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# Structural and Thermal Analysis on Rotor of Disc Brake by Varying Materials Using ANSYS

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ABSTRACT:

*A brake disk rotor forms pan of a foundation brake and rotates with the wheel hub assembly. The disc brake works on the principle of pascal's law which states that whenever pressure is applied to a fluid as it should be confined then it is equally distributed throughout the fluid in all directions and the force acting right angle to walls of the surface contact with the fluid. A brake disk rotor forms pan of a foundation brake and rotates with the wheel hub assembly. The main function of a foundation brake is to generate a retarding torque by converting mechanical energy to thermal energy by virtue of the frictional work done in relative sliding at the rotor-pad interface.*

*The main objective of the study is to design a disc brake rotor. Here two models of the disc brake rotor are considered without holes and with holes. And then structural and thermal analysis are done on the disc brake rotor made of two models with holes and without holes by varying the materials*

*In this thesis, comparison is done by varying materials with conventional materials and functionally graded materials, conventional materials are Cast Iron, Aluminum Alloy 6061. The Functionally Graded Material with metal Aluminum alloy 6061 using Ceramic as interface zone is taken for analysis. FGM's are considered for volume fractions of K=2. Theoretical calculations are done to calculate the material properties for each layer up to 10 layers.*

*3D modeling of the disc brake rotor is done in Pro/Engineer wildfire 5.0 and analysis is done in ANSYS* 14.5

**KEYWORDS**: Disc Brake, structural analysis, thermal analysis, Pro/Engineer wildfire 5.0, ANSYS

**Introduction:**

A brake is a device which inhibits motion. A brake disk rotor forms pan of a foundation brake and rotates with the wheel hub assembly. The disc brake works on the principle of pascal's law which states that when ever pressure is applied to a fluid as it should be confined in a vessel then it is equally distributed throughout the fluid in all directions and the force acting at right angle to the walls of the surface contact with the fluid.

Most commonly, brakes use friction to convert kinetic energy into heat, though other methods of energy conversion may be employed

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.

Main aim of the project:

The main aim of the project is to analyse the structural as well as thermal behavior of disc brake rotor under extreme conditions with holes and with out holes.

For this thesis i considered the following materials for comparision of structural and thermal analysis results

- Cast iron
- Al 6061
- 
- FGM (ceramic and aluminum as interface zone)

**Methodology:**

A geometric model is used to represent the disc brake rotor. The geometric modeling of the disc brake rotor is carried out in the Computer-Aided Design-software Pro/E which is capable of producing precise solid and surface geometry. After modelling in Pro/E it was then converted into <.step or IGES format>, then imported to ANSYS. By considering meshing parameters required for proper mesh automatic meshing is done in ANSYS.

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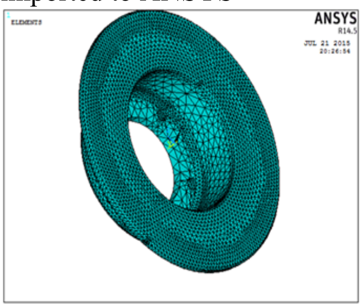


Fig: Mesh model

**material property calculations for FGM (k=2)**

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( $\rho t$=0.00000396)
Aluminium($\rho b$=0.0000027)

1)For k=2;z=1

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

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

$= 0.00000315$

2)For k=2;z= -1

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

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

$=0.0000029016$

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

**STRUCTURAL ANALYSIS:**

Structural analysis is probably the most common application of the finite element method. In this thesis displacement, stress and strain under different loading conditions are determined. The analysis results are shown in the following figures.

