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Thermal and Stress Analysis of a Drum Brake by using Functional Graded Materials

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ABSTRACT

The Drum brake is a device for slowing or stopping the rotation of a wheel. A brake Drum (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 Drum.

Friction causes the Drum 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.

Drum brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking.

The aim of the project is to model a drum brake used in AUDI A100. Structural and Thermal is done on the Drum brake. The materials used are Cast Iron, stainless steel , Aluminum Alloy 6061 & functional graded materials (ceramic and aluminum). Analysis is also done by changing the design of Drum brake. Actual Drum brake has no holes; design is changed by giving holes in the Drum brake for more heat dissipation. Modeling is done in CATIA V5 R 20 parametric software and analysis is done in ANSYS 17 workbench.

KEYWORDS: Drumbrake, FGM, Ansys, Materials.

1. INTRODUCTION

1.1 BRAKE

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction.

1.2 BACKGROUND OF BRAKES

Most brakes commonly use friction between two surfaces pressed together to convert the kinetic energy of the moving object 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. Eddy current brakes use magnetic fields to convert kinetic energy into electric current in the brake disc, fin, or rail, which is converted into heat. 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} K=mv^{2}/2), an object moving at 10 m/s has 100 times as much energy as one of the same mass moving at 1 m/s, 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.

1.3 TYPES OF BRAKES

The most common types of car brakes today are typically hydraulic, frictional, pumping, electromagnetic, and servo. Of course, there are several additional components that are involved to ensure car brakes operate smooth on different road conditions and circumstances. Car accidents often happen due to poor braking systems. The more you know about these crucial systems, the better. Here are the most common types of brakes:

1.3.1 Electromagnetic Brake System

A rising style of brake system, electromagnetic brakes use an electric motor that is included in the automobile which help the vehicle come to a stop. These types of brakes are in most hybrid vehicles and use an electric motor to charge the batteries and regenerative brakes. On occasion, some buses will use a secondary retarder brake which uses an internal short circuit and a generator.

1.3.2 Frictional Brake System

A frictional brake system is found in many automobiles. They are service brakes, and typically found in two forms; pads and shoes. As the name implies, these brakes use friction to stop the automobile from moving. They typically include a rotating device with a stationary pad and a rotating weather surface. On most band brakes the shoe will constrict and rub against the outside of the rotating drum, alternatively on a drum brake, a rotating drum with shoes will expand and rub against the inside of the drum.

1.3.3 Hydraulic Brake System

A hydraulic brake system is composed of a master cylinder that is fed by a reservoir of hydraulic braking fluid. This is connected by an assortment of metal pipes and rubber fittings which are attached to the cylinders of the wheels. The wheels contain two opposite pistons which are located on the band or drum brakes which pressure to push the pistons apart forcing the brake pads into the cylinders, thus causing the wheel to stop moving.

1.3.4 Pumping Brake System

Pumping brakes are used when a pump is included in part of the vehicle. These types of brakes use an internal combustion piston motor to shut off the fuel supply, in turn causing internal pumping losses to the engine, which causes braking.

1.3.5 Servo Brake System

Servo brake is found on most cars and is intended to augment the amount of pressure the driver applies to the brake pedal. These brakes use a vacuum in the inlet manifold to generate extra pressure needed to create braking. Additionally, these braking systems are only effective while the engine is still running.

In some vehicles we may find that there are more than one of these braking systems included. These can be used in unison to create a more reliable and stronger system. Unfortunately, on occasion, these combination types of brakes may fail, resulting in automobile accidents and injuries.

1.3.6 Parking and Emergency Braking Systems

Parking and emergency braking systems use levers and cables where a person must use mechanical force or a button in newer vehicles, to stop the vehicle in the case of emergency or parking on a hill. These braking systems both bypass normal braking systems in the event that the regular braking system malfunctions.

These systems begin when the brake is applied, which pulls a cable that passes to the intermediate lever which causes that force to increase and pass to the equalizer. This equalizer splits into two cables, dividing the force and sending it to both rear wheels to slow and stop the automobile.

In many automobiles, these braking systems will bypass other braking systems by running directly to the brake shoes. This is beneficial in the case that your typical braking system fails.

1.4 Principle of braking system:

While operating the braking system the kinetic energy of moving vehicle is converted in to heat energy.

