

Design and Analysis of Aluminium–SiC Composite Brake Disc Using ANSYS Workbench

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Abstract - Brake disc performance significantly influences vehicle safety, thermal stability, and structural reliability. Conventional grey cast iron discs provide acceptable mechanical strength but contribute to higher unsprung mass and thermal inefficiency. In this work, a numerical investigation of an Aluminium 6061–Silicon Carbide (Al–SiC) composite brake disc is carried out using ANSYS Workbench. Structural and steady-state thermal analyses were performed and compared against grey cast iron material. Finite element results indicate that the Al–SiC composite exhibits reduced von-Mises stress, lower peak temperature, improved heat dissipation capability, and superior strength-to-weight ratio. The study validates the feasibility of replacing conventional cast iron discs with lightweight metal matrix composite alternatives based purely on numerical simulation.

Key Words: Aluminium composite, Silicon carbide, Brake disc, ANSYS Workbench, Structural analysis, Thermal analysis.

1. INTRODUCTION

Automotive brake discs convert mechanical kinetic energy into thermal energy during braking. The material selected must sustain high contact pressure and elevated temperature gradients without structural failure.

Grey cast iron has been widely adopted due to its:

- Good damping characteristics
- Adequate wear resistance
- High compressive strength

However, its high density increases vehicle mass and negatively affects fuel economy and dynamic response.

Aluminium metal matrix composites reinforced with Silicon Carbide (SiC) particles offer:

- Reduced density
- Higher specific strength
- Improved thermal conductivity
- Better wear resistance

This research focuses exclusively on finite element numerical evaluation of structural and thermal behavior using ANSYS Workbench

2. Body of Paper

Section 1

(Material Properties)

Table -1: Grey Cast Iron

Property	Value
Density	7050 kg/m ³
Young's Modulus	110 GPa
Poisson's Ratio	0.28
Thermal Conductivity	54 W/m·K

Table -2: Aluminium 6061–SiC Composite

Property	Value
Density	2820 kg/m ³
Young's Modulus	120 GPa (effective)
Poisson's Ratio	0.30
Thermal Conductivity	180 W/m·K

The composite shows nearly **60% reduction in density**, directly contributing to weight reduction.

Section 2

(Finite Element Modeling in ANSYS Workbench)

A. Meshing

The 3D brake disc model was imported into ANSYS Workbench and discretized using tetrahedral elements.

Meshing Details:

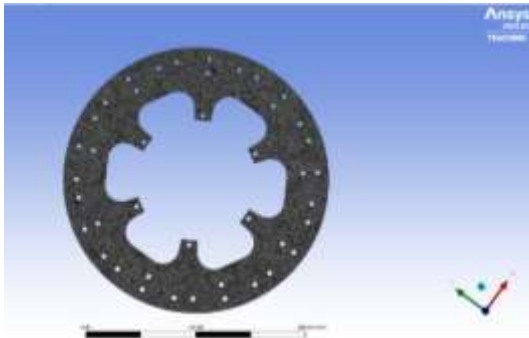


Fig -1: Meshing

- Element type: Tetrahedral
- Element sizing method: Sizing control
- Global element size: 2 mm
- Refined mesh applied at:
 - Bolt mounting holes
 - Friction surface region
- Fine mesh ensures accurate stress and temperature distribution
- Mesh quality verified to avoid skewness and distortion

The mesh resolution of 2 mm provided stable and converged results.

B. Structural Analysis

Boundary Conditions

Structural analysis was performed to evaluate stress and deformation under braking conditions.

The following boundary conditions were applied:

1. Fixed Support
 - Applied at bolt mounting holes
 - All translational and rotational degrees of freedom constrained
2. Rotational Velocity
 - Applied about Z-axis
 - Magnitude = 347.22 rad/sec
 - Calculated using:

Where:

$$v = \text{Linear velocity} = 150 \text{ km/hr} = 41.67 \text{ m/s}$$

$$r = \text{Radius} = 0.12 \text{ m}$$

Substituting the values:

$$\omega = \frac{41.67}{0.12}$$

$$\omega = 347.22 \text{ rad/s}$$

The angular velocity is **347.22 rad/s**.

3. Moment Applied

- Applied about Z-axis
- Magnitude = 360000 N·mm

Represents braking torque during deceleration.

C. Structural Results

1. Total Deformation

Grey Cast Iron:

- Maximum deformation = 0.008835 mm
- Located at outer friction ring
- Minimum deformation ≈ 0 mm at fixed bolt holes

Al-SiC Composite:

- Maximum deformation = 0.016289 mm
- Located at outer rim region

Although composite shows slightly higher deformation, it remains within elastic limits.

