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Design and Analysis of a Disc Brake by Using Functional Graded Materials

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ABSTRACT

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.

The aim of the project is to model a disc brake used in Honda Civic. Structural and Thermal is done on the disc brake. The materials used are Cast Iron and Aluminum Alloy. Analysis is also done by changing the design of disc brake. Actual disc brake has no holes, design is changed by giving holes in the disc brake for more heat dissipation.

Modeling is done in CREO and analysis is done in ANSYS.

Key words: Finite element analysis, disc brake rotor, structural and, thermal analysis.

1. 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 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.

2. LITERATURE REVIEW

Stress Analysis of Functionally Graded Disc Brake Subjected To Mechanical Loading

In this thesis, analytical investigation is to be done

for functionally graded disc brake subjected to internal pressure. Different models of the disc brake are considered i.e. disc brake with 40, 50 and 60 holes. In this thesis, comparison is to be done by varying materials for disc brake, the materials are Cast Iron, FGM 1(Al2O3-Al) and FGM 2 (Zr-Al). FGM's are considered for material variation profile through the thickness for k =2, k =4 and k =6 .Theoretical calculations are done to calculate the material properties for each layer up to 10 layers for FGM's. Structural analysis and thermal analysis are done on the three models by varying materials. 3D modeling is to be done in Pro/Engineer and analysis is to be done in Ansys 14.5.

Keywords: Disc brake, Functionally graded material, Material variation Parameter.

3. PROBLEM DESCRIPTION:

The objective of this project is to make a 3D model of the disc brake and study the structural and thermal behavior of the disc brake by performing the finite element analysis.3D modeling software (PRO-Engineer) was used for designing and analysis software (ANSYS) was used for structural and thermal analysis.

The methodology followed in the project is as follows:

- Create a 3D model of the disc brake assembly using parametric software pro-engineer.
- Convert the surface model into Para solid file and import the model into ANSYS to do analysis.
- Perform structural analysis on the steam Boiler assembly for thermal loads.
- Perform thermal analysis on the existing model of the surface disc brake.

4. INTRODUCTION TO CAD/CAE:

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

4.1. INTRODUCTION TO PRO-ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Different modules in pro/engineer

Part design, Assembly, Drawing& Sheet metal.

4.2. INTRODUCTION TO FINITE ELEMENT METHOD:

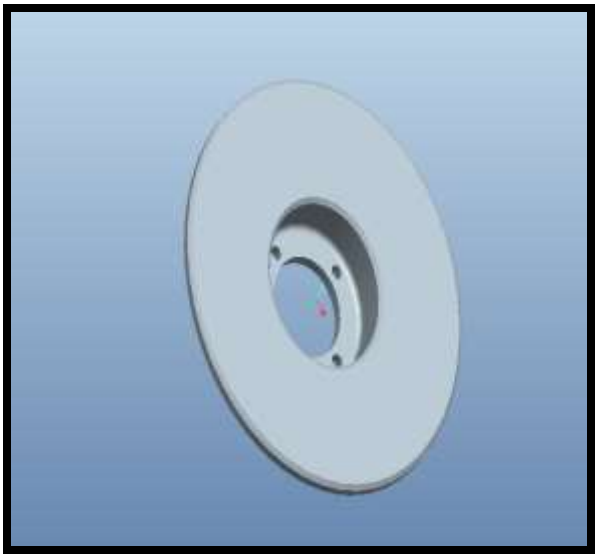
Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite

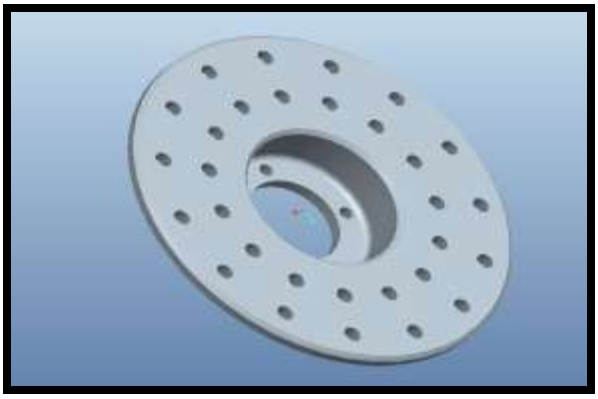
element method it is feasible to generate the relative results.

5. RESULTS AND DISCUSSIONS:

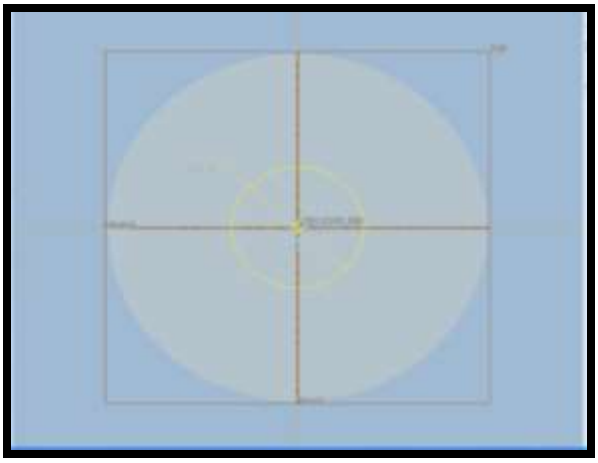
5.1. Models of disc brake using pro-e wildfire 5.0: The disc brake is modeled using the given specifications and design formula from data book. The isometric view of disc brake is shown in below figure. The disc brake outer casing body profile is sketched in sketcher and then it is extruded by using using extrude option.

