International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

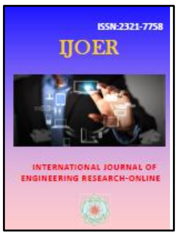
Vol.7., Issue.5, 2019
Sept-Oct

RESEARCH ARTICLE

ISSN: 2321-7758

TEMPERATURE DISTRIBUTION IN GREY CAST IRON BRAKE DISC AND ALUMINIUM METAL MATRIX COMPOSITE BRAKE DISC

SYAMBABU NUTALAPATI[1], CHANDRA SHEKHAR SOMBOJI[2], PALNATI DEVENDAR[3]
UPPALA SAI PRASANARAJ[4]
[1]Research Scholar, M.E (Machine Design), (Ph.D), JNTUK & Assistant Professor, Department Of Mechanical Engineering, Jyothishmathi Institute Of Technology & Science, Karimnagar, Telangana
[2,3,4]Assistant Professor, Department of Mechanical Engineering, Jyothishmathi Institute Of Technology & Science, Karimnagar, Telangana
https://doi.org/10.33329/ijoer.75.22



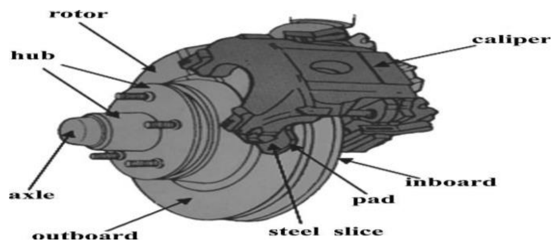
ABSTRACT

An automotive brake disc or rotor is a device for slowing or stopping the motion of a wheel while it runs at a certain speed. The aim of this project is to compare the existed cast iron disc brake with the brake made of Aluminium composite material and suggest the better material by performing the thermal analysis on the both brakes. In this project two different bikes of Pulsar and Unicorn are considered for the analysis of their brake discs.

Keywords: Brake Disc, Pulsar, Unicorn, Aluminium Metal Matrix Composite, Grey Cast Iron, CATIA, ANSYS, Thermal Analysis

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 to the surrounding atmosphere.



Fig(1.1). Disc Brake

2. LITERATURE REVIEW & MATERIALS SELECTION

2.1 Literature review

- **Guru Murthy Nathi, T N Charyulu, K.Gowtham, P Satish Reddy** have done the work on the coupled structural / thermal analysis of disc brake made to investigate the effect of stiffness, strength and variations in disc brake rotor design on the predicted stress and temperature distributions.

- **G. Ranjith Kumar, S. Thriveni, M. Rajasekhar Reddy, Dr. G. Harinath Gowd** in their work have done the optimization of Automotive Brake Disc and analysis the steady state thermal behavior of the dry contact between the brake disc and pads during the braking phase. . In these results, we get that, by changing the straight vents to curved vents in the brake disc the vonmises stresses & displacement vector

KY Publications

sum & mass of the brakes disc has been reduced. And also curved vented brake disc is generated a high thermal flux than a straight vented brake disc.

- **Telang A ,Rehman A,Dixit G,Das** have done the Redesigning of the braking system by substitution of lighter material like aluminum and carbon composite brakes primarily have been responsible for this state of the art technology, which is being used in aircrafts and formula one racing cars. The requirement is of the materials that have light weight, are strong, abrasion resistant and are not corroded easily. Composite materials provide such unique combination of properties. In this review the alternate materials for automobile brake applications with special attention to aluminum composites have been done. They have concluded that,

    a) The friction coefficient of AMC is 25- 30% times that of cast Iron and better wear characteristics.

    b) The thermal conductivity of AMC can be two or three times higher than cast iron.

    c) An MMC disc could be 60 % lighter than an equivalent cast iron component.

    d) The Thermal Diffusivity, which is the rate of heat dissipation compared to that of storage, is four times that of cast iron.

- **N. Balasubramanyam, Prof. Smt. G. Prasanthi** analyzed the thermo elastic phenomenon occurring in the disk brakes, the occupied heat conduction and elastic equations are solved with contact problems. Thermo elastic instability (TIE) phenomenon (the unstable growth of contact pressure and temperature) is investigated in the present study, and the influence of the material properties on the thermo elastic behaviors (the maximum temperature on the friction surfaces) is investigated to facilitate the conceptual design of the disk brake system.

