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TRIBOLOGICAL ANALYSIS OF BRAKE DISC FOR LMV USING DIFFERENT COMPOSITIONS THROUGH PIN-ON-DISC METHOD

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Abstract

The performance and durability of brake pads are crucial for the safety and efficiency of Light Motor Vehicles (LMVs). The wear rate, thermal behaviors, and frictional performance of brake pads depend on their material composition, which can include organic, semi metallic, and ceramic materials. This study investigates the tribological performance of brake pads using the Pin on Disc method under controlled conditions. Additionally, numerical simulations using Finite Element Analysis (FEA) are conducted to predict thermal and wear behaviors. Results from experimental and numerical analyses are compared to identify optimal compositions. This integrated approach enhances brake pad design, ensuring improved performance, durability, and safety.

Keywords: Brake pad, Pin on Disc, FEA, wear rate, friction, LMV, thermal analysis.

1. INTRODUCTION

Brake pads play a critical role in vehicle safety, acting as the interface that converts kinetic energy into thermal energy through friction. The materials used in brake pads directly influence their performance, including wear resistance, friction stability, and heat dissipation. This paper explores different material compositions of brake pads through experimental testing and FEA simulation, focusing on their impact on Light Motor Vehicles (LMVs).

Objectives

Analyze the wear and friction behaviors of different brake pad materials using the Pin-on-Disc method.

Evaluate thermal and frictional performance under varying operating conditions.

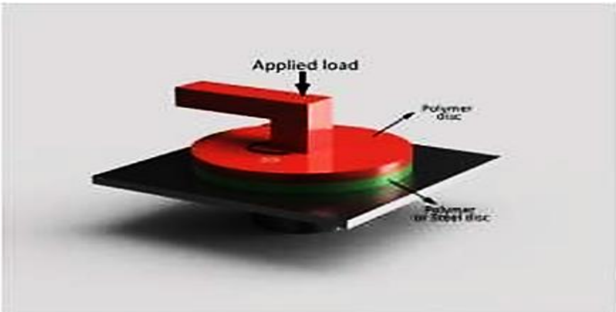

Figure 1 Failures Occurring in Bearing Materials.

Literature Review

Several studies have been conducted on brake pad performance using Pin-on-Disc testing and simulation:

Zhang et al. [1] observed reduced wear rates in lubricated conditions for semi-metallic pads.

Lin et al. [2] noted high wear but good noise-reduction in organic pads.

Patel et al. [3] highlighted thermal performance benefits of semi-metallic materials.

Nguyen et al. [4] found ceramic pads to offer excellent wear resistance at high temperatures.

Lee et al. [5] validated FEA for simulating temperature distribution during braking.

These studies support the approach of combining experimental and numerical analysis to optimize brake pad materials.

Problem Definition

Despite various material advancements, the following issues remain:

- High wear rate in organic materials
- Frictional inconsistency affecting performance
- Excessive heat generation under heavy braking
- Environmental concerns due to material disposal

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2. METHODOLOGY

Figure 2 Methodology

Experimental Setup

The Pin-on-Disc apparatus is used for wear testing under controlled speed, load, and temperature conditions. Samples of different compositions are tested, and wear rate, friction coefficient, and temperature rise are recorded.

Numerical Simulation

FEA is performed using software such as ANSYS to simulate wear and thermal behavior. The simulation considers load, material properties, sliding speed, and heat generation.