1.5 Functions of Brakes:

Brakes have the following functions.

1. It is used to stop the vehicle.
2. It is used to control the speed where and when required.
3. It is used to control the vehicle while descending along the slope.
4. To park the vehicle and held it in stationary position

1.5.1 DRUM BRAKE

A drum brake is a brake that uses friction caused by a set of shoes or pads that press outward against a rotating cylinder-shaped part called a brake drum.

The term drum brake usually means a brake in which shoes press on the inner surface of the drum. When shoes press on the outside of the drum, it is usually called a clasp brake. Where the drum is pinched between two shoes, similar to a conventional disc brake, it is sometimes called a pinch drum brake, though such brakes are relatively rare. A related type called a band brake uses a flexible belt or "band" wrapping around the outside of a drum.

Fig: 1 Drum Brake

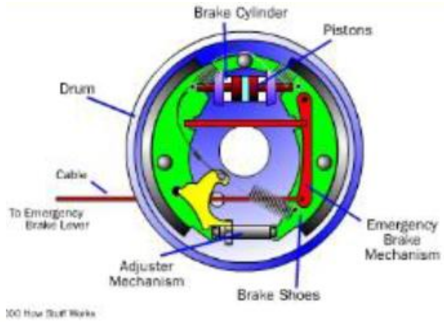


Fig: 2 Parts of a drum brake

1.6 DRUM BRAKE IN OPERATION

This is where it gets a little more complicated. Many drum brakes are self-actuating. Figure 5 shows that as the brake shoes contact the drum, there is a kind of wedging action, which has the effect of pressing the shoes into the drum with more force.

The extra braking force provided by the wedging action allows drum brakes to use a smaller piston than disc brakes. But, because of the wedging action, the shoes must be pulled away from the drum when the brakes are released. This is the reason for some of the springs. Other springs help hold the brake shoes in place and return the adjuster arm after it actuates.

2. LITERATURE REVIEW

Allan Michael Lang et al [1] in his research concluded that no simple relationship exists between the natural frequencies of the brake components and the squeal frequency and during squeal both the drum and shoes hold complex modes, which can be best visualized as the superposition of pairs of similar normal modes phase shifted both spatially and in time relative to each other.

MohdZald Bin Akop et al [2] in his project concluded that safety aspect in automotive engineering has been considered as a number one priority in development of new vehicle and it is a must for all vehicles to have proper brake system.

Ramesha.D.K et al [3] in his thesis concluded that the maximum temperature obtained for aluminum alloy brake drum is less as compared to the cast iron brake drum for a truck. Also, concluded that thermal deformation is less for aluminum alloy brake drum than the cast iron brake drum. As his study states that the weight of Aluminum is lesser than the Cast iron, it is better to use the Aluminum material in the construction of brake drum.

NurulhudaBinti Khalid et al [4] In his project concluded that the temperature changes on the brake drum during the deceleration providing the heat distribution and the distribution of temperature depends on the various factors such as friction, surface roughness, speed, and others.

Ray W.Murphy et al [5] in their report concluded that the braking efficiency of trucks and can be improved by careful distribution of braking effort among the axles of the vehicle

3. OBJECTIVES OF PROJECT

The objectives of the project are as follows

(i) To develop structural modeling of Drum Brake.

(ii) To perform finite element analysis of Drum Brake.

(iii) Suitable material study.

(iv) Study of load and Thermal factors.

(v) Study of stress, strain deformation, temperature and heat flux induced in the Drum Brake and Brake