Disc brake 3D model



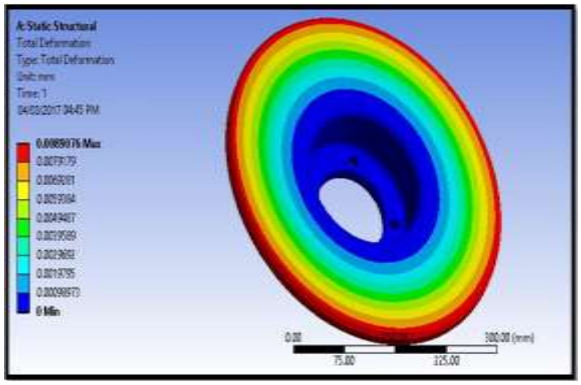


Disc brake 2D model



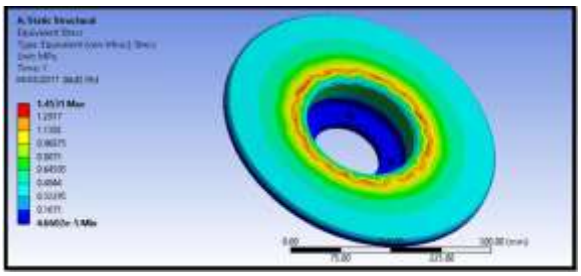
5.2. STRUCTURAL ANALYSIS OF DISC BRAKE

Deformation

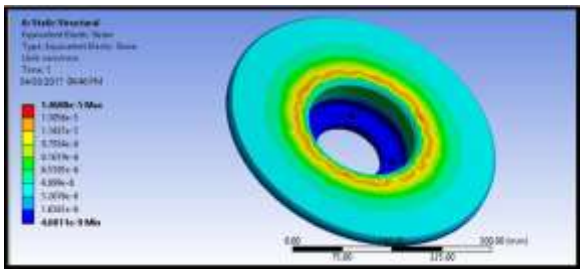


According to the above contour plot, the maximum deformation is at the outer edge of the brake i.e., 0.0089076.

Stress



Strain



5.3. THERMAL ANALYSIS OF DISC BRAKE ROTOR

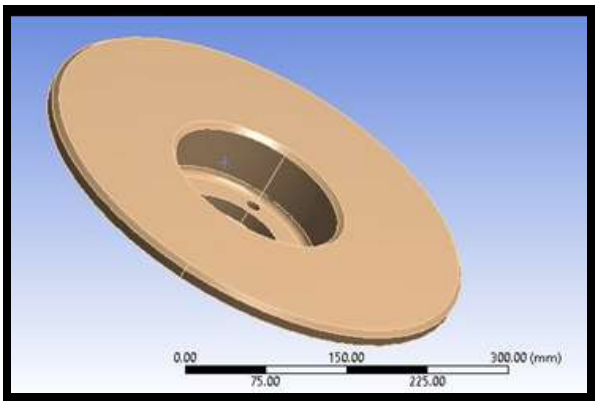
FORGED IRON MATERIAL PROPERTIES

Thermal conductivity of aluminum = 50w/mk

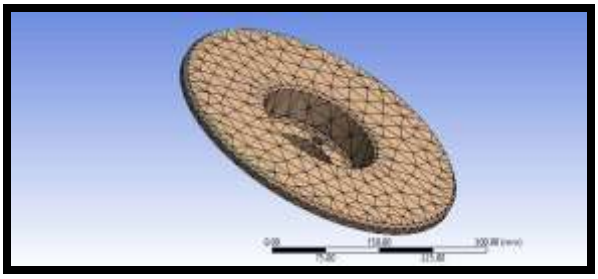
Specific heat =540 j/kg k

Density = 0.0000071kg/mm^3

IMPORTED MODEL



MESHED MODEL



Finite element analysis or FEA representing a real project as a "mesh" a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