3. DESIGN AND ANALYSIS

Figure 3 CAD Model

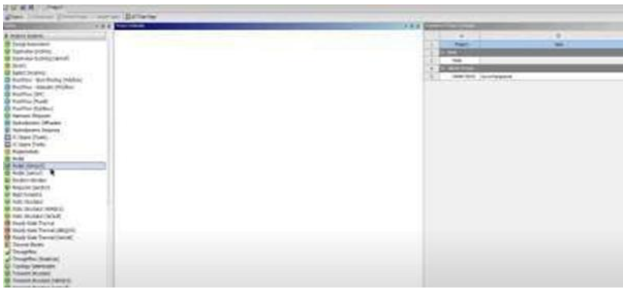

Figure 4 Structure analysis part material selection as structural steel

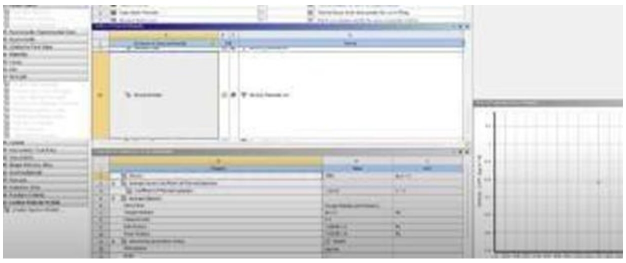

Figure 5 Selection of material and material properties

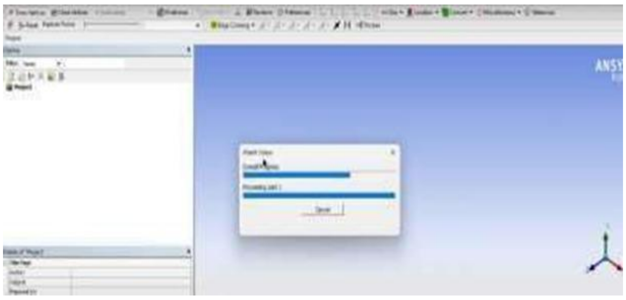

Figure 6 Importing part geometry in Ansys workbench

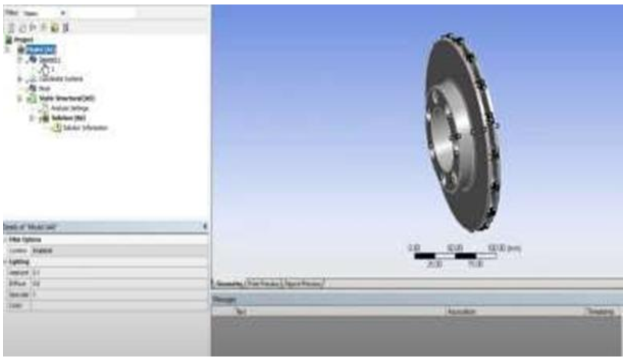

Figure 7 Geometry Imported

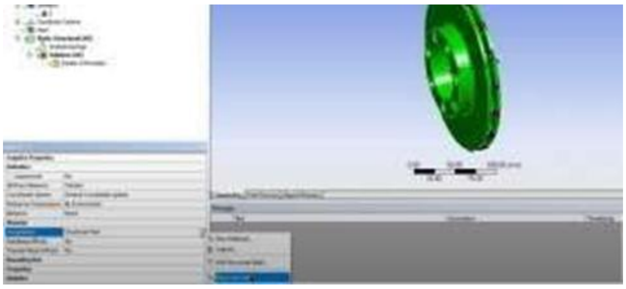

Figure 8 Changing Material to Gray Cast iron

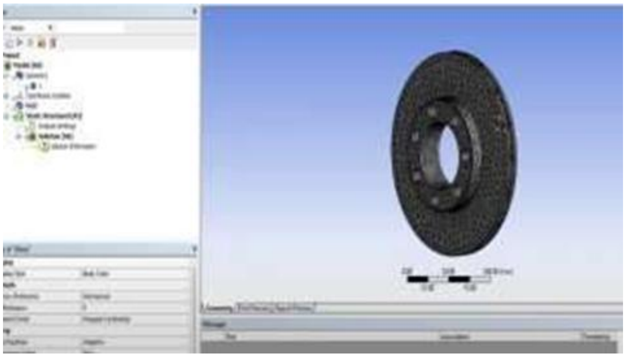

Figure 9 Fine meshing of component

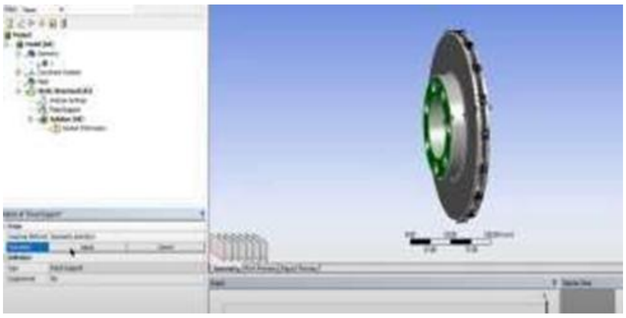

Figure 10 Using static structural giving fixed support to it

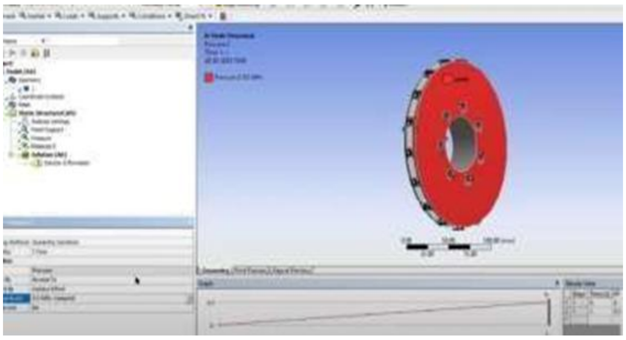

Figure 11 Applying Pressure of 0.5 Mpa on both sides

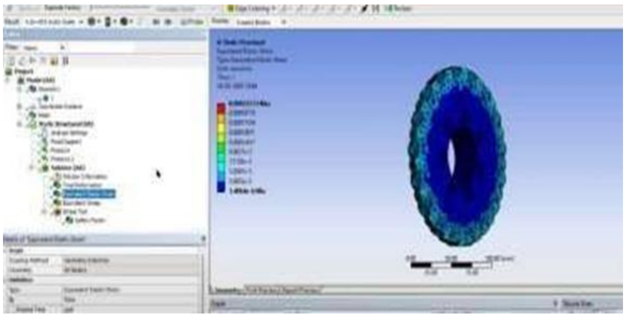

Figure 12 Equivalent elastic strain

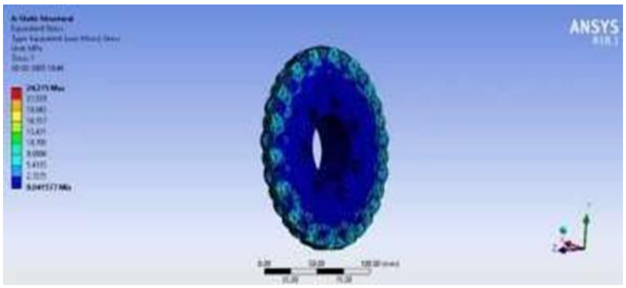

Figure 13 Equivalents Stress

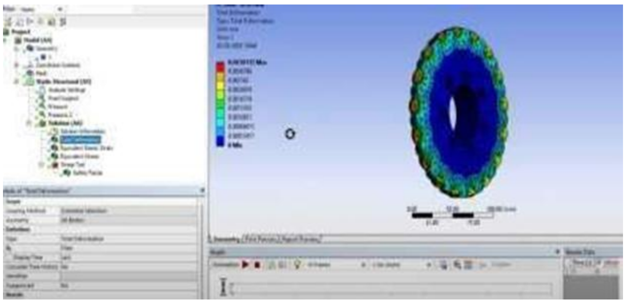

Figure 14 Static structural total deformation

Table 1 Design and Analysis

S. No	Material	Key component	Load(N)	Speed (rpm)	Temperature Â°C)	Wear rate (mm Â 3/Nm)
1	Asbestos-based	Asbestos, resin, steel/copper, friction modifiers	50	1000	100	2.30E-05
2	Semi metallic	Iron, steel, copper, graphite, resin	60	1200	120	1.80E-05
3	Ceramic	Aluminum oxide, silicon carbide, copper, graphite, resin	55	1100	110	1.50E-05
4	Kevlar reinforced	Kevlar fibers, resin, carbon, metallic/ceramic Particles	65	1300	130	1.20E-05
5	Carbon Composite	Carbon fibers, resin, ceramic, metallic fibers,	70	1400	140	1.00E-05
6	Organic	Rubber, Kevlar, cellulose, resin, graphite	50	1000	90	2.80E-05
7	Sintered metal	Copper, iron, steel, friction modifiers, nickel/tin binders	75	1500	150	9.00E-06
8	Graphite e-based	Graphite, resin, metallic/ceramic additives, silica	55	1200	115	1.40E-05
9	Fiber, composite	Glass/Kevlar/Carbon fibers, resin, metallic fillers	65	1300	125	1.60E-05
10	Hybrid composite	Mix of ceramic, semi-metallic, organic materials	60	1250	120	1.30E-05

4. RESULTS & DISCUSSION

The expected results include:

