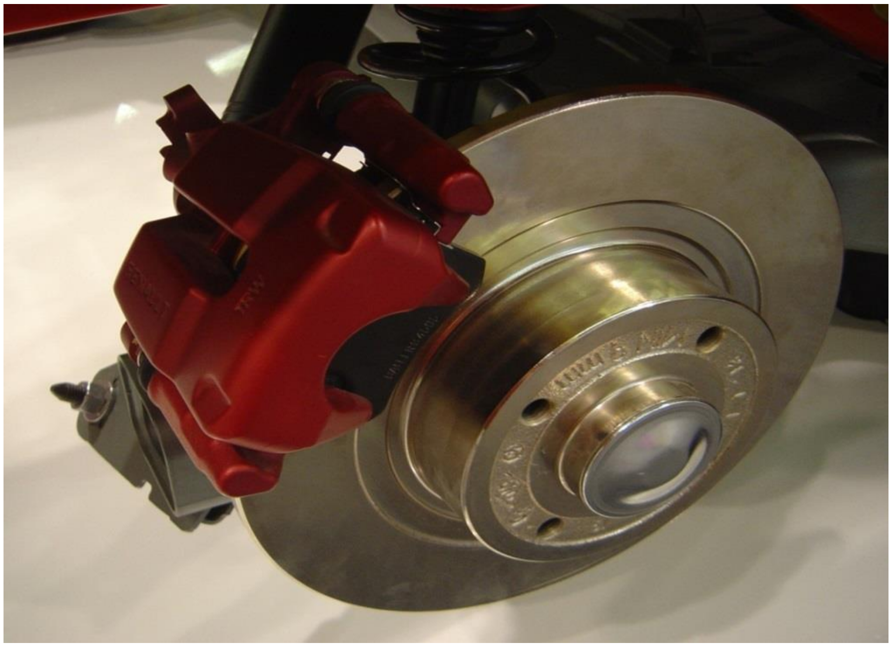

Fig1: Disc Brake of a Car

MATERIAL OF DISC

- Cast Iron
- Stainless Steel
- Aluminium Alloy

DISC APPLICATIONS

Fig: 2 ***A cross-drilled disc*** on a modern motorcycle.

The design of the disc varies somewhat. Some are simply solid cast iron, but others are hollowed out with fins or vanes joining together the disc's two contact surfaces (usually included as part of a casting process). This "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily-loaded front discs.

Many higher performance brakes have holes drilled through them. This is known as cross-drilling and was originally done in the 1960s on racing cars. Brake pads will outgas and under use may create boundary layer of gas between the pad and the disc that is detrimental to braking performance. Cross-drilling provides a place for the gas to escape. Although modern brake pads seldom suffer from outgassing problems, water residue may build up after a vehicle passes through water, and this can also impede braking performance. For this reason, and for heat dissipation purposes, cross drilling is still used on some braking components, but is not favoured for racing or other hard use as the holes are a source of stress cracks under severe conditions.

Discs may also be slotted, where shallow channels are machined into the disc to aid in removing dust and gas. Slotting is the preferred method in most racing environments to remove gas, water, and de-glaze brake pads. Some discs are both drilled and slotted. Slotted discs are generally not used on standard vehicles because they quickly wear down brake pads; however, this removal of material is beneficial to race vehicles since it keeps the pads soft and avoids vitrification of their surfaces.

