INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
IJTE
ISSN: 2057-5688

DESIGN AND ANALYSIS OF DISK BRAKE ROTAR

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Abstract: *The aim of this paper was to investigate the temperature fields and also structural fields of the solid disc brake during short and emergency braking with four different materials. The distribution of the temperature depends on the various factors such as friction, surface roughness and speed. The effect of the angular velocity and the contact pressure induces the temperature rise of disc brake. The finite element simulation for two-dimensional model was preferred due to the heat flux ratio constantly distributed in circumferential direction. We will take down the value of temperature, friction contact power, nodal displacement and deformation for different pressure condition using analysis software with four materials namely cast iron, cast steel, aluminum and carbon fiber reinforced plastic. Presently the Disc brakes are made up of cast iron and cast steel. With the value at the hand we can determine the best suitable material for the brake drum with higher life span. The detailed drawings of all parts are to be furnished.*

I. INTRODUCTION

In today's growing automotive market the competition for better performance vehicle is growing enormously. The racing fans involved will surely know the importance of a good brake system not only for safety but also for staying competitive. The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc usually made of cast iron or ceramic composites includes carbon, Kevlar and silica, is connected to the wheel and the

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axle, to stop the wheel. A friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. This friction causes the disc and attached wheel to slow or stop. Generally, the methodologies like regenerative braking and friction braking system are used in a vehicle. A friction brake generates frictional forces as two or more surfaces rub against each other, to reduce movement. Based on the design configurations, vehicle friction brakes can be grouped into drum and disc brakes. If brake disc are in solid body the heat transfer rate is low. Time taken for cooling the disc is low. If brake disc are in solid body, the area of contact between disc and pads are more. In disc brake system a ventilated disc is widely used in automobile braking system for improved cooling during braking in which the area of contact between disc and pads remains same. Brake assembly which is commonly used in a car.

Fig 1.0 Disc brake

HISTORY AND DEVELOPMENT OF DISC BRAKE ROTOR

Ever since the invention of the wheel, if there has been "go" there has been a need for "whoa." As the level of technology of human transportation has increased, the mechanical devices used to slow down and stop vehicles has also become more complex. In this report I will discuss the history of vehicular braking technology and possible future developments.

Before there was a "horse-less carriage," wagons, and other animal drawn vehicles relied on the animal's power to both accelerate and decelerate the vehicle. Eventually there was the development of supplemental braking systems consisting of a hand lever to push a wooden friction pad directly against the metal tread of the wheels. In wet conditions these crude brakes would lose any effectiveness.

The early years of automotive development were an interesting time for the designing engineers, "a period of innovation when there was no established practice and virtually all ideas were new ones and worth trying. Quite rapidly, however, the design of many components stabilized in concept and so it was with brakes; the majority of vehicles soon adopted drum brakes, each consisting of two shoes which could be expanded inside a drum."

In this chaotic era is the first record of the disk brake. Dr. F.W. Lanchester patented a design for a disk brake in 1902 in England. It was incorporated into the Lanchester car produced between 1906 through 1914. These early disk brakes were not as effective at stopping as the contemporary drum brakes of that time and were soon forgotten. Another important development occurred in the 1920's when drum brakes were used at all four wheels instead of a single brake to halt only the back axle and wheels such as on the Ford model T. The disk brake was again utilized during World War II in the landing gear of aircraft. The aircraft disk brake system was adapted for use in automotive applications, first in racing in 1952, then in production automobiles in 1956. United States auto manufacturers did not start to incorporate disk brakes in lower priced non-high-performance cars until the late 1960's.

DISC BRAKE

A disc brake is a device, composed of cast 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. Disc brakes use friction to create braking power. Disc brakes create braking power by forcing flat friction pads against sides of rotating disc.

Higher applied forces can be used in disc brakes than in drum brakes, because the design of the rotor is stronger than the design of the drum.

INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
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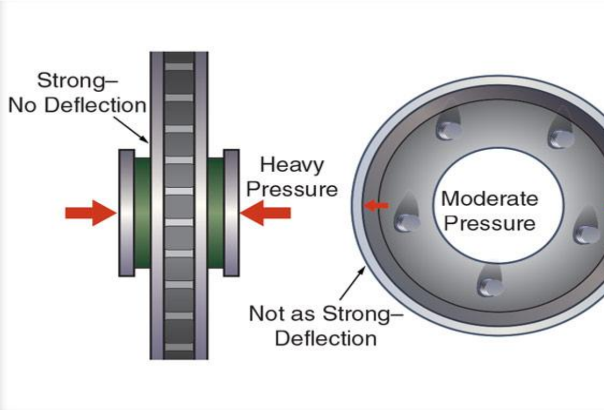

Fig 1.1Disc versus drum brakes.