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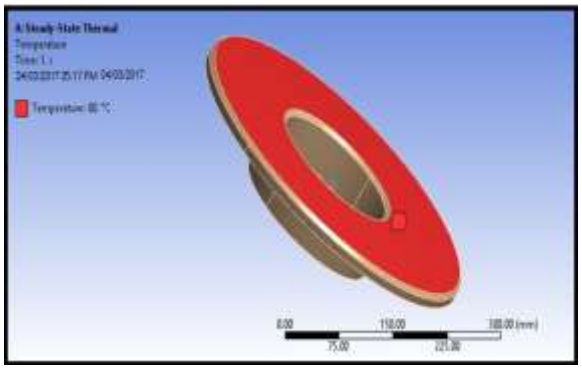
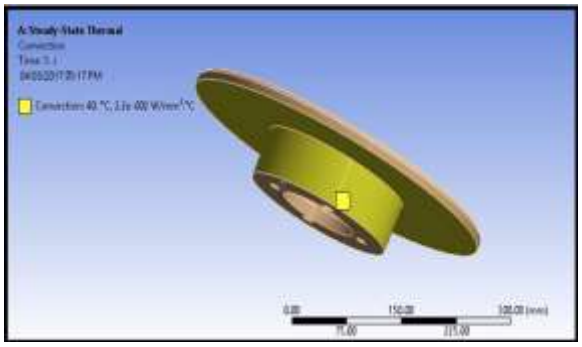
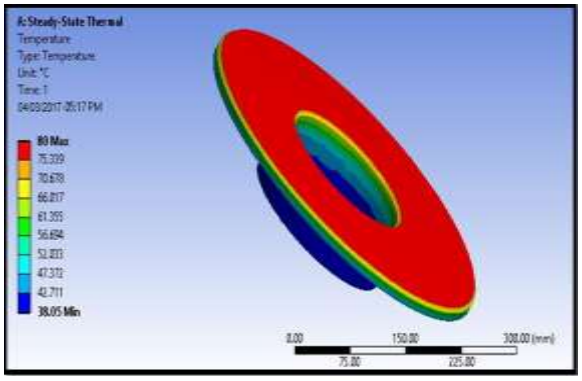
BOUNDARY CONDITIONS

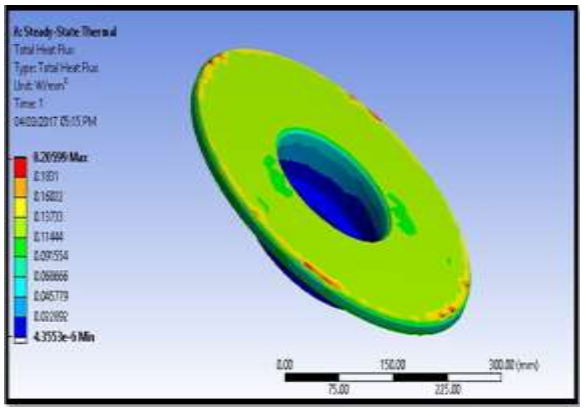




Temperature



Heat flux



6. RESULTS AND DISCUSSIONS

STRUCTURAL RESULTS

WITHOUT HOLES

MATERIAL	DISPLACEMENT (mm)	STRESS (N/mm²)	STRAIN
CAST IRON	0.0089076	1.4531	0.00001456
AL-6061	0.10935	1.1062	0.00016131

WITH HOLES

MATERIAL	DISPLACEMENT (mm)	STRESS (N/mm²)	STRAIN
CAST IRON	0.0081639	1.2734	0.00001271
AL-6061	0.091848	1.0428	0.00015446

RESULTS OF FGM

		RESULTS		
		DISPLACEMENT (mm)	STRESS (N/mm²)	STRAIN
WITHOUT HOLES	K=2	0.004255	2.1026	0.00000716
WITH HOLES	K=2	0.0037155	1.957	0.00000666

THERMAL RESULTS

WITHOUT HOLES

MATERIAL	TEMPERATURE (⁰C)	THERMAL FLUX (W/mm²)
CAST IRON	80	0.2045
AL-6061	80	0.53415

WITH HOLES

MATERIAL	NODAL TEMPERATURE (⁰C)	THERMAL FLUX (W/mm²)
CAST IRON	80	0.29822
AL-6061	80	0.5849

RESULTS OF FGM

WITH HOLES

MATERIAL	RESULTS	
	TEMPERATURES(⁰C)	HEAT FLUX (W/mm²)
K=2	80	1.009e-15

WITHOUT HOLES

MATERIAL	RESULTS	
	TEMPERATURES(⁰C)	HEAT FLUX (W/mm²)
K=2	80	0.20523

7. CONCLUSION

In this project a disc brake used in two wheeler is designed and modeled in 3D modeling software CREO. Two models one with holes and the other one without holes are modeled. Structural and thermal analysis is done on the disc brake using two materials Cast iron and Aluminum alloy 6061.

By observing the structural analysis results, the stress values are more disc brake with holes than that of disc brake without holes. So as per structural analysis, using disc brake without holes is better. By comparing the materials, using Aluminum alloy6061 is better as the stresses are less than the allowable stress and weight of the disc brake is less than that of Cast Iron since its density is less.

By observing the thermal analysis results, the disc brake with holes yields better results, as the thermal gradient and thermal flux is more increasing the heat transfer rate than that of disc brake without holes. By comparing the two materials, thermal flux is more for aluminum alloy 6061; the heat transfer rate is more when compared with of Cast Iron.

By observing linear layer analysis both thermal and structural analysis thermal gradient and thermal flux is more increasing the heat transfer rate than that of disc brake without holes and the stress values are more disc brake with holes than that of disc brake without holes. So as per structural analysis, using disc brake without holes is better.

So it can be concluded that disc brake with holes and using aluminum alloy 6061 is better.

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