DESIGN MODEL OF BRAKE DISC

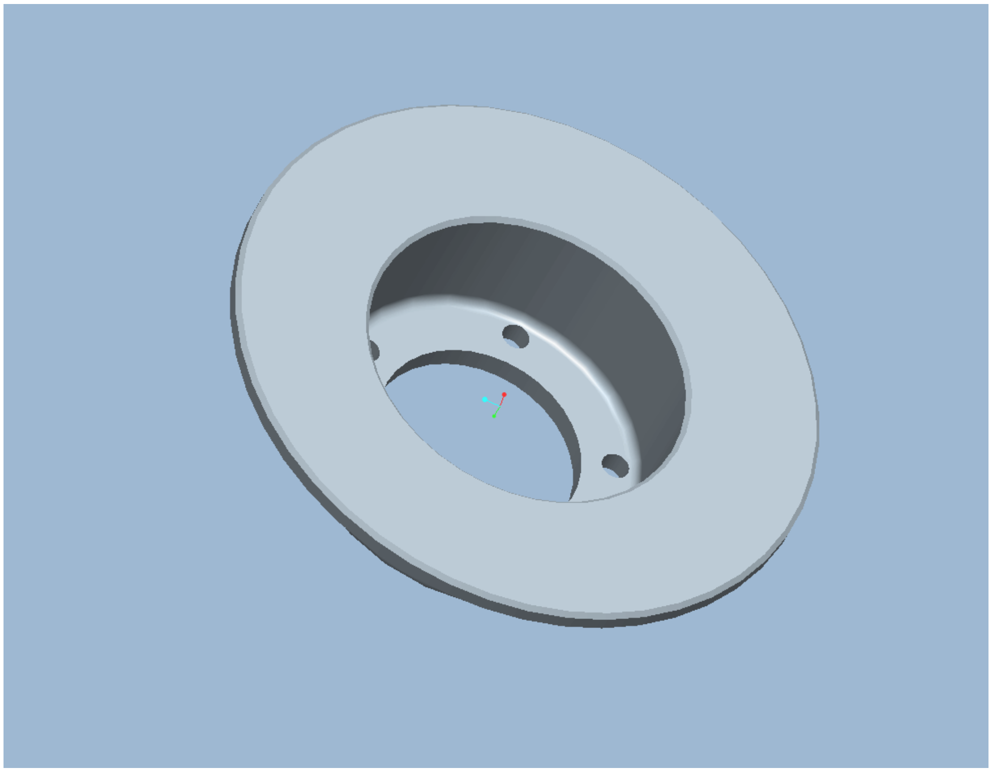

Fig: 3. Extruded Model of Disc

OPTIMIZATION AND ANALYSIS OF A SOLID DISC

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

STRUCTURAL ANALYSIS OF SOLID DISC

Stainless steel

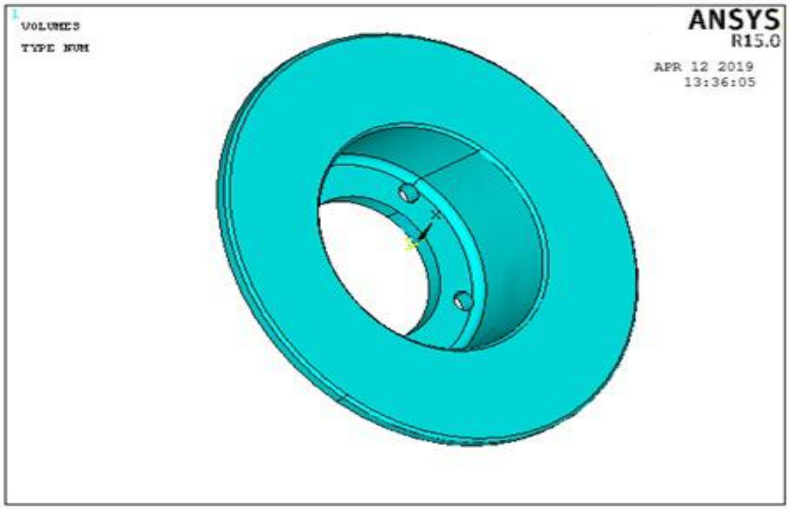

Fig: 4 (a) Imported Model from Pro/Engineer

Loads

