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A Review of the Effectiveness of Fibrous Materials in Reducing Noise and Heat in Automotive Engines

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ABSTRACT

Automotive engines generate a lot of heat and noise which can reduce performance, make driving less comfortable and accelerate component wear. Therefore, noise reduction (acoustic damping) and heat control (thermal insulation) are important goals in automotive design. This review analyzes how different fibrous materials such as natural, synthetic and mixed (composite) fibers can help solve these problems when used in engine systems. The review explains how these fibers block sound and heat depending on their structure, material type and performance under real-world engine conditions. Natural fibers such as flax, jute and hemp are lightweight and environmentally friendly but their durability may be limited at high temperatures. Synthetic fibers such as fiberglass and polyester are better at handling heat and noise but are not environmentally friendly. Composite fibers made from a combination of natural and synthetic materials seek to offer the best of good performance and greater sustainability. By comparing different types of fibrous materials, this review highlights which materials are most effective at reducing engine noise and heat. It also demonstrates that choosing the right material depends on how and where it will be used. Finally, the review urges further research to improve these materials so they can better meet the needs of modern vehicles.

Keywords; *Automotive engines, Fibrous materials, Acoustic damping, Thermal insulation*

1. Introduction

In the past, common materials used in automotive engines included metals such as iron, steel and aluminum. In recent years, fibrous materials have been incorporated into vehicle engines and these have significantly influenced the performance, efficiency and durability of automobile engines. As technology advanced, composite polymers became widely used due to their lightweight, so were ceramics for their applicability in high-temperature environments as well as fibrous materials which combine multiple advantages (Smith and Jones, 2020). Likewise, Brown et al., (2018) assert that metals provide strength as well as thermal conductivity while composite polymers and ceramics contribute to weight reduction and heat resistance

Thus, with the passage of time, fibrous materials have gained popularity for their lightweight properties, excellent thermal insulation, sound and vibration damping. On the other hand, natural fibers such as wool and cotton are environmentally friendly, offering good thermal resistance while synthetic fibers such as aramid and carbon composite fibers provide durability and thermal stability (Davis and Kim, 2020). Furthermore, composite materials optimize performance by integrating the advantages of natural and synthetic fibers (Williams and Patel, 2022). Hence, acoustic materials such as foams, mass-filled vinyl, fiberglass and rubber are specifically designed to control sound and vibration (Yang et al., 2023).

ln his study, Johnson (2021), highlighted that the use of composite fibers contributed to engine weight reduction, fuel efficiency and lower emissions while Zhang and Chen, (2021) pointed out that thermal and acoustic insulation properties help maintain engine performance and minimize noise pollution. In light of the above, the growing environmental concerns and the demand for sustainable manufacturing, fibrous materials represent a promising alternative for modern vehicle engines (Rodriguez and Huang, 2024).

1.1 Methodology

This review article is drawn from reputable international journals.

2. Different fibrous materials for vehicle engine noise reduction.

2.1 Acoustic fibers

The growing demand for noise reduction and vibration damping materials in automotive engines has led to extensive research on the soundproofing properties of fibrous materials. These materials improve passenger comfort, comply with noise regulations and enhance vehicle performance. Effective sound absorption is crucial in vehicle design as research highlights the benefits of microfibers and nanofibers for their sound absorption capabilities. Their small diameter, large surface area and high porosity enhance sound insulation while electro spinning techniques refine their characteristics for optimal performance (Li et al. 2022). This section classifies the fibrous materials used in modern automotive engines into natural, synthetic and composite fibers, while evaluating their noise control effectiveness.

2.2 Natural fibers

Natural fibers are gaining popularity due to their sustainability, affordability and excellent acoustic properties. They have porous structures that enable high sound absorption capability, making them effective for noise reduction in automotive applications (Brown et al., 2018). Wang and Li., (2019), point out that cotton as a natural fiber has excellent sound absorption capability, especially at mid and high frequencies. Cotton structures are integrated into multi-layer composites which enhance sound insulation and overall performance.

Wool fibers, as Johnson (2021) posits, dampen vibrations effectively due to their natural flexibility. They are made up of crimped structure which increases surface area, thereby improving sound absorption at various frequencies hence they are widely used on engine covers and firewall insulation.

Other natural fibers like jute, cork, wood waste, cellulose, straw, hemp, coconut fiber, glass waste and kenaf are increasingly used for their environmental benefits and acoustic performance comparable to synthetic alternatives. Their lightness and biodegradability make them attractive for sustainable automotive applications (Garcia et al., 2022).

