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Application of Metal Matrix Composites to reduce stress in Disc Brake Rotor using FEA

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ABSTRACT

Disc brake is a critical component in mechanical breaking system. A pair of disc and pads is in action generally subjected to static dynamic load and bending stresses. Therefore the combined action of these loads a region of failure of surface of disc brake. These types of failures can be minimized by careful analysis of the problem during design state and proper manufacturing methods.

Hence an attempt is made in this work to minimize stresses by the application of metal matrix composites. The Finite Element Method is capable to solve the above problem but the time needed to such a model is more complex, with the help of computer simulation technique the accurate results can be estimated in less computational time. The geometry of 3-D model disc brake was created using CATIA V5 software, and the file saved as iges. The saved iges file is imported to ANSYS analysis software. The results are drawn for different material properties, and results are validated for ventilated type disc brake with AL-MMC.

Key Words: TEI, Ventilated Type, Static Analysis FEA

1. INTRODUCTION

A brake is a device by means of which artificial frictional resistance is applied to moving machine member, in order to stop the motion of a machine. In the process of performing this function, the brakes absorb either kinetic energy of the moving member or the potential energy given up by objects being lowered by hoists, elevators etc. The energy absorbed by brakes is dissipated in the form of heat. This heat is dissipated in the surrounding atmosphere to stop the vehicle,

1.1 CLASSIFICATION OF BRAKES

The mechanical brakes according to the direction of acting force may be classified as radial brake and axial brake. In radial brakes the force acting on the brakes drum is in radial direction. These may be subdivided into external brakes and internal brakes. In case of axial brakes the force acting on the brake drum is only in the axial direction, example for such type of brakes is disk brakes and cone brakes.

1.2 DISK BRAKE

A disk brake consists of a cast iron disk bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of the vehicle like the axle casing or the stub axle as is cast in two parts each part containing a piston. In between each piston and the disk there is a friction pad held in position by retaining pins, spring plates etc. passages are drilled in the caliper for the fluid to enter or leave each housing. The passages are also connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston. A schematic diagram is shown in the figure 1.1

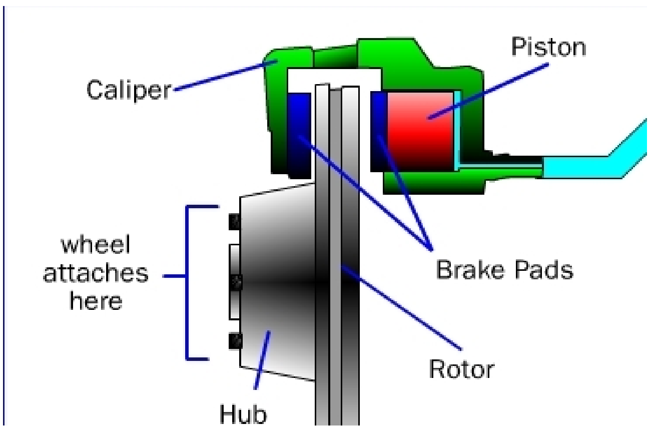

Fig 1.1 Nomenclature of Disc brake

The main components of the disc brake are the brake pads, The Caliper which contains the piston, the rotor, which is mounted to the hub. When the brakes are applied, hydraulically actuated pistons move the friction pads in to contact with the rotating disk, applying equal and opposite forces on the disk. Due to the friction in between disk and pad surfaces, the kinetic energy of the rotating wheel is converted into heat, by which vehicle is to stop after a certain distance. On releasing the brakes the brakes the rubber-sealing ring acts as return spring and retract the pistons and the friction pads away from the disk.

In the course of brake operation, frictional heat is dissipated mostly into pads and a disk, and an occasional uneven temperature distribution on the components could induce severe thermo elastic distortion of the disk. The thermal distortion of a normally flat surface into a highly deformed state, called thermo elastic transition.

The thermo elastic instability phenomenon occurs more easily as the rotating speed of the disk increases. This region where the contact load is concentrated reaches very high temperatures, which cause deterioration in braking performance. Moreover, in the course of their presence on the disk, the passage of thermally distorted hot spots moving under the brake pads causes low-frequency brake vibration. Objective of the present study is to suggest the Best combination of disk brake rotor material.

2. LITERATURE REVIEW

K.Lee et al Thermo elastic instability in an automotive disk brake system was investigated experimentally under drag braking conditions. The onset of instability was clearly identifiable through the observation of non uniformities in temperature measured using embedded thermocouples. A stability boundary was established in temperature/speed space, the critical temperature being attributable to temperature dependence of the brake pad material properties.

S. Du et al Finite element method was used to reduce the problem of thermo elastic instability (TEI) for a brake disk to an Eigen value problem for the critical speed. Conditioning of the Eigen value problem was improved by performing a preliminary Fourier decomposition of the resulting matrices. Results were also obtained for two dimensional layer and three-dimensional strip geometries, to explore the effects of increasing geometric complexity on the critical speeds and the associated mode shapes.