Pressure – 1.2N/mm^2

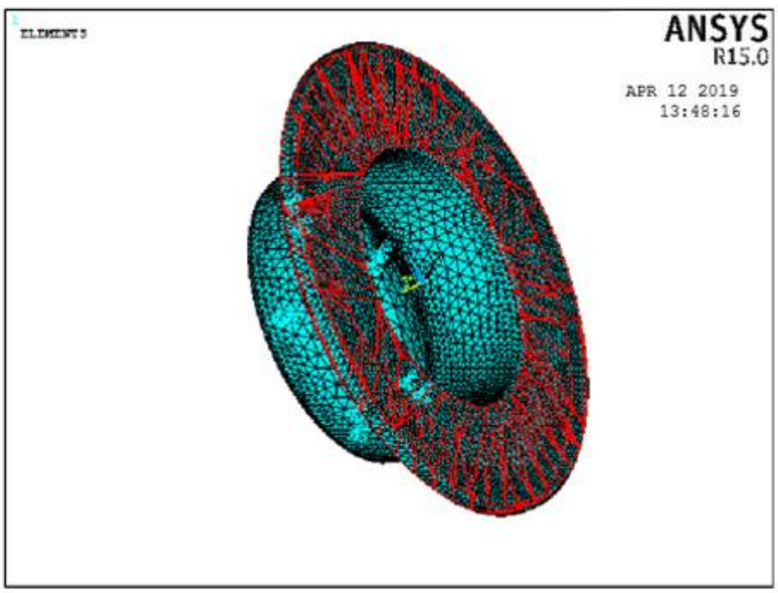

Fig: 4.1 Pressure applied on the Model

Solution

Solution – Solve – Current LS – ok

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution –
DOF Solution – Displacement Vector Sum

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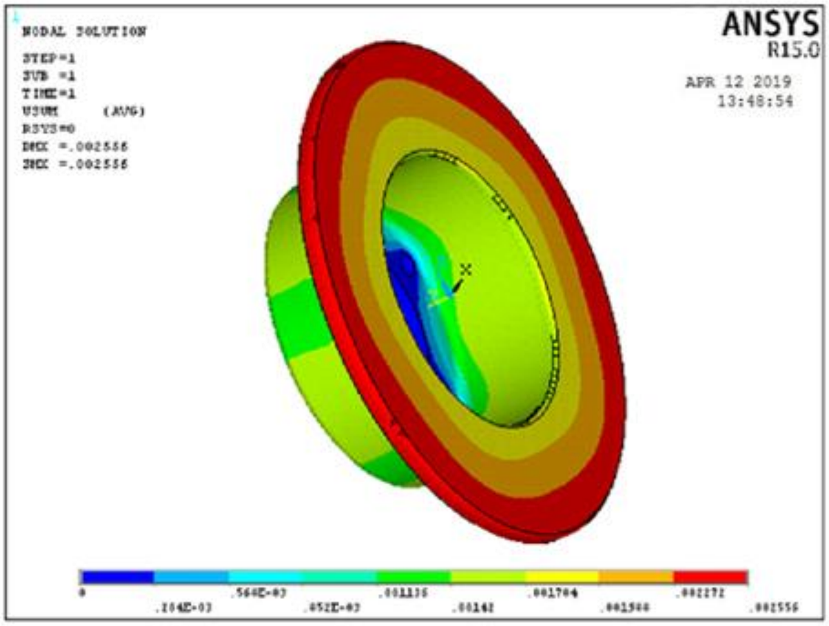