**CAST IRON**

Element Type: Solid 20 node 95

Material Properties: Young"s Modulus: 103000N/mm2
Poisson"s Ratio: 0.3
Density: 0.0000071 kg/mm3

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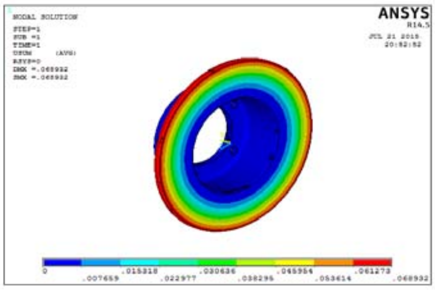


Fig: Displacement

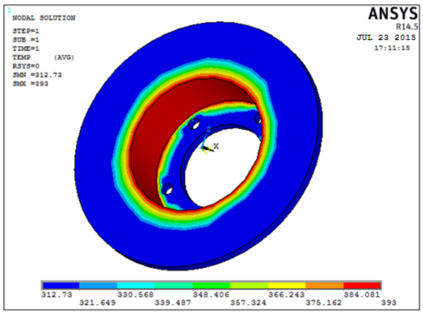


Fig: Nodal temperature

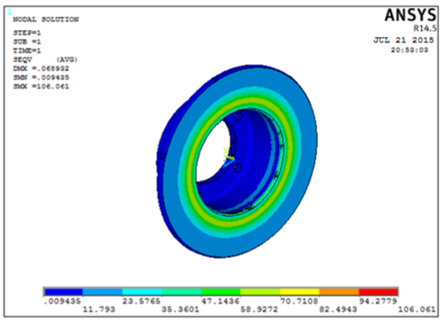


Fig: Von misses stresses

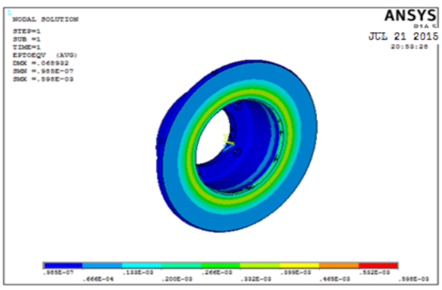


Fig: Strian

## THERMAL ANALYSIS:

A thermal analysis calculates the temperature distribution and related thermal quantities in a systeor component. Typical thermal quantities of interest are

- The amount of heat lost or gained
- Thermal gradients
- Thermal fluxes.

## CAST IRON

Element Type: Solid 20 node 95

Material Properties: Thermal Conductivity – 50w/mk

Specific Heat – 540j/kg k

Density - 0.0000071 kg/mm$^3$

The analysis results are shown in the following figures.

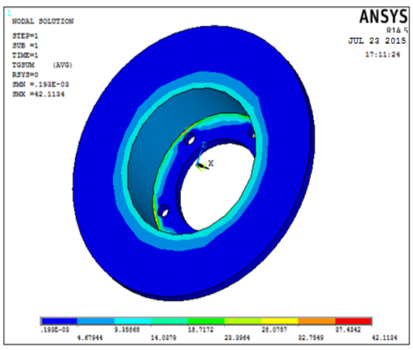


Fig: Thermal gradient

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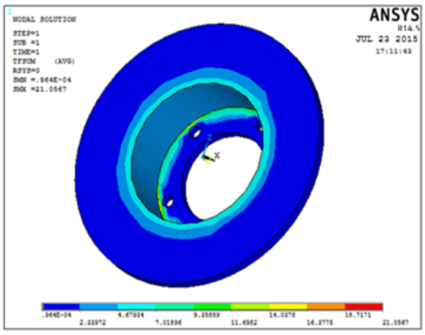



Fig: Thermal flux

Similarly the structural and thermal analysis is carried out for the disc brake rotor with holes and the analysis results are shown in the following figures.

