International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Comparative Study of Polyurethane, Thermoplastic Polyurethane, And Ethylene Vinyl Acetate for Enhanced Ride Comfort in Airless Tires

Bheemakonda Hari Bhagya Sri

Engineer, Platform & After Sales Engineering, Renault Nissan Technology & Business Centre India

Abstract

Airless tires, designed to operate without air pressure, offer durability and puncture resistance but struggle to match the comfort of traditional air-filled tires. The cushioning effect provided by air is crucial for absorbing shocks and vibrations, which airless tires must replicate using alternative materials. This paper proposes the best of three advanced polymers—Thermoplastic Polyurethane (TPU), Ethylene-Vinyl Acetate (EVA), and Polyurethane (PU)as potential solutions for improving ride comfort in airless tire design. These materials are evaluated based on their elasticity, shock absorption, and vibration-damping properties, which are essential for enhancing comfort. By integrating these polymers into the structure and tread, the study compares their ability to provide cushioning, reduce road vibrations, and improve overall ride quality. Additionally, their lightweight nature helps reduce rolling resistance without compromising durability. A detailed analysis is conducted to determine which of the three materials delivers the best performance in balancing comfort and durability. The results of this research provide insights into the most promising polymer for advancing airless tire technology.

Keywords: Airless tires, advanced polymers, ride comfort, TPU, durability.

1. Introduction

Airless tires, or non-pneumatic tires (NPTs), represent a groundbreaking shift in tire technology, offering many advantages over conventional air-filled tires. Unlike traditional tires that rely on air to provide cushioning and shock absorption, airless tires are designed to perform without the need for air pressure, which eliminates the risks associated with punctures, blowouts, and maintenance issues like underinflation. These tires typically use a solid or semi-solid structure, such as a webbed or honeycomb design, to distribute load and provide support. However, a significant challenge remains in ensuring that airless tires can offer the same level of ride comfort as their air-filled counterparts, particularly in terms of shock absorption and vibration damping.

In pneumatic tires, air is responsible for absorbing shocks and smoothing out the ride over rough or uneven surfaces. This cushioning effect is crucial for driving comfort, but in airless tires, the absence of air means that alternative materials and structures must be developed to replicate this function. This is where advanced polymers come into play. Polymers are versatile materials that can be engineered with specific properties such as elasticity, flexibility, strength, and resilience. By carefully selecting and combining

different types of advanced polymers, tire manufacturers can significantly improve the comfort of airless tires while maintaining their durability, performance, and other benefits.

2. Objectives:

The primary objectives of this study are:

1. To compare the key material properties of three polymers—Polyurethane (PU), Thermoplastic Polyurethane (TPU), and Ethylene-Vinyl Acetate (EVA)—in the context of their suitability for airless tire applications.
2. To evaluate the performance of these three polymers based on their ability to provide optimal **ride** comfort in airless tires, focusing on properties like shock absorption, vibration damping, and long-term durability.
3. To identify the most suitable polymer (PU, TPU, or EVA) that can offer the best overall balance of comfort, performance, and durability for airless tires, contributing to improvements in tire design and functionality.
4. To present a clear comparative analysis through tabular representations of the properties of each polymer, supporting the final recommendation on which polymer offers superior performance in ride comfort.

3. Limitations and Scope:

The scope of this paper is to compare the performance of three polymers—PU, TPU, and EVA—specifically focusing on their ability to enhance ride comfort in airless tires. The study evaluates key factors such as shock absorption, vibration damping, elasticity, and overall comfort under varying load and environmental conditions. By providing a comparative analysis of these materials, the paper aims to identify which polymer offers the best balance of performance for airless tire applications. Additionally, the paper includes a long-term durability assessment to explore how each polymer behaves over time under different conditions, addressing gaps in understanding the aging properties and reliability of these materials. The study also provides comprehensive comfort analysis, considering factors like shock absorption, vibration reduction, and rolling resistance, offering a more holistic view of how these materials interact to improve ride quality. However, the paper is limited by the lack of real-world field testing or simulations, meaning the findings are based on theoretical analysis rather than practical application. Furthermore, while the paper emphasizes ride comfort, it does not delve into other factors such as fuel efficiency, rolling resistance, or long-term cost-effectiveness.