Fig: 4.1.1 (d) Displacement Vector Sum for Stainless Steel

General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stress

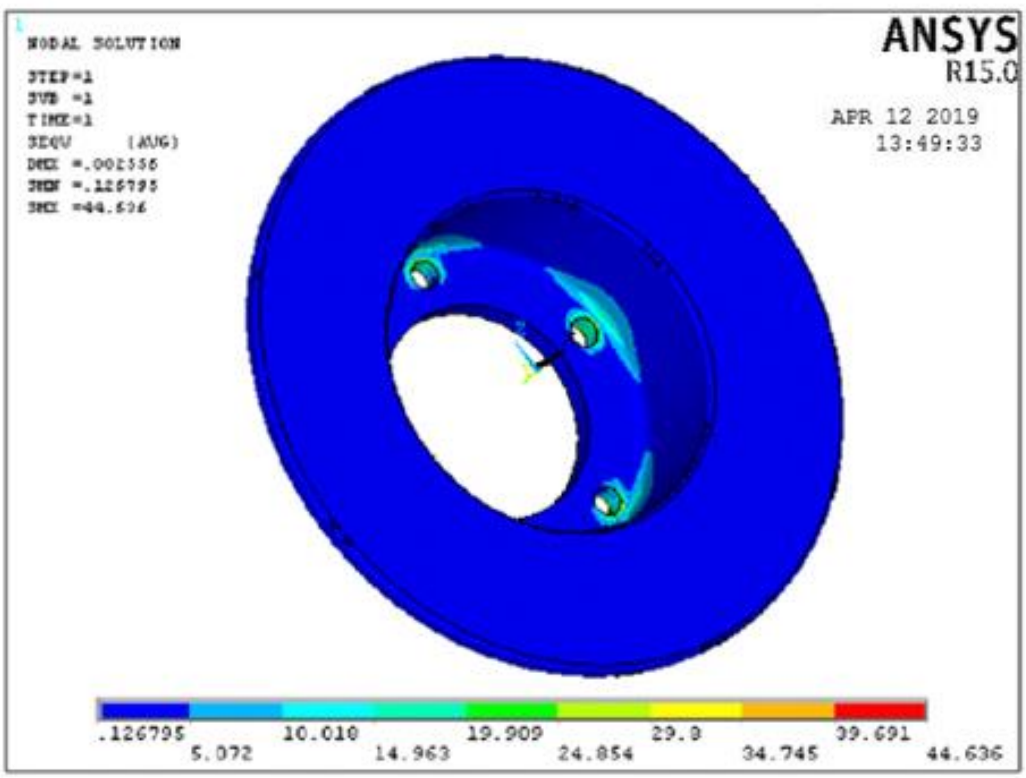

Fig: 4.2.1 (e) VoinMisesStress for Stainless Steel

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CAST IRON

Element Type **:** Solid 20 nodes 95

Material Properties : Young’s Modulus (EX) : 103000N/mm^2

Poisson’s Ratio (PRXY) : 0.211

Density : 0.0000071 kg/mm^3

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution –
DOF Solution – Displacement Vector Sum

Fig: 4.3.1 (a) Displacement Vector Sum for Cast Iron

General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stress

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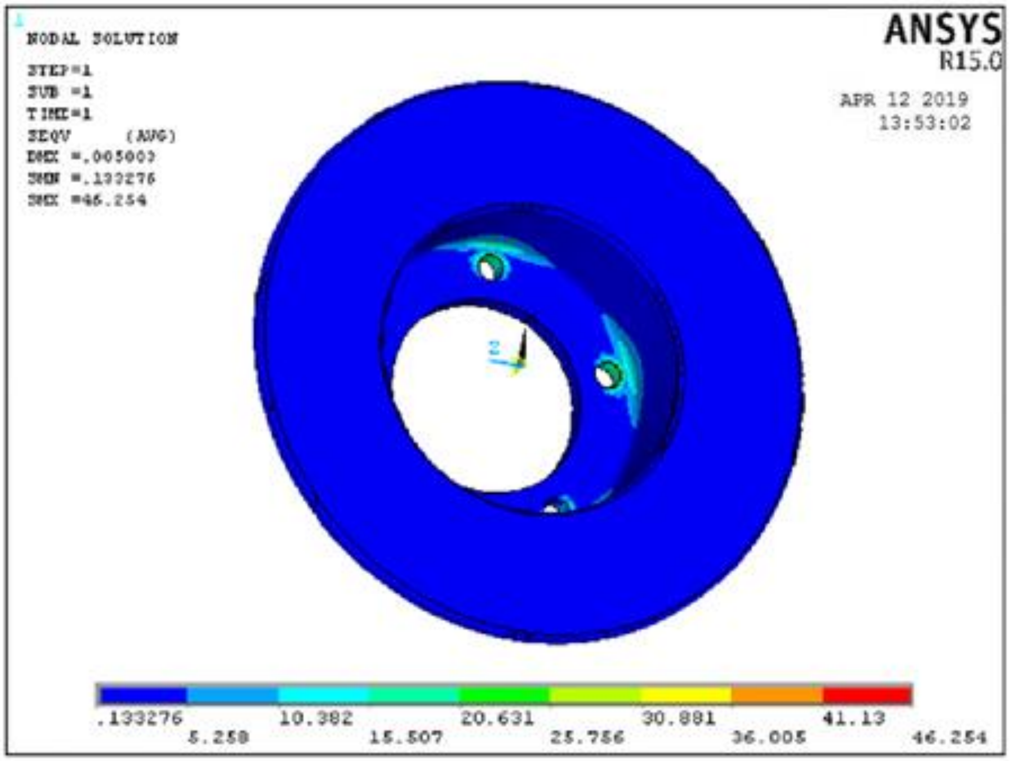

