

Design & Analysis of Brake Disc using Metal Matrix Composites

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Abstract— Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. The disc brake is a device for decelerating or stopping the rotation of a wheel. A brake disc (or rotor) usually made of cast iron or ceramic composites, is connected to the wheel and/or the axle. Friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc to stop the wheel. The present research is basically deals with the modeling and analysis of solid disc brake using Pro-E and Ansys. Finite element (FE) models of the brake-disc are created using Pro-E and simulated using ANSYS which is based on the finite element method (FEM). In this research Coupled Analysis (Structural & Thermal analysis) is performed in order to find the strength of the disc brake. In structural analysis displacement, ultimate stress limit for the design is found and in thermal analysis heat flow rates, and heat fluxes to be calculated by varying the two different materials of the disc. Comparison can be done for displacement, stresses and nodal temperatures. Results will be compared for the two different material of the disc.

Key words: Brake Disc, Metal Matrix Composites

I. INTRODUCTION OF BRAKE

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.

II. LITERATURE REVIEW

Anirudh Biswas and Deepak Bhalla carried out research work on Mechanical properties of silicon based Aluminium alloy 22.92. Aluminum-Silicon alloys are sought in a large number of automotive and aerospace applications due to their low coefficient of thermal expansion and high wear resistance. The present study focused on Mechanical properties of the silicon based aluminum alloys. Commercial cast aluminum-silicon alloys are poly phase materials of composed microstructure belonging to the Aluminum Association classification series 3xx.x for aluminum silicon plus copper and/or magnesium alloys and 4xx.x aluminum silicon alloys. They are designated by standards such as CEN EN 1706, "Aluminum and Aluminum Alloys. Castings Chemical Composition and Mechanical Properties," and are designated in ASTM standards according to the method of casting. This study aimed to investigate solidification and mechanical behavior of Al- Si alloy against both the molding conditions and silicon content (15%- 24% Si). Grain size analysis

mechanical properties and non-destructive test of the alloys have been studied. The results showed that. With the increasing of silicon content the solidification time increased, as also a decrease of the liquids temperature was observed up to 12% and then increased with increasing Si%. However, an increase of both the ultimate tensile strength and the hardness is obtained by the increase of the silicon content. With the increase of silicon content the wear rate decrease and Coefficient of friction increase.

V. Chengal Reddy, M. Gunasekhar Reddy, Dr. G. Harinath Gowd carried out research work on Modeling and Analysis of FSAE Car Disc Brake Using FEM.

Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. The disc brake is a device for decelerating or stopping the rotation of a wheel. A brake disc (or rotor) usually made of cast iron or ceramic composites, is connected to the wheel and/or the axle. Friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc to stop the wheel. The present research is basically deals with the modeling and analysis of solid and ventilated disc brake using Pro-E and Ansys. Finite element (FE) models of the brake-disc are created using Pro-E and simulated using ANSYS which is based on the finite element method (FEM). In this research Coupled Analysis (Structural & Thermal analysis) is performed in order to find the strength of the disc brake. In structural analysis displacement, ultimate stress limit for the design is found and in thermal analysis thermal gradients, heat flow rates, and heat fluxes to be calculates by varying the different cross sections, materials of the disc. Comparison can be done for displacement, stresses, nodal temperatures, etc. for the three materials to suggest the best material for FSAE car.

Guru Murthy Nathi, T N Charyulu, K.Gowtham , P Satish Reddy carried research work on Coupled structural / thermal analysis of disc brake. The motive of undertaking this project of "Coupled Structural / Thermal Analysis of Disc Brake" is to study and evaluate the performance under severe braking conditions and there by assist in disc rotor design and analysis. This study is of disc brake used for cars. ANSYS package is a dedicated finite element package used for determining the temperature distribution, variation of stresses and deformation across the disc brake profile. In this present work, an attempt has been made to investigate the effect of stiffness, strength and variations in disc brake rotor design on the predicted stress and temperature distributions. By identifying the true design features, the extended service life and long term stability is assured. A transient thermal analysis has been carried out to investigate the temperature variation across the disc using axisymmetric elements. Further structural analysis is also carried out by coupling thermal analysis. An attempt is also made to suggest a best

combination of material and flange width used for disc brake rotor, which yields a low temperature variation across the rotor, less deformation, and minimum vonmises stress possible.

Madhu Kumar YC, Uma Shankar carried out research work on Evaluation of Mechanical Properties of Aluminum Alloy 6061-Glass Particulates reinforced Metal Matrix Composites. Aluminum matrix composites (AMCs) refer to the class of light weight high performance aluminum centric material systems. The reinforcement in AMCs could be in the form of continuous/discontinuous fibers, whisker or particulates, in volume fractions. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route. This work focuses on the fabrication of aluminum alloy (6061) matrix composites (AMCs) reinforced with 3 to 12 wt% glass particulates of 75 μ m, 88 μ m, 105 μ m and 250 μ m using stir casting route. The microstructure and mechanical properties of the fabricated AMCs were analyzed. The mechanical properties like hardness and tensile strength of the unreinforced alloy and composites have been measured. The mechanical properties like hardness and tensile strength have improved with the increase in weight percentage of glass particulates in the aluminum matrix.

