OPEN ACCESS

International Journal Of Modern Engineering Research (IJMER)

Comparative Study of Disc Brake Materials through Computer Aided Engineering

S. Dhiyaneswaran[1], Dr. K. S. Amirthagadeswaran[2]

[1]P.G.Scholar, Department of Mechanical Engineering, Government College of Technology, Coimbatore, India

[2]Professor, Department of Mechanical Engineering, Government College of Technology, Coimbatore, India

Abstract: *In automobile field, the contributions of composite materials are appreciable. Cast iron is commonly used material for disc brake. Composite materials are less in weight and have more strength to weight ratio which can be chosen as an alternate material for disc brake. The objective of this work is comparative study of disc brake with two different materials. Disc brake is analyzed for dynamic load conditions and the contact stress pattern, displacement and elastic strain of existing material and alternative material of disc brake are compared. In this study Al based MMC is chosen as an alternate material and the analysis done using Abaqus software package.*

Keywords: *Disc brake, Aluminum, SiC, composite materials, Abaqus.*

I. Introduction

Brake is an integral part of a vehicle which is used to retard or stop the vehicle from moving. From the safety aspect, the brake is an important and crucial component. So the brake rotor should be strong enough to withstand the thermal effect and dissipate the generated heat quickly. The material for brake should be suitably selected. Commonly used material for disc brakes is cast iron. Density of cast iron is high and leads to more fuel consumption and emissions. Composite materials are light weight and have good mechanical properties. In this study Al based metal matrix composite with 20% SiC is chosen as alternate material, and it has good mechanical properties compared to cast iron.

Disc brakes are commonly used in all variety of cars and two wheelers. In disc brakes, friction surfaces are always exposed to atmospheric air and hence it can reject generated heat quickly than other type of brakes. Disc is commonly produced by cast iron and in some special cases it may be in ceramic reinforced composites. Disc is directly coupled with axle. For retardation of disc, a pair of friction pads is used. To improve the co-efficient of friction and durability, the pads are produced by steel fibers with organic binders. A caliper is used to hold the brake pads. Brake pads are placed on the two sides of brake disc. Disc is in rotation when vehicle is in moving. When the retardation of the vehicle is needed, the brake pads are forced towards the disc. Brake pads can be operated mechanically, hydraulically pneumatically and electro magnetically. Due to the contact of brake pad with disc, the kinetic energy of vehicle is converted into heat energy. The generated heat should be dissipated or otherwise the fading will occur.Telang A K[1] reported that, thefriction coefficient of AL-MMC is 25-30% times more than that of cast Iron. Thermal conductivity of AL-MMC is about two or three times higher than cast iron. An MMC disc could be 60% lighter than an equivalent cast iron disc. Sourav Das[2], Studied the braking performance of Al-Si alloys [ADC12 & LM30] brake drums using a brake drum dynamometer test rig. The comparison of the performance of ADC12 and LM30 alloys on the basis of experimental parameters such as coefficient of friction, rise in temperature, braking torque, and rotational speed were studied. Stopping distance after applying the brake was also calculated and it was observed that stopping distance reduces as a function of brake force and concluded that LM30 alloy performs better than ADC 12. M.A. Maleque[3] et al developed the material selection method and selects the optimum material for the application of brake disc system using digital logic system. In this analysis the material performance requirements and alternative solutions were evaluated among cast iron, aluminium alloy, titanium alloy, ceramics and composites. Mechanical properties including compressive strength, friction coefficient, wear resistance, thermal conductivity and specific gravity as well as cost, were used as the key parameters in the material selection stages and conclusion leads to the aluminium metal matrix composite as the most appropriate material for brake disc system. K. L. Meena[4], developed and analyzed the properties of Al-MMC prepared by stir casting techniques. In this experiment aluminium with 10%, 15%, and 20% of SiC were analyzed and concluded thataluminium with 20% of SiC shows superior property than other compositions. XIA0 Cheng-yong[5] made an investigation on disc brake for noise generation using Complex Modal Analysis theory. HuajiangOuyang,[5], made a numerical analysis on disc brake for brake squeal and covered two major approaches used in the automotive industry, the complex eigenvalue analysis and the transient analysis. The advantages and limitations of each approach are examined and found that the complex eigenvalue analysis is better.

