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Design And Analysis of Disc Brake Plates

Sainath Kasuba
Associate Professor,
Thermal Engineering,
Sreyas Institute of Science & Technology.

Ather Nawaz Khan
M.Tech Scholar,
Department of Mechanical,
Sreyas Institute of Science & Technology.

Abstract:

The main objective behind undertaking the project "Analysis of Disc Brake Rotor" is to study and evaluate the performance of disc brake under severe braking conditions and thereby assisting in disc brake rotor design and analysis. ANSYS 11.0 is a dedicated general purpose Finite Element package used for determining the temperature, stress and strains. ANSYS is a flexible and cost effective tool. ANSYS is used in industries in order to solve several mechanical problems. In this project, an Axis-Symmetric disc brake rotor is considered for analysis. Flange width of 8mm, 10mm and 12mm made of Cast Iron, Aluminum and Aluminum composite are considered. A Coupled Field Analysis (Transient Thermal Analysis and Structural Analysis) is performed to obtain the Temperature Distribution and Von Mises Stress. After the Coupled field analysis is performed, a graph is plotted between the distance and temperature. An attempt is made to suggest the best combination of material and flange width for disc brake rotor, which yields a low temperature variation across the rotor disc and minimum von mises stress possible

1. INTRODUCTION:

A brake is an instrument or equipment that makes use of artificial frictional resistance to stop the motion of a moving member. While performing this function, the brakes imbibe potential energy or kinetic energy of the moving member. The energy that is absorbed by the brakes is dissipated in the form of heat. The dissipated heat is in turn liberated into the surrounding atmosphere.

1.1 Braking Requirements:

1. Brakes should be a good anti wear resistant.
2. While braking the driver should have good control over the vehicle i.e. the vehicle should not skid.
3. Brakes of a vehicle should be strong so that it can stop a vehicle in minimum time.
4. Brakes should have good anti fade characteristics.

1.2 Classification of brakes:

1. Hydraulic brakes
2. Electric brakes
3. Mechanical brakes

- Radial Brakes
- Axial Brakes
- Radial Brakes. Then force acting on brake drum is in radial direction for Radial brakes. These brakes are of two types: Internal Brakes and external brakes.
- Axial Brakes. The force acting on the brake drum is in axial direction for axial brakes.

1.3 Disc Brake:

A disc brake is a device, composed of iron or ceramic composites that are connected to the wheel hub or axle and a caliper. In order to stop the wheel hub,friction material is automatically or hydraulically forced on both sides of the brake in the form of brake pads. This friction in turn originates the wheel hub and the disc to slow down and stop. A disc brake is a device, composed of cast

Project Statement:

This project deals with the analysis and optimization of disc brake rotor using ANSYS 11.0 software.

Objective:

For analysis, the axis symmetric model of disc brake is carried out using ANSYS 11.0 software.

1. A transient thermal analysis is carried out using direct time integration technique of 4 seconds.
2. Static structure analysis coupled with thermal solution is carried out.
3. Different combinations of flange width-8mm, 10mm and 12mm and materials-Cast iron, Aluminum and Aluminum composites are considered.

Deliverables:

1. Minimum temperature at the contact surface of the disc brake rotor is observed.
2. Minimum Von Mises stress is observed.
3. A graph is plotted between Distance on X-axis and Temperature on Y-axis.

Obtained results are compared and analyzed to arrive at the best possible combination.

2. LITERATUREREVIEW:

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. In the present day, finite element method is one of the most effective and widely used tools. By doing more computational analysis the approximate solution can be improved or refined in Finite element method.

Introduction to ANSYS:

ANSYS stands for Analysis System Product. Dr. John Swanson was the founder of ANSYS Inc. in the year 1970. ANSYS was founded in order to establish a technology that facilitates several companies/industries to compute or simulate analysis issues. ANSYS is a general-purpose finite element analysis (FEA) software package that is extensively used in industries to resolve several mechanical problems. FEA is a method of fragmenting a composite system into small pieces called Elements. The ANSYS software carries out equations that regulate the performance of these elements and solves them resulting in an overall description of how the system works integrally. The obtained results are displayed in a tabulated or graphical form. This type of system is used for optimization of systems.