Classification of brakes

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

Radial Brake: 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 brake: The force acting on the brake drum is in axial direction for axial brakes.

Working Principle of disc brake

Disc brake is a very essential brake application device in a vehicle. This part of the brake helps in the slowing and stopping the motion of the vehicle. The principle of disc brake is to produce a braking force on the brake pads which in turn compresses the rotating disc.

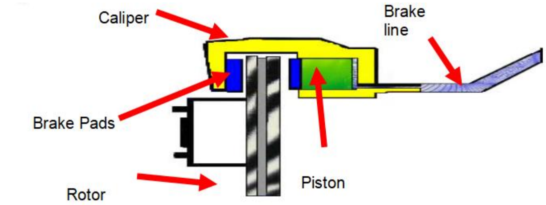

Fig 1.2 components of disc brake rotor

II MATERIALS

Grey Cast Iron

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

Composition Carbon=3to5%; silicon= 1to 2.75%; manganese=0.40 to 1%; phosphorous= 0.15 to 1%; sulphur =0.02to 0.15%; & the remaining iron

Brake
line

Advantages of Grey Cast iron.

It is easy to mould and acquire any desired shape.

It has High compressive strength and damping capacity.

Grey Cast iron resists corrosion after application of protective coating.

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Grey cast Iron acts as a tool lubricant due to the presence of graphite in it.

Cast Iron has relatively low prices compared to all other materials.

Disadvantages of Grey Cast Iron.

It has low tensile strength and ductility.

Production of higher strength of Grey Cast Iron is more expensive.

ALUMINUM ALLOY

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

Aluminium (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. Aluminium is one of the most widely used metals. Aluminium composite is a good corrosion resistant material.

Advantages of Aluminium.

Aluminium is an efficient conductor of heat and electricity.

Aluminium is had a low density and melting point.

Aluminium is ductile in nature.

Aluminium is a good electrical and thermal conductor.

Aluminium is a good corrosion resistant material.

NICKEL CHROME STEEL

A Nickel chrome Steel containing 3.25 %of nickel and 1.5% of chromium and 0.25% carbon is much used for Armour plates. Low cost, max abrasion resistance, more strength and exerting moderate impact, higher strength.

Properties:

(i) It is practically non-corrosive.

(ii) It can with stand high temperatures without oxidation.

(iii) Alloyed with cast iron, it increases resistance of the latter to corrosion and heat, as well as to wear.

Uses: it is used in making electrical resistance wire for electric furnaces and heating elements

CARBON REINFORCED POLYMER

CERP is a polymer matrix composite material reinforced by carbon fibers. Very

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high modulus of elasticity exceeding that of steel.

Carbon Reinforced Polymers are characterized by the following properties:

- Light weight
- High electric conductivity
- Very low coefficient of thermal expansion
- Low density
- High strength-to-weight ratio
- High Fatigue strength
- Goodcorrosion resistance
- High cost.

III Design

Existing designing of disk break rotor

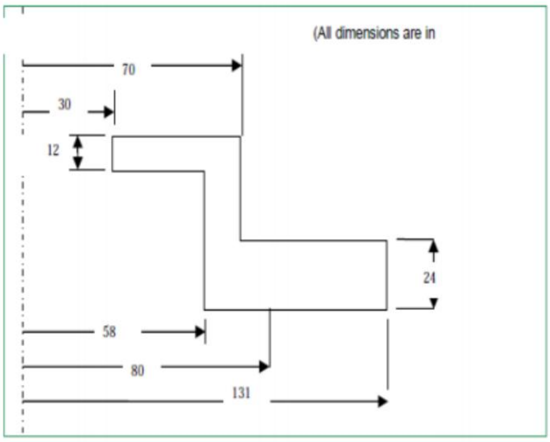

Fig 4.1 Existing designing of disk break rotor

MODELING OF DISC BRAKE

It is very difficult to exactly model the brake disk, in which there are still There always a need of some assumptions to model any complex geometry. These assumptions are made, keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling we always ignore the things that are of less importance and have little impact on the analysis.

