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ADVANCES IN THE COMPOSITION, FUNCTIONAL ROLE OF ADDITIVES AND TESTING OF AUTOMOTIVE FRICTION BRAKE MATERIALS

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Abstract: Friction brake materials play a vital role in ensuring safety, performance, and durability in automotive and industrial applications. The composition of these materials and the functions of their additives directly influence braking efficiency, wear resistance, noise, and thermal stability. This paper reviews the composition, classification, and functions of various constituents in friction materials, while also highlighting the standard testing procedures used for evaluating their performance. The study integrates literature from recent research to provide a holistic overview of advancements in friction brake materials.

Keywords: Friction materials, Brake additives, Wear resistance, Tribology, Brake testing, automotive safety

1. INTRODUCTION

Braking systems are fundamental for vehicle safety and operational control. The development of advanced friction brake materials has gained significant attention due to increasing demands for performance, comfort, and environmental compliance. Friction materials are composite systems consisting of various ingredients such as binders, fibers, fillers, lubricants, and abrasives, each playing a specific role. The optimization of these materials requires balancing performance properties such as coefficient of friction, wear rate, noise suppression, and thermal stability.

2. LITERATURE REVIEW

Research on friction brake materials has evolved significantly over the last two decades. Studies by Bijwe (2016) highlighted the importance of eco-friendly replacements for asbestos fibers. Cho et al. (2018) investigated the effects of steel and aramid fibers on mechanical strength and thermal stability. Recent advancements focus on bio-based materials, such as cashew nut shell liquid (CNSL) and natural fibers, as sustainable alternatives. Additionally, tribological investigations (Jang & Kim, 2020) have demonstrated that Nano-additives such as graphene and carbon nanotubes can enhance wear resistance and reduce noise.

3. COMPOSITION OF FRICTION BRAKE MATERIALS

Brake materials are engineered composites made up of several ingredients, each serving a specific function:

- Binders (e.g., phenolic resins): Provide structural integrity and thermal stability.
- Fibers (e.g., steel, aramid, glass): Reinforce the matrix and improve mechanical properties.

- Fillers (e.g., barites, vermiculite): Improve manufacturability and thermal properties.
- Friction Modifiers: Control coefficient of friction, including abrasives (alumina, silica) and lubricants (graphite, mos_2).
- Additives: Enhance wear resistance, noise reduction, and oxidation stability.

4. TYPES OF PAD ARE LISTED AS FOLLOW:

- Asbestos organic lining: Asbestos fibres are used as reinforcement in the formulation. However, asbestos was banned to use in brake lining material in 1993, as medical research showed that it can lodge in the lungs and induce adverse respiratory conditions.
- Non asbestos organic lining (NAO): which use a variety of fibres as alternatives of asbestos, e.g. nylon fibres.
- Semi-metallic lining (or resin-bonded metallic): Semi-metallic linings typically comprise about 65 wt.% total iron content, 10-25 wt.% steel wool, about 15 wt.% graphite and 10 wt.% organic binder.
- Metallic brake linings: Metallic brake linings can be based on either copper or iron, often with inorganic additives to improve performance. Most of them are solid state sintered. These have been developed and used for heavy duty brakes and racing car
- Carbon based brake linings: Carbon based brake linings, such as carbon-carbon, were developed for friction against Cf/C brake disc material. For example, aircraft disc brakes and racing cars, where light weight brake lining materials are needed

5. FUNCTIONS OF ADDITIVES

- Additives in friction materials serve multiple roles:
- Abrasives such as alumina and silica increase friction and stability.
- Solid lubricants like graphite and molybdenum disulphide reduce wear and noise.
- Metal sulphides (e.g., antimony trisulphide) enhance thermal stability and friction consistency.
- Fibrous reinforcements improve toughness and thermal conductivity.
- Nano-additives (e.g., grapheme, cents) provide advanced wear resistance and reduce fade at high temperatures

6. TESTING OF FRICTION BRAKE MATERIALS

Brake materials are evaluated using standardized tests to determine frictional, mechanical, and thermal properties. Common testing procedures include:

- Chase test (SAE J661): Determines coefficient of friction under controlled conditions.
- Inertia dynamometer test: Simulates real braking events for performance evaluation.
- Fade and recovery tests: Assess material stability under high temperature cycles.
- Wear rate measurement: Determines durability under repeated use.
- NVH (Noise, Vibration, Harshness) analysis: Evaluates comfort aspects of braking.