4. STATIC ANALYSIS OF DRUM BRAKE

4.1 Modelling of drum

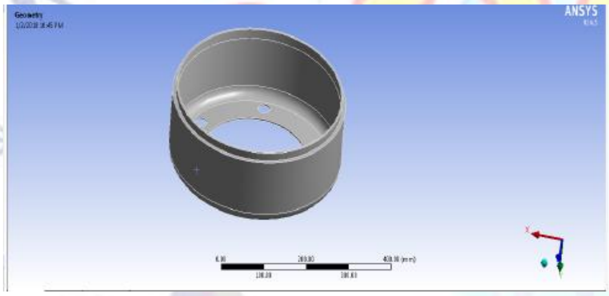


Fig 3: Imported model of brake drum for static analysis

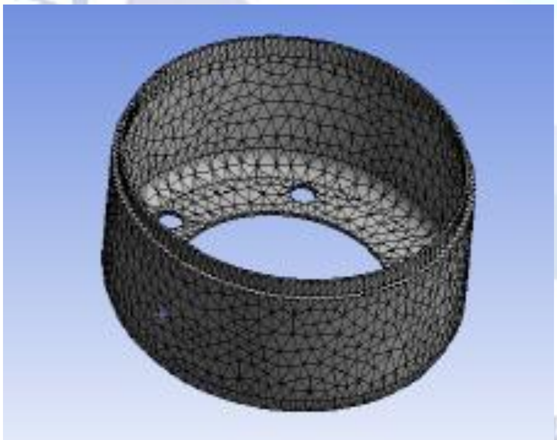


Fig 4: Meshed model of brake drum for static analysis

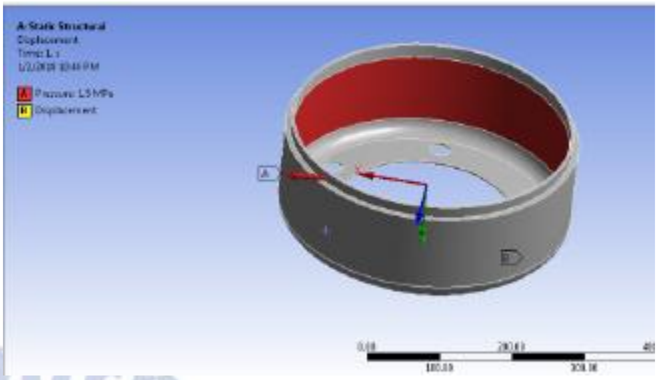


Fig 5: Boundary conditions to brake drum for static analysis

4.2 STATIC ANALYSIS OF BRAKE DRUM BY MATERIAL: CAST IRON

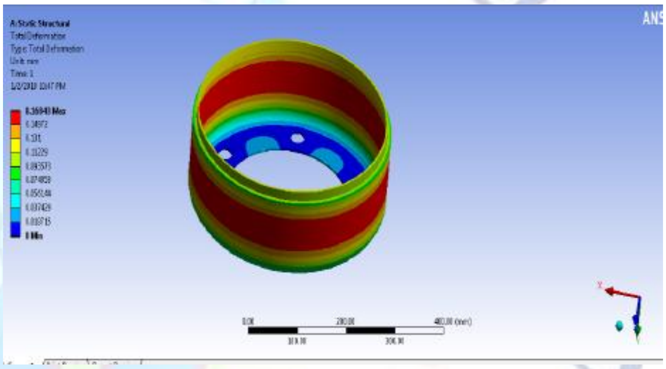


Fig 6: Total deformation of cast iron brake drum

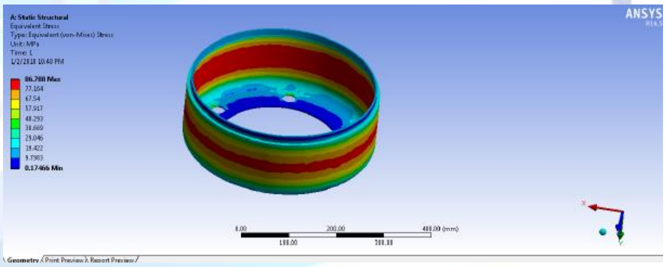


Fig 7: Stress distribution on cast iron brake drum

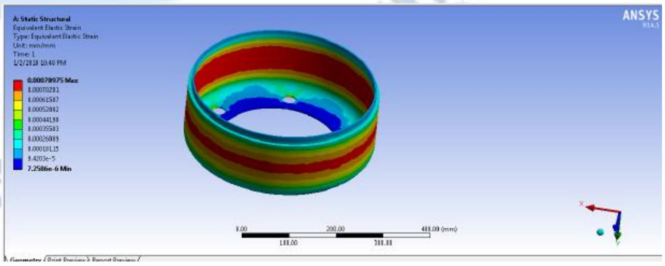


Fig 8: strain on cast iron brake drum

4.3 STATIC ANALYSIS OF BRAKE DRUM BY STAINLESS STEEL MATERIAL

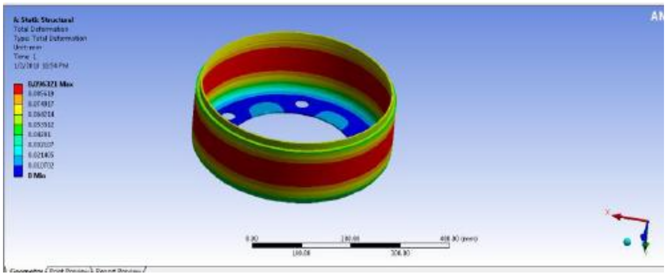
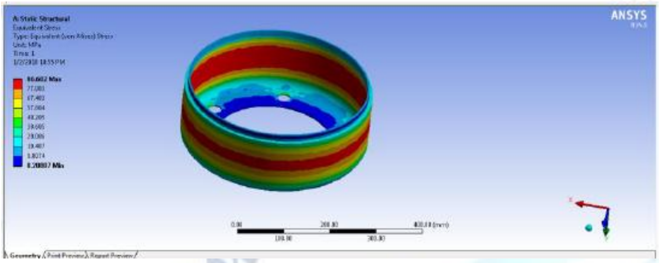


