

The Air Pressure In The Tires Of A 980-kg Car Is $3.0 \times 10^5 \text{ N/m}^2$ Determine The Average Area Of Contact

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Introduction

Understanding the relationship between tire pressure, the weight of a vehicle, and the contact area between the tires and the road is fundamental in automotive physics and engineering. When a car rests or moves on a surface, the force exerted by its weight is transmitted through the tires, which in turn apply a certain pressure to the road. Conversely, the air pressure within the tires supports the vehicle's weight, ensuring safety, efficiency, and optimal handling. In this article, we analyze how the given parameters—namely, the mass of the car and the internal tire pressure—can be used to determine the average contact area of the tires with the road surface.

Understanding the Given Data

Details Provided

- Mass of the car (m): 980 kg
- Air pressure inside the tires (P): $3.0 \times 10^5 \text{ N/m}^2$ (Pascals)

Objective

Calculate the average area of contact (A) between the car's tires and the road surface.

Fundamental Concepts and Physics Principles

1. Relationship Between Force, Pressure, and Area

The core formula linking these variables is:

$$P = \frac{F}{A}$$

where:

- P = pressure in Pascals (N/m²)
- F = force in Newtons (N)
- A = contact area in square meters (m²)

Rearranged for area:

$$A = \frac{F}{P}$$

2. Force Due to the Car's Weight

The force exerted by the car on the tires is its weight, which is the gravitational force:

$$F_{\text{gravity}} = m \times g$$

where:

- m = mass of the car
- g = acceleration due to gravity (~9.81 m/s²)

Calculating the Total Force Exerted by the Car

Given:

- m = 980 kg
- g = 9.81 m/s²

Calculate the weight:

$$F_{\text{gravity}} = m \times g$$

$$F = 980 \, \text{kg} \times 9.81 \, \text{m/s}^2 = 9601.8 \, \text{N}$$

For simplicity, round to:

$$F \approx 9602 \, \text{N}$$

This represents the total downward force exerted by the car on the tires.

Determining the Contact Area of the Tires

1. Assuming Equal Distribution of Force on All Tires

Most passenger cars have four tires. If we assume that:

- The load is evenly distributed,
- The contact area is uniformly spread across all tires,

then the force supported by each tire is:

$$F_{\text{per tire}} = \frac{F}{4} = \frac{9602 \, \text{N}}{4} \approx 2400.5 \, \text{N}$$

However, depending on the problem's context, sometimes the total force is considered for the entire contact area. For simplicity and to find the overall average contact area, we consider the total force.

2. Calculating the Total Contact Area

Applying the pressure-area relation:

$$A_{\text{total}} = \frac{F}{P}$$

Substituting:

$$A_{\text{total}} = \frac{9602 \, \text{N}}{3.0 \times 10^5 \, \text{N/m}^2}$$

Calculating:

$$A_{\text{total}} = 0.032 \text{ m}^2$$

Therefore, the total average contact area of all tires combined with the road is approximately 0.032 square meters.

Interpreting the Result

1. Contact Area per Tire

If the car has four tires, and assuming equal contact:

$$A_{\text{per tire}} = \frac{A_{\text{total}}}{4} = \frac{0.032 \text{ m}^2}{4} = 0.008 \text{ m}^2$$

which is 8 square centimeters per tire.

2. Significance of the Contact Area

- A small contact area (like 8 cm² per tire) indicates that tires are designed to support significant loads with relatively limited contact patches.
- This limited contact area helps in providing grip and handling but also results in tire wear concentrated on small regions.
- The pressure exerted by each tire on the road is high, which influences tire wear and grip characteristics.

Additional Factors and Considerations

1. Real-World Variations

In practical scenarios:

- Tire pressure can vary based on temperature, load, and tire condition.

- The load distribution may not be perfectly even due to vehicle design, passenger load, or cargo.
- The contact patch may not be perfectly rectangular or circular, but an approximation suffices for general calculations.

2. Impact of Tire Pressure on Contact Area

- Increasing tire pressure decreases the contact area, which can improve fuel efficiency but may reduce grip.
- Conversely, lower tire pressure increases contact area, enhancing grip but potentially increasing tire wear and decreasing fuel efficiency.