II. Methodology

Brake are commonly made of cast iron and because of the high density it consumes more fuel. Hence a light material is needed to minimize the consequences of high density material. Composite materials are less in weight and comparatively good in mechanical properties. So it may be chosen as an alternative. In this studyaaluminium composite with SiC[20%] reinforcement is proposed as an alternate material.
The disc brake is modeled for selected dimensions and tested virtually using FEM package under same working conditions for present and proposed material.

Typical disc brake of a vehicle has been modeled from the data availableonline. The details of dimensions of disc brake are shown in figure[1].

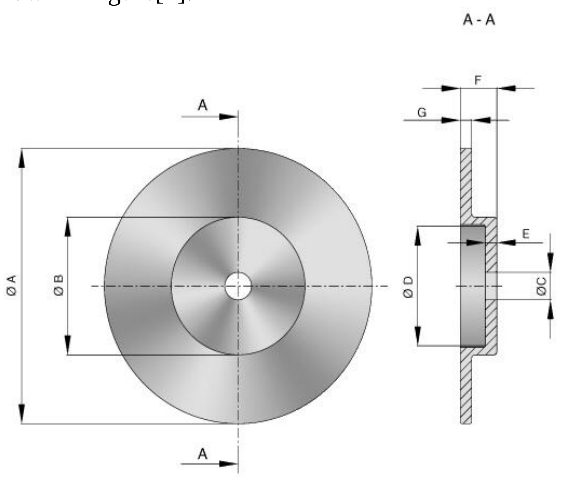

Fig.1 Disc Brake

ΦA=272 mm	E=14 mm
ΦB=154 mm	F=68 mm
ΦC=82 mm	G=12.5 mm
ΦD=126 mm	

Steps involved in the analysis are:
a) PRE-PROCESSING
i. Model
ii. Property assignment
iii. Meshing
iv. Assembly

Standard explicit data base is selected for the model.The brake disc and pad are simple to model and were modeled in Abaqus software itself. The assembly of the model is done using instane, translate and rotate comments which are all available in model tree. The assembly model developed in Abaqussoftware is shown in figure [2].

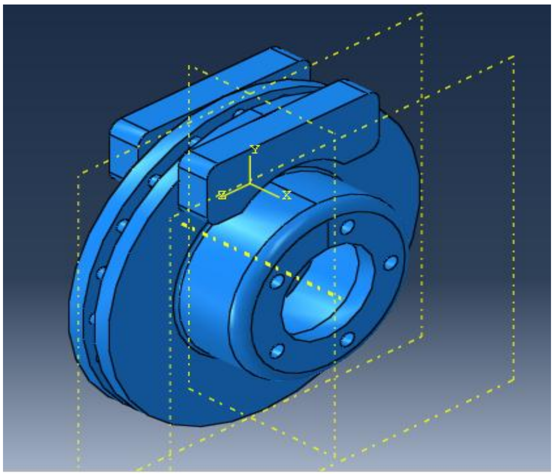

Fig [2] Disc Brake Model

The disc and pad are individually meshed and meshed assembly is shown in figure[3]. The details of meshed model are as follows.

Type of mesh : TETRAHEDRAL
Sizing : Coarse
No. of Nodes : 28727
No. of Elements : 14909

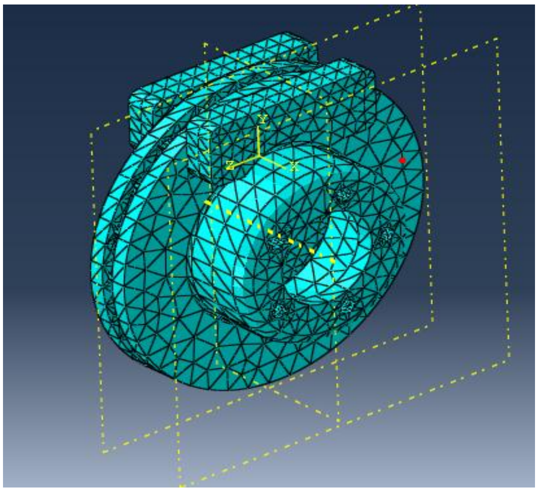

Fig [3] Meshed Model

The material is elastic in nature and so Young's modulus, Poisson's ratio and density of the material were assigned.

b) PROCESSING

i. Step creation
ii. Boundary conditions
iii. Solver

In step module, the dynamic explicit step has created under general condition. Then the boundary conditions are given as per the analysis requirement. The boundary conditions are presented below.