Fig 9: Total deformation of stainless steel brake drum



'Fig 10: Stress distribution on stainless steel brake drum

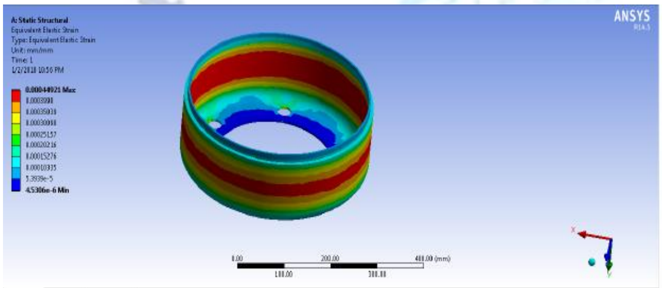


Fig 11: strain on stainless steel brake drum

4.4 STATIC ANALYSIS OF BRAKE DRUM BY ALUMINUM ALLOY 6061

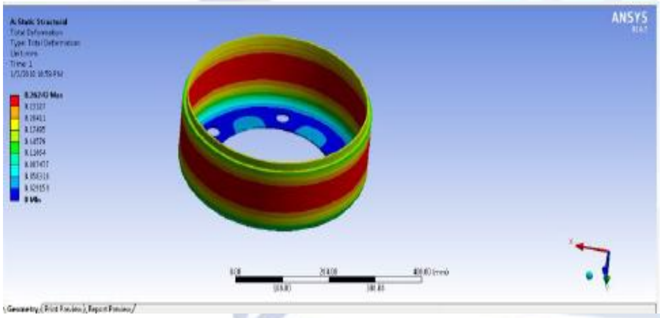


Fig 12: Total deformation of aluminum alloy 6061 brake drum

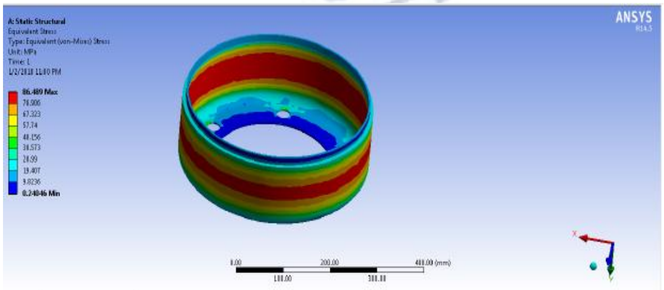


Fig 13: Stress distribution on aluminum alloy 6061 brake drum

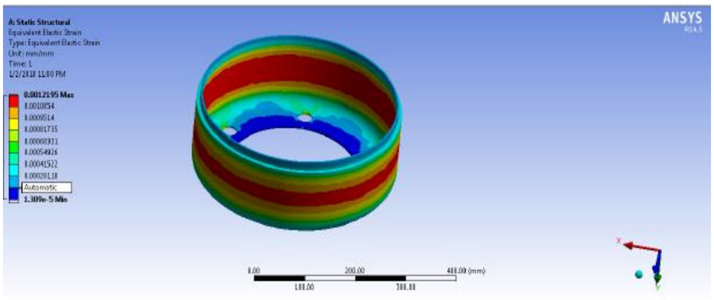


Fig 14: strain on aluminum alloy 6061 brake drum

Table 1: Static analysis result for three materials

Material	Deformation (mm)	Stress (N/mm^2)	Strain
Cast iron	0.16843	86.73	0.00078975
Stainless steel	0.096321	86.602	0.00044921
Aluminum alloy 6061	0.26243	86.489	0.0012195