- **Parth S. Joshi, Kiran C. Hegade, Apoorv S. Kulkarni & Omkar V. Karale ,** have dealed with the manufacturing of disc brake rotor using AMMC. AMMC is the combination of aluminium and silicon carbide along with small quantity of other material like magnesium, aluminium oxide, graphite which are added in precise quantity to enhance the chemical, mechanical and thermal strength of material. The whole process is carried out in controlled

Environment. Gravity die casting is the suitable process used for the purpose. Pre-processing of additives are carried out precisely. This paper presents an overview of stir casing process, process parameter and preparation of AMC using aluminium alloy as matrix phase and alumina (Al2O3) as reinforcement

- **Malek ali1, ali samer muhsan1, m.i. fadhel, m.a. alghoul, k. Sopian2 & a. Zaharim** have worked on the mechanical properties of Al–12% Si matrix composite reinforced (which can used in light devices and energy storage) by various amounts of Titanium Nitride (TiN) particles. Macrostructural studies have shown near uniform distribution of TiN particles in the matrix.

1. The results suggested that the reinforced Al-12Si matrix composites showed significant improvement in their wear resistance accordingly with increasing the reinforcement's percentage at different conditions.

2. From their work TiN reinforced samples have shown higher wear resistance than unreinforced samples. Similarly, when the speed increases with different applied loads, TiN Reinforced samples have exhibited higher wear resistance than the rest. Where, after adding 15% of Ti particles it showed that the loss wear in average has Been decreased about 49.5% compared to the base sample.

- **Swapnil R. Abhang, D.P.Bhaskar,** has worked on the carbon ceramic matrix disc brake material use for calculating normal force, shear force and piston force. And also calculating the brake distance of disc brake. The standard disc brake two wheelers model using in Ansys and done the Thermal analysis and Modal analysis also calculate the deflection and Heat flux, Temperature of disc brake model. This is important to understand action force and friction force on the disc brake new material, how disc brake works more efficiently, which can help to reduce the accident that may happen in each day [7].

- **D M Nuruzzaman1, F F B Kamaruzaman** In this study, aluminium-silicon carbide (Al-SiC) metal matrix composites (MMCs) of different compositions were prepared under different compaction loads. Three different types Al-SiC composite specimens having 10%, 20% and 30% volume fractions of silicon carbide were fabricated using conventional powder metallurgy (PM) route. The specimens of different compositions were prepared under different compaction loads 10 ton and 15 ton. The effect of volume fraction of SiC particulates and compaction load on the properties of Al/SiC composites was investigated. The increase in the volume fraction of SiC enhances the density and hardness of the Al/SiC composites. For 15 ton compaction load, the composites show increased density and hardness as well as improved microstructure than the composites prepared under 10 ton compaction load [8].
- **MALEK ALI ET AL** in their study presented the mechanical properties of Al–12% Si matrix composite reinforced (which can used in light devices and energy storage) by various amounts of Titanium Nitride (TiN) particles.. The mechanical properties such as hardness and wear resistance are observed to be increased considerably compared to the matrix composite The wear behavior was investigated using a pin-on-disc wear testing machine with varying parameters such As normal load, reinforcement's percentage and track velocity. The results suggested that the reinforced Al-12Si matrix composites showed significant improvement in their wear resistance accordingly with increasing the reinforcement's percentage at different conditions [9].
- **Amro M. Al-Qutub, Ibrahim M. Allam M. A. Abdul S amad** addresses the dry wear behavior of A1203 6061 Aluminum particulate composite under different sliding speeds and applied load using pinon-disk tribometer at room temperature. Three grades of the submicron particle composites containing 10, 20, and 30 vol.% A1203 were tested. The results illustrate that higher load and higher concentration of A1203 particles lead to higher wear rates. For 10 and 20% A12O3 concentrations, the wear rate decreases with increasing sliding speed, while it increases for 30% A1203 [10].
- **Abhishek Kumar Tiwari, Akhilesh Kumar Tiwari, Pramod Yadav, Harigovind Singh Yadav, Shyam Bihari Lal** made an attempt to investigate the effect of stiffness, strength and variations in disc brake rotor design on the predicted stress. By identifying the true design features, the extended service life and long term stability is assured. An attempt is also made to suggest a best combination of material and flange width used for disc brake rotor which has less deformation and minimum von-mises stress possible [11].
- **Venkatramanan R, Kumaragurubaran SB, Vishnu Kumar C, Sivakumar S, Saravanan B** This work deals with the thermal analysis of disc brake of a vehicle. Heat generation and dissipation of disc brake are analyzed. The objective of this work is to investigate and analyze the temperature distribution of rotor disc during operation using Ansys. In this research work design of a disc brake is proposed with copper liner on its brake

disc, the heat transfer of existing and hybrid disc will be calculated for finding the effectiveness of heat transfer. The cast iron has the maximum temperature produced is about 335.98c with the presence of copper liner [12]. .

