Investigation of Brake disc using Metal Matrix Composites

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Abstract. The Brake disc is used to control the rotation of a wheel. Usually the brake disc made up of cast iron or ceramic composites. The current research is primarily deals with the modelling and analysing the disc brake using Pro-E and ANSYS. The brake-discs are designed using Pro-E and simulated using ANSYS which is based on the finite element method (FEM). The Structural & Thermal analysis is carry out in order to identify the firmness 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. Differentiation can be concluded for displacement, stresses and nodal temperatures. Results will be compared for the two different material of the disc.

1. Introduction of Brake
It is a device by means of frictional resistance is appeal to the moving member, to arrest the movement of a machine. During this process, the brake absorbs kinetic energy or potential energy of the moving member. The absorbed energy is scatter in the form of heat. Then the heat is vanished to the atmosphere.

2. Literature Review
Anirudh Biswas and Deepak Bhalla carried out research work on Mechanical properties of silicon based Aluminium alloy. Aluminum-Silicon alloys are pursue in a large number of automotive and aerospace utilities because of their low coefficient of thermal expansion and high wear resistance. The current research focused on Mechanical properties of the silicon based aluminum alloys. This study focused to analyse solidification and mechanical behavior of Aluminium and Silica alloy in opposition to both the moulding conditions and silicon content (15%- 24%). Grain size investigate and non-destructive test of the alloys has been measured. The results concluded that, if the silicon content is increased the solidification time increased. The liquids temperature was observed up to 12% and then increased with increasing Silica. Although, an increase of both the ultimate tensile strength and the hardness is acquired by increasing the silicon content.
V. Chengal Reddy, M. Gunasekhar Reddy et al., carried out research work on Modeling and Analysis of FSAE Car Disc Brake Using FEM. Braking action which transforms the kinetic energy of the vehicle into mechanical energy which must be scatter in the form of heat. The Brake disc is used to control the rotation of a wheel. Usually the brake disc made up of cast iron or ceramic composites. Friction material in the state of brake pads enforced mechanically, hydraulically, pneumatically or electromagnetically in opposition to both sides of the disc to stop the wheel. Comparison can be done for displacement, stresses, nodal temperatures for the three materials to suggest the best material for FSAE car.

Guru Murthy Nathi, T N Charyulu, K. Gowtham et al. carried research work on Coupled structural / thermal analysis of disc brake. The objective of this research is to study and measure the performance under serious braking conditions and there by aid in disc rotor design and analysis. ANSYS package is an exclusive finite element package used for identifying the temperature spread over, difference of stresses and distortion across the disc brake profile. The current work is an effort has been made to investigate the effect of stiffness, strength and variations in disc brake rotor design on the estimated stress and temperature distributions. By recognizing the true design features, the increased service life and long term solidity is assured. A temporary thermal analysis has been done to investigate the temperature distribution across the disc using axisymmetric elements. Further structural analysis is also done by coupling thermal analysis.

Madhu Kumar YC, Uma Shankar et al., had done research work on Evaluation of Mechanical Properties of Aluminum Alloy 6061-Glass Particulates reinforced Metal Matrix Composites. Aluminum composites mention to the class of light weight high performance aluminum centric material systems. Properties of Aluminium matrix composites can be customize to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route. This work concentrates on the fabrication of aluminum composites reinforced with glass particulates using stir casting route. The microstructure and mechanical properties of the fabricated Aluminium composites were investigated. The mechanical properties like hardness and tensile strength of the unreinforced alloy and composites have been observed. The hardness and tensile strength have increased with the increase in weight percentage of glass particulates.