4.3 THERMAL ANALYSIS OF DRUM BRAKE

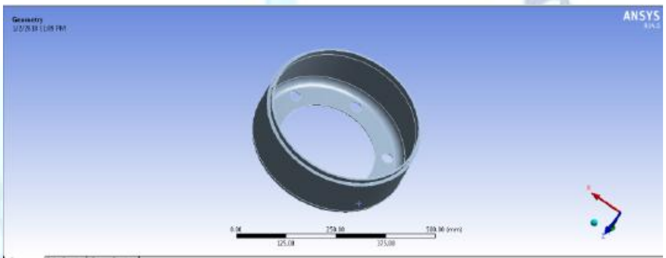


Fig 15: Imported model of brake drum for thermal analysis

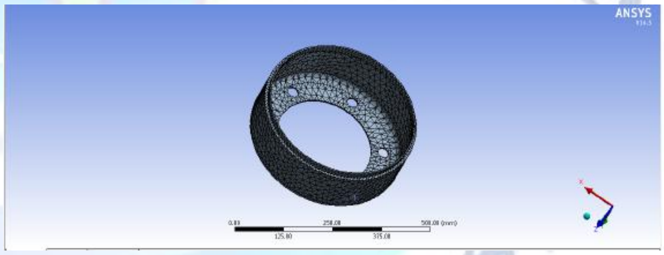


Fig 16: Meshed model of brake drum for thermal analysis

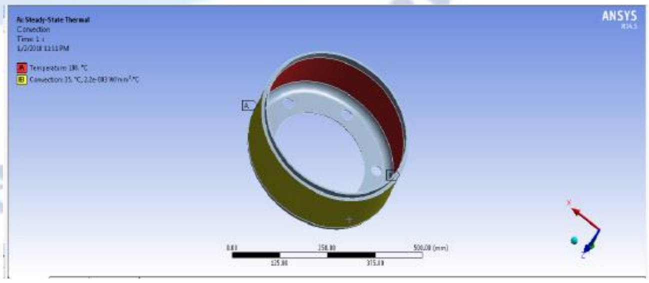


Fig 17: Boundary conditions to brake drum for thermal analysis

4.4 THERMAL ANALYSIS OF BRAKE DRUM BYCAST IRON

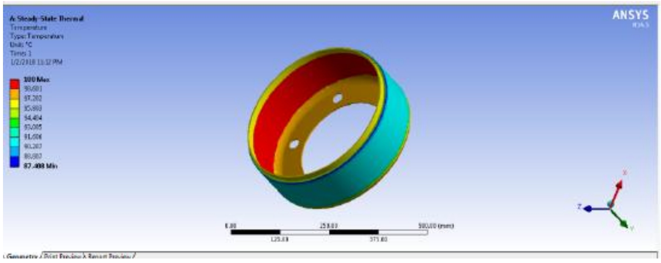


Fig 18: Temperature distribution on cast iron brake drum

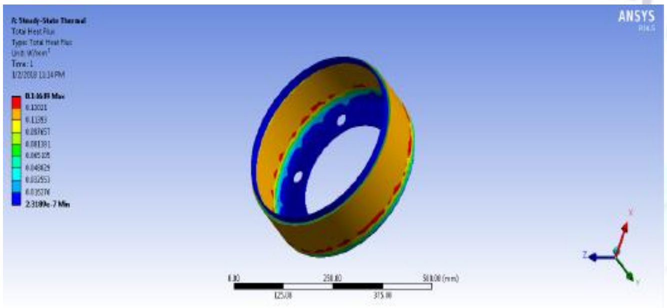


Fig 19: heat flux on cast iron brake drum

4.5 THERMAL ANALYSIS OF BRAKE DRUM STAINLESS STEEL

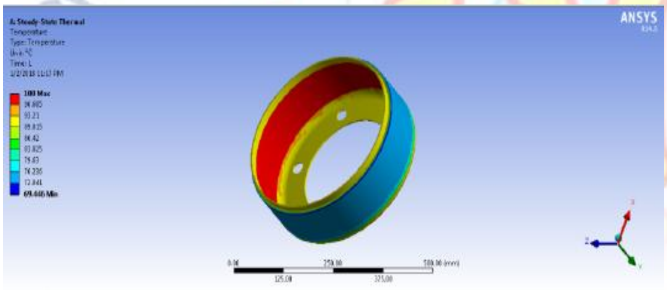


Fig 20: Temperature distribution on stainless steel brake drum

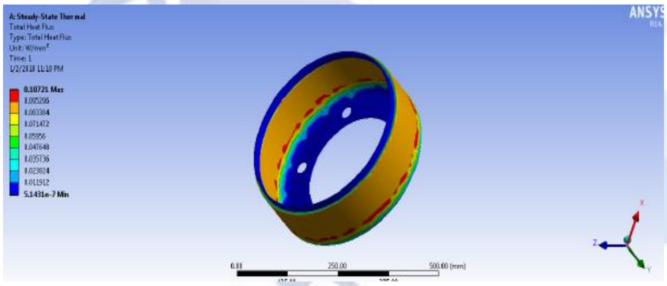


Fig 21: heat flux on stainless steel brake drum

4.6 THERMAL ANALYSIS OF BRAKE DRUM ALUMINUM ALLOY 6061

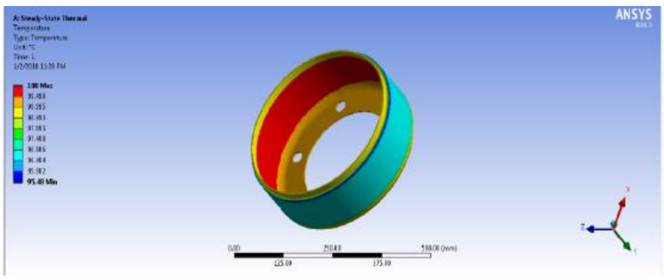


Fig 22: Temperature distribution on aluminum alloy 6061 brake drum

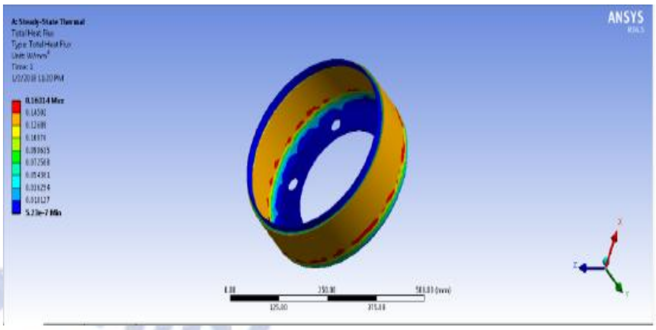


Fig 23: heat flux on aluminum alloy 6061 brake drum

Table 2: Thermal analysis results of three materials

Material	Temperature (^{0}C)		Heat flux(w/m-^{2})
	Min	Max	
Cast iron	87.408	100	0.14649
Stainless steel	69.446	100	0.10721
Aluminum alloy 6061	95.48	100	0.16314

5. FUNCTIONALLY GRADED MATERIALS (FGM)

5.1 ABOUT FGM

The reinforcement in composites used as structural materials in many aerospace and automobile applications is generally distributed uniformly. Functionally graded materials (FGMs) are being used as interfacial zone to improve the bonding strength of layered composites, to reduce the residual and thermal stresses in bonded dissimilar materials and as wear resistant layers in machine and engine components. They have therefore attracted considerable attention in recent years. One of the advantages of FGMs over laminates is that there is no stress build-up at sharp material boundaries due to continuous material property variation to eliminate potential structural integrity such as delimitation.

In materials science functionally graded material (FGM) may be characterized by the variation in composition and structure gradually over volume, resulting in corresponding changes in the properties of the material. The materials can be designed for specific function and applications. Various approaches based on the bulk (particulate processing), preform processing, layer processing and melt processing are used to fabricate the functionally graded materials.