2.2 Material selection for thermal analysis

In recent times, there is an increasing demand for developing advanced engineering materials which are multi-functional and these materials are gaining popularity for high performance applications. Metal matrix composites (MMC) are new generation engineering materials to fulfill multiple functions in many engineering fields and substantial progress in the development of metal matrix composites has been achieved so that these composites can be used for high performance structures such as in aerospace, automotive and armor industries

Material used: Aluminium metal matrix composite with 30%SiC composition

Properties of Aluminium

Aluminium is the second most abundant ore in earth crust. It became an economic competitor to steel & cast iron in engineering applications because of its excellent combination of properties like,

- Light weight
- High specific strength
- Stiffness
- Good corrosion resistance
- Higher ductility
- Low cost
- Good Machinability

3. EXPERIMENTAL WORK

3.1 Problem Definition

In this study two brake disc's of different bikes are considered .The brake disc's of pulsar and unicorn are modeled in CATIA V5 and then meshed in ANSYS workbench 16.0 using appropriate elements. The finite element model obtained is then used to study the characteristics of Brake Disc's using Finite Element Analysis software under certain assumptions. Thermal analysis has been carried out using the ANSYS 16.0 finite element package.

Appropriate boundary conditions are applied to the Disc specifications to the finite element mode. The material used is Aluminium Metal matrix composite of 30% Silicon carbide (SiC) and compared with the cast iron material under thermal analysis.

3.2 Design of Discs made in CATIA V5R20

The following models are of Brake Disc's of Pulsar and Unicorn bikes made in CATIA V5

Table(3.1): Specicifications of Pulsar brake disc and Unicorn brake disc:

Parameter	**Pulsar brake**	**Unicorn brake**
Outer Diameter	270mm	240mm
Inner Diameter	200mm	180mm
Thickness	5mm	4mm
Diameter of smaller hole	8mm	6mm
Diameter of hole for bolted support	12mm	12mm

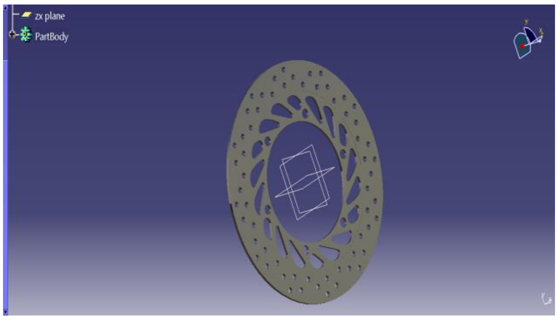


Fig 3.1 Brake Disc of Unicorn bike modeled in CATIA

3.3 Meshing of Disc

The disc's modeled in CATIA are saved in Initial Graphics Exchange Specification (IGES) format and are been imported into ANSYS 16.0.The initial step in the imported model is to discretize into number of parts. In the Discretization, element types used are triangle, tetrahedron, square, cubes etc…

Mesh generation is one of the most critical aspects of engineering simulation. Too many cells may result in long solver runs, and too few may lead to inaccurate results. ANSYS Meshing technology provides a means to balance these requirements and obtain the right mesh for each simulation in the most automated way. The strongest aspect of these separate tools has been brought together in a single environment to produce some of the most powerful meshing available.