Fig: 4.3.2 (b) Von Mises Stress for Cast Iron

ALUMINIUM ALLOY

Element Type : Solid 20 nodes 95
Material Properties : Young's Modulus (EX) : 70000N/mm^2
Poisson Ratio (PRXY) 0.33
Density : 0.0000028kg/mm^3

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution –
DOF Solution – Displacement Vector Sum

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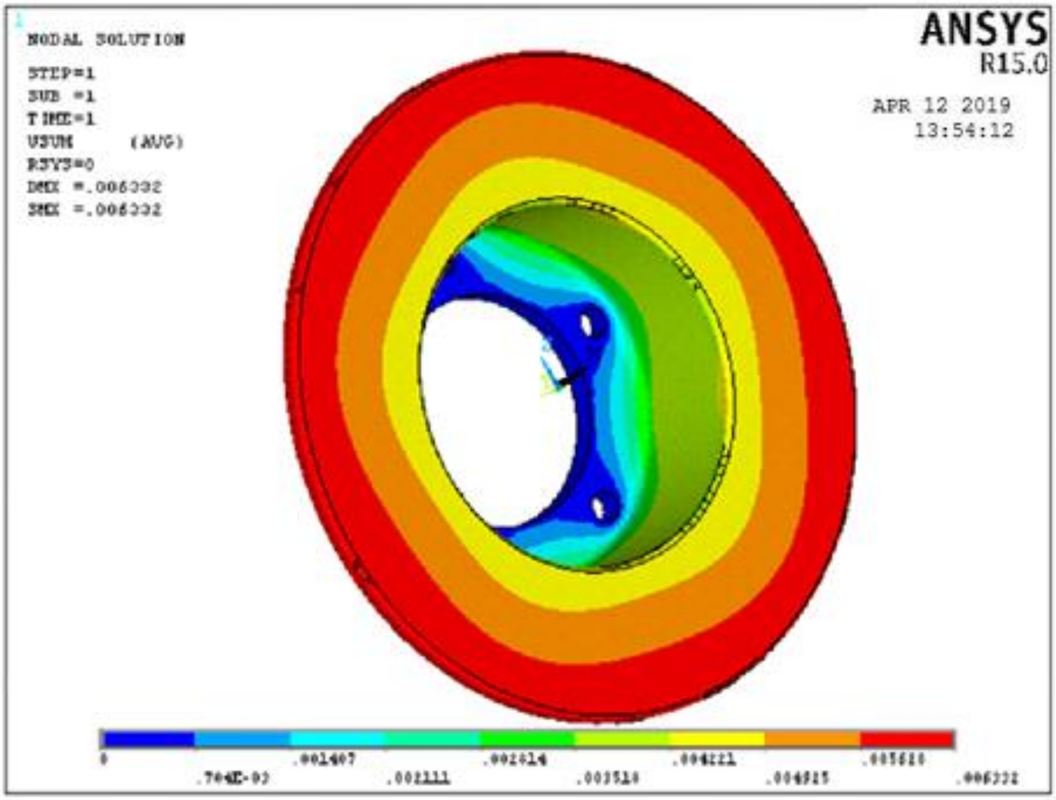