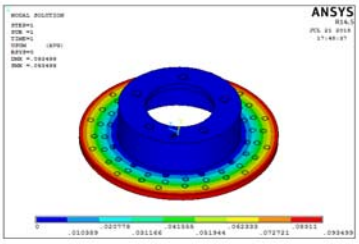



Fig: Displacement

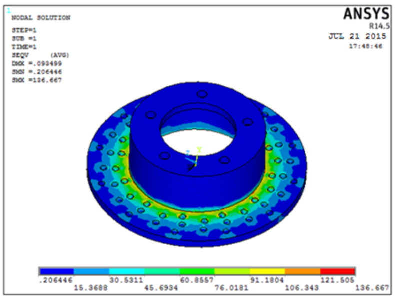



Fig: von misses stresses

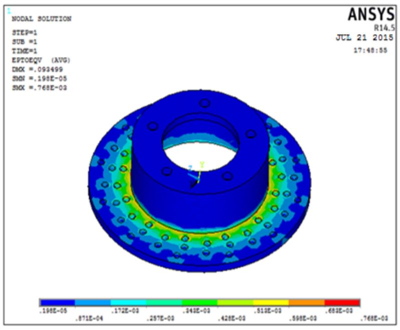



Fig: Strain

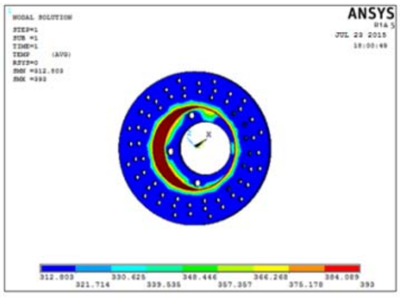



Fig: Nodal temperature

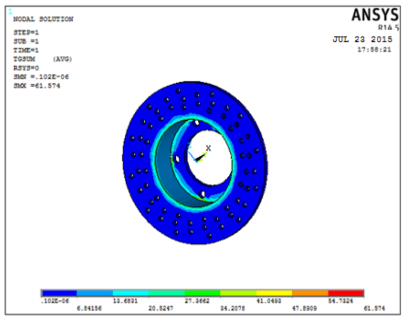
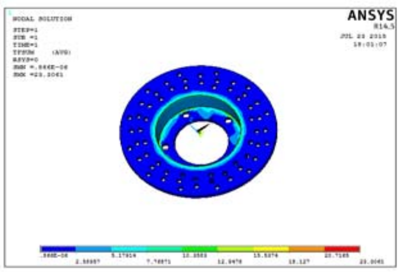



Fig: Thermal gradient



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# RESULTS:

| | Structural analysis | | | | | |
|---|---|---|---|---|---|---|
| material | Without Holes | | | With holes | | |
| | Displacement(mm) | Stress ($N/mm^2$) | Strain | Displacement (mm) | Stress ($N/mm^2$) | Strain |
| **AL-6061** | 0.017289 | 104.821 | 0.153E-03 | 0.235846 | 132.491 | 0.001925 |
| **CAST IRON** | 0.068932 | 106.061 | 0.598E-03 | 0.093499 | 136.667 | 0.768E-03 |
| **FGM** | 0.170276 | 105.325 | 0.977E-03 | 0.1598258 | 150.074 | 0.001091 |

| | Thermal analysis | | | | | |
|---|---|---|---|---|---|---|
| material | Without Holes | | | With holes | | |
| | Nodal temperature (k) | Thermal gradient (k/mm) | Thermal flux (w/mm) | Nodal temperature (k) | Thermal gradient (k/mm) | Thermal flux ($w/mm^2$) |
| **AL-6061** | 393 | 9.94291 | 55.2384 | 393 | 61.574 | 11.0833 |
| **CAST IRON** | 393 | 42.1134 | 21.0567 | 393 | 61.574 | 23.3061 |
| **FGM** | 392.704 | 44.2026 | 12.494 | 392.688 | 53.9586 | 14.953 |

**Conclusions:**

By observing the structural analysis results, the stresses and displacements are less for Functionally Graded Material, so it is better to use FGM and the stresses are less for the disc brake without hole. By observing the thermal analysis results, the heat transfer rate is more for disc brake with holes than without holes since thermal flux is more. Using FGM is better since heat transfer rate is more. So it can be concluded that using FGM for disc brake rotor is better with holes since the stresses are within the permissible limit and more heat transfer rate.

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