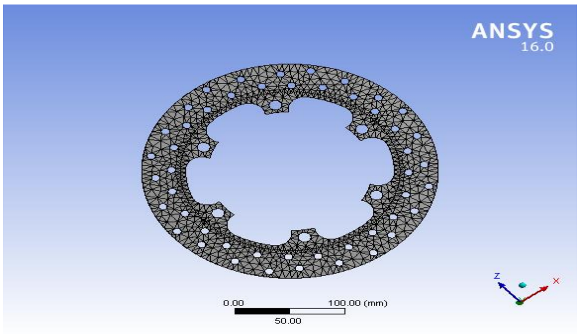


Fig 3.2 Meshed model of Pulsar Disc

Mesh details

Number of Nodes: 19534

Number of Elements: 9853

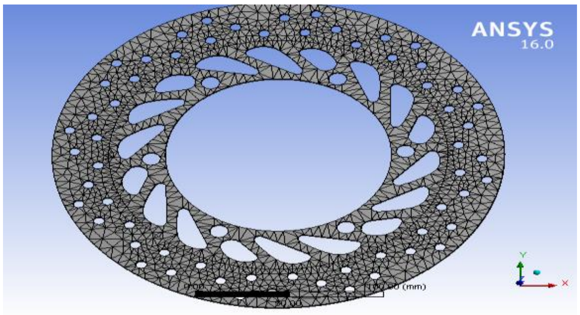


Fig 3.3 Meshed model of Unicorn Disc

Mesh details

Number of Nodes: 29568

Number of Elements: 14890

3.4 Properties of Aluminium metal matrix composite

The properties of Aluminium metal matrix composite of 30% silicon carbide are added to ANSYS for comparing with the general cast iron disc are given below,

S.no	Property	Units	Al/Sic Metal Matrix Composite
1	**SiC concentration**	**Vol%**	**30%**
2	Matrix		359 Aluminium
3	Elastic Modulus	Gpa	120
4	Density	g/cm^3	2.80
5	Specific stiffness	Gpa- cm^3 /g	42.9
6	Mean CTE	ppm/°C	14.6
7	Thermal conductivity	W/m°C	185
8	Specific heat	J/kg K	795
9	Tensile strength	Mpa	216
10	Yield strength	Mpa	210

3.5 Theoretical calculations

a) Design Specification of Rotor

1	**Rotor disc dimension**	270mm
2	**Rotor disc material**	Aluminium Metal Matrix composite(30% Sic)
4	**Pad brake area**	0.0067 m^2
5	**Pad brake material**	Asbestos
6	**Coefficient of friction (Wet)**	0.07-0.13
7	**Coefficient of friction (Dry)**	0.3-0.5
8	**Maximum pressure**	1MPa (10e6 Pa)

b) Tangential Force between Pad And Rotor

FTRI = Normal force between pad brake and Rotor [12]

μ = Coefficient of friction = 0.5

A =Pad brake area

FTRI = μ FRI –Eq.(1)

FRI= (P max/2).A–Eq.(2)

FTRI = 0.5 x 0.5 x 1e6 x 0.0067 =1675 N

c) Brake Torque (Tb)

TB =FT.R –Eq. (3)

TB = (1675) (135×10e-3) = 226.125 Nm

We know that tangential braking force acting at the point of contact of the brake, and

Work Done=F.T /X Eq- (4)

Where FT is the total normal forces on disc brake and x is the distance travelled (in meter) by the vehicle before it come to rest.

We know kinetic energy of the vehicle.

Kinetic Energy= 1/2 m v^2 -- -Eq.(5)

Where "m" is the mass of vehicle and v is the velocity of vehicle

In order to stop the vehicle to, the work done against friction must be equal to kinetic energy of the vehicle.

FT. x= 1/2 m v^2

Comparing Eq. (4) and (5)

FT. x= 1/2 m v^2

Assuming, v = 100 km/h =27.77 m/s

m =150 kg. (Dry weight of Vehicle)

So, we get

X= (m $v^{2)}$) /2FT

x = (150×27.77*27.77) / (2×1675) = 34.53 m

d).Heat Generated Through Braking

1 Heat Generated in disc rotor (J/s) – Eq.(6)

Q= mc (ΔT) =0.4016x795x15=4789.08 J

Where, mass of disc is 0.4016kg, specific heat capacity of disc is 795 J/kg K, time taken for Stopping the vehicle is 5 sec, developed temperature difference (ΔT) is 15 °C and area of disc is 0.06328 m2.

