GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

STATIC AND THERMO-MECHANICAL ANALYSIS OF DISC BRAKE

M. Saran Theja* & M. Vamsi Krishna**

Mechanical Engineering,(M.Tech) Machine Design,
MITS (J.N.T.U.A), Madanapalle, Chittor (Dist), A.P., India. # 9502527078
**Asst.Professor M.E.,(Ph.D), mamidivk@gmail.com
Mechanical Engineering, MITS (J.N.T.U.A), Madanapalle, Chittor (Dist), A.P., India.

Abstract

Disc(Rotor) brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. The aim of the project is to design, model a disc brake. Modeling is done using Pro/Engineer. Structural and Thermal analysis is to be done on the disc brakes using two materials Stainless Steel and Carbon Steel. Structural analysis is done on the disc brake to validate the strength of the disc brake and thermal analysis is done to analyze the thermal properties. Comparison can be done for displacement, stresses, thermal gradient etc. for the two materials to check which material is best. We are also providing manufacturing process for making disc brake and also preparing prototype. Manufacturing process is done using Pro/Engineer. Pro/Engineer is a 3d modeling software widely used in the design process. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements.

Key Words: *Rotor Brake, Pro/Engineer, FEA, Thermal analysis, Static analysis.*

Introduction

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD).CAD describes the process of drafting with a computer , and the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CADD describes the purpose of streamlining design processes, drafting, documentation, and manufacturing processes.CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. It can also be used to design objects.CAD has become an especially important technology within the scope of computer-aided technologies, with benefits such as lower product development costs and a greatly shortened design cycle. CAD enables designers to lay out and develop work on screen, print it out and save it for future editing, saving time on their drawings.

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.

Pro/Engineer Wildfire Benefits

Unsurpassed geometry creation capabilities allow superior product differentiation and manufacturability

- ✓ Fully integrated applications allow you to develop everything from concept to manufacturing within one application
- ✓ Automatic propagation of design changes to all downstream deliverables allows you to design with confidence
- ✓ Complete virtual simulation capabilities enable you to improve product performance and exceed product quality goals
- ✓ Automated generation of associative tooling design, assembly instructions, and machine code allow for maximum production efficiency

Introduction to FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. In practice, a finite element analysis usually consists of three principal steps.

Preprocessing: The user constructs a model of the part to be analyzed in which the geometry is divided into a number of discrete sub regions, or elements," connected at discrete points called nodes." Certain of these nodes will have fixed displacements, and others will have prescribed loads. These models can be extremely time consuming to prepare, and commercial codes vie with one another to have the most user-friendly graphical “preprocessor" to assist in this rather tedious chore. Some of these preprocessors can overlay a mesh on a preexisting CAD file, so that finite element analysis can be done conveniently as part of the computerized drafting-and-design process.

Analysis: The dataset prepared by the preprocessor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations

Kijuj = fi

where u and f are the displacements and externally applied forces at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

Postprocessing: In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. Typical postprocessor display overlays colored contours representing stress levels on the model, showing a full field picture similar to that of photo elastic or moiré experimental results.

Introduction to ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

Characteristics

Brakes are often described according to several characteristics including:Peak force - The peak force is the maximum decelerating effect that can be obtained. The peak force is often greater than the traction limit of the tires, in which case the brake can cause a wheel skid.

✓ Continuous power dissipation - Brakes typically get hot in use, and fail when the temperature gets too high. The greatest amount of power (energy per unit time) that can be dissipated through the brake without failure is the continuous power dissipation. Continuous power dissipation often depends on e.g., the temperature and speed of ambient cooling air. Fade - As a brake heats, it may become less effective, called brake fade. Some designs are inherently prone to fade, while other designs are relatively immune. Further, use considerations, such as cooling, often have a big effect on fade.