5.2 MATERIAL PROPERTY CALCULATIONS FOR FGM (K=2)

◎ FOR STRUCTURAL ANALYSIS

Material properties

Top material: Ceramic (E=380000)

Bottom material: Aluminium (E=70000)

For YOUNGS MODULUS

1) For k=2;z=1

$E(Z)=(Et-Eb)(z/h+1/2)^K+Eb$

$=(380000-70000)(1/10+1/2)^2+70000$

$=(310000)\ (0.36)+70000$

$=181600$

2)For k=2;z=-1

$E(Z)=(Et-Eb)(z/h+1/2)^K+Eb$

$=(380000-70000)(-1/10+1/2)^2+70000$

$=310000\ (0.16)+70000$

$=119600$

Above Same Procedure Is Repeated For k=2;and Z=2,3,4,5,-2,- 3,-4,- 5.

FOR DENSITIES:

Material Properties:

Ceramic($\varrho t=0.00000396$)

Aluminium($\varrho b=0.0000027$)

1)For k=2;z=1

$\varrho(Z)=(\varrho t-\varrho b)(z/h+1/2)^K+\varrho b$

$=(0.00000396-0.0000027)(1/10+1/2)^2+0.0000027$

$= 0.00000315$

2)For k=2;z= -1

$\varrho(Z)=(\varrho t-\varrho b)(z/h+1/2)^K+\varrho b$

$=(0.00000396-0.0000027)(-1/10+1/2)^2+0.0000027$

$=0.0000029016$

Above Same Procedure Is Repeated For k=2;and Z=2,3,4,5,-2,- 3,-4,- 5.

FOR THERMAL ANALYSIS

For thermal conductivity:

Material properties:

Top material:ceramic (K=0.4498)