Implementing A Transient Thermal Analysis Involves Three Main Tasks:

1. Building the model, Building a model involves tasks such as defining the element types, material properties, model geometry and meshing the model.
2. Applying loads and obtaining the solutions. The first step in applying transient loads in a transient thermal analysis is to specify the analysis type and establish the initial conditions for the analysis.
3. Reviewing the results

STRUCTURAL ANALYSIS:

Structural analysis is the most widely used application in Finite element method in our project we used is as follows:

Static Analysis:

A static analysis calculates a structure’s steady loading conditions, ignoring damping effects and inertia. Static analysis analyzes the stresses: displacements, forces and strains under static loading conditions. Static analysis is either Liner or Non-linear. The types of nonlinearities include plasticity, stress stiffening, large deflection and deformations, contact or gap elements, creep and hyper elasticity. The procedure for implementing the structural static analysis involves the following main tasks

1. Building the model
2. Setting the solution controls
3. Applying the loadsand
4. Solving the analysis.

Materials:

1. Gray Cast Iron

Gray Cast Iron is also known as Cast Iron. Gray Cast Iron is a material that is most extensively used material in engineering applications. Gray Cast iron has high thermal conductivity. The name Gray cast Iron came into existence since the fractures in the gray cast iron appear to be Gray. Cast iron possesses carbon in the form of graphite flakes in a matrix that comprises of pearlite, ferrite or a combination of the two.

2. ALUMINUM:

Aluminum is a most abundantly used light weight metal. It is soft and durable. Aluminum is widely used in several engineering applications. Aluminum has several important properties such as conductivity, low density, strength, durability, versatility, workability, corrosion.

3. Aluminum (Al) COMPOSITE:

A composite material is developed by combining the elements of an already existing material in order to form a new material. Composite materials act as exceptional fire resistors when compared to other light weight alloys. Composite materials are fatigue resistive materials which in turn saves the costs of products. Aluminum is one of the most widely used metals. Aluminum composite is a good corrosion resistant material.

3. METHODOLOGY:

1. The methodology for the analysis of disc brake rotor is Coupled Field Analysis i.e.
   A. Transient Thermal Analysis
   B. Structural Analysis

Thermal Analysis:

1. In thermal analysis, three different flange widths of 8mm, 10mm, 12mm and three different materials such as Cast Iron, Aluminum, and Aluminum composite are considered respectively.
2. An axis-symmetric model of disc brake rotor is created with flange width of 8mm.
3. In order to create the disc brake, lines are created.
4. The created model should obtain four sides in order to generate areas in ASYSY through lines.
5. In order to mesh the model, the element type considered for thermal analysis is Plane 55.
6. After the creation of the areas and allocation of element types, the model is meshed with a line division of 10 on all the sides.
7. The material properties such as Thermal conductivity, Specific heat and Density are defined.
8. The boundary conditions such as heat flux, convection, heat flow and temperature are applied to the model. The calculations are as follows:

❖ Heat Flux Calculation for 8mm:

Velocity of the vehicle= 70 mph= 112kmph= 31.11m/s
Time for stopping the vehicle = 4 seconds
Mass of the vehicle = 1800kg
Kinetic Energy (K.E) = ½ * m * υ2
= ½ * 1800 * 31.112
= 871048.89 Joules

The above value is the Total Kinetic Energy induced while the vehicle is under motion.

Total Kinetic Energy = Heat Generated
Heat Generated = 87104.889 Joules
Heat Generated/Wheel = 871048.89/4
= 217762.222 Joules.

The area of the rubbing faces
A = 2* Π * (0.2 – 0.1036) * 0.008
= 0.00484 m2

Heat Flux = Heat Generated / Time / Twice the projected area
= 217762.222 / 4 / 2 * 0.00484
= 5624024.33 Watts / m2

The analysis is done by taking the Brake Efficiency of 30% and hence the distribution of braking torques between the front and rear axle is 70:30.

Thus

- Heat Flux = 5624024.33 * 0.7 = 3936817 Watts / m2
- Convection values = 50
- Heat flow = 0
- Temperature = 50

Structural Analysis:

a) In Structural analysis, the element type considered is Plane 42.

b) The material properties such as Young's modulus, Poisson's ratio and

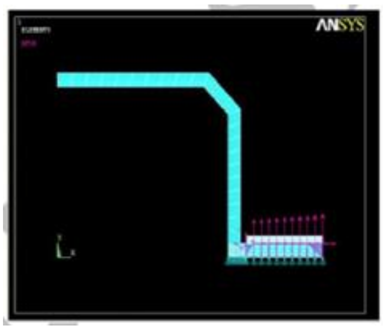
c) Coefficients of linear expansion are defined.

d) In structural analysis two boundary conditions are applied as they are

(i) Symmetric boundary condition that is applied on bottom side of the flange.

(ii) The second boundary condition is the output of transient thermal analysis.

e) After applying the boundary conditions, the structural analysis problem is solved and the results are obtained.



2 The same procedure is followed for 10mm and 12mm flange width disc brake rotor but with different measures of heat flux.

3 The results are tabulated and compared.

4. RESULTS:

The results discussed below are of 8mm, 10mm and 12mm flange width made of Cast Iron, Aluminum and Aluminum composite. These results are obtained after the thermal and structural boundary conditions are applied to the model and the analysis is performed. The minimum and maximum temperature and stress are interpreted in the form of colors such as blue being the minimum, green being the intermediate temperature and red being the maximum.