Fig: 4.4.1 (a) Displacement Vector Sum for Aluminium Alloy

General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stress

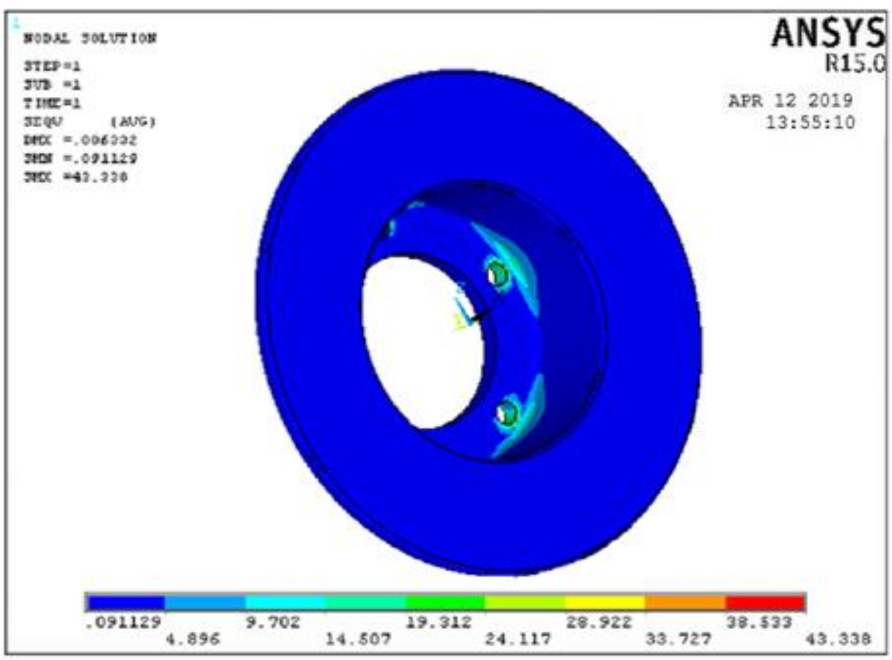

Fig:4.4.2 (b) Von Mises Stress for Aluminium Alloy

As per the analysis images

	Displacement (mm)	Von Mises Stress (N/mm^2)	Nodal Temperature(K)	Thermal Gradient (K/mm)	Thermal Flux (W/mm^2)
Stainless Steel	0.002556	44.636	353	84.381	21.095
Cast iron	0.005003	46.254	353	98.891	0.593665
Aluminium Alloy	0.006332	43.338	353	118.733	11.175

Comparison between solid disc and drilled hole disc

MATERIAL	SOLID DISC		DRILLED HOLE DISC	
	Von Mises Stress (N/mm^2)	Thermal Gradient (K/mm)	Von Mises Stress (N/mm^2)	Thermal Gradient (K/mm)
Stainless Steel	44.636	84.381	70.022	99.803
Cast iron	46.254	98.891	45.174	200.49
Aluminium Alloy	43.338	118.733	41.621	220.033

CONCLUSIONS

Structural and thermal analysis is done on the disc brake for three materials Stainless Steel, Cast Iron and Aluminium Alloy. Present used materials for disc brake are stainless steel and cast iron. I have are replacing the material with Aluminium alloy, since its density is less than that of other two materials thereby reducing the weight of disc brake.

By observing the stress values obtained in structural analysis, they are less than the yield stress value of Aluminium alloy, so using Aluminium alloy for disc brake is safe. And also by comparing with other two materials, the stress value is less for Aluminium alloy. So using Aluminium alloy is better. By observing thermal analysis results, thermal gradient is more for Aluminium alloy that is heat transfer rate is more for Aluminium alloy by comparing with other two materials.

I have suggest design of disc brake, by adding holes on disc brake. I have performed structural and thermal analysis on that model. By adding holes, thermal gradient has increased when compared with the present design. I conclude that by changing the design of disc brake the heat transfer rate increases and using Aluminium alloy is better when compared to other materials.

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