The assumptions are always made depending upon the details and accuracy required in modeling. The assumptions which are made while modeling the process are given below:

1. The disk material is considered as homogeneous and isotropic.

2. The domain is considered as axis-symmetric.

3. Inertia and body force effects are negligible during the analysis.

4. The disk is stress free before the application of brake

5. Brakes are applied on the entire four wheels.

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6.The analysis does not determine the life of the disk brake.

7. The disk brake model used is of solid type

we have designed the DISK BRAKE ROTAR in CATIA as follows

Sketch drawn by using profile tool in sketcher module

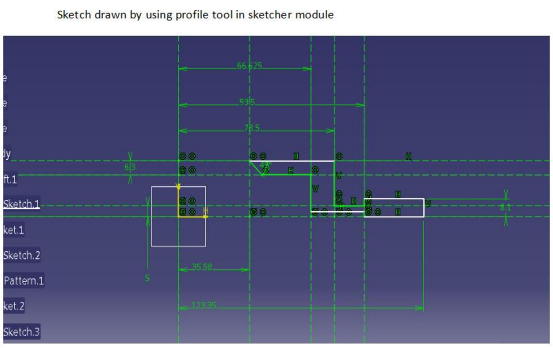


Fig 4.2 sketcher module

Solid object was made by using revolve tool in part module

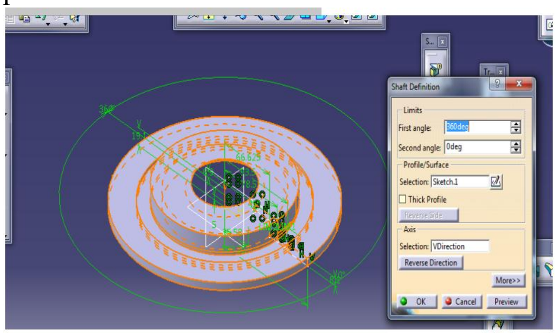
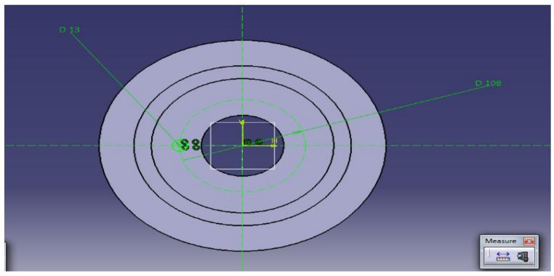
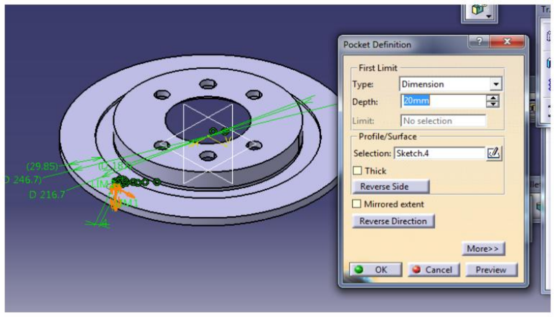


Fig 4.3 part module

Circular shape of holes used for fixing nuts, bolts



Removal of material



Removal of material by chamfer tool

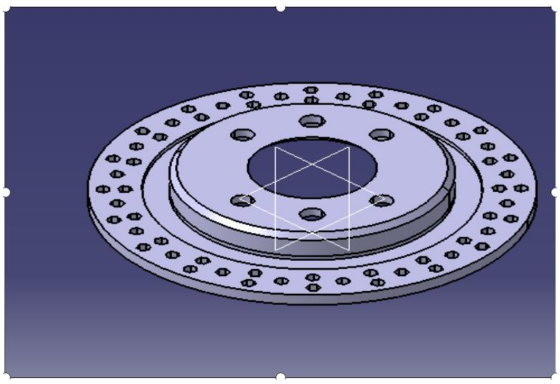


Fig 4.4 final design in catia

IV FEA Software - 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. The screenshot of ANSYS user interface is shown in Figure

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2. 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.