2.3 Synthetic fibers

Synthetic fibers are widely used in automotive applications due to their durability, heat resistance and superior mechanical properties (Lee, 2019). The most common synthetic fibers include aramid fibers (kevlar) which according to Mohammed Mohaideen et al., (2023), are known for their toughness, high tensile strength and excellent thermal stability which effectively dampen vibrations while maintaining structural integrity under extreme conditions, hence, they are used in composite sound insulation panels. At the same time, kevlar materials can withstand high fatigue (cyclic) degradation and hence, their use in making car engine timing belts (Deshmukh, and Patwardhan, 2015).

Zhang and Chen, (2021), point out that glass fibers have excellent high-frequency sound absorption capabilities and are resistant to environmental degradation which makes them suitable for under-hood applications whereas carbon fibers help reduce noise by minimizing engine-induced resonance. Anderson, (2018), also discusses about Polytetrafluoroethylene (PTFE) based materials as providing superior thermal and chemical resistance while reducing mechanical noise within the engine.

2.4 Composite materials

To optimize acoustic performance, modern automotive engines are incorporating hybrid materials that combine natural and synthetic fibers (Williams and Patel, 2022). Natural-synthetic hybrid composites incorporating cotton and kenaf with synthetic fibers such as glass and aramid offer improved noise absorption, durability and fire resistance (Kumar and Singh, 2020). Nguyen et al., (2021) observed that multi-layer insulation systems of different materials improves noise attenuation across a wider frequency range with combinations such as wool, glass fibers and polymeric foams used in engine compartments. To further advance the performance, inclusion of nanofiber composites with advances in electrospun polymeric fibers provide higher porosity and tunable acoustic properties, making them promising for future automotive applications (Chowdhury and Tan, 2023).

3.0 Acoustic performance and industry trends

Fibrous materials in vehicle engines play a crucial role in noise reduction by converting sound energy into heat through viscous and thermal dissipation. Materials such as glass wool and polyester fibers are commonly used due to their excellent acoustic properties. Glass wool, for example, is very effective at dampening engine noise in the 500 Hz to 4000 Hz frequency range (Perrot, et al., 2023).

In hybrid electric vehicles (HEVs), noise-reducing composite materials such as polyester-polypropylene bicomponent fibers and butyl rubber help reduce noise, vibration and harshness levels. Research shows that proper integration of these materials into vehicle structures significantly improves acoustic comfort (Liao et al., 2018).

Research by Rajadurai et al., (2015), indicate that factors such as surface area, density and fiber orientation of the composite material influence sound absorption. Larger surface areas and finer fibers improve absorption by creating smaller pores and increasing contact points while open-structured and less dense materials absorb low-frequency sounds. They point out that denser structures perform better at higher frequencies.

The use of fibrous materials in automotive engine design has evolved with the emergence of biodegradable composites as a response to environmental concerns. Sustainable polymer composites including biocomposites reinforced with natural fibers are gaining momentum due to their lightweight, thermal stability and eco-friendly production processes (Ramli, et al., 2018).

Several automakers, such as BMW, Mercedes-Benz, Ford and Toyota integrate recycled polyester fibers and glass wool into their vehicle compartments to balance performance and sustainability. Glass wool remains a popular choice due to its excellent thermal stability and sound absorption across a wide frequency range (NEAMȚU, 2024). Effective thermal management in automotive engines is essential for optimal performance, energy efficiency and the longevity of engine components as it determines a material's suitability for high-temperature environments such as automotive engines. Fibrous materials play an important role in thermal insulation due to their ability to withstand high temperatures, minimize heat transfer and improve fuel efficiency (Smith & Jones, 2020).

According to Brown et al., (2018), natural fibers are valued for automotive applications due to their biodegradability, sustainability and moderate thermal resistance. They also have porous structures which promote heat dissipation and insulation. Fibers like cotton have low thermal conductivity which makes them suitable for moderate insulation. However, when treated with flame-retardant coatings, cotton's thermal resistance improves, which makes it suitable for multi-layer insulation systems. Cotton is also used for soundproofing or as reinforcement in biocomposites with thermally stable matrices (Wang and Li, 2019).