III. DESIGN OF COMPOSITE BRAKE DISC

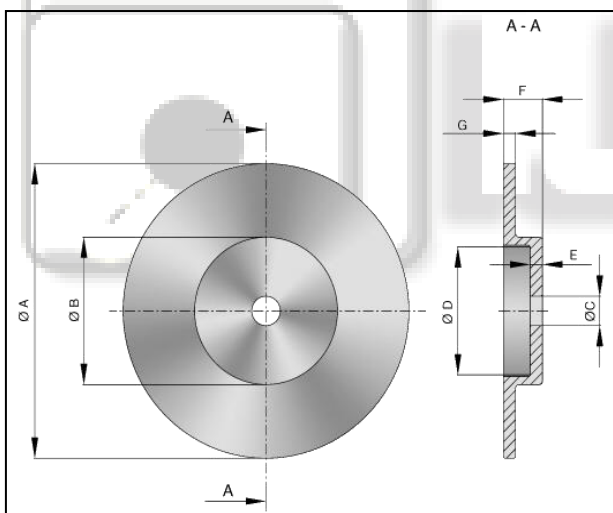


Fig. 1:

- DIMENSIONS:

- 1) ϕA = 250 mm
- 2) ϕB = 128 mm
- 3) ϕC = 20 mm
- 4) ϕD = 116 mm
- 5) ϕE = 6 mm
- 6) ϕF = 36 mm
- 7) ϕG = 12.7 mm

A. Specification of the Vehicle

- Weight of the vehicle (m) : 840 kg
- Speed of the vehicle (v) : 30m/s
- Vehicle stopping time (t) : 4 seconds

B. Theoretical Calculation

1) Step - 1

- Kinetic Energy (K. E) = $\frac{1}{2} m v^2$

- K.E = 378000 J

2) Step - 2

- The total kinetic energy = The heat generated

- $Q_g = 378000$ J

3) Step - 3

- Rubbing Area = $\pi/4 * (D_o^2 - D_i^2)$

- Rubbing Area = $20.3315 \times 10^{-3} \text{ m}^2$

4) Step - 4

- Heat Flux = $2323.98 \times 10^3 \text{ W/m}^2$

5) Step - 5

The analysis is done by taking braking efficiency 30% and heat distributed from front and rear axle is 70:30

- Heat Flux = $2.32398 \times 10^6 * 0.7$

- Heat Flux in front wheel = $1626.18 \times 10^3 \text{ W/m}^2$

- Heat Flux in each wheel = $813.09 \times 10^3 \text{ W/m}^2$

The steps involved are building model, apply boundary conditions and loads and review the solution. Optimization is the act of obtaining the best result under given circumstances. Optimization can be defined as the process of finding the condition the gives the maximum or minimum values of a function. There is no single method available for solving all optimization problems efficiency.

IV. STATIC ANALYSIS

Used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analyses. Nonlinear can include plasticity, stress stiffening, large strain, hyper elasticity, contact surfaces, and creep.

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia, that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include.

- Externally applied forces and pressures
- Steady-state inertia forces (such as gravity or rotational velocity)
- Imposed (non-zero) displacements
- Temperatures (for thermal strain)
- Fluences (for nuclear swelling)