✓ Smoothness - A brake that is grabby, pulses, has chatter, or otherwise exerts varying brake force may lead to skids. For example, railroad wheels have little traction, and friction brakes without an anti-skid mechanism often lead to skids, which increases maintenance costs and leads to a "thump thump" feeling for riders inside.

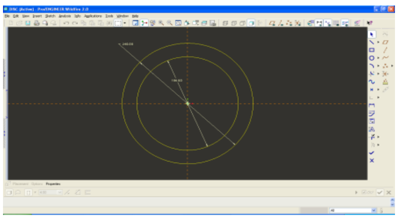
✓ Power - Brakes are often described as "powerful" when a small human application force leads to a braking force that is higher than typical for other brakes in the same class. This notion of "powerful" does not relate to continuous power dissipation, and may be confusing in that a brake may be "powerful" and brake strongly with a gentle brake application, yet have lower (worse) peak force than a less "powerful" brake.

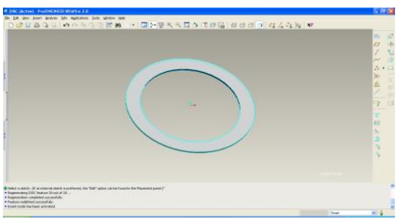
✓ Durability - Friction brakes have wear surfaces that must be renewed periodically. Wear surfaces include the brake shoes or pads, and also the brake disc or drum. There may be tradeoffs, for example a wear surface that generates high peak force may also wear quickly.

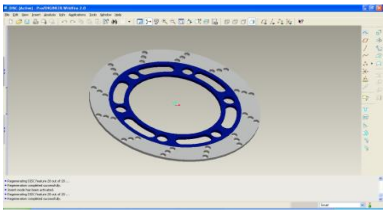
✓ Weight - Brakes are often "added weight" in that they serve no other function. Further, brakes are often mounted on wheels, and unsprung weight can significantly hurt traction in some circumstances. "Weight" may mean the brake itself, or may include additional support structure.

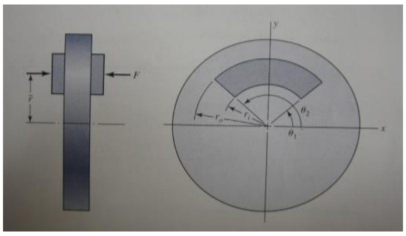
✓ Noise - Brakes usually create some minor noise when applied, but often create squeal or grinding noises that are quite loud.

MODEL OF DISC BRAKE Sketch







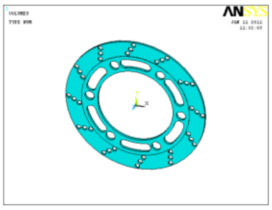


Results of Finite Element Analysis

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested. In practice, a finite element analysis usually consists of three principal steps: 1.Preprocessing, 2.Analysis, 3. Postprocessing.

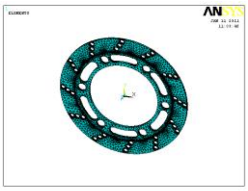
Structural Analysis of Disc Brake using Stainless Steel

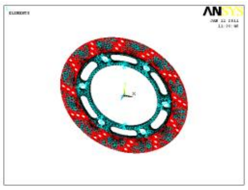
Imported Model from Pro/Engineer



Element Type: Solid 20 node 95
Material Properties:
Youngs Modulus (EX) : 200000N/mm^2
Poissons Ratio (PRXY) : 0.29
Density : 0.000007612 kg/mm^3

Meshed Model

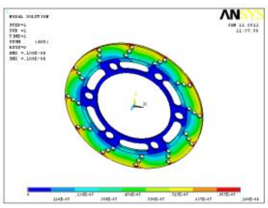


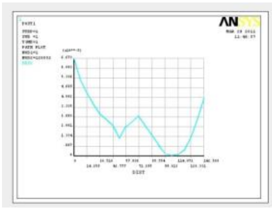


Load : Pressure–1.2N/mm^2
Solution: Solution – Solve – Current LS – ok

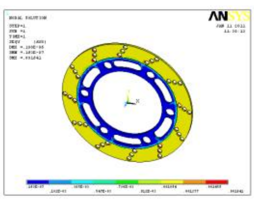
Post Processor

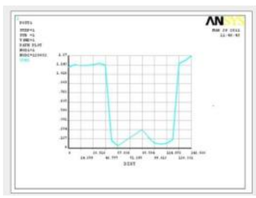
General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Displacement Vector Sum