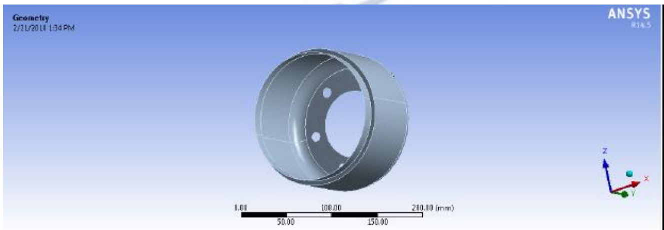


Fig 24: imported model for FGM brake drum

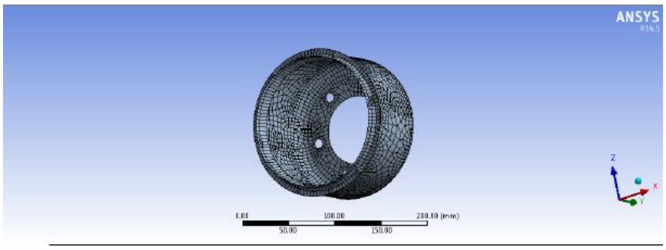


Fig 25: Meshed model for FGM brake drum

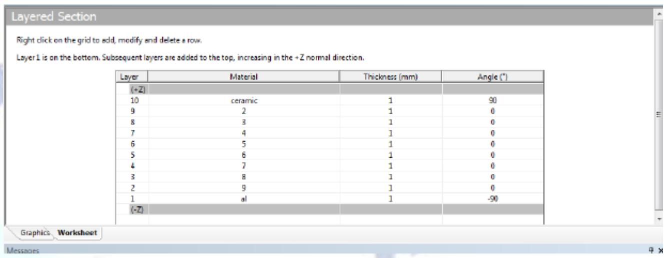


Fig 25: Layers stacking for FGM brake drum

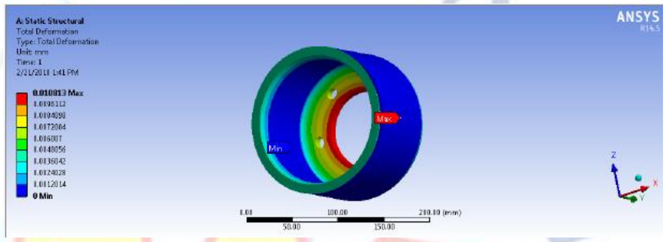


Fig 26: total Deformation of FGM brake drum

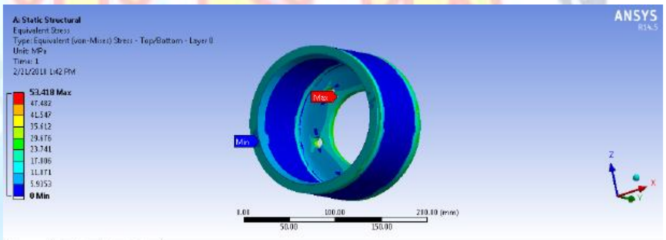


Fig 27: stress distribution of FGM brake drum

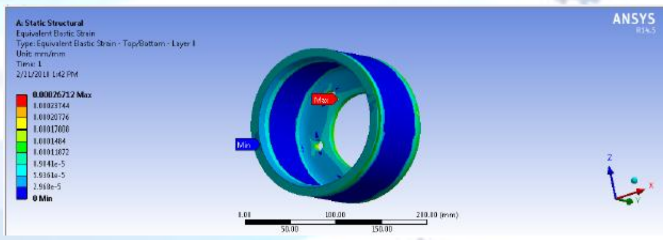


Fig 28: strain distribution of FGM brake drum

Table 3: static analysis results of FGM materials

Material	Deformation (mm)	Stress (N/mm^2)	Strain
FGM	0.010813	53.418	0.00026712

6. CONCLUSION

- Modeling and analysis of drum brakes and drum brake pads is done.
- Modeling of drum brake and drum brake pads are done in CREO design software.

● Thus both files are saved as IGES to import into ANSYS workbench Structural and
thermal analysis is carried on drum brake in ANSYS workbench First structural
analysis of pressure of 1.5Mpa is applied with three different materials such as cast
iron, stainless Steel, Aluminum alloy 6061 .

● Maximum stress, deformation, strain, Temperature and Heat flux are found and
tabulated.

● Next steady state thermal analysis of drum brake with three different materials cast
iron, stainless Steel, Aluminum alloy 6061 and FGM. at 100 c temperature and 220 c
ambient temperature of convection is applied Temperature distribution and total heat
flux are obtained and tabulated.

● Thus the stress, strain, shear stress and total deformations values are obtained and
tabulated.

● The aluminum alloy 6061 has low stress and strain when compared with the
remaining materials are 86.489 N/mm2 and 0.0012195 respectively

● The temperature and heat flux are more for aluminum alloy 6061 material when
compared with the remaining materials.

● The stress and strain for FGM are 53.415 N/mm2 and 0.00026712.

● Finally, this thesis concluded that the aluminum alloy 6061 material is suitable for
brake drum when compared with remain materials of cast iron and stainless steel.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Anup Kumar and R. saharish. Structural and Thermal Analysis of Brake Drum.Middle East Journal of Scientific Research Vol20. (8). IDOSI Publication. Pp 1012-1016. . 2014.

[2] Brake Drum. Available at en.wikipedia.org/wiki/Drum_brake.Cited March 2015.

[3] Frank Kreith. Mechanical Engineerimg Handle Book. Boca Raton: CRC Press LLC. Pp 4-7. 1999.

[4] Daniel Dannelley, John Baker, Clark K. Midkeff, Robert P. Taylor, Keith A. Woodburry. Enhancement of Extended Surface Heat Transfer Using Fractal-like Geometry.Department of mechanical Engineering, Graduate School of the University of Alabama. Pp 14-15. 2013.

[5] Fred Puhn. Brake Handbook. 2rd edition.HP Books Pp4, 15-21. 1985.

[6] Giri N.K. Automobile Technology. Sixth edition (reprint).Khanna Publisher. Pp 1269-1272.2012.

[7] James Carvill. Mechanical Engineer's Data Handbook. First Edition.Butterworth Heinemann Publication.Pp129-131.1993.

[8] Karim Nice. How Drum Brakes Works. Available at www.howstuffworks.com/autoparts/brake/brake-types/drum-brake 1.htm. cited March 2015

[9] Kicreyco Brake Drum Catalog. Kic Holding IncPp 1-12. Available at www.kicgroup.com.Cited April 2015.