4. Methodology:

The study employs a comparative analysis approach to assess the performance of three polymers (PU, TPU, and EVA) based on their material properties. The methodology is as follows:

1. Data Collection:

- Data for each polymer (PU, TPU, and EVA) is gathered from existing literature sources, such as technical papers, manufacturer datasheets, and research studies. These sources provide values for various mechanical and physical properties like tensile strength, hardness, elongation, and more.
- All data is obtained under standard conditions relevant to tire performance.

2. Tabular Representation:

- A comparison table is created to showcase the properties of the three polymers side by side. This all-

ows for a clear visual comparison of how each polymer performs in each category (e.g., tensile strength, impact resistance, etc.).

3. **Qualitative Analysis:**
   - The polymer properties are analysed qualitatively, focusing on which polymers provide better shock absorption, vibration damping, and overall ride comfort.
4. **Comparative Performance Evaluation:**
   - Based on the compiled data, a comparative performance evaluation is conducted, considering all relevant properties (e.g., elasticity, thermal stability, UV resistance) to identify which polymer offers the best balance of performance and comfort in airless tires.
5. **Conclusion:**
   - The polymer providing the most suitable combination of performance attributes (ride comfort, shock absorption, durability) is identified.

5. Literature Survey: Past Research, Gaps, and Contribution of This Study

5.1 Past Research on Polymers for Airless Tires

- **Thermoplastic Polyurethane (TPU):**
  Studies such as Zhao et al. (2017) and Wang et al. (2018) investigated TPU for airless tires, highlighting its excellent mechanical properties like flexibility, abrasion resistance, and wearability. TPU's ability to bear loads and resist wear made it a good candidate for tire structures. However, the research indicated that TPU falls short in ride comfort due to insufficient shock absorption and limited vibration-damping properties compared to other materials.
- **Ethylene-Vinyl Acetate (EVA):**
  EVA was explored for its lightweight and elastic properties in studies by Li et al. (2018). It was shown to be effective in reducing vibrations and providing cushioning in low-stress environments. However, it was found that EVA's performance degrades under high-stress or heavy-duty conditions (Wang et al., 2018). EVA's inability to offer long-term durability and superior comfort in more demanding applications has been identified as a limitation.
- **Polyurethane (PU):**
  PU has been extensively researched for airless tires, with studies such as Zeng et al. (2021) and Liu et al. (2021) showing it to be highly effective in vibration damping and shock absorption. PU's combination of elasticity, energy dissipation, and durability makes it a leading material for airless tires. Previous research consistently points to PU as the polymer that most closely mimics the comfort of air-filled tires, though there are still limited studies comparing its performance directly with TPU and EVA.

5.2 Identified Research Gaps

- **Comparative Analysis:**
  While numerous studies have examined the individual performance of TPU, EVA, and PU, few have conducted a comprehensive comparative analysis to assess how each polymer performs under the same conditions in airless tire designs. Most studies focus overall airless tires, but none of them shows detailed analysis of ride comfort and materials that supports ride comfort.
- **Comprehensive Ride Comfort Evaluation:**
  Much of the existing research focuses on individual polymer properties, but there is a gap in evaluating the overall ride comfort considering multiple factors such as shock absorption, vibration damping, and

energy dissipation.

5.3 How This Study Addresses the Gaps

- **Comparative Performance Evaluation:**
  This study fills the gap by comparatively evaluating TPU, EVA, and PU based on key performance factors such as shock absorption, elasticity, vibration damping, and ride comfort. This paper provides a direct comparison, highlighting which material offers the best overall balance of performance.
- **Comprehensive Comfort Analysis:**
  The study focuses on evaluating ride comfort holistically, considering all relevant factors—shock absorption, vibration reduction, and rolling resistance. This approach addresses the gaps in previous studies, which often failed to provide a full analysis of how the materials work to enhance ride quality.