3. Design of Composite Brake disc

![Composite Brake disc diagram](image)

Dimensions

| ØA   | = | 250 mm |
| ØB   | = | 128 mm |
| ØC   | = | 20 mm  |
∅D = 116 mm  
∅E = 6 mm  
∅F = 36 mm  
∅G = 12.7 mm

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

3.2. Theoretical Calculation:
Based on the dimensions from Figure 1, the theoretical calculations were made.

Step-1:
\[
\text{Kinetic Energy} = \frac{1}{2} mv^2 \\
K,E = 378000 \text{ J}
\]

Step-2:
The total kinetic energy = Heat generated
Qg = 378000 J

Step-3:
\[
\text{Rubbing Area} = \frac{\pi}{4} \times (D_o^2 - D_i^2) \\
\text{Rubbing Area} = 20.3315 \times 10^{-3} \text{ m}^2
\]

Step-4:
\[
\text{Heat Flux} = 2323.98 \times 10^3 \text{ W/m}^2
\]

Step-5:
\[
\text{Heat Flux} = 2.32398 \times 106 \times 0.7 \\
\text{Heat Flux in front wheel} = 1626.18 \times 103 \text{ W/m}^2 \\
\text{Heat Flux in each wheel} = 813.09 \times 103 \text{ W/m}^2
\]

The steps involved are building model, apply boundary conditions and loads and review the solution. Optimization is the move of identifying the result under given conditions. Optimization can be described as the action of detecting the condition that offers the maximum or minimum values of a function.

4. Static Analysis
Static analysis method is to discover the displacements, stresses and others below static loading conditions. Nonlinear comprise plasticity, stress stiffening, large strain, hyper elasticity, contact surfaces, and creep.

Static analysis compute the outcome of steady loading conditions on a structure, and damping effects generated by time-fluctuating loads. Static analysis although, encompass steady inertia loads, and time-fluctuating loads that can be approximated as static equivalent loads.

Static analysis used to determine the displacements, stresses, strains, and forces in structures produce by loads that do not influence significant inertia, that is, the loads and the structure’s response are supposed to vary with respect to time. The different 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)

Stress distribution and elastic strain were analysed from Figure 2-5. The total deformation of MMC and Cast iron were investigated in Figure 6 &7. The deformation of cast iron is $7.4355 \times 10^{-6}$ mm and for MMC is $1.8701 \times 10^{-4}$ mm.

![Figure 2. Stress distributions in cast iron brake disc](image1)

![Figure 3. Stress distributions in MMC brake disc](image2)
Figure 4. Equivalent Elastic Strain in cast iron brake disc

Figure 5. Equivalent Elastic Strain in MMC brake disc

Figure 6. Total Deformation in cast iron brake disc
5. Thermal analysis

A thermal analysis computes 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 analysis plays a critical part in the design of various engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components.

5.1. Steady-State Thermal analysis:

The investigation decides the temperature distribution and other thermal quantities under steady-state loading conditions. A steady-state loading condition is a state where heat storage effects fluctuate over a period of time can be excluded. From Figure 8 & 9, the heat flux for cast iron is $8.2507 \times 10^5$ W/m², heat flux where as it is $9.3833 \times 10^5$ W/m² for MMC material.

Figure 7. Total Deformation in MMC brake disc

Figure 8. Total Heat Flux in cast iron brake disc
6. Result and discussion

| Table 1. Comparison between CI Brake Disc and MMC Brake Disc |
|-----------------|-----------------|
| Result           | CI                | MMC                |
| Equivalent Stress (MPa) | 0.090129        | 0.035301           |
| Equivalent Elastic Strain | 8.6718×10⁻⁷    | 2.181×10⁻⁴         |
| Total deformation (mm)     | 7.4355×10⁻⁶      | 1.8701×10⁻⁴        |
| Total Heat flux (W/m²)      | 8.2507×10⁵       | 9.3833×10⁵         |
| Mass (kg)       | 4.45             | 1.725             |

7. Conclusion

Thermal analysis and static analysis of the proposed brake discs show the following results. The heat flux for cast iron 8.2507e5 W/m², heat flux where as it is 9.3833e5 W/m² 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 in comparison with cast iron brake disc. Thus the weight reduction will indirectly improve the fuel efficiency.

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