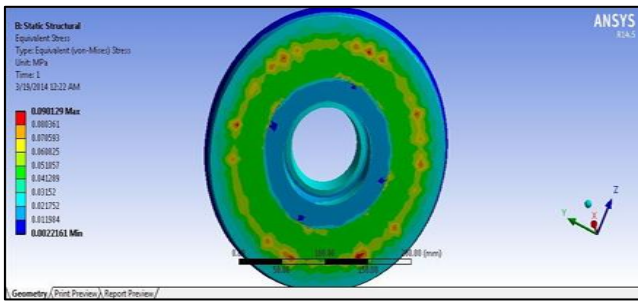


Fig. 4.1: Stress Distribution in Cast Iron Brake Disc

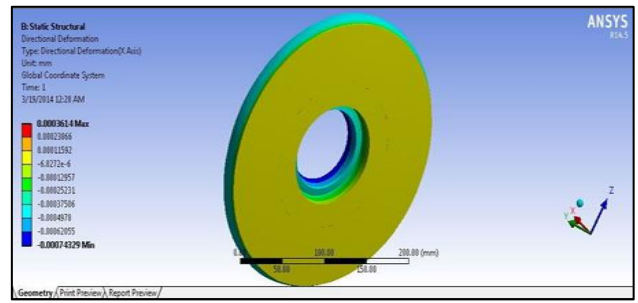


Fig. 4.6: Directional Deformation in MMC Brake Disc

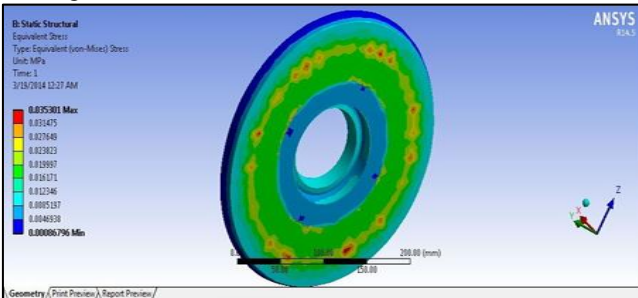


Fig. 4.2: Stress Distribution in MMC Brake Disc

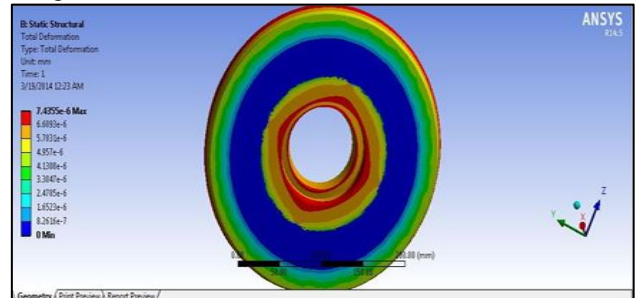


Fig. 4.7: Total Deformation in Cast Iron Brake Disc

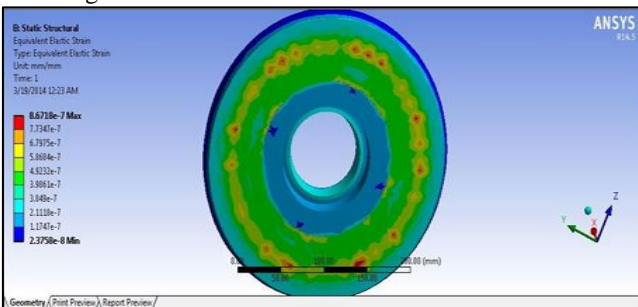


Fig. 4.3: Equivalent Elastic Strain in Cast Iron Brake Disc

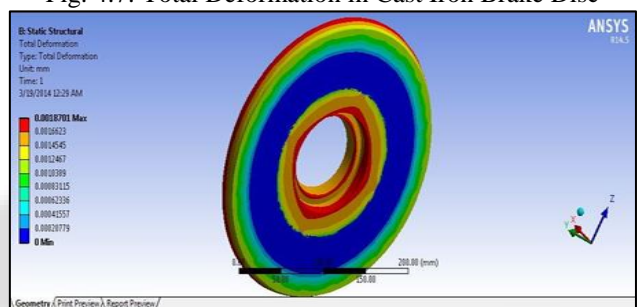


Fig. 4.8: Total Deformation in MMC Brake Disc

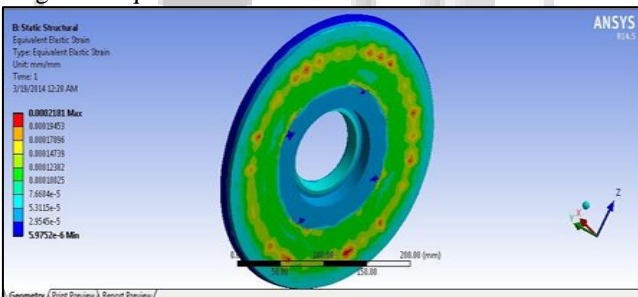


Fig. 4.4: Equivalent Elastic Strain in MMC Brake Disc

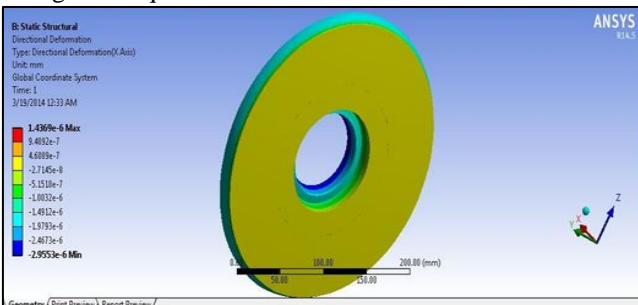


Fig. 4.5: Directional Deformation in Cast Iron Brake Disc

V. THERMAL ANALYSIS

A thermal analysis calculates the temperature distribution and related thermal quantities in a system or components. Typical thermal quantities of interest are

- The temperature distributions
- The amount of heat lost or gained
- Thermal gradients
- Thermal fluxes.

Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components.

A. Steady-State Thermal Analysis

The analysis determine the temperature distribution and other thermal quantities under steady-state loading conditions. A steady-state loading condition is a situation where heat storage effects varying over a period of time can be ignored.

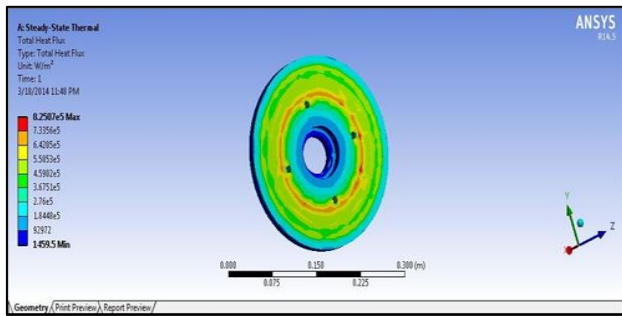


Fig. 4.9: Total Heat Flux in Cast Iron Brake Disc

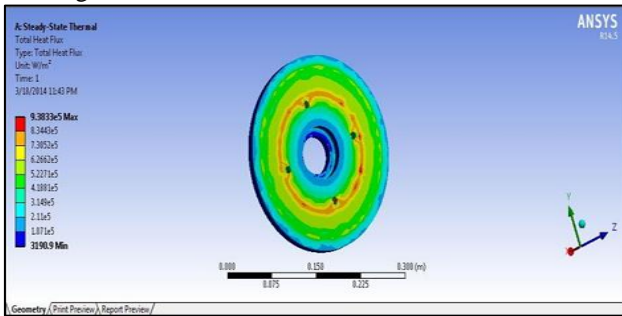


Fig. 5.1: Total Heat Flux in MMC Brake Disc

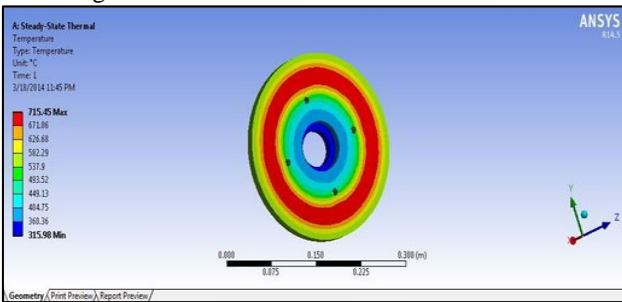


Fig. 5.2: Temperature Distribution in Cast Iron Brake Disc

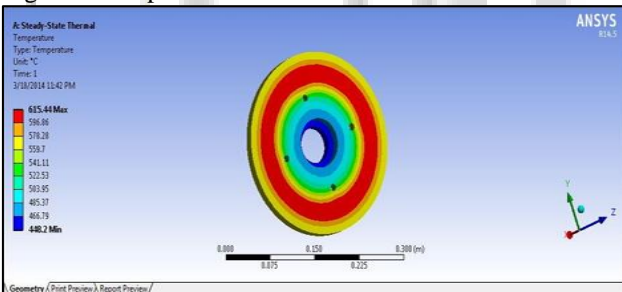


Fig. 5.3: Temperature Distribution in MMC Brake Disc

VI. RESULT

	CAST IRON	MMC
EQUIVALENT STRESS (Mpa)	0.090129	0.035301
EQUIVALENT ELASTIC STRAIN	8.6718×10^{-7}	2.181×10^{-4}
DIRECTIONAL DEFORMATION (mm)	1.4369×10^{-6}	3.614×10^{-4}
TOTAL DEFORMATION (mm)	7.4355×10^{-6}	1.8701×10^{-4}
TOTAL HEAT FLUX (W/m^2)	8.2507×10^5	9.3833×10^5
TEMPERATURE ($^{\circ}C$)	715.45	615.44
MASS (kg)	4.45	1.725

Table 6.1: Comparison between CI Brake Disc & MMC Brake Disc

VII. CONCLUSION

Thermal analysis and static analysis of the disc brake shows the following results.

The heat flux for cast iron $8.2507e^5 W/m^2$, heat flux where as it is $9.3833e^5 W/m^2$ for MMC material. This shows that the heat dissipation is faster in MMC material. Hence better cooling is achieved. Due to this brake fading is reduced.

The deformation of cast iron is $7.4355e^{-6}$ mm and for MMC is $1.8701e^{-4}$ mm. This deformation in MMC is very less. Hence it is negligible which ensures that the strength of the material is safe for the given dimensions of the disc brake. The mass of the MMC brake disc is less compared to the cast iron brake disc. Thus this weight reduction will indirectly improve the fuel efficiency.

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