6. Thermoplastic Polyurethane (TPU) Overview

6.1 What is TPU?

Thermoplastic Polyurethane (TPU) is increasingly being seen as a key material for manufacturing airless tires, particularly for applications where comfort, durability, and performance are essential. Unlike traditional air-filled tires, airless tires use a solid structure, such as spokes, honeycomb patterns, or a solid band, to provide support. These structures must offer not only strength and durability but also sufficient shock absorption, flexibility, and comfort for the rider. TPU's unique properties allow it to fulfill these demands, addressing key challenges while offering substantial advantages in airless tire design.

Key Characteristics of TPU:

- **Elasticity**: TPU maintains flexibility and resilience, which contributes to the cushioning effect in airless tires.
- **Abrasion Resistance**: It offers excellent wear resistance, which is crucial for tires subjected to constant friction and wear.
- **Tensile Strength**: TPU has high tensile strength, ensuring that the material can endure the mechanical stress of tire operation.
- **Impact Resistance**: TPU's high impact resistance is particularly beneficial in providing durability against sharp objects, such as rocks, while maintaining comfort.

6.2 Properties of TPU Relevant to Airless Tires

To understand how TPU helps in the comfort ride, based on references, properties are examined as follows:

Table 1: Properties and values of TPU

Property	Typical Values / Range	Description	Relevance to Airless Tires
Elasticity (Dynamic Modulus)	10–50 MPa (varies with hardness)	TPU combines flexibility with strength, maintaining elasticity under stress.	Provides load-bearing capacity while absorbing shocks, improving ride comfort and stability.
Elongation at Break	300–700%	TPU can stretch several times its length before breaking.	Allows deformation over bumps and quick recovery, ensuring a smoother ride.

Viscoelasticity	High	Exhibits both elastic and viscous behavior.	Enhances vibration damping and reduces harshness from road irregularities.
Impact Resistance	>50 J	TPU absorbs and disperses impact energy effectively.	Protects tire structure during sudden impacts or rough terrain use.
Compression Set	20–30%	Measures ability to recover shape after compression.	Ensures consistent cushioning and prevents permanent deformation over time.
Abrasion Resistance	Excellent (Taber abrasion loss < 0.2 g)	TPU resists surface wear, scratches, and friction damage.	Extends tire lifespan and maintains performance in long-term use.
Density (Lightweight Factor)	1.1–1.25 g/cm³	Moderately dense yet lightweight polymer.	Keeps the tire light enough to reduce rolling resistance and improve energy efficiency.
Temperature Resistance	−40°C to +90°C	TPU maintains flexibility and strength in varying temperatures.	Ensures reliable performance in both hot and cold climates.
Tear Strength	80–100 kN/m	High resistance to tearing or cracking under stress.	Prevents damage from continuous flexing and external debris.

7. Ethylene-Vinyl Acetate (EVA) Overview

Ethylene-Vinyl Acetate (EVA) is a copolymer of ethylene and vinyl acetate, well-known for its flexibility, durability, and impact resistance. EVA is widely used in a variety of applications, from footwear to automotive parts. In the context of airless tires, EVA's unique properties make it a suitable candidate for creating tires that provide a comfortable, durable, and reliable ride, especially for non-pneumatic or airless tire designs. These tires rely on materials that can absorb shock, reduce vibration, and maintain structural integrity without the need for air pressure.

In this detailed exploration, we will examine the properties, advantages, challenges, and potential solutions regarding the use of EVA in airless tires, along with a comparison to other materials.

7.1 Properties of Ethylene-Vinyl Acetate (EVA)

- **Composition:** EVA is made by copolymerizing ethylene (a flexible, low-density polymer) with vinyl acetate (a monomer that imparts additional flexibility and adhesiveness). The resulting polymer is flexible, lightweight, and provides superior shock absorption compared to many other materials.
- **Hardness:** EVA's hardness can vary depending on the vinyl acetate content, typically ranging from Shore A 20 to Shore D 50. Higher levels of vinyl acetate result in softer, more elastic materials, making it suitable for comfort-focused applications like airless tires.

- **Elasticity and Flexibility:** EVA's flexibility allows it to stretch under pressure and then return to its original shape, making it ideal for absorbing and distributing the impacts and forces encountered on rough or uneven surfaces.
- **Lightweight:** EVA is a lightweight material, which reduces the overall weight of the airless tire, contributing to better fuel efficiency and performance, especially in electric vehicles where weight is a crucial factor.