DISC:
Rotation speed= 150 rpm
Displacement[X, Y, Z directions are arrested]
$U_1=0$; $U_2=0$; $U_3=0$
The directions of X, Y, Z are shown in figure[2]
PAD:
Surface traction force=1000 N
Displacement[Y, Z directions are arrested]
$U_1=5$ mm; $U_2=0$; $U_3=0$
The solver module solves the problem for the given boundary conditions and generates the results.

c) POST PROCESSING

The results for stress pattern, elastic strain, displacement and strain energy are taken from post processor module.

Table 1. MATERIAL PROPERTIES

Material	Strength [Comp.] [Mpa]	[μ]	Wear rate [x10-6 mm3/ N/m]	Cp[kJ /kg. K]	Specific gravity[kg/m3] X10^3
CI	1293	0.41	2.36	0.46	7.2
Al-20% SiC	761	0.44	2.91	0.92	2.8

The details of material properties are presented in table 1. The values are taken from a literature[3].

III. Results and Discussions

A. CAST IRON DISC BRAKE

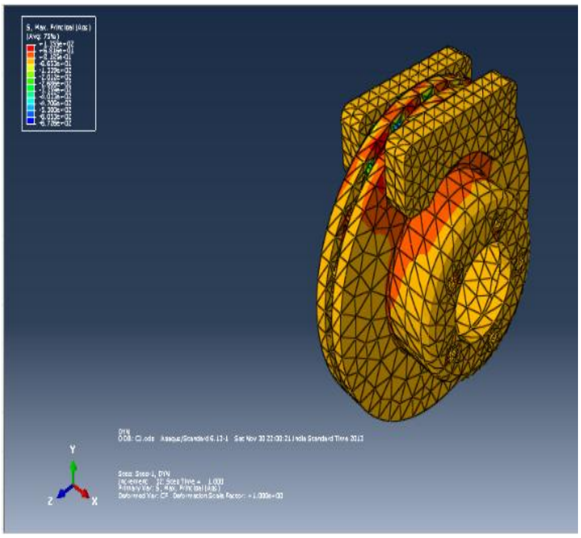

Fig [4] Contact stress pattern for CI

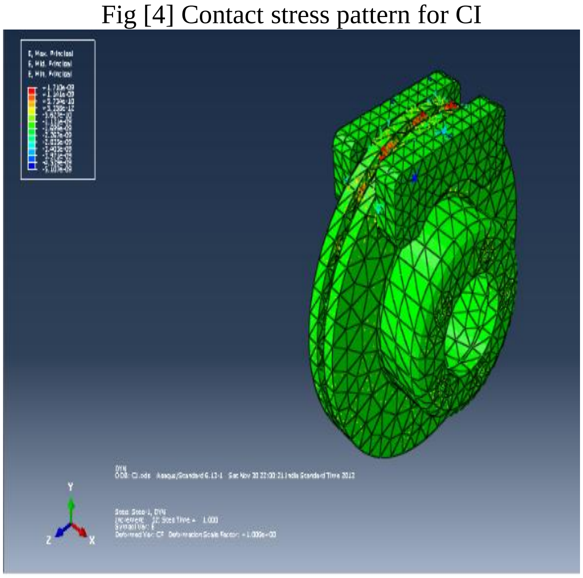

Fig [5] Equivalent Elastic Strain for CI

