A Comparative Study of Traditional and Sustainable Materials in Automotive for Noise, Vibration and Harshness

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Abstract - In recent days, with the shift of the car industry to Electric Vehicles (EVs), managing Noise, Vibration, and Harshness (NVH) has become a major challenge. This paper focuses on a comparative study of polyurethane (PU) foam with eco-friendly alternatives such as flax, jute, and recycled rubber. The study differentiates the materials based on damping ratios and peak absorption, as well as other non-acoustic factors useful in automotive applications. It also discusses current usage by some major automakers. Experimental results show that these materials are viable options, though a significant gap remains regarding long-term durability. Lastly, future trends show the hybridization of these materials to cope with industrial standards.

Keywords- Sustainable Acoustic Materials, Natural Fibers, Recycled Material, Acoustic Absorption Coefficient(α), Viscoelastic Damping Materials (VDMs), Damping Loss Factor (η), UL-94 Flammability Rating, Moisture Absorption, Life Cycle Assessment (LCA).

I. INTRODUCTION

The car industry is going through huge changes today, mostly because of the shift to electric vehicles (EVs). For many years, cars had loud gassed engines that hid other noises. Now, without a gas engine, drivers can clearly hear high-pitched sounds from the electric motors, the wind, and the tires.[1] Because of this, engineers must use better materials to block noise and stop vibrations, a field known as NVH (Noise, vibration, and Harshness).

Old synthetic materials, like polyurethane (PU) foam, block sound very well but are bad for the environment. One study shows that making these synthetic foams creates up to 7.3 kg of carbon dioxide equivalent per kilogram (kg CO_2-eq/kg) of material.[2] Strict new recycling rules require car makers to use materials that can be easily recycled at the end of the car's life.

This paper shows the research data from the last 10 to 15 years. It compares the hard numbers of traditional synthetic materials against sustainable, natural, and recycled materials to see which ones perform best.

Figure 1. NVH transmission of vibration energy from source to receiver. Adapted from [3]

II. CLASSIFICATION OF MATERIALS

To compare these materials fairly, we group them into two main categories:

A. Traditional (Synthetic/Mineral)

These are man-made materials that have been used for decades. They include polyurethane (PU) foams, mineral wool, glass fiber, bitumen, and synthetic rubber. While they

are very effective, their production harms the environment. For example, making glass fiber creates between 1.7 and 2.5 kg CO_2-eq/kg.[4]

B. Sustainable (Natural/Recycled)

Figure 2. Comparison of synthetic, natural, and recycled materials commonly utilized in structural, insulation, and textile applications.

These materials come from nature or are made from waste. The chemical composition of natural fibers heavily influences how they handle moisture and sound.

- Natural Fibers: Jute, hemp, coir (coconut fiber), ramie, and sheep's wool.
- Recycled Materials: PET felt (from plastic bottles), cotton waste, and recycled rubber from old tires.[5]

TABLE 1

COMPOSITION AND AUTOMOTIVE APPLICATION OF NATURAL FIBERS

Fiber Type	Cellulose Content (%)	Moisture Content (%)	Application
Jute [6]	45-71.5	12	Door panels
Hemp [6]	57-77	8	Sound proofing, dashboards
Ramie [6]	68-91	12-17	Trunk panel. covers
Flax [7]	60-81	1.7	Insulation materials

III. COMPARATIVE PERFORMANCE ANALYSIS

For a sustainable material to be used in a car, it must block noise and vibration just as well as traditional plastics.

A. Acoustic Absorption (Blocking Airborne Noise)

The sound absorption coefficient(α) measures how well a material blocks sound. A score of 0 means no sound is blocked, and 1 means all sound is blocked.

A study comparing sheep's wool to traditional mineral wool

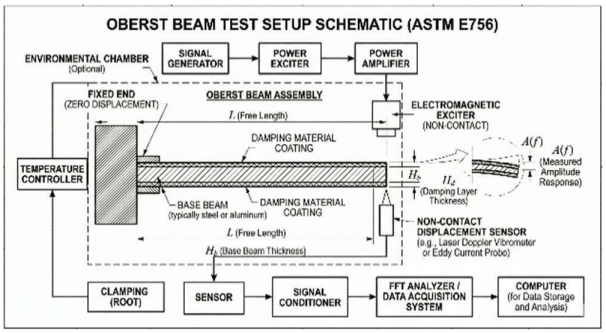

Figure 3. Schematic of the Oberst Beam Test setup used for evaluating damping properties, based on ASTM E756 standards [10].

showed that sheep's wool is very effective.[8] When sheep's wool is pressed with heat into a 50 mm thick pad, it gets a sound absorption score of over 0.72 for frequencies between 800 Hz and 3150 Hz.[8]

Another paper tested plant fibers and found they are also excellent at blocking sound.[9] A different study proved that simply adding 20% jute fiber to a standard plastic part increases its sound absorption by 120%.[11]

TABLE 2

PEAK ACOUSTIC ABSORPTION OF SUSTAINABLE MATERIALS [9]

Material	Peak Absorption Score	Frequency
Flax Fiber	0.95	1250
Kenaf Fiber	0.92	1600
Rice Husk	0.88	2000
Coir Fiber	0.80	Below 1360

For heavy recycled rubber, a study showed that using 7 cm of tightly packed rubber pieces (smaller than 1 mm) successfully blocked 25.14 dB of noise, making it a great replacement for heavy synthetic foams.[12]

B. Damping Ratios (Stopping Vibrations)

To stop metal car parts from vibrating, engineers look at the loss factor(η). A higher number means the material stops shaking faster.