T. A. Dowat et al Proposed to contribute to dynamic and thermal analysis of the braking phenomenon. A dynamic model was established. Using this model the equation of motion of a car was derived for straight line braking. In this context, firstly the pressure variations in the brake hydraulic circuit versus pedal force were determined. Afterwards, the expression for friction torques and associated braking force induced by hydraulic pressure was taken into account, and substituted into the equation of motion of vehicle.

J. R. Barber et al The frictional heat generated during braking causes thermo elastic distortion that modifies the contact pressure distribution. If the sliding speed is sufficiently high, this can lead to frictionally-excited thermo elastic instability (TEI), characterized by major non-uniformities in pressure and temperature.

Choi and Lee developed an axisymmetric finite element model for the thermoelastic contact problem of brake disk and investigated the thermoelastic instability phenomenon of disc brake during the drag-braking processand repeated braking process

Gao and Lin et al. analyzed the transient temperature field and thermal fatigue fracture of the solid brake disc by a three-dimensional thermal-mechanical coupling model.

Floquet et al determined of temperature distribution and comparison of simulation results and experimental results in the disc by 2D thermal analysis using axis-symmetric model.

3. METHODOLOGY

3.1 MODELING OF THE DISK BRAKE:

It is very difficult to exactly model the brake disk, in which there are still researches are going on to find out transient thermo elastic behavior of disk brake during braking applications. There is always a need of some assumptions to model any complex geometry.

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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.

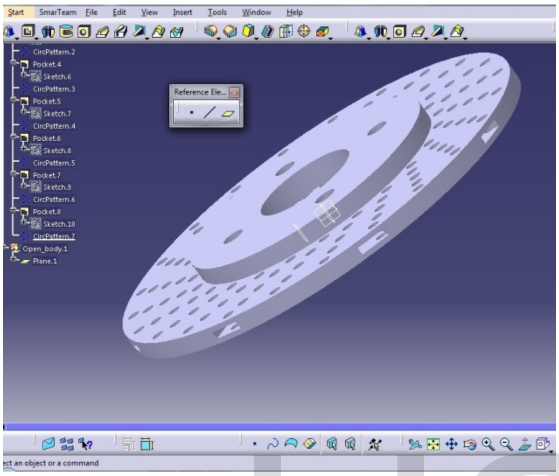

Fig 3.1: 3D model of a ventilated type Disk Brake

3.2 FINITE ELEMENTS MODEL OF DISK BRAKE

Fig 3.2 shows the elastic finite element model of disk brakes with boundary conditions. The inner radius, outer radius, and thickness of a disk are as 0.08, 0.131 and 0.024m, respectively. The thickness of pad is 0.010m. The hydraulic pressure is applied to the boundary along radius of the piston side pad and the immobility condition in the axial direction is applied to the boundary along the radius of the finger side one. The heat finite element model o disk brakes with boundary conditions are shown in Fig .

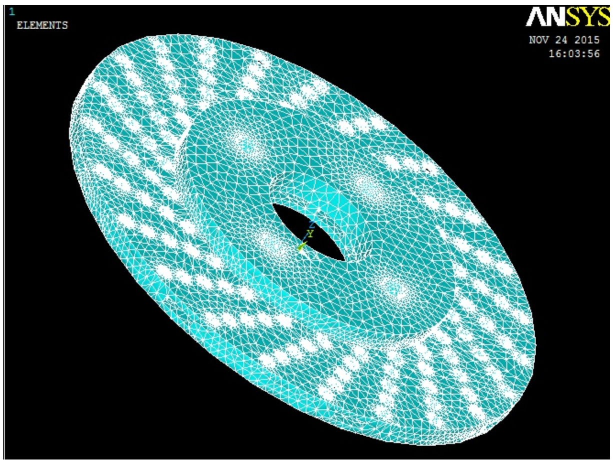

Fig 3.2: Finite Element model of Disk Brake

3.3 MATERIALS USED FOR DISC BRAKE

3.1.1 CAST IRON:

Cast iron usually refers to grey cast iron, but identifies a large group of ferrous alloys, which solidify with a eutectic. Iron accounts for more than 95%, while the main alloying elements are carbon and silicon. The amount of carbon in cast iron is the range 2.1-4%, as ferrous alloys with less are denoted carbon steel by definition. Cast irons contain appreciable amounts of silicon, normally 1-3%, and consequently these alloys should be considered ternary Fe-C-Si alloys. Here graphite is present in the form of flakes. Disc brake discs are commonly manufactured out of a material called grey cast iron. The SAE maintains a specification for the manufacture of grey cast iron for various applications. For normal car and light truck applications, the SAE specification is J431 G3000 (suspended to G10). This specification dictates the correct range of hardness, chemical composition, tensile strength, and other properties that are: low cost of production and good tribological properties are the main reason for use of this material.

3.3.2 METAL MATRIX COMPOSITES

Metal composite materials have found application in many areas of daily life for quite some time. These materials are produced in situ from the conventional production and processing of metals. Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminum crank case with strengthened brake discs.

3.3.3 Aluminum Based Metal Matrix Composites:

There has been interest using aluminum based metal matrix composites for brake disc and drum materials in recent years. While much lighter than cast iron they are not as resistant to high temperatures and are sometimes only used on rear axles of automobiles because the energy dissipation requirements are not high as compared

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to front axle. While the friction and wear of AL-MMC were high speeds and loads the behavior could be greatly improved beyond that of iron discs, given the correct match of pad and disc material.