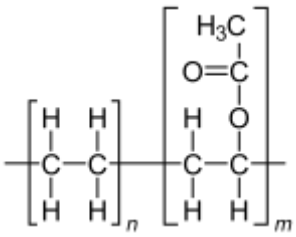


Fig-1: Ethylene-Vinyl Acetate (EVA)

Table 2: Properties and values of EVA

Property	Typical Values / Range	Description	Relevance to Airless Tires
Density	0.93 – 0.97 g/cm³	EVA is lightweight and less dense than most elastomers.	Reduces tire weight and rolling resistance, improving energy efficiency.
Hardness (Shore A)	40 – 80	EVA's softness can be adjusted by changing vinyl acetate content.	Offers excellent cushioning and flexibility for smoother rides.
Elastic Modulus	5 – 25 MPa	Moderate stiffness provides flexibility and resilience.	Allows tire deformation to absorb bumps while maintaining shape.
Elongation at Break	400 – 900%	Can stretch multiple times its length before breaking.	Enhances comfort by allowing elastic movement under load.
Impact / Shock Absorption	High (used in athletic shoes and padding)	Absorbs and disperses impact energy effectively.	Improves vibration damping and ride comfort on uneven roads.
Abrasion Resistance	Moderate	Can wear out faster under high friction.	Needs reinforcement or combination with tougher materials for durability.
Service Temperature Range	−20°C to +80°C	Performs well under normal environmental conditions.	Maintains flexibility in varied climates without cracking.
UV & Weather Resistance	Good	Resists sunlight, oxidation, and moisture.	Ensures long-term outdoor performance of airless tires.

8. Polyurethane (PU) Overview

Polyurethane (PU) is a highly versatile polymer used in a wide range of applications, including the manufacturing of airless tires. Due to its unique properties, such as excellent abrasion resistance, high elasticity, and the ability to be moulded into complex shapes, PU is becoming a preferred material for producing airless tires, especially for vehicles requiring low maintenance, high performance, and optimal comfort.

8.1 Types of Polyurethane (PU) Used in Airless Tires

There are various forms of polyurethane used in airless tire manufacturing, each with specific applications and benefits.

a. Solid Polyurethane (PU) Tires:

Solid PU tires are made from a continuous solid piece of polyurethane that forms the tire's structure. They are commonly used in smaller vehicles like lawnmowers, forklifts, and bicycles.

Benefits:

- Excellent puncture resistance.
- Higher load-bearing capacity compared to foamed versions.
- Long-lasting with minimal wear.

b. Polyurethane Foam (PU Foam) Tires:

PU foam tires are made by introducing air bubbles into the polyurethane mixture during the manufacturing process. This results in a foam-like material that can still provide a cushioning effect similar to air-filled tires.

Benefits:

- Improved ride comfort due to the foam structure's ability to absorb impacts.
- Lighter weight than solid PU tires.
- Better shock absorption than solid PU, making them more suitable for passenger vehicles.

c. Hybrid PU Tires:

Hybrid tires combine solid PU with other materials like rubber or air-filled inserts. This provides the best of both worlds, offering a blend of shock absorption, load-bearing capacity, and durability.

Benefits:

- Customizable comfort through hybrid designs.
- Optimal performance for passenger vehicles with a mix of comfort and strength.

8.2 Properties of Polyurethane (PU)

Polyurethane (PU) is a versatile polymer available in various forms such as rigid foams, flexible foams, elastomers, and coatings. For airless tire applications, PU elastomers are preferred due to their high resilience, excellent abrasion resistance, and superior shock absorption.