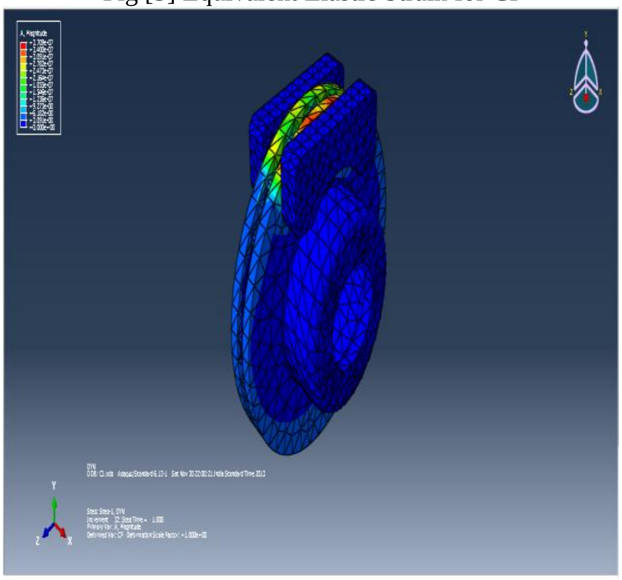

Fig [6] Displacementfor CI

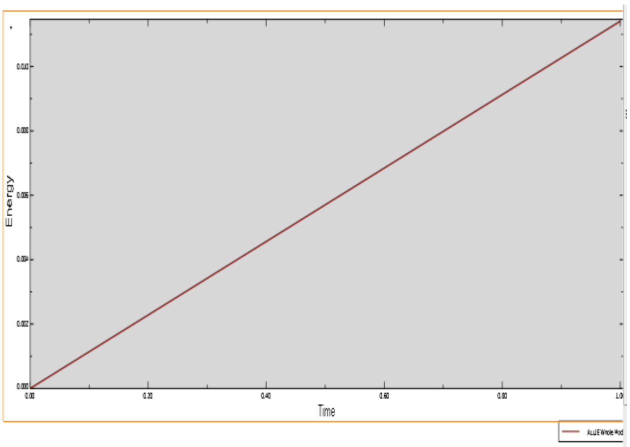

Fig [7] Strain energy plotfor CI

Contact stress pattern of cast iron disc brake is shown in figure[4]. The stress is concentrated and distributed near pad contacting regions. Also the maximum stress is induced in the pad contact area.
Figure[5] shows the elastic strain of cast iron disc brake. The maximum elastic strain occurs in disc and pad contact area which is the weaker section.
Figure[6] shows the displacement of cast iron disc brake. The maximum displacement occurs in disc and pad contact area only.
Figure[7] shows the strain energy plot. And the cast iron disc brake stores 0.01 J of strain energy during the application of brake.

B. COMPOSITE DISC BRAKE [Al-MMC]

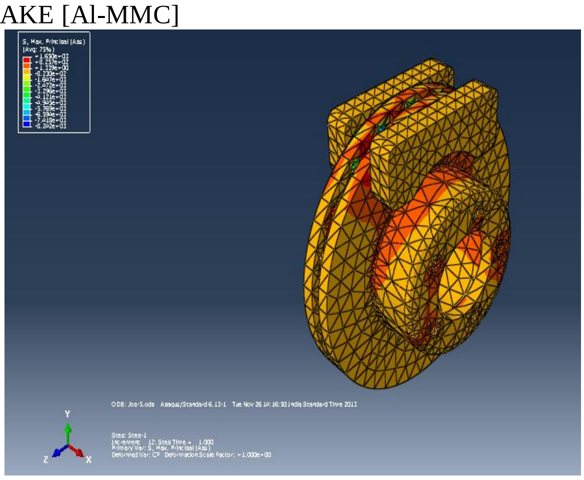

Fig [8] Contact stress pattern for Al composite

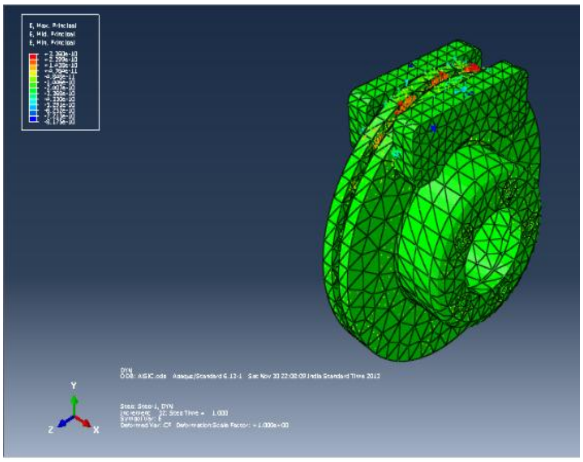

Fig [9] Equivalent Elastic Strain for Al composite.