Table 3.1: Properties of materials used

Property	Gray cast Iron	MMC1 (Al_2O_3)	MMC-2 (AlSic)
YoungsvModulus(GPa)	125	370	450
Possion's ratio	0.25	0.22	0.22
Density (Kg/m^3)	7100	2765.2	2820.6

4. RESULTS AND DISCUSSIONS:

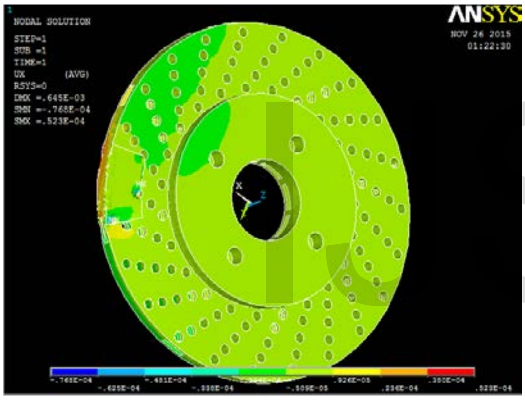


Fig 4.1: Displacement for ventilated disc having MMC1

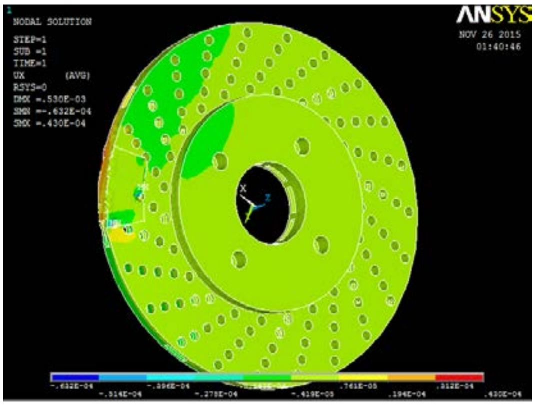


Fig 4.2: Displacement for ventilated disc having MMC2

5. VALIDATION OF RESULTS:

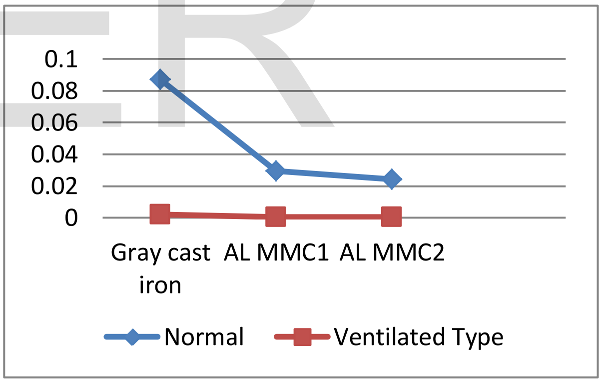
The FEA results of deflection and stress are compared with the different materials. The FEA results are found to be in close agreement with the mmc-2 (Alsic) specific geometry configuration of the disc brake.

Table 5.1 validation of Results

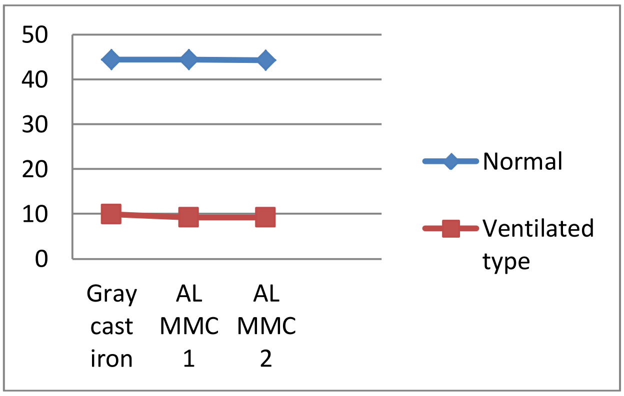
	Cast Iron	Al MMC-1	Al MMC-2
Ordinary type Disk Brake			
Displacement (mm)	0.08703	0.02953	0.02428
Stress (MPa)	44.425	44.314	44.314
Strain	0.324E-3	0.11E-3	0.910E-4
Ventilated type Disk Brake			
Displacement (mm)	0.00191	0.645E-3	0.530E-3
Stress (MPa)	9.2993	9.2370	9.2370
Strain	0.663E-4	0.227E-4	0.187E-4

6. CONCLUSION:

In this study can provide a useful design tool and improve the brake performance of disk brake system. From the comparison table we can say that all the values obtained from the analysis are less than their allowable values. Hence the brake disk design is safe based on the strength and rigidity criteria. Comparing the different results obtained from analysis. It is concluded that ventilated type disk brake having mmc-2 material is the best possible for the present application So the optimum result to minimize the stress value whiles ventilated disc having mmc-2 material.



Graph 6.1: material Vs Displacement



Graph 6.2: material Vs Stress

7. ACKNOWLEDGEMENT:

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