Table 1: Thermal conductivity of fibrous material

Type of fiber	Thermal conductivity range	Reference
Cotton fiber	0.029–0.035 W/m·K	Ghosh et al., (2021)
Aramid fiber (Kevlar)	0.04–0.06 W/m·K	Haque, et al., (2023)
Glass fiber	0.2–0.4 W/m·K	Lei et al., (2019)
Carbon fiber	10–100 W/m·K	Zhao, et al., (2022)
Aluminum (engine block material)	205 W/m·K	Kim, et al., (2023)

In Table 1 above, it is shown that natural fibers have varying thermal conductivity and stability which affect their suitability for different engine components. Despite this, natural fibers play a critical role in thermal insulation for automotive applications due to lightweight and environmentally friendly properties. However, according to Haque et al., (2023), natural fibers such as cotton are susceptibility to thermal degradation at temperature ranges of 250–300°C which limits its use in direct engine components with high heat intensity.

Wool fibers are widely used in car engines as thermal shields to protect sensitive components from excessive heat since they have high thermal stability due to their crimped structure which traps air and minimizes heat transfer (Johnson, 2021). According to Ghosh et al., (2021), fibers such as flax, hemp and jute have good insulation properties, are light in weight and biodegradable hence their integration as composite thermal insulators, in addition they have low thermal conductivity (0.03–0.05 W/m²K) making them suitable for thermal barriers and insulation coatings on non-load-bearing engine components. However, they are easily affected by excessive heat, are less durable and cannot be coated/treated easily posing challenges to their long-term viability in automotive applications (Garcia et al., 2022).

In Automotive industry, several automakers have begun incorporating natural fiber composites into non-structural engine components for thermal protection and insulation. These efforts highlight the growing interest in the use of sustainable materials in the automotive industry.

Table 2: Automotive industry adoption of natural and synthetic fibers

Company	**Natural fiber**	**Use**	**Synthetic Polymer**	**Use**	**Reference**
BMW	Flax fiber	Composites reinforced for engine components	Polyurethane	Epoxy coating for high temperature resistance and durability	(Zhao, et al., 2022)
Mercedes-Benz`	Hemp	Composites for thermal insulation in engine compartments	Phenolic	Resin treatments improves lifespan and strength	(Haque, et al., 2023)
Volvo	Jute	Composites for under hood applications	Polypropylene (PP)	Matrix Composites enhance strength , stiffness and lightweight	(Kim, et al., 2023)

As shown in Table 2 above, automakers such as BMW, Mercedes-Benz and Volvo are incorporating bio-composites into their designs. Nevertheless, the continued reliance on non-biodegradable polymer coatings presents a significant environmental concern. Advancing future research toward the development of fully bio-based or recyclable alternatives is imperative to enhance sustainability while preserving essential performance attributes (Garcia et al., 2022). Due to technological advancement, synthetic fibers such as aramid, with good thermal stability and fire resistance capability, are now widely used in automotive thermal insulation as heat shields and engine covers (Lee, 2019), due to their durability, high heat resistance and excellent mechanical properties (Davis and Kim, 2020). Synthetics such as fiberglass materials provide excellent thermal insulation; they are durability and resistance to extreme temperatures making them ideal for insulation blankets and engine shields (Miller and Thompson, 2017).

According to Chen (2021), carbon fiber composites exhibit inherently low thermal conductivity, and expansion rate which is important for heat dissipation enabling high engine performance. On the other hand, Polytetrafluoroethylene (PTFE) textiles provide superior chemical and thermal resistance, reducing heat buildup in engines (Anderson, 2018).

4. **Comparison of natural, synthetic and composite fibers for noise and heat control**.

As the industry moves toward a circular economy, the adoption of recycled materials and bio-based composites continues to grow. While numerous studies have asserted that natural fiber sound absorbers have many advantages compared with conventional absorbers, not every natural fiber has the potential property to substitute mineral fiber and glass fiber (Yang, et al., 2020). Thus, it is essential to compare the sound absorption properties of natural fibers and a conventional absorber. The sound absorption coefficients of different kinds of natural fiber sound absorbers were extracted from some selected articles that met the selection criteria. Research into nanotechnology-based solutions and material innovations will further improve sound insulation, ensuring quieter, more efficient and environmentally friendly vehicles. See Table 3 below for properties of natural fibers for automotive industry.