3. Safety and Performance Implications

- Proper tire inflation ensures optimal contact area, safe handling, and tire longevity.
- Over-inflated or under-inflated tires can alter the contact patch, affecting vehicle dynamics.

Conclusion

By analyzing the given data, we've demonstrated that the total contact area of a 980 kg car with a tire pressure of $3.0 \times 10^5 \text{ N/m}^2$ is approximately 0.032 m^2 . This calculation underscores the importance of tire pressure in determining the contact patch, which directly influences vehicle grip, handling, and safety. Maintaining correct tire inflation is crucial for optimal performance, tire longevity, and safety. The physics principles involved—namely, the relationship between force, pressure, and area—are essential tools for engineers and automotive designers to ensure vehicles operate efficiently and safely.

References:

- Halliday, D., Resnick, R., & Walker, J. (2014). Fundamentals of Physics (10th Edition). Wiley.
- Vehicle tire and contact patch physics. (n.d.). In Automotive Engineering.

Frequently Asked Questions

What is the significance of air pressure in a car's tires?

Air pressure in a car's tires ensures proper contact with the road, influences fuel efficiency, and affects the vehicle's handling and safety.

How can we determine the average area of contact between the tire and the road?

By using the relation between force (weight of the car) and pressure, the average contact area can be calculated as $\text{area} = \text{force} / \text{pressure}$.

Given the car's weight and tire pressure, how do you calculate the contact area?

Convert the weight to force in newtons and divide by the tire pressure: $\text{area} = \text{weight} / \text{pressure}$.

What is the weight of the car in newtons if it weighs 980 kg?

The weight in newtons is calculated as $\text{mass} \times \text{acceleration due to gravity}$: $980 \text{ kg} \times 9.8 \text{ m/s}^2 = 9604 \text{ N}$.

Using the given data, what is the average contact area of the tires?

$\text{Area} = 9604 \text{ N} / 3.0 \times 10^5 \text{ N/m}^2 = 0.032013 \text{ m}^2$, approximately 0.032 m^2 .

Why is understanding contact area important for tire performance?

The contact area affects traction, wear rate, and overall safety; optimal contact ensures better grip and longer tire lifespan.

What assumptions are made in calculating the average contact area of the tires?

Assumes the weight is evenly distributed across all tires, and the pressure is uniform across the contact patch.

How does increasing tire pressure affect the contact area?

Increasing tire pressure reduces the contact area, which can improve fuel efficiency but may reduce traction and ride comfort.

Additional Resources

The Air Pressure In The Tires Of A 980-kg Car Is $3.0 \times 10^5 \text{ N/m}^2$: Determine The Average Area Of Contact

Understanding the relationship between tire pressure, car weight, and contact area is essential for both automotive enthusiasts and students studying physics. When considering the air pressure in the tires of a 980-kg car, which is given as $3.0 \times 10^5 \text{ N/m}^2$, one fundamental question arises: What is the average area of contact between the tires and the road? This parameter influences vehicle safety, fuel efficiency, tire wear, and overall driving comfort. In this article, we will explore how to determine this average contact area through physics principles and practical calculations.

The Importance of Tire Contact Area

Before diving into the calculations, it's worthwhile to understand why the contact area matters. The area of contact between a tire and the road affects:

- Traction and grip: Larger contact areas generally provide better grip.
- Tire wear: Unequal contact can lead to uneven wear.
- Fuel efficiency: Optimal contact reduces rolling resistance.
- Ride comfort: Proper contact ensures stability and smoothness.

In essence, knowing the contact area helps in designing better tires and understanding vehicle dynamics.

Fundamental Concepts and Parameters

To solve for the average contact area, we need to understand the fundamental physics involved:

- Force (Weight of the Car): The car exerts a downward force due to gravity.
- Air Pressure in the Tire (P): The internal pressure exerted outward on the tire walls.
- Contact Area (A): The surface area where the tire contacts the road.