A technical paper notes that standard bitumen (a black, sticky material often used on car floors) has a loss factor between 0.25 and 0.45 when paired with aluminium foil.[13] Synthetic rubbers, like butyl rubber, are also used because they do not crack in the cold and can survive heat up to 150 °C. [14]

However, new studies show that mixing recycled tire rubber powder into bitumen makes it 110 times thicker and doubles its ability to bounce back compared to normal bitumen.[15]

TABLE 3

DAMPING LOSS FACTOR COMPARISON FOR VIBRATION CONTROL

Material	Loss Factor	Temperature Sensitivity
Bitumen (Aluminium Sandwich) [13]	0.25-0.45	Upto 50^0 C
Butyl Rubber [16]	0.1to 0.35	Low
Recycled Rubber (Particle) [12]	0.05 to >0.25	Moderate
High Viscosity Modified Bitumen [15]	>0.45	Very Low

C. Non-Acoustic Factors (Fire and Water)

Car parts must be safe from fire and water. This is where natural fibers often struggle.

- Fire Safety: A study tested PU foam using the strict UL-94 fire test.[17] By adding 60% chemical fire retardants, the foam's safe temperature went up to 292 °C, and it achieved a top "V-0" safety rating, meaning it stops burning quickly.[17] Unmodified natural fibers usually fail this test and only get a low "HB" rating, meaning they catch fire and burn across their surf

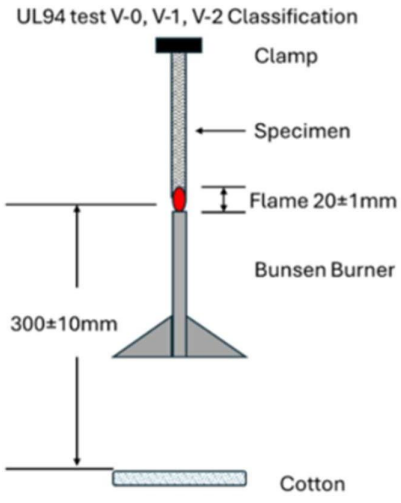

Figure 3. Schematic representation of the UL 94 vertical burn test setup used to determine V-0, V-1, and V-2 flammability classifications. Reprinted from [18].

TABLE 4

UL-94 FIRE SAFETY RATINGS BEFORE AND AFTER TREATMENTS

Material	Base UL-94 Rating	Treated UL-94 Rating	Treatment Method
Polyurethane Foam [17]	HB	V-0	60% Exolete OP 935 & APP
Hemp Fabric / Epoxy [9]	HB	V-0	Cold phosphoric acid & amino silane
Silicone Foams [19]	-0 or HF-1	N/A	Inherently flame resistant

- Moisture Absorption: Plant fibers naturally soak up water. A research paper showed that a plastic part mixed with 15% raw jute fiber lost 28.93% of its strength after sitting in water for two months.[20] However, another study found that treating hemp fibers with special chemicals
kept their moisture absorption down to just 9%, even in extremely humid air (95% humidity).[21]

IV. SUSTAINABILITY & LIFE CYCLE ASSESSMENT (LCA)

The biggest advantage of sustainable materials is their low impact on the earth.

A. Carbon Footprint

A comparative study highlighted that making 1 cubic meter of synthetic mineral wool releases 135 kg of CO_2 [8], but making the same amount of sheep's wool insulation releases only 5.4 kg of CO_2. Another verified report found that raw jute fiber has a very low carbon footprint of just 1.31 kg CO_2e/kg.[22] Car makers are already using this data. For example, BMW reports that using flax fiber instead of carbon fiber in their race car roofs cuts CO2 emissions by 40%.[23]

B. End-of-Life

When a car is too old to drive, its parts need to be thrown away. A study on biodegradable car parts tested a roof liner made of jute and poly lactic acid (PLA).[24] During a composting test, the part safely lost 48% of its weight and 90% of its strength, proving it can safely return to the earth.[24] Another paper found that rotting jute can even create up to 480 NM/g of useful biogas energy when broken down without oxygen.[25]

V. CHALLENGES & FUTURE TRENDS

Even with all these benefits, there are still problems to solve before every car uses natural fibers.

a) The Durability Gap: The biggest missing piece of research is long-term testing. Scientists do not know exactly how natural fibers will perform in a car after 10 or 15 years of hot, cold, and wet weather.[26] Traditional plastics easily last this long without rotting or growing Mold.
b) Hybridization in production: To fix these issues, engineers are mixing natural materials with synthetic plastics for example, studies show that covering jute and hemp with thin layers of plastic or glass fiber protects them from water while keeping the part light and quiet.[27]

TABLE 5

INTEGRATION OF SUSTAINABLE HYBRIDS BY MAJOR AUTOMAKERS

Manufacturer	Material Hybrid	Targeted Automotive Parts
BMW [28]	Flax and Natural Fibers	Door panels, headliners, boot lining
Mercedes-Benz [29]	Recycled PET and Nylon	Seat covers, floor coverings, door panels
Ford [30]	Agave, Soy and Wheat	Air conditioning systems, wiring harnesses

IV. CONCLUSION

Natural and recycled materials are great for making cars quieter and greener. Studies prove they can block sound just as well as old plastics. Sheep wool and flax are excellent for airborne noise, and recycled rubber is highly effective in stopping heavy vibrations.

Using these materials massively lowers a car's carbon footprint. However, natural fibers still need chemical treatments to prevent them from catching fire and growing Mold. The main "Research Gap" is that scientists still need to perform long-term aging studies to see how these natural parts survive over a full 15-year car lifespan.

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