Heat Flux (W/m^2) q=Q/A

Heat Flux= (Heat Generated/second)/ Area of the Disc

= (4789.08/5)/.02869

=33,385 W/m^2

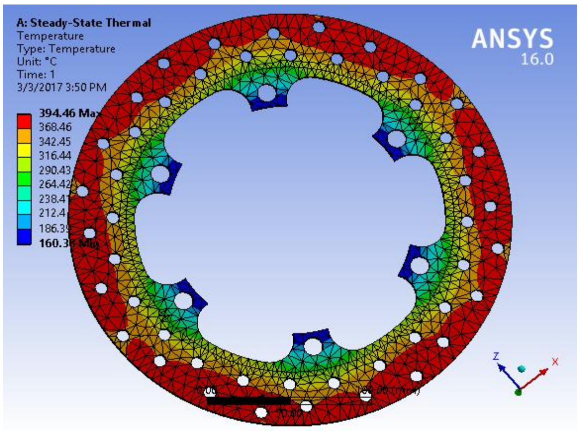
3.6 Boundary conditions for Analysis

S.No	Parameter	Value
1	Heat flux	33,385 W/m^2
2	Surrounding temperature	30°*C*
3	Heat transfer coefficient	220 W/m^2K
4	Thermal conductivity AMMC	185 W/m°*C*
5	Grey cast Iron	46 W/m°*C*

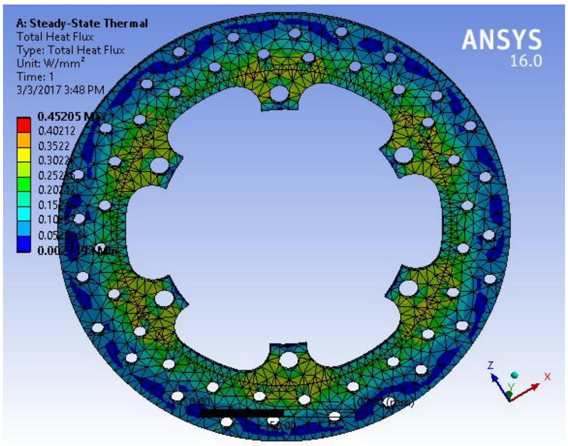
4. RESULTS AND DISCUSSION

The output result of the thermal analysis of both the modeled discs are analyzed on both the materials of Grey cast iron and Aluminium Metal Matrix composite and the results are given below.

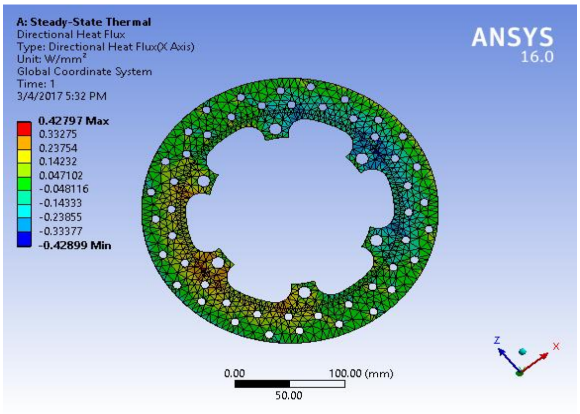
4.1. Grey Cast Iron of Pulsar brake disc