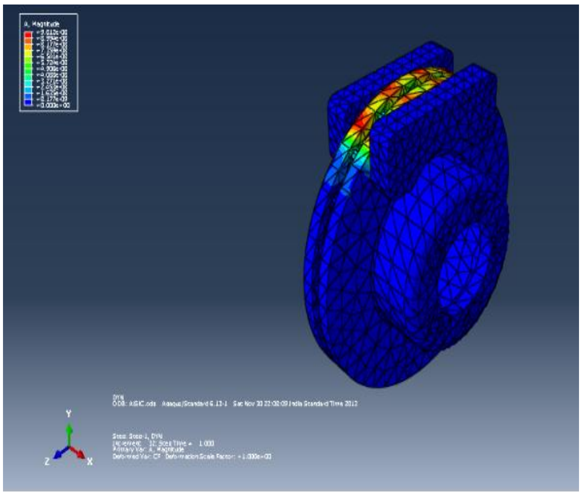

Fig [10] Displacement for Al composite

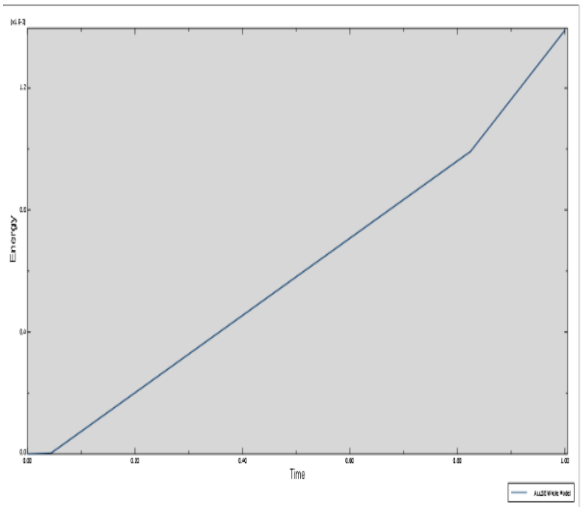

Fig [11] Strain energy plot for Al composite

Contact stress pattern of composite disc brake is shown in figure[8]. The stress is concentrated and distributed near pad contact regions. The distribution of stress in composite disc is higher than the CI disc. But maximum stress in both CI and Al MMC are within the elastic limit.

Figure[5] shows the elastic strain of composite disc brake. The maximum elastic strain occurs in disc and contactarea. The maximum elastic strain in composite brake disc is higher than the CI brake disc as the material is relatively ductile.

Figure[6] shows the displacement of composite disc brake. The maximum displacement occurs near pad contact area. Greater displacement occurs in composite disc brake compared to CI disc brake.

Figure[7] shows the strain energy plot. And the composite disc brake stores 0.012 J of strain energy. The energy stored by the composite disc brake is comparatively high than CI disc brake. Hence the composite disc brake absorbs more strain energy within its elastic limit. It reveals the composite material disc brake can withstand more number of braking cycles than CI disc brake.

The comparisons of results are presented in table 2.

Table.2 Comparisons of response for CI and Al MMC

Experiment results

Material	Stress [N/m^2]	Elastic Strain	Disp.[m]	Strain Energy [J]
CI	$1.361E^{2}$	$1.710E^{-9}$	$3.709E^{-7}$	0.01
Al- MMC	$1.391E^{2}$	$2.241E^{-10}$	$4.383E^{-8}$	0.012

IV. Conclusions

Cast iron disc brakes are commonly used. Since its heavy weight results in high fuel consumption. So weight reduction in disc brake is needed. Aluminium metal matrix composites particulate with 20% silicon carbide provides appreciable weight reduction with improved wear resistance, hardness and thermal conductivity. In this study an attempt has been made to replace disc brake material from Cast iron to Aluminium silicon carbide composite.

The modeling and analysis have been done using finite element analysis software. A model of disc brake was created virtually and this model tested with conventional and proposed material. The observations and inferences are presented.

Comparison of stress distribution, equivalent elastic strain, displacement and strain energy for conventional and proposed material indicates that Aluminiumsilicon carbide composite satisfies the requirement for disc brake application. It is concluded thatAluminium silicon carbide composite can be used in automotive to replace the conventional material for improved vehicle performance.

REFERENCES

[1] Telang A K*1,Rehman A2,Dixit G3,Das S4“Alternate Materials In Automobile Brake Disc Applications With Emphasis On Alcomposites”

[2] Sourav Das, AmeenurRehmanSiddiqui, VishvendraBartaria “Evaluation Of Aluminum Alloy Brake Drum For Automobile Application”

[3] M.A. Maleque¹, S.Dyuti2 and M.M. Rahman[Member, IAENG]3, “Material Selection Method in Design of Automotive Brake Disc” in 2010.

[4] K. L. Meena1, Dr. A. Manna2, Dr. S. S. Banwait3, Dr. Jaswanti4,“An Analysis of Mechanical Properties of the Developed Al/SiC-MMC’s”

[5] XIA0 Cheng-yong1,a, JIANGYong1,b,HAO Zhi-jun1,c “Analysis on Wet Multi-Disc Brake Noise Based on ABAQUS”

[6] Abd Rahim AbuBakar and HuajiangOuyang “Complex eigenvalue analysis and dynamic transient analysis in predicting disc brake squeal”