Table 3: Properties of natural fibres for automotive industry (Ahmed et al ., 2022)

Fibers	**Mechanical properties of fibre**			**Chemical properties**	
	Tensile strength	Failure strain	Young modulus	Cellulose %	Hemicellulose
Flax	343-1830	1.2-3.3	27-100	71	18.6-20.6
Kenaf	295-930	-	22-60	72	20.3
Jute	187-800	1.16-1.5	10-55	61-71	14-20
Hemp	550-1110	2-4	30-70	68	15
Sisal	468-855	3-7	9-28	65	12
Coir	130-580	15-40	4-62	32-43	0.15-0.25
Ramie	400-938	-	44-128	68.6-76.2	13-16

From Table 3 above, effective noise and heat control materials in vehicle engine environments must combine high mechanical strength to withstand vibrations and thermal stresses with chemical compositions that provide good thermal and acoustic insulation. Among the natural fibers reviewed, hemp and ramie are the best materials for engine component insulation due to the balance which exist between their mechanical and chemical properties (Sahib, et al., 2023).

According to a review by Ahmed et al., (2018) hemp fiber has a tensile strength of 550-1110 Mpa and a Young's modulus of 68 Gpa, as a result, it offers strong resistance to stress and vibration. It also has a high cellulose content of 65–70% which enhances its thermal insulation capacity and a moderate failure strain of 2–4% which ensures durability under dynamic engine conditions.

Ramie has high stiffness with a Young's modulus of 44-128 Gpa, a tensile strength of 400-938 Mpa and high cellulose content of 68.6-76.2%. This makes it very effective in reducing heat transfer and dampening engine noise where rigidity and insulation are critical (Latif et al., 2019). Flax and jute fibers, with cellulose contents of 71% and 61-71% respectively, are good for thermal insulation. Although they have lower tensile strength and stiffness compared to hemp and ramie, they are capable of controlling noise and heat in smaller engines (Nazari et al., 2024).

Coir has low strength but has an elastic structure which gives it a high failure strain of 15-40%, which is good for noise absorption, this structure enables it to trap and dissipate sound waves effectively (Ahmed et al., 2018). However, it has low cellulose which makes it poor for insulation.

Table 4: **Application of natural fibers in engines**

Type of fiber	**Noise control contribution**	**Heat control contribution**
Jute	Good acoustic absorption and vibration damping	Moderate insulation, high cellulose support thermal barrier

Hemp	Excellent vibration control and sound absorption	High insulation performance and thermal stability
Cotton	Soft and porous, good for high-frequency sound damping	Good insulation but lower heat resistance, needs treatment

Haque et al., (2023) suggest that if further research could be done on natural fiber composites, they have a potential for increased performance and less environmental impact. In automotive engine applications, thermosetting resins such as epoxy, phenolic and polyimide are widely used due to their superior thermal performance.

According to Abedom et al., (2021), composites from bagasse fiber and bamboo charcoal have higher tensile strength compared to that of synthetic fibers, making them suitable for automotive applications. Furthermore, in the same vein, Skhosana et al., (2024) highlighted the need for surface treatment and inclusion of nanofillers in natural fiber-reinforced polymer composites (NFRPCs) for lightweight and eco-friendly automotive solutions.

Table 5: Thermal stability of matrix materials in composites (Haque et al., 2023)

Matrix material		**Properties**
Thermosetting matrices	a. Epoxy and Phenolic resins	High heat resistance with degradation temperatures ranging from 350-500°C.
	b. Polyimide resins	High thermal stability, can withstand temperatures above 600°C
Thermoplastic matrices	a. Polypropylene (PP) and Polyethylene (PE)	Lower heat resistance of 200-300°C
	b. Polyetheretherketone (PEEK)	High performance with superior thermal stability of 500°C.

Table 6: Sound absorption rates according to vehicle brands

Fibre	**Sound Absorption**	**Car brand**	**Properties**	**Reference**
Polyester fibers	High-frequency sounds (>3000 Hz)	BMW, Audi Toyota	hollow polyester enhances sound absorption	Khedr et al., 2025
Polypropylene (PP) Fibers	Mid-range frequencies (500 - 2000Hz)	Ford, Hyundai, VW	Dampen engine and road noise	Marmol, et al., (2021)
Jute, Hemp, Cotton	Low-frequency sounds (<1000Hz)	BMW, Ford, VW	Reduces engine vibrations and enhances comfort	Kim, et al., (2023)
Fiberglass	Mid-high frequencies (1000- 5000 Hz)	VW, Ford	Reduce wind and engine noise	Naik, et al., (2021)
Polyurethane (PU) foam	Mid-high frequencies (500-3000 Hz).	Tesla, Volvo & Mercedes-Benz	Reduces engine and road noise	(Mallick, 2020)