Fig(4.1): Temperature for Grey Cast Iron



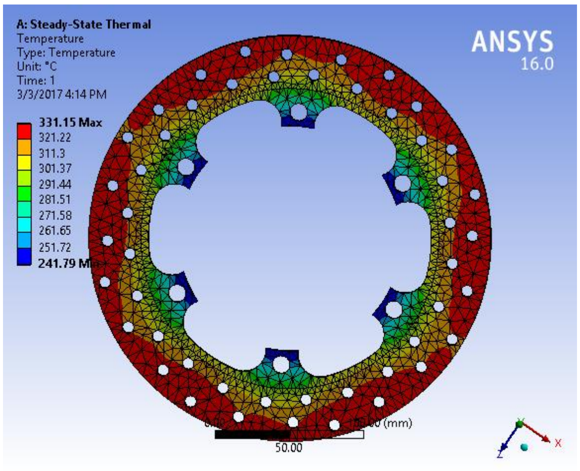
Fig(4.2): Heat flux for Grey Cast Iron



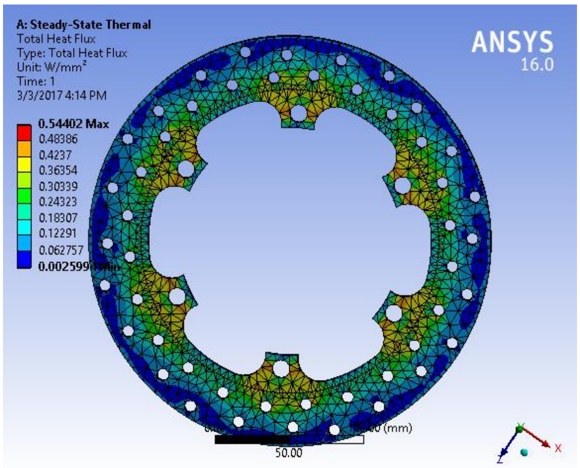
Fig(4.3):Directional heat flux

x-axis for Grey Cast Iron

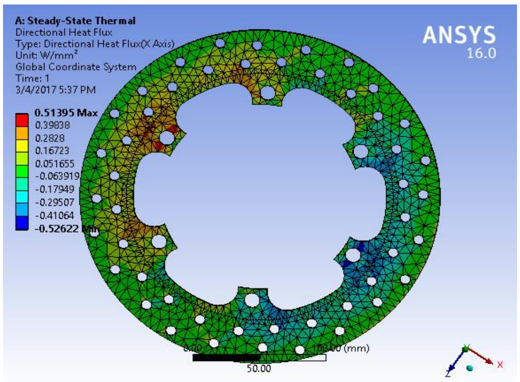
4.2) Aluminium Metal Matrix Composite of Pulsar brake disc



Fig(4.4): Temperature for AMMC

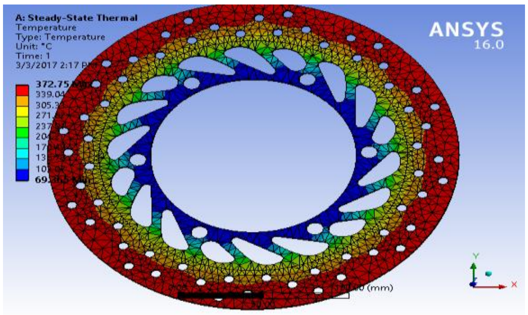


Fig(4.5): Heat flux for AMMC

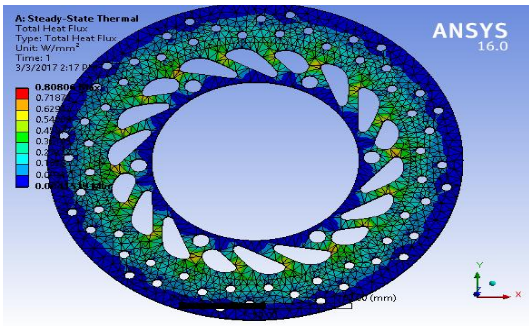


Fig(4.6):Directional heat flux x-axis for AMMC

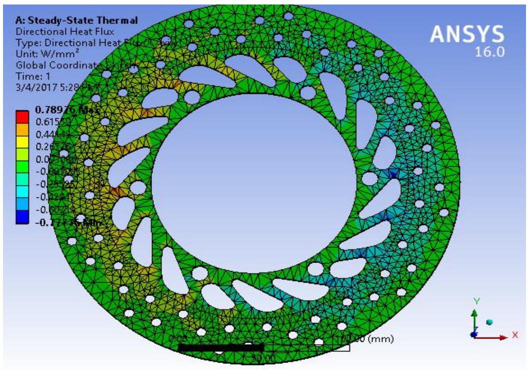
4.3. Grey Cast Iron of Unicorn brake Disc