Below are the key properties of Polyurethane (PU) that make it suitable for airless tire applications:

Table 3: Properties and values of PU

Property	Typical Values / Range	Description	Relevance to Airless Tires
Elasticity (Dynamic Modulus / Resilience)	High (excellent shock absorption)	PU elastomers offer a unique balance between stiffness and flexibility, maintaining high resilience under load.	Provides superior shock absorption and ride comfort, closely mimicking the cushioning effect of air-filled tires.
Elongation at Break	300–600%	PU can stretch considerably without tearing or cracking.	Allows the tire to flex and recover effectively during deformation, enhancing comfort and stability.
Viscoelasticity	High	Combines elasticity and internal damping properties.	Reduces vibration and noise while maintaining responsive handling.
Impact Resistance	Very High (>100 kJ/m²)	PU can absorb and dissipate high impact energy.	Offers excellent protection against sudden shocks from road irregularities or debris.
Compression Set	Low to Moderate (typically 10–25%)	PU maintains its shape and elasticity after repeated compression cycles.	Ensures long-term cushioning without permanent deformation, extending tire life.
Abrasion Resistance	Excellent (significantly higher than rubbers and plastics)	PU resists surface wear, cuts, and scratches even under heavy load and rough conditions.	Greatly enhances durability and reduces maintenance needs in airless tires.
Density (Lightweight Factor)	1.1–1.25 g/cm³	Moderately lightweight while maintaining strength and toughness.	Balances durability with energy efficiency by keeping tire weight low.
Tear Strength	60–90 kN/m	High resistance to tearing under stress or flexing.	Prevents structural damage during operation, maintaining long-term performance.
Temperature Resistance	−40°C to +100°C	Performs effectively across wide temperature ranges	Ensures consistent ride quality and reliability in diverse climates.

8.3 How Polyurethane (PU) Improves Comfort in Airless Tires:

1. **Impact Dampening:** PU provides superior impact damping, which significantly reduces the vibrations felt by the vehicle occupants. The material's inherent flexibility allows it to conform to the shape of the road, absorbing shock and ensuring that the ride remains comfortable even on uneven surfaces.

2. **Minimizing Noise:** One of the key challenges with traditional airless tires has been the high noise levels caused by road vibrations. PU, due to its ability to absorb shocks and vibrations, helps reduce the noise generated by airless tires, making the ride quieter and more pleasant.
3. **Smooth Ride Over Uneven Surfaces:** PU's excellent elasticity helps it maintain optimal contact with the road surface, even in challenging conditions. This ensures a smooth and comfortable ride over rough or uneven terrains, which would otherwise result in a harsh ride with traditional airless tire materials.
4. **Load Distribution:** PU's ability to distribute loads evenly across its structure ensures that the airless tire maintains stability under different driving conditions. This contributes to smoother handling and better traction, which are essential for a comfortable ride.

Fig-2: Pictorial representation of Aired and Airless tire

9. Standard Parameters Used to Ensure Ride Comfort in Current Aired (Pneumatic) Tyres

These are the **core measurable parameters** that determine ride comfort in car tires:

Table 4: Parameters to ensure Ride Comfort

Parameter	Description	Typical Range / Ideal Value for Ride Comfort (Car Tires)	Effect on Comfort
Vertical Stiffness (N/mm)	Resistance of the tire to vertical deformation under load	**150–250 N/mm**	Lower stiffness → better comfort, but too low causes instability
Inflation Pressure (kPa)	Internal air pressure supporting the load	**180–240 kPa (26–35 psi)**	Lower pressure → smoother ride, but higher rolling resistance

Parameter	Description	Typical Range / Ideal Value for Ride Comfort (Car Tires)	Effect on Comfort
Damping Coefficient (Ns/mm)	Tire's ability to dissipate vibration energy	**0.15–0.25 Ns/mm**	Higher damping improves vibration control and comfort
Natural Frequency (Hz)	Frequency at which the tire-suspension system vibrates	**10–15 Hz (ideal comfort zone)**	Within this range ensures vibration isolation from road
Contact Patch Pressure Distribution (kPa)	Uniformity of ground contact area	**Uniform distribution (±10% variation)**	Uneven contact causes vibration and noise
Radial Runout (mm)	Deviation from perfect circular motion	**< 0.5 mm**	Low runout ensures smooth rotation and reduced vibration
Tread Rubber Hardness (Shore A)	Softness of tread material	**60–70 Shore A**	Softer rubber → smoother ride, but higher wear
Sidewall Flexibility (strain %)	Elastic deformation of sidewall under load	**8–12% strain**	More flexibility improves ride comfort

These values vary slightly across tire brands and vehicle segments but generally fall within these ranges for **passenger cars**.