7. ANALYSIS AND DISCUSSION

The efficiency of friction brake materials depends on the synergistic behavior of their constituents. Balancing high friction stability with low wear remains a central challenge. Eco-friendly materials show promise but often suffer from reduced thermal stability. Nano-materials have emerged as a breakthrough, enhancing wear resistance and noise suppression, though cost and large-scale manufacturability remain concerns. Future trends point towards hybrid composites integrating natural fibers with advanced nanomaterial for sustainable and high-performance solutions.

Table 1: Typical Composition of Friction Brake Materials

Constituent	Typical Percentage by Weight
Binder (Phenolic Resin)	10–20%
Fibers (Steel, Aramid, Glass)	10–30%
Fillers (Barite, Vermiculite)	20–40%
Friction Modifiers (Graphite, Alumina, Silica)	10–20%
Lubricants (Graphite, mos_2)	5–10%
Additives (Nano-materials, Metal Sulfides)	1–5%

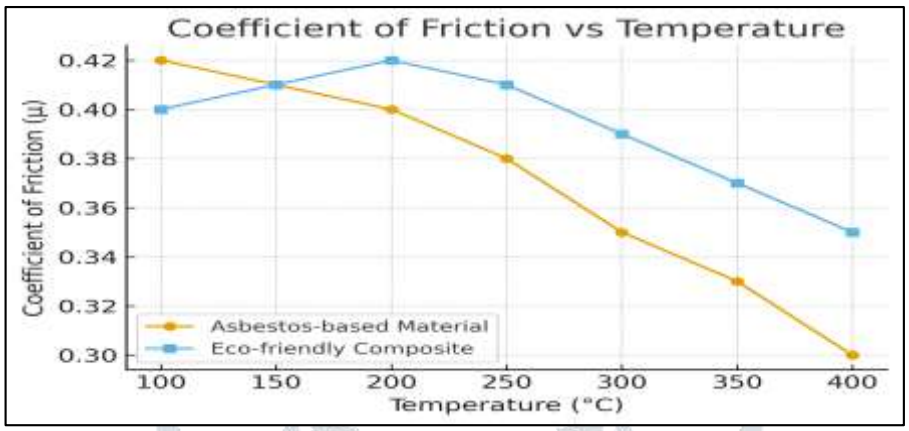

Figure 1: Coefficient of Friction vs Temperature

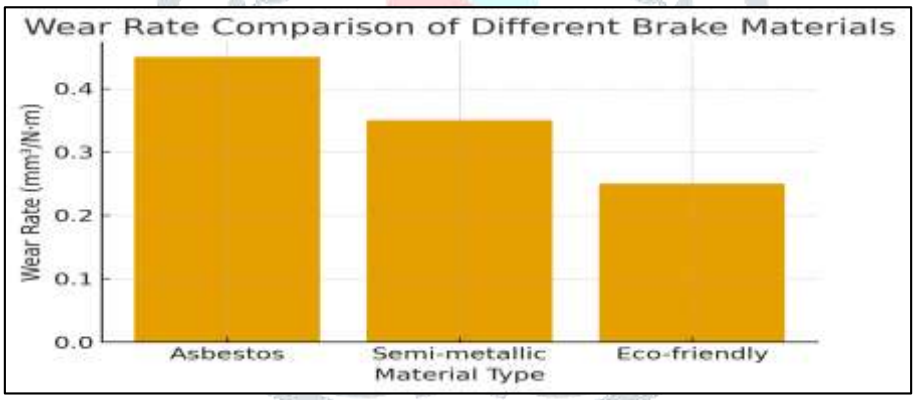

Figure 2: Wear Rate Comparison

8. CONCLUSION

Friction brake materials are complex composites where each constituent plays a vital role in determining overall performance. Additives such as abrasives, lubricants, and Nano-materials enhance friction stability, thermal resistance, and durability. Advanced testing ensures safety and reliability, while ongoing research focuses on sustainable alternatives to meet environmental regulations. Future developments are expected to integrate nanotechnology with eco-friendly materials for optimized performance.

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