Fig(4.7):Temperature for Grey Cast Iron



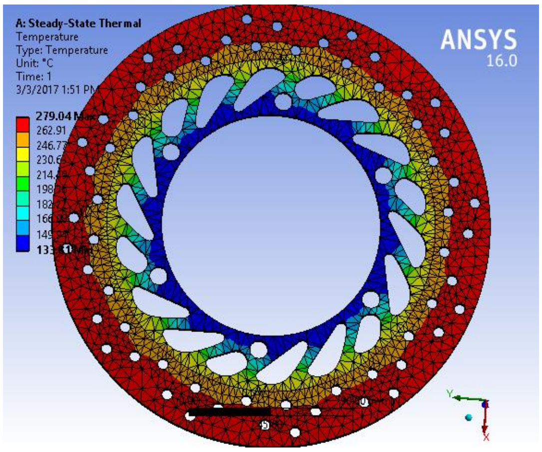
Fig(4.8): Heat flux for Grey Cast Iron



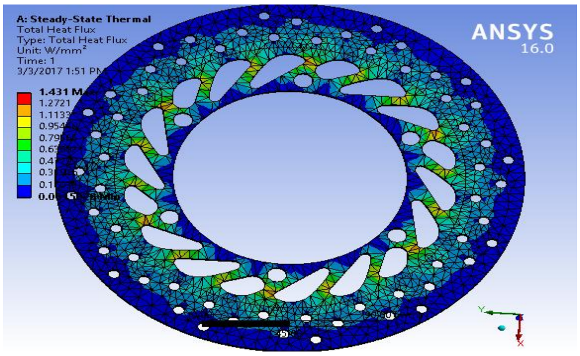
Fig(4.9): Directional heat flux for Grey Cast Iron

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com
Vol.7., Issue.5, 2019
Sept-Oct

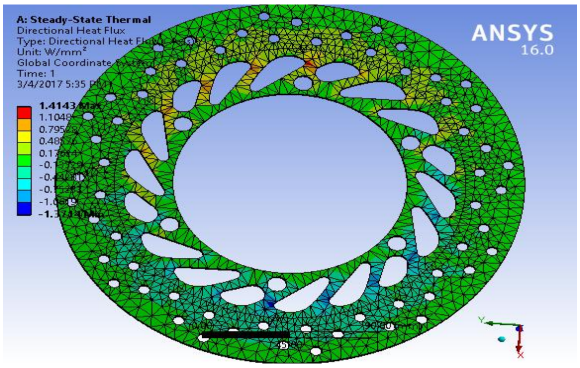
4.4 Aluminium Metal Matrix Composite of Unicorn brake Disc



Fig(4.10): Temperature for AMMC



Fig(4.11):Heat flux for AMMC



Fig(4.12): Directional heat flux for AMMC

5. RESULTS

Table (5.1): Temperature, Total heat flux, Directional heat flux.

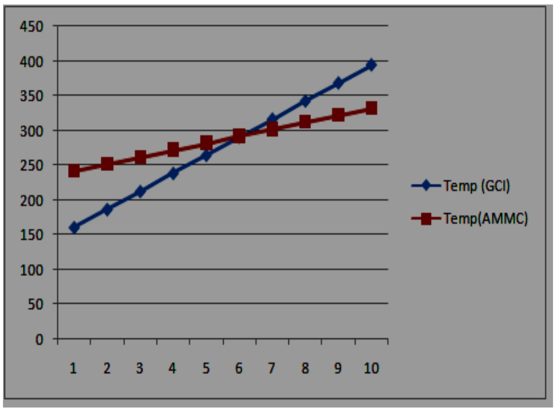
	Pulsar brake disc		Unicorn brake disc	
DISC	Grey Cast Iron	Aluminium Metal Matrix Composite	Grey Cast Iron	Aluminium Metal Matrix Composite
Temp. °*C* Max Min	394.46 160.38	331.15 241.79	372.75 69.635	279.04 133.81
Total Heat Flux W/mm^2 Max Min	0.45205 0.0027193	0.54402 0.0025994	0.80806 0.0044519	1.431 0.081562
Directional Heat Flux (W/mm^2) Max Min	0.42797 -0.42899	0.51395 -0.52622	0.78976 -0.77776	1.4143 -1.371

Table (5.2): Temperature distribution in two bikes

Bike	pulsar Brake Disc		Unicorn Brake Disc	
s.no	Temp (GCI)	Temp (AMMC)	Temp (GCI)	Temp (AMMC)
1	160.38	241.79	69.365	133.61
2	186.39	251.72	103.07	149.95

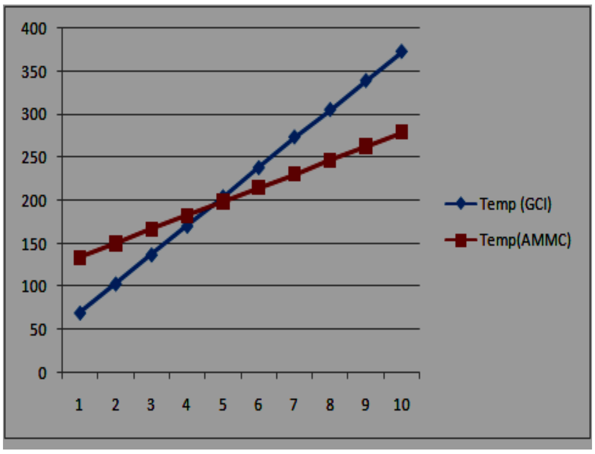
3	212.4	261.65	136.78	166.09
4	238.41	271.58	170.4	182.2
5	264.42	281.51	204.2	198.36
6	290.43	291.44	237.91	214.49
7	316.44	301.37	273.52	230.63
8	342.45	311.3	305.33	246.77
9	368.46	321.22	339.04	262.91
10	394.46	331.15	372.75	279.04