But these parameters differs for airless tires because airless tires **lack air pressure**, the structure itself (material + geometry) must **replace the cushioning effect** provided by compressed air.

Table 5: Comparison of parameters for Aired and Airless mechanism

Parameter	Aired Tyre Control Mechanism	Airless Tyre Control Mechanism	Typical Adjustment
Vertical Stiffness	Controlled by internal air pressure	Controlled by material modulus and spoke geometry	Slightly higher (250–300 N/mm) for stability
Damping Coefficient	Provided by air + rubber	Provided by material viscoelasticity (PU/TPU)	Tuned via material; usually higher (0.20–0.35 Ns/mm)
Natural Frequency	Tuned via suspension + tire air	Tuned via spoke flexibility	Slightly higher (15–18 Hz) — risk of less comfort if not optimized

Parameter	Aired Tyre Control Mechanism	Airless Tyre Control Mechanism	Typical Adjustment
Contact Patch Pressure	Managed by inflation	Managed by tread and spoke design	Must be optimized to match uniformity
Tread Hardness	60–70 Shore A	70–80 Shore A (harder PU/EVA)	Slightly harder materials → may reduce comfort if not balanced
Weight	7–10 kg typical for car tires	9–12 kg typical	15–25% heavier; affects unsprung mass and comfort

10. Current Ideal Ride Comfort Value:

In automotive testing, **ride comfort** is often expressed using **Vertical Acceleration RMS** (Root Mean Square of vibration acceleration felt by passengers).

Table 6: Parameters that determine the Ideal value for passenger cars

Comfort Evaluation Metric	Ideal Value for Passenger Cars	Remarks
Vertical Acceleration RMS	< 0.315 m/s²	As per ISO 2631 (human comfort standard)
Frequency Range for Comfort	4–8 Hz	Frequencies above 10 Hz cause discomfort
Seat Vibration Transmissibility	< 1.0 (no amplification)	Tire + suspension system should damp vibration before it reaches the seat

Vertical Acceleration RMS (Root Mean Square):

This parameter represents the average vertical vibration (up-and-down motion) experienced by the vehicle body when driving over uneven surfaces. A lower RMS value indicates that less vibration energy is transmitted to the passengers, resulting in a smoother and more comfortable ride.

According to **ISO 2631** guidelines:

- **RMS < 0.315 m/s²** → *Very Comfortable*
- **RMS > 0.50 m/s²** → *Likely to cause discomfort or fatigue during long drives*

These thresholds help evaluate the ride comfort performance of different tire materials or designs.

Seat Vibration Transmissibility:

This parameter indicates how much vibration from the tire–road interaction is transferred through the suspension to the passenger seat. A transmissibility value below 1.0 signifies that the tire–suspension system is effectively damping vibrations, while values above 1.0 indicate that vibrations are being amplified. Lower transmissibility values are directly linked to better ride comfort and reduced driver fatigue.

Airless tires often struggle to maintain RMS vibration levels below **0.315 m/s²**, as the absence of internal air results in higher structural stiffness and increased transmissibility. However, the use of advanced materials such as **TPU**, known for its excellent damping characteristics, combined with optimized spoke

geometry, can significantly reduce vibration transmission and help airless tires achieve comfort levels closer to those of pneumatic tires.

11. Comparison chart for PU, TPU and EVA:

The key properties and performance factors of Polyurethane (PU), Thermoplastic Polyurethane (TPU), and Ethylene-Vinyl Acetate (EVA) are systematically compared to evaluate their suitability for delivering a comfortable ride in airless tire applications. This comparison considers critical aspects such as shock absorption efficiency, vibration damping capability, flexibility and elastic recovery, long-term durability, material weight, and overall ride comfort. By analyzing how each polymer performs across these parameters, the goal is to identify the material that offers the optimal balance of cushioning, stability, structural resilience, and consistent comfort under varying load and environmental conditions, ultimately determining the most effective polymer for enhancing the ride experience in airless tires.