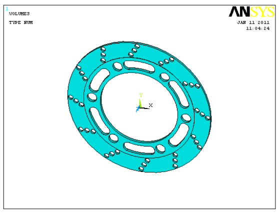
General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stress



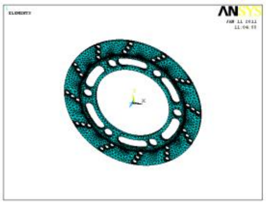


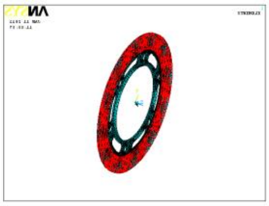
Structural Analysis of Disc Brake using Carbon steel

Imported Model from Pro/Engineer



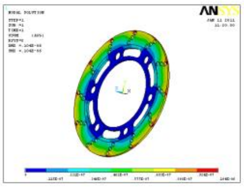
Element Type: Solid 20 node 95
Material Properties:
Young's Modulus (EX) : 200000N/m
Poissons Ratio (PRXY) : 0.295
Density : 0.00007872 kg/mm^3
Meshed Model

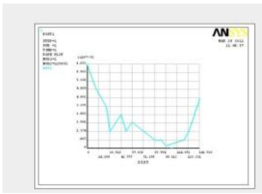




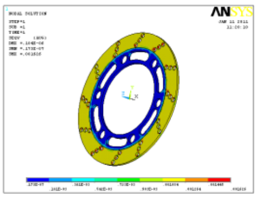
Load :Pressure–1.2N/mm^2
Solution Solution – Solve – Current LS – ok

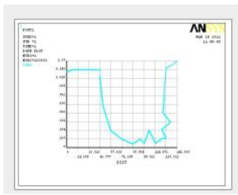
Post Processor
General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Displacement Vector Sum



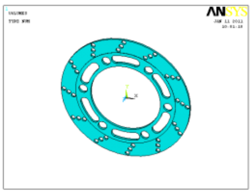


General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stress



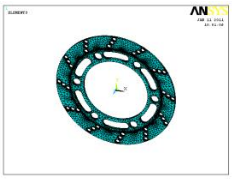


Thermal Analysis of Disc Brake using Stainless Steel
Imported Model from Pro/Engineer



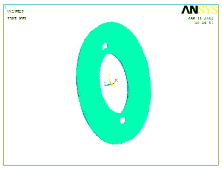
Element Type: Solid 20 node 90
Material Properties:
Thermal Conductivity – 25w/mk
Specific Heat – 460.5 j/kg k
Density - 0.00007612 kg/mm^3

Meshed Model

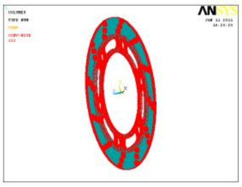


Apply Loads

Loads – Define Loads – Apply – Thermal – Temperature– 353k
Loads – define Loads – Apply – Thermal – Heat flow – On nodes
Heat flow – 2kj/sec



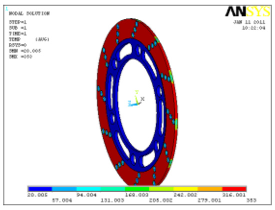
Loads – define Loads – Apply – Thermal – Convection – on areas
Bulk Temperature – 20k
Film Coefficient – 222W/mmK



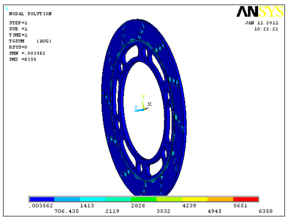
Solution: Solution – Solve – Current LS - ok