5.1. Graph of pulsar Brake Disc



Graph (5.1): Comparison of GCI and AMMC on Pulsar brake disc

5.2. Graph of Unicorn Brake Disc



Graph (5.2): Comparison of GCI and AMMC on unicorn brake disc

6. CONCLUSION

- Brake discs of two different bikes are modeled and are thermally analyzed with the generally used Grey cast iron and Aluminium Metal Matrix Composite.
- The analysis is done on steady state thermal condition by giving heat flux as input. Finally, the temperature distribution and Directional heat flux are considered as solution in this work.
- The maximum temperature rise of Grey cast iron is much more as compared to Aluminium Metal Matrix Composite on the basic of thermal analysis; AMMC is the best preferable material for manufacturing disc brake than Cast-iron.

7. References

[1]. Coupled structural / thermal analysis of disc brake Guru Murthy Nathi1, T N Charyulu2, K.Gowtham3, P Satish Reddy4 IJRET: International Journal of Research in Engineering and Technology ISSN: 2319-1163. Volume: 01 Issue: 04, Dec-2012,

[2]. Design Analysis & Optimization of an Automotive Disc Brake G.Ranjith Kumar, S.Thriveni, M. Rajasekhar Reddy, Dr. G. Harinath Gowd, International Journal of Advanced Engineering Research and Science (IJAERS) [Vol-1, Issue-3, Aug- 2014] ISSN: 2349-6495

[3]. Alternate materials in automobile brake disc applications with emphasis on al composites-a technical review telang A k*1,rehman a,dixit g,das Journal of Engineering Research and Studies

[4]. Design and Analysis of Disc Brake Rotor for a Two Wheeler N. Balasubramanyam, Prof. Smt. G. Prasanthi, (7-12), Month: October 2013- March 2014.

[5]. Manufacturing of Disc Brake Rotor Using Aluminium Metal Matrix Composite (AMMC) reinforced with Silicon Carbide by Parth S. Joshi, Kiran C. Hegade, Apoorv S. Kulkarni & Omkar V. Karale, Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-6, 2016 ISSN: 2454-1362,

[6]. Developments of Al-12Si alloys by reinforcing TiN particles by MALEK ALI1, ALI SAMER MUHSAN1, M.I. FADHEL1, M.A. ALGHOUL2, K.

SOPIAN2 & A. ZAHARIM2 1Faculty of Engineering and Technology, Multimedia University, 75450 Melaka, MALAYSIA 2Solar Energy Research Institute, University Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, MALAYSIA.

[7]. Design and Analysis of Disc Brake Swapnil R. Abhang, D.P.Bhaskar International Journal of Engineering Trends and Technology (IJETT) – Volume 8 Number 4- Feb 2014

[8]. Processing and mechanical properties of aluminium-silicon carbide metal matrix composites D M Nuruzzaman1, F F B Kamaruzaman IOP Conf. Series: Materials Science and Engineering 114 (2016) 012123 doi:10.1088/1757-899X/114/1/012123

[9]. Developments of Al-12Si alloys by reinforcing tin particles malek ali, ali samer muhsan, m.i. fadhel, m.a. alghoul, k. Sopian & a. Zaharim ISBN: 978-1-61804-105-0.

[10]. Wear and friction of Al-A1203 composites at various sliding Speeds Article in Journal of Materials Science · September 200 DOI: 10.1007/s10853-008-2867-8

[11]. Finite Element Analysis of Disc Brake for Aluminium Alloys by Abhishek Kumar Tiwari, Akhilesh Kumar Tiwari, Pramod Yadav, Harigovind Singh Yadav, Shyam Bihari Lal International Journal of Scientific & Engineering Research, Volume 5, Issue 4, April-2014 ISSN 2229-5518