Material: Cast Iron

The Figures displays the temperature for 8mm flange width made of cast iron. As it is evident from the screenshot, the minimum temperature represented in blue color, is .489 K and the maximum temperature that is in red color is 620.090 K. It is also clearly visible from the screenshot that the temperature distribution is evenly distributed along the length of the flange and mainly it is towards the surface of the flange.

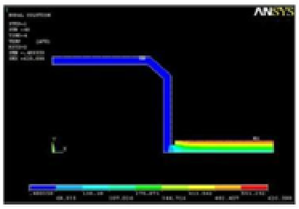


Figure Close view of Nodal Temperature for 8mm flange width made of Cast Iron

Tabulation and Analyzation Results

Flange Width 8mm	**Cast Iron**	**Aluminum**	**Aluminum Composite**
Nodal Temperature(K)	620.098	690.068	752.58
VonMises Stress(MPa)	$589*10^6$	$1230*10^6$	$1470*10^6$
Flange Width 10mm	**Cast Iron**	**Aluminum**	**Aluminum Composite**
Nodal Temperature(K)	496.08	552.381	602.174
VonMises Stress(MPa)	487*106	1040*106	1230*106
Flange Width 12mm	**Cast Iron**	**Aluminum**	**Aluminum Composi**

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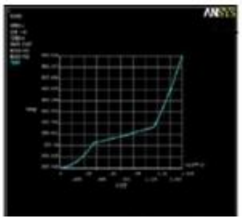
Nodal Temperature(K)	413.183	460.094	501.543
VonMisesStress(MPa)	415*106	882*106	1050*106

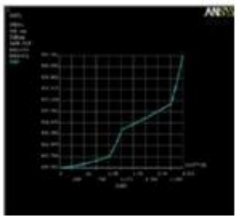
The above Table is the tabulation of all the results obtained from analysis of 8mm, 10mm and 12mm flange width made of different materials- Cast Iron, Aluminum and Aluminum Composite. As it is evident from the table, Cast Iron of 12mm flange width, when compared to Aluminum and Aluminum composites has minimum temperature and stress than that of 8mm and 10mm flange width. It can also be observed that as the length of the flange is increasing, the temperature and stress is decreasing.

Graph plotted between Temperature and Distance:

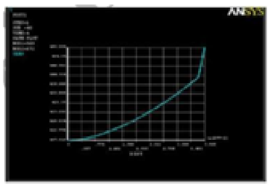
Following are the graphs plotted between Temperature and Distance for the materials- Cast Iron, Aluminum and Aluminum Composite of flange width 8mm, 10mm and 12mm respectively. For all the graphs below, as the distance increases the temperature is also increasing.8 mm. The following graphs shown in the figure (a), (b) and (c) are plotted between distance on X-axis and temperature on Y-axis. These graphs are of 8mm flange width made of Cast Iron, Aluminum and Aluminum Composite.



(a) Cast Iron



(b) Aluminum



(c)Aluminum Composite

Figure (a), (b) and (c) are the graphs of 8mm flange width plotted between Temperature and Distance.

5. CONCLUSION:

The following conclusions are drawn from the present work:

1. An Axis-symmetric analysis of disc brake has been carried out using Plane55 and Plane 42 through ANSYS11.0 software.

2. A coupled field analysis is performed on disc brake rotor with different flange widths of 8mm, 10mm, 12mm and different materials such as cast iron, aluminum and aluminum composite.

3. A transient thermal analysis is carried out using the direct time integration technique for the application of braking force due to friction for time duration of4 seconds for different widths and different materials.

4. A steady state structural analysis coupled with thermal analysis is carried out for various widths and various materials.

5. The obtained results are compared and analyzed.

6. The minimum temperature distribution obtained on the disc brake rotor at the contact surface is observed to be **413.183 °K** for 12mm flange width made of cast iron.

7. Static structural analysis is carried out by coupling the thermal solution with the structural analysis. The minimum Von Mises stress is observed to be $415*10^6$MPa for 12mm flange width made of cast iron.

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First Author:

Mr.Sainath Kasuba (Associate Professor) Thermal Engineering (PHD), Working at Sreyas Institute of Science & Technology, Hyderabad.
sainathkasuba@gmail.com. (+919848093630)

Second Author:

Mr.Ather Nawaz Khan completed his B.Tech (Mechanical Engineering) degree from Jaya Prakash Narayan Engineering College. In the year 2015. He will complete his M.Tech in CAD/CAM Mechanical Engineering department from Sreyas Institute of Science & Technology in the year 2016-2017, Hyderabad.
ather1502@gmail.com.(+919505591502).