2. Equivalent (von-Mises) Stress

Grey Cast Iron:

- Maximum stress = 78.596 MPa
- Stress concentration near bolt mounting region

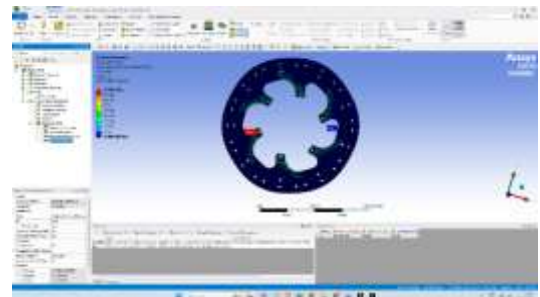


Fig -2: Equivalent (von-Mises) Stress of Grey Cast Iron

Al-SiC Composite:

- Maximum stress = 62.101 MPa
- More uniform stress distribution

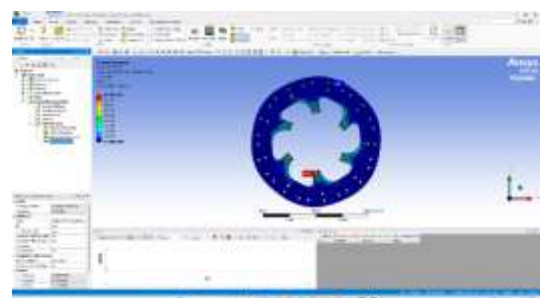


Fig -3: Equivalent (von-Mises) Stress of Al-SiC Composite

The composite reduces stress by approximately 21%.

D. Transient Thermal Analysis

A transient thermal analysis was performed to evaluate time-dependent temperature distribution during braking.

A. Thermal Boundary Conditions

1. Initial Temperature
 - Entire disc temperature initialized at 22°C
2. Heat Flux
 - Applied at friction surface
 - Magnitude = 0.8 W/mm²
 - Represents frictional heat generation during braking
3. Convection
 - Applied on exposed surfaces
 - Film coefficient = 2.5×10^{-5} W/mm²·°C
 - Ambient temperature = 22°C

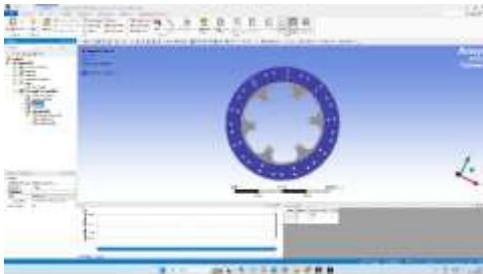


Fig -4: Boundry Conditions of Thermal Analysis

The convection boundary simulates natural air cooling around the rotating disc

E. Thermal Results

1. Maximum Temperature

Grey Cast Iron:

- Peak temperature = 274.53 °C
- Observed at outer friction surface

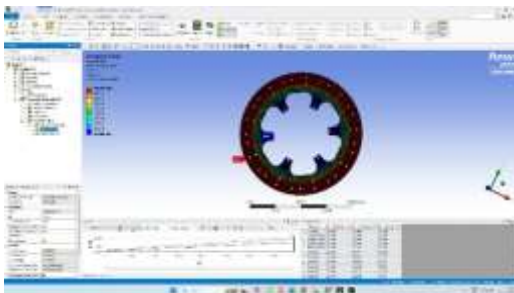


Fig -5: Temp Distribution of Grey Cast Iron

Al-SiC Composite:

- Peak temperature = 126.8 °C
- More uniform temperature distribution

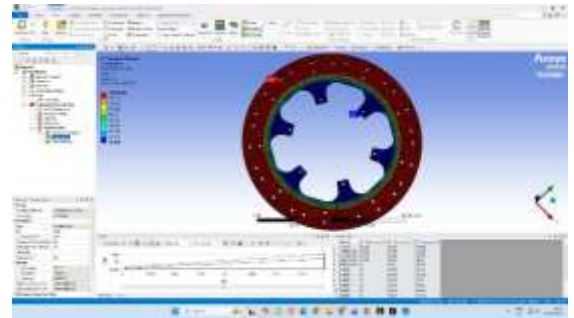


Fig -6: Temp Distribution of Al-SiC Composite

Temperature reduction $\approx$ 54% using composite.

2. Total Heat Flux

Grey Cast Iron:

- Maximum heat flux = 4.6663 W/mm²

Al-SiC Composite:

- Maximum heat flux = 1.3223 W/mm²

Composite shows improved heat dissipation characteristics.

3. OVERALL PERFORMANCE COMPARISON

Parameter	Grey Cast Iron	Al-SiC Composite
Max Deformation (mm)	0.008835	0.016289
Max Stress (MPa)	78.596	62.101
Rotational Speed (rad/s)	347.22	347.22
Applied Moment (N·mm)	360000	360000
Max Temperature (°C)	274.53	126.8
Density (kg/m ³)	7050	2820

4. CONCLUSIONS

The finite element investigation using ANSYS Workbench shows that:

- Aluminium-SiC composite significantly reduces weight
- Lower von-Mises stress compared to cast iron
- 54% reduction in peak temperature
- Better heat dissipation under transient conditions
- Suitable for high-speed braking (347.22 rad/sec)

Although cast iron shows slightly lower deformation, the composite demonstrates superior structural and thermal efficiency.

Therefore, based purely on numerical FEA results, Aluminium-SiC composite is a highly promising lightweight alternative for automotive brake disc applications.

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