

Influence of Tire Pressure on Vehicle Dynamic Response

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Abstract: Tire pressure is a critical parameter affecting vehicle performance, safety, and dynamic behaviour. Variations in tire inflation pressure significantly influence ride comfort, handling stability, braking performance, and tire-road interaction characteristics. This study investigates the influence of tire pressure on vehicle dynamic response by analysing its effects on contact patch behaviour, stiffness characteristics, and vibration transmission. The analysis combines theoretical principles with vehicle dynamics concepts to evaluate how underinflation and overinflation impact system performance. Results indicate that deviations from optimal tire pressure alter suspension response, stability behaviour, and energy dissipation mechanisms. The findings emphasise the importance of proper tire pressure management for maintaining vehicle safety and performance.

Keywords: Tire pressure, critical parameter, vehicle performance, safety, handling stability, braking performance, maintaining vehicle safety.

1. INTRODUCTION

Tires serve as the primary interface between a vehicle and the road surface. Beyond providing traction, tires contribute significantly to vehicle dynamics, influencing ride quality, stability, steering response, and braking efficiency.

Tire pressure directly affects:

- Tire stiffness
- Contact patch geometry
- Load distribution
- Vibration characteristics

Improper tire inflation can lead to:

- Reduced handling performance
- Increased rolling resistance
- Uneven tire wear
- Compromised safety

Understanding the dynamic consequences of tire pressure variation is essential for optimising vehicle performance.

2. LITERATURE REVIEW

Previous studies highlight the strong relationship between tire characteristics and vehicle dynamics.

Gillespie (1992) noted that tire stiffness plays a dominant role in ride and handling behaviour. Pacejka (2006) demonstrated that tire pressure significantly affects lateral and longitudinal force generation.

Research findings suggest:

- Underinflated tires → Increased deformation, higher energy losses
- Overinflated tires → Reduced contact patch, harsher ride
- Optimal pressure → Balanced comfort and stability

Studies by Wong (2008) emphasised that tire pressure modifies contact mechanics and vibration transmission.

3. THEORETICAL BACKGROUND

Tire pressure influences tire stiffness:

$$k_{tire} \propto P_{inflation}$$

Where:

- Higher pressure → Increased stiffness
- Lower pressure → Increased compliance

Contact patch behaviour:

$$A_{contact} \propto \frac{Load}{Pressure}$$

Implications:

- Low pressure → Larger contact area
- High pressure → Smaller contact area

These changes affect force transmission and dynamic response.



Figure 3. Effect of tire pressure on tire–road contact patch geometry.

4. METHODOLOGY

This study employs an analytical vehicle dynamics approach.

4.1 Assumptions

- Constant vehicle mass
- Linear suspension behavior
- Uniform road conditions
- Tire pressure treated as variable

4.2 Parameters Evaluated

- Ride comfort response
- Handling stability
- Vibration transmission
- Force distribution

5. DYNAMIC RESPONSE ANALYSIS

5.1 Underinflated Tires

Characteristics:

- Increased tire deformation
- Larger contact patch
- Reduced stiffness

Dynamic effects:

- ✓ Delayed steering response
- ✓ Increased rolling resistance
- ✓ Excessive heat generation
- ✓ Higher energy losses

Ride behaviour:

- Improved absorption of small irregularities
- Reduced high-frequency vibration transmission

5.2 Overinflated Tires

Characteristics:

- Increased stiffness
- Smaller contact patch
- Reduced compliance

Dynamic effects:

- ✓ Sharper steering response
- ✓ Reduced damping capability
- ✓ Increased vibration transmission
- ✓ Reduced grip on uneven surfaces

Ride behaviour:

- Harsher ride
- Increased cabin vibration

5.3 Optimal Tire Pressure

Balanced behaviour:

- ✓ Stable handling
- ✓ Controlled vibration
- ✓ Efficient force transmission
- ✓ Uniform load distribution

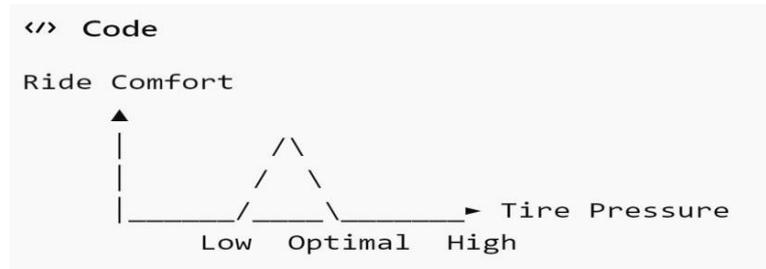


Figure 1. Relationship between tire pressure and ride comfort, showing maximum comfort near the optimal inflation pressure.

Shape of curve:

Bell-shaped / inverted U

6. ENGINEERING INTERPRETATION

Tire pressure acts as a **dynamic tuning parameter**.

Effects on:

Ride Comfort

- Lower pressure → Softer response
- Higher pressure → Stiffer response

Handling Stability

- Higher pressure → Faster response
- Excessive pressure → Reduced grip

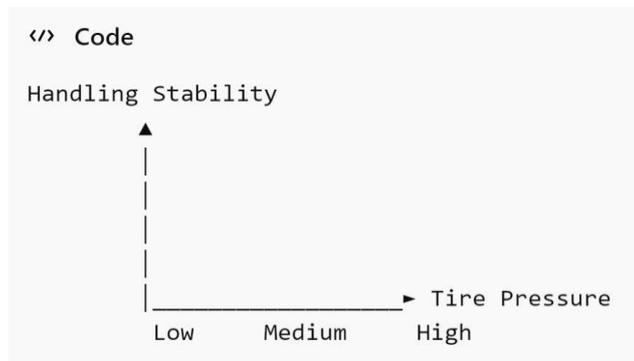


Figure 2. Influence of tire pressure on handling stability, illustrating improved response with increasing pressure.

Shape of curve:

Rising line (possibly slight drop at extreme high)

Energy Efficiency

- Underinflation → Higher rolling losses

7. PRACTICAL IMPLICATIONS

Improper tire pressure leads to:

- Increased fuel consumption
- Reduced braking efficiency
- Compromised stability
- Accelerated tire wear

Engineering recommendation:

- ✓ Maintain manufacturer-recommended pressure
- ✓ Consider load and temperature effects

8. CONCLUSION

Tire pressure significantly influences vehicle dynamic response through its effect on tire stiffness, contact mechanics, and vibration transmission. Both underinflation and overinflation introduce undesirable dynamic behaviours that affect comfort, stability, and safety.

Maintaining optimal tire pressure ensures:

- Improved ride quality
- Enhanced handling stability
- Reduced energy losses
- Extended tire lifespan

Tire pressure management remains a critical aspect of vehicle performance optimisation.

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