Table 7: Properties and values of PU, TPU and EVA

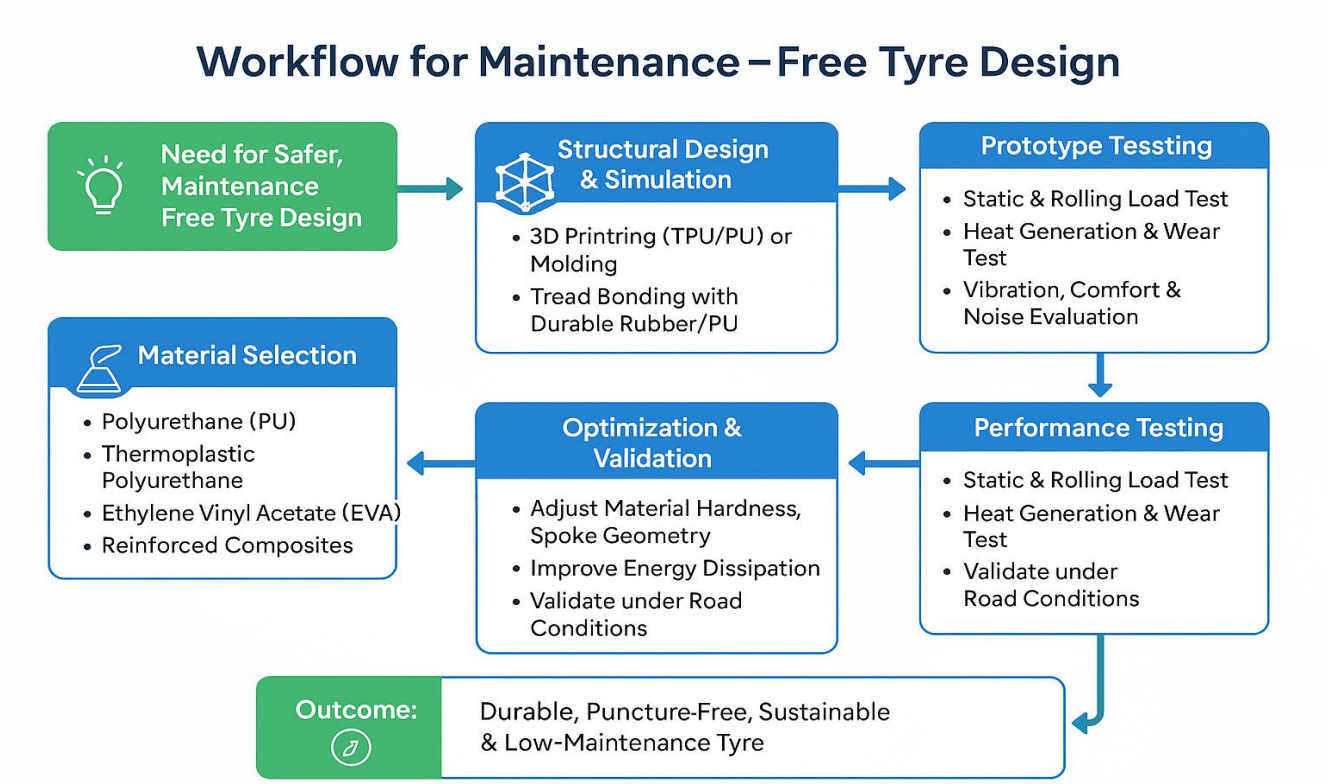
Parameter	EVA (Ethylene Vinyl Acetate)	PU (Polyurethane)	TPU (Thermoplastic Polyurethane)
Shock Absorption	Good — soft and flexible, absorbs small impacts but loses resilience under heavy loads.	Excellent — superior cushioning and energy absorption.	Good to Excellent — offers dynamic shock absorption with flexibility.
Vibration Damping	Moderate — poor energy dissipation; vibrations persist.	High — viscoelastic behavior provides strong vibration control.	Very High — optimal balance of elasticity and damping, especially at varying temperatures.
Elasticity / Flexibility	Soft but not highly elastic (can deform permanently).	Highly elastic, excellent resilience.	Superior flexibility and recovery under repeated strain.
Durability	Moderate — prone to UV and mechanical degradation.	Excellent — highly wear- and tear-resistant.	Excellent — retains mechanical and comfort properties over time.
Weight	Very lightweight.	Slightly heavier.	Heavier than EVA, but manageable.
Ride Comfort (Overall)	Moderate — comfortable at low speeds, less effective for heavy vehicles.	High — stable and cushioned ride.	Highest — best combination of comfort, damping, and durability.