Wear Rates: Detailed measurements of wear rates for each material composition under varying test conditions.

Frictional Behavior: Data on the coefficient of friction for each composition, including variations with temperature and load.

Thermal Performance: Temperature profiles during testing, with an analysis of the effects of temperature on brake pad performance.

Numerical Model Validation: Comparison of experimental and simulation results to validate the accuracy of the FEA model.

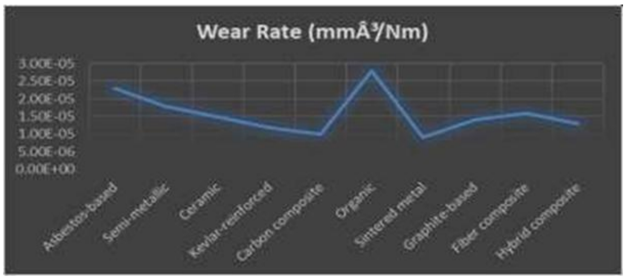

Figure 15 Material V/s Wear rate

Material Performance Comparison: A comparative analysis of wear rates, friction coefficients, and thermal behavior for organic, semi-metallic, and ceramic brake pads.

Impact of Temperature and Load: How different compositions perform under varying operational conditions (load, speed, temperature).

FEA Validation: An evaluation of the accuracy of the numerical model in predicting the wear and thermal performance of brake pads.

Optimized Brake Pad Composition: Recommendations for the most effective material composition for LMVs based on performance data.

- Organic pads: High wear rate but smooth operation.
- Semi-metallic pads: Good balance between wear and heat resistance.
- Ceramic pads: Lowest wear, best thermal stability.

The FEA results closely matched experimental data, validating the simulation model. The temperature distribution plots revealed thermal hotspots, which help in optimizing design.

Applications

- Improved material selection for automotive brake pads.
- Predictive maintenance using wear rate data.
- Enhanced thermal management in braking systems.
- Eco-friendly design by eliminating harmful materials.

5. CONCLUSION

This study demonstrates that a combination of experimental and numerical analysis offers a comprehensive understanding of brake pad performance. Ceramic materials emerged as the most durable, while semi-metallic pads provided a good compromise between performance and cost. Future work will focus on testing under dynamic real-world braking scenarios and exploring eco-friendly materials.

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