Post Processor

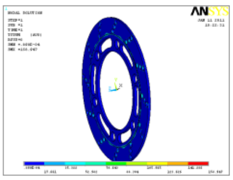
General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Nodal Temperature Vector sum

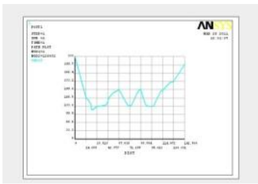


General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal Gradient Vector sum



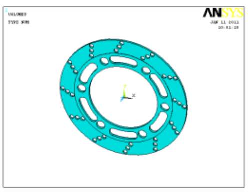
General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal flux vector sum





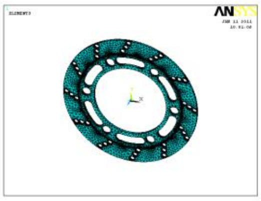
Thermal Analysis of Disc Brake using Carbon Steel

Imported Model from Pro/Engineer



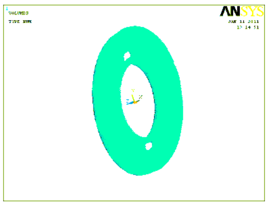
Element Type: Solid 20 node 90
Material Properties: Thermal Conductivity – 64.9w/mk
Specific Heat – 481 j/kg k
Density - 0.00007872 kg/mm^3

Meshed Model

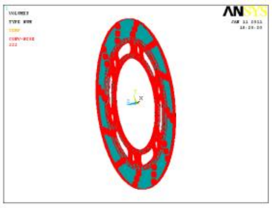


Apply Loads

Loads – Define Loads – Apply – Thermal – Temperature – 353k
Loads – define Loads – Apply – Thermal – Heat flow – On nodes
Heat flow – 2kj/sec



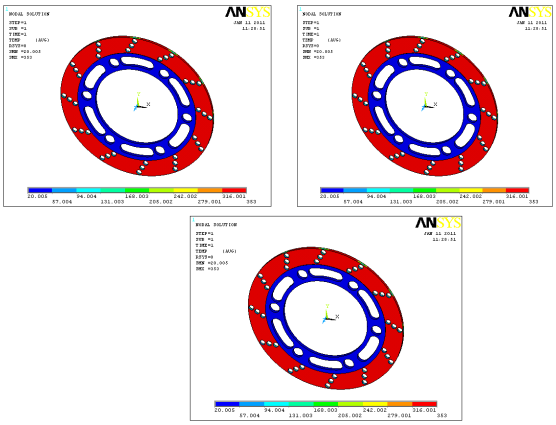
Loads – define Loads – Apply – Thermal – Convection – on areas
Bulk Temperature – 20k
Film Coefficient – 222W/mmK



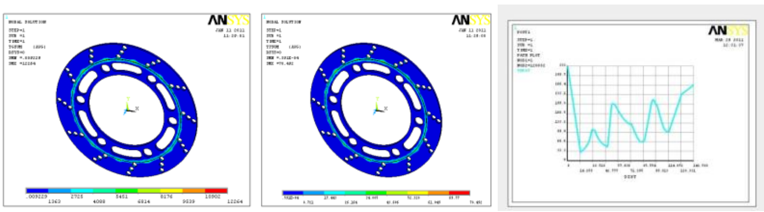
Solution Solution – Solve – Current LS - ok

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Nodal Temperature Vector sum



General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal Gradient Vector sum – Thermal flux vector sum



Definitions of Results Obtained

Displacement - A vector quantity which refers to the distance which an object has moved in a given direction. It is measured as the length of a straight line between the initial and final positions of a body.
Von Mises Stress - The Von Mises criteria is a formula for combining these 3 stresses into an equivalent stress, which is then compared to the tensile stress of the material.