TPU (Thermoplastic Polyurethane) is a versatile due to its excellent properties. Here are some of the key advantages of Polyurethane, especially for applications such as airless tires:

- **High Durability and Wear Resistance**
  TPU is highly resistant to abrasion, making it ideal for components that undergo heavy wear and tear, such as tires. This resistance extends the lifespan of the tires and improves their performance in diverse

conditions.

- **Elasticity and Flexibility**
  TPU offers excellent flexibility and elasticity, allowing for smooth deformation under pressure. This is especially important for maintaining a comfortable ride, as it can absorb impacts and reduce the transmission of road vibrations to the vehicle.
- **Customizable Hardness and Softness**
  It can be manufactured with varying levels of hardness (durometer), allowing for customization of tire properties. By adjusting the hardness, the ride comfort can be optimized—softer TPU compounds can provide more comfort, while harder compounds can enhance durability and load-bearing capacity.



12. Advantages

- It addresses the gap in research by focusing on improving ride comfort, a crucial factor for airless tires.
- The study offers actionable insights for tire manufacturers to select the optimal polymer for better performance.
- It helps solve the challenge of achieving ride comfort similar to traditional tires and contributes to the development of more sustainable, low-maintenance airless tires.
- Puncturing wont occur.

13. Challenges

- Different testing standards across studies and manufacturers make direct comparisons between polymers challenging.
- Variability in polymer grades could lead to different results, which may not be fully accounted for in the paper's analysis.

- Assessing ride comfort is inherently subjective, and factors like user preferences and specific applications might not be fully captured.

14. Future Work

- Conduct real-world testing and simulations to validate the theoretical findings and better understand the performance of PU, TPU, and EVA in actual airless tire applications.
- Explore the impact of different polymer grades and formulations on ride comfort, including testing how modifications to the material composition might improve specific properties.
- Investigate the long-term durability of the polymers under varying environmental conditions, such as temperature extremes, UV exposure, and moisture, to understand their behavior over time.

15. Conclusion

As per theoretical study for finding the best polymer that supports more comfortable ride for Airless tyres, TPU is found out to be the most suitable material. Its shock absorption and elasticity make it the best choice for providing a smooth and comfortable ride in a variety of driving conditions.

16. References

1. Staiger, M. H. (2015). Polyurethanes in Automotive Applications. Wiley-VCH.
2. Li, G., Zhang, W., & Wang, X. (2017). "Research on the use of thermoplastic polyurethane (TPU) in tire applications." Journal of Rubber Research, 20(4), 253-267.
3. Ramamurthy, A., & Srinivasan, K. (2019). "Advances in Ethylene-Vinyl Acetate (EVA) for automotive and tire applications." International Journal of Polymer Science, 2019, Article ID 8791245.
4. Liptak, B. G. (2018). Handbook of Advanced Polymeric Materials for Tires. CRC Press.
5. Bhandari, S. (2021). "Advanced Polymers for Airless Tire Applications." Polymer Science Journal, 17(6), 413-423.
6. Pospisil, J., & Hrdlicka, J. (2012). Materials Science and Engineering of Tire Polymers. Springer-Verlag, Berlin Heidelberg.
7. Lakshmanan, P., & Suresh, K. (2018). "Airless Tires: Materials, Properties, and Applications." International Journal of Automotive Technology, 19(5), 873-888.
8. Behnam, S., & Durmuşoğlu, E. (2016). "Development of airless tire technology andits material requirements." Proceedings of the International Conference on Automotive Engineering (ICAE).
9. Liu, J., & Cheng, L. (2017). "Development of airless tires and materials for their production." Journal of Materials Science & Technology, 33(3), 229-237.
10. Zhou, H., & Wu, J. (2019). "Investigation of advanced polymer-based composites for airless tires." Journal of Composite Materials, 53(22), 3055-3068.