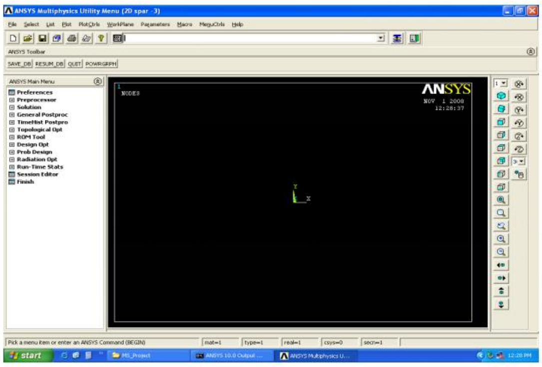

Fig 7.0 Screenshot of ANSYS User Interface

THERMAL ANALYSIS

The temperature distribution and related thermal quantities in a system or component are calculated using a Thermal Analysis technique. The most frequently used thermal quantities are:

Thermal fluxes

The amount of heat lost or gained

Temperature distributions

Implementing a thermal analysis involves four main tasks:

1. Building the model
2. Applying loads
3. Obtaining the solutions and
4. Reviewing the results

Thermal analysis is an important aspect in designing various engineering applications such as heat exchanges, internal combustion engines, turbines, pining systems etc. Thermal stresses are usually calculated by a combination of thermal analysis and stress analysis.

There are two types of Thermal Analysis:

1. A steady-state thermal analysis
2. A transient thermal analysis

A steady-state thermal analysis: In a steady-state thermal analysis, temperature distribution and various thermal quantities are determined under steady-state loading conditions. A steady-state loading condition characterizes the time that can be ignored when heat storage effects the varying period of time. In order to validate the initial conditions, a steady-state analysis is accomplished before performing a transient thermal analysis. The steady-state thermal analysis is mainly used to determine the heat flow rates,

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temperatures, heat fluxes and thermal gradients that are generated by the thermal loads. A steady-state thermal analysis can be linear or non-linear. A linear steady state thermal analysis has constant material properties and a non-linear steady-state thermal analysis uses material properties that depend on temperature.

A transient thermal analysis: In transient thermal analysis, the temperature distribution and other thermal quantities are analyzed under the conditions that vary over a period of time. A transient thermal analysis comprises of various heat transfer applications such as engine blocks, heat treatment problems, pressure vessels, nozzles and piping systems. The transient thermal analysis process is almost the same as steady-state thermal analysis. The main difference among the two is that the loads applied in transient analysis are functions of time.

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.

Advantages of ANSYS

1. The ANSYS program is a flexible and cost effective tool which helps in the reduction of rework on prototype.
2. ANSYS program is a graphical user interface that facilitates the users with easy and intuitive path to program commands, documentation and functions.
3. In order to reduce the production costs, ANSYS enables to optimize the design in the development process itself.
4. ANSYS program helps in designing the computer models and study the physical responses such as stress levels, temperature distribution.

HEAT FLUX

TEMPE RATURE (^{0}C)	CAS T IRO	ALUM INIUM ALLO	NIC KEL CHR	CARB ON REINF

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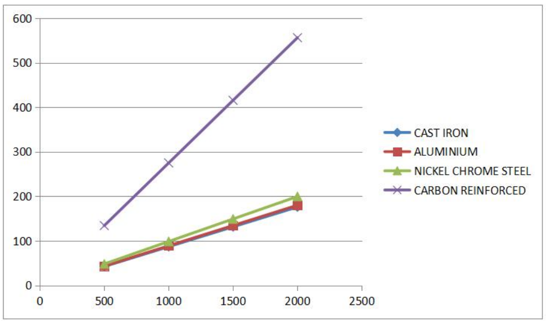
	N (W/mm^2)	Y (W/mm^2)	OME STEEL (W/mm^2)	ORCED POLYMER (W/mm^2)
500	42.581	43.527	48.271	134.41
1000	87.122	89.057	98.764	275.01
1500	131.66	134.59	149.26	415.61
2000	176.2	180.12	199.75	556.21



Graph 8.3 Heat flux

V CONCLUSION

The suitability of aluminium alloy, Grey cast iron , nickel chrome steel and carbon reinforced polymer as rotor of a disc brake has been examined by transient thermal analysis and structural analysis .From the results obtained it has been found that the aluminium alloy and carbon reinforced polymer exhibit stress and strain values with in permissible limits. It has also been noticed that both these materials are prone to vibrations with in safe limits. Among these two materials carbon reinforced polymers is preferred as the material has higher specific strength and higher heat flux. Hence, carbon reinforced polymer has been found to be the best choice for the application

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