Nodal Temperature - A temperature can be applied to nodes, surfaces, or parts in a model. A surface temperature applies nodal temperatures to each node on the surface, and a part temperature applies nodal temperatures to each node in the part.

Thermal Gradient - A temperature gradient is a physical quantity that describes in which direction and at what rate the temperature changes the most rapidly around a particular location.

As per the analysis images

Thermal flux - Heat flux or thermal flux is the rate of heat energy transfer through a given surface.
The yield stress for Stainless Steel is 793Mpa.
The yield stress for Carbon Steel is 165Mpa

	Displacement (mm)	Von Mises Stress (N/mm^2)	Nodal Temperature (K)	Thermal Gradient (K/mm)	Thermal Flux (W/mm^2)
Stainless Steel	0.108 e^{-6}	0.001641	353	6358	158.947
Carbon Steel	0.104 e^{-6}	0.001626	353	12264	78.492

Conclusion

1. The disc brake is a device for slowing or stopping the rotation of a wheel. In our project, we have designed and modeled a disc brake.
2. Modeling is done using Pro/Engineer. We have performed Structural and Thermal analysis using Stainless steel and Carbon Steel on the disc brake.
3. From the structural analysis, by observing stress values for both the materials, both the values are less than their respective yield stresses. So we can decide that our design is safe.
4. From thermal analysis, by observing the thermal gradient for both the materials, the value is more for Carbon Steel.
5. Thermal gradient is the rate of temperature change on a surface. The rate of temperature change for brake surface using carbon steel is more than that of using stainless steel.
6. So we conclude that for our designed disc brake, the better material is carbon steel.
7. To manufacture disc brake the following operations are done:Turning, Cylindrical Grinding, Jig Boring, Lapping.

Bibliography

[1].Introduction to Finite Elements in Engineering, Tirupathi, R. Chandrupatla Ashok D.Belegundu.

[2]. Finite Element Procedures, Klaus-Jurgen Bathe.

[3]. Finite Element Method, J.N.Reddy.

[4]. User Guide for ANSYS version 5.4.

[5] http://auto.howstuffworks.com/disc-brake.htm.

[6]. Design Data Book,PSG college of technology.

[7]. Heat and Mass Transfer Data Book,C P Kothandaraman, S Subramanyan.

[8].Finite Element Analysis For Engineering & Tech. Author, T. Chandrupatla. Edition, illustrated. Publisher, Universities Press, 2004. ISBN, 8173714274.

[9]. ISBN-10: 1932709444 ISBN-13: 978-1932709445 Pro/ENGINEER Wildfire 4.0 for Designers textbook is a comprehensive textbook that introduces the users to Pro/ENGINEER Wildfire

[10]. Machine Design Edition : 14th. Author **:** R.S. Khurmi & J.K. Gupta

[11]. Analysis of Ventilated Disc Brake Squeal Using a 10 DOF Model," SAE Technical Paper 2012-01-1827, 2012.

[12]. A Textbook of Design of Machine Elements by Bandari.

Biographies:

M. Vamsi Krishna received the B.Tech degree in Automobile Engineering from Sri Ram Engineering College, Veppampattu in 2007, then M.Tech degree in Engineering Design from Government College of Technology, Coimbatore, and TamilNadu. Currently, He is an Asst.Professor of Mechanical Engineering Dept at Madanapalle Institute of Technology & Science. His teaching and research areas include all areas of mechanical Engineering Design and doing PhD. He has authored/co-authored for more than coupled papers, and he is writing a book on Machine Design for M.Tech (JNTUA). Presently he is guiding more than two M.Tech projects.

M. SARAN THEJA received the B.Tech degree in Mechanical Engineering from Madanapalle Institute of Technology & Science, Madanapalle in 2010, and then worked as Asst. Prof in SVIST in Mechanical Dept. at Madanapalli. Now pursing M.Tech in Machine Design from Madanapalle Institute of Technology & Science, Madanapalle, and Andhra Pradesh.