The usage of natural fibers as sound absorbers can give a positive contribution to develop a competitive, resource efficient and low carbon economy due to the great advantages, such as easy availability, light weight, renewability, low CO2 emission, economical price and biodegradability. According to a review by Yang et al., (2020), the choice between natural and synthetic fiber composites depends on the specific thermal and mechanical requirements. Synthetic fiber composites such as carbon/epoxy, aramid/polyimide are preferred in engine applications due to their superior heat resistance, mechanical strength and durability (Zhao et al., 2022). However, natural fiber composites such as flax/epoxy, hemp/phenolic are good in non load bearing engine parts where lower thermal stresses and sustainability issues are prioritized (Ghosh et al., 2021). However, advances in nanotechnology have led to the development of nanofiber enhanced materials which have high thermal insulation and heat resistance, properties ideal for vehicle engines application (Chowdhury and Tan, 2023).

According to Hallal et al., (2013), ceramic matrix composites (CMCs) possess key performance requirements with thermal efficiency of 40% at a temperature of 1350°C leading to improved fuel economy and reduced exhaust emissions. Further research shows that carbon fiber-reinforced (CMC) composites have high mechanical properties, enhanced reliability against thermal shock, improved resistance to particle impact damage and increased creep resistance which makes them better materials for high performance engine applications, Aluminium based hybrid composites, having superior tribological and mechanical characteristics (Wazeer et al., 2023).

5. Effective fibrous materials for comfort, improving engine performance, managing sound and temperature.

Rodriguez and Huang, (2024) point out that fibrous material play a key role in noise reduction and vibration damping in car engines. Natural fibers offer sustainability and cost-effectiveness while synthetic fibers provide superior durability and heat resistance. Hybrid materials combine the strengths of both categories, thereby enhancing acoustic performance. As a result, there is need for continued research and use of sustainable materials and nanotechnology in order to drive the future of automotive acoustics, improving vehicle performance and passenger comfort.

Synthetic fibers provide superior thermal stability compared to natural fibers in automobile engine application due to their high decomposition temperatures and resistance to heat induced degradation. This makes them ideal for applications requiring durability and reliability under extreme conditions (Abedom et al., (2021).

Blended materials, which integrate both natural and synthetic fibers, have demonstrated enhanced thermal insulation performance and durability (Williams & Patel, 2022). Natural-synthetic hybrid composites further contribute to improved insulation properties while ensuring cost-efficiency and environmental sustainability (Kumar & Singh, 2020). Moreover, the adoption of multilayer insulation systems has shown significant improvements in thermal resistance and structural stability under elevated temperatures (Nguyen et al., 2021)

6. Conclusion

The use of fibrous materials in automotive engine systems has shown good results in reducing noise and heat. This review demonstrates that the performance of these materials depends on their composition, heat management and sound absorption capabilities. Natural fibers such as jute and hemp are environmentally friendly and useful for sound and heat control but often require improvements to withstand high engine temperatures. Synthetic fibers, such as fiberglass offer better performance in hot and noisy conditions but are more expensive and less environmentally friendly. Blended or composite fibers (made from natural and synthetic materials) offer a useful compromise, delivering good performance while reducing environmental damage. However, there is no perfect material that works for all situations. The right choice depends on how and where the material will be used including engine temperature, the type of noise to be blocked, available space and environmental objectives. This review also highlights the need for new thinking on the treatment and processing of these fibers. More research and better testing standards will help improve these materials so they can be more widely used in future vehicle designs where comfort, performance and sustainability must converge.

7. Recommendations

a. Create blended materials which combine the strength and heat resistance of synthetic fibers with the environmental friendliness of natural fibers.

b. Focus on sustainability using more biodegradable and recyclable materials for engine insulation to help reduce environmental impact and meet global green standards.

c. Establish standardized testing protocols for the design and optimization of multilayer insulation systems that integrate natural and synthetic fibers with advanced polymers and foams.

d. Accelerate the adoption of natural fibers in the automotive industry by developing and implementing more efficient pretreatment methods that minimizes environmental impact while enhancing heat resistance and fire-retardant properties.

e. lntegrating Life Cycle Assessment (LCA) into the development of natural fiber based sound absorbers will contribute to the long-term sustainable growth and broader application of these materials.

f. Prioritize the development of fully bio-based or recyclable composite fibers from the onset to minimize environmental impact while maintaining or improving thermal and acoustic performance. This approach involves exploring sustainable polymer matrices as alternatives to conventional synthetic resins.

g. Promote the development of collaborative networks among researchers, automotive manufacturers and materials experts to facilitate the conversion of innovative ideas into practical products.

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