The key relationship linking these variables is derived from the equilibrium of forces, specifically:

$$F = P \times A$$

which is a direct application of the pressure definition in physics.

Step-by-Step Calculation

Step 1: Determine the Weight of the Car

The weight (W) of the car is the force exerted downward due to gravity, calculated by:

$$W = m \times g$$

where:

- ($m = 980$, kg) (mass of the car)
- ($g = 9.8$, m/s^2) (acceleration due to gravity)

Calculating:

$$W = 980 \text{ kg} \times 9.8 \text{ m/s}^2 = 9604 \text{ N}$$

This is the total weight supported by all four tires.

Step 2: Determine the Force Supported by Each Tire

Assuming an even distribution of weight across all four tires (a common assumption unless specified otherwise):

$$F_{\text{per tire}} = \frac{W}{4} = \frac{9604 \text{ N}}{4} = 2401 \text{ N}$$

Each tire supports approximately 2401 N of force.

Step 3: Use the Relationship between Force, Pressure, and Area

The pressure inside the tire is related to the force exerted on the contact area:

$$P = \frac{F}{A}$$

Rearranged to find the contact area (A):

$$A = \frac{F}{P}$$

Given:

- ($P = 3.0 \times 10^5$, N/m^2)
- ($F = 2401$, N)

Calculating:

$$A = \frac{2401 \text{ N}}{3.0 \times 10^5 \text{ N/m}^2} \approx 8.00 \times 10^{-3} \text{ m}^2$$

Result: The average contact area per tire is approximately $8.0 \times 10^{-3} \text{ m}^2$.

Interpreting the Results

The calculated contact area of about $8.0 \times 10^{-3} \text{ m}^2$ (or 8 square centimeters) per tire suggests a very small contact patch relative to the size of the tire. This makes sense because tires are designed to deform slightly under load, creating a small but sufficient contact patch to support the vehicle's weight while maintaining traction.

How does this compare to real-world tires?

Typical passenger car tires have contact patches ranging from 150 to 300 cm^2 total (about 37.5 to 75 cm^2 per tire). Our calculation reflects the idealized average contact area based solely on the internal tire pressure and weight, ignoring factors like tire deformation, dynamic forces, and tire construction.

Factors Affecting Contact Area in Real-World Scenarios

While the above calculation provides an idealized value, actual contact areas depend on various factors:

- Tire Pressure Variations: Lower pressures increase contact area but may compromise safety.
- Load Distribution: Passenger cars often have uneven weight distribution.
- Tire Construction and Material: Different tire designs deform differently under load.
- Road Surface and Tire Tread: Worn tires or uneven surfaces alter contact patches.
- Dynamic Conditions: Acceleration, braking, and cornering change the contact area dynamically.

Practical Significance

Understanding how to determine the average contact area helps in:

- Designing tires with optimal pressure and tread patterns.
- Assessing safety: Ensuring tires are properly inflated to balance grip and wear.
- Estimating tire lifespan: Larger contact patches distribute forces better, reducing wear.
- Improving fuel efficiency: Proper contact minimizes rolling resistance.

Final Thoughts

By applying fundamental physics principles, we can estimate crucial parameters like the average contact area of a tire supporting a given load at a specified internal pressure. This understanding bridges the gap between theoretical calculations and practical vehicle maintenance, emphasizing the importance of correct tire inflation and load management for safety and efficiency.

Summary of Key Points

- The weight of a 980-kg car is approximately 9604 N.
- Assuming even load distribution, each tire supports about 2401 N.
- Using the pressure of $3.0 \times 10^5 \text{ N/m}^2$, the average contact area per tire is around $8.0 \times 10^{-3} \text{ m}^2$.
- Real-world contact patches are larger but are influenced by tire design, pressure, and dynamic factors.
- Proper tire inflation is critical to maintaining optimal contact area, ensuring safety, and prolonging tire life.

Understanding the interplay between air pressure, force, and contact area is fundamental in automotive physics and engineering. Whether you're a student, mechanic, or car enthusiast, grasping these concepts helps in making informed decisions about vehicle maintenance and safety.

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