

Impact of Technical Condition of Tires (Motorcycles) on Passenger Safety

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Abstract

Motorcycles are a ubiquitous mode of transportation in Malaysia, with millions of riders navigating the country's roads daily. Despite their convenience and flexibility, motorcycles are also prone to accidents, which can have far-reaching consequences for both riders and pedestrians. The safety, performance, and efficiency of a motorcycle are heavily dependent on its tire components, which play a critical role in maintaining traction, stability, and control on the road. The primary objective of this research project is to investigate the impact of tire pressure on fuel consumption in motorcycles. To achieve this goal, a Honda Wave Alpha motorcycle was employed as the test vehicle, with experiments conducted at various tire pressure conditions: normal inflation, under-inflation, and over-inflation. The experiment was conducted at the Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh campus, with a goal distance of 19 km under dry conditions. The results indicated that normal tire pressure conditions yielded the best fuel efficiency, with a consumption rate of 450 milliliters per 19 Km, while under-inflation and over-inflation led to increased fuel consumption by 5.18% and 7.40%, respectively. By examining the relationship between tire pressure and fuel consumption, as well as investigating the attitudes and behaviors of motorcycle riders towards tire maintenance, this research provides valuable insights that can inform strategies for improving road safety and reducing the risk of accidents involving motorcycles in Malaysia.

1. Introduction

The number of road traffic fatalities in Malaysia is skyrocketing. The development of the motorization sector is one of the causes of road accidents. Even though various preventive measures have been implemented to reduce the rate of road accidents, the situation is extremely critical [1]. More concerningly, According to statistics, Malaysia has the highest road fatality risk (per 100,000 population) among ASEAN countries, with motorcyclists accounting for more than half of all fatalities [2]. According to Royal Malaysian Police national statistics, motorcyclists are responsible for a significant proportion of fatal accidents. The accidents have also resulted in a total loss of 8.85 billion in 2019 [3].

Tires are crucial for vehicle safety and performance, as they handle all driving, braking, and steering forces through a small contact patch. They support the vehicle's weight and provide necessary traction for acceleration, braking, and steering. Proper air pressure and tire structure are essential for load-bearing and weight

distribution. Motorcycle tires come in various types, including off-road, touring, cruiser, sport-touring, and sport tires [4]. Each type is designed for specific conditions and riding styles, with features like different tread patterns, construction, and compounds to enhance performance. For example, off-road tires have deeper treads for better traction on unpaved surfaces, while touring tires offer comfort for long-distance travel.

Proper tire pressure is vital for safety and efficiency. Most manufacturers recommend pressures between 28 to 40 PSI, typically around 32 PSI for optimal traction [5]. Correct tire pressure extends tire life, improves fuel efficiency, and enhances vehicle performance. Advanced tire pressure monitoring systems (TPMS) can help maintain proper pressure by monitoring tire conditions in real-time, though they can be costly and occasionally give false alarms [6].

Various factors affect tire condition, including wear from mileage, aging, and the impact of under-inflation or over-inflation. Regular inspections and maintenance are necessary to ensure tires remain safe and effective. Correct tire pressure balance helps maximize traction, reduce wear, and ensure a comfortable and safe driving experience.

2. Material and Method

This chapter explains the method used in this study in detail. It provides step-by-step procedures for addressing the issue in a specific field. The research methodology describes the methods, approaches, and strategies used, highlighting their benefits and practical applications.

2.1 Materials

The primary focus of this project is to investigate how different tire pressures affect fuel consumption. To achieve this, several key components and software tools have been selected.

- PROSKIT NT-312 Digital Temperature and Humidity
- Tire Pressure Gauge
- Cycle GPS Logger Apps

The sensor selected for this experiment is the PROSKIT NT-312 Digital Temperature and Humidity meter with probe. This sensor's range is suitable for our experiment, and its accuracy ensures precise data collection. The experiment is conducted in dry conditions, requiring temperatures above 32°C and humidity levels below 60% to maintain optimal measurement conditions.

The tire pressure gauge has been selected for this experiment. It is connected directly to the tires to ensure they maintain the appropriate pressure throughout the study. This gauge is straightforward to operate and makes data extraction simple and efficient.

The Cycle GPS Logger app was selected for its user-friendly interface and compatibility with smartphones. It conveniently displays key travel metrics like elapsed time, average speed, total distance, and maximum speed attained during the experiment. This app simplifies data extraction and analysis, making it straightforward for users to interpret and utilize the gathered information.

2.2 Method

The flowchart in Figure 1 outlines a systematic process for researching the effects of tire inflation pressure on motorcycle performance. It begins with defining the research title, objectives, and scope, ensuring a focused and relevant study. Following this, a literature review is conducted to understand the current knowledge and identify gaps. The next step involves studying the fundamental principles related to tires, their inflation pressure, and their impact on the fuel system. With this foundational knowledge, the necessary experiment equipment is prepared.

A test run of the experiment is then conducted to ensure that all equipment and procedures function correctly. If the test run is unsuccessful, adjustments are made before trying again. Once the test run is successful, the equipment is installed on the motorcycles. If there are issues with the installation, these are addressed, and the process is repeated until successful. The actual experiment is then conducted, collecting data on the effects of tire inflation pressure.

After the experiment, data analysis is performed to draw meaningful conclusions. If the analysis reveals issues or incomplete results, further experimentation or refinement of data collection methods is carried out. Successful data analysis leads to a discussion of the findings, comparing them with existing literature and theories. Finally, based on the findings, recommendations are made, and conclusions are drawn regarding the impact of tire inflation pressure on motorcycle performance. This structured approach ensures the research is thorough, iterative, and reliable.

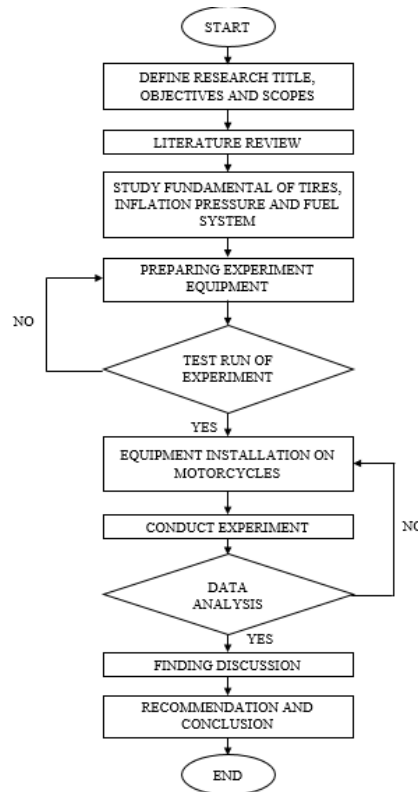


Figure 1 Flowchart of the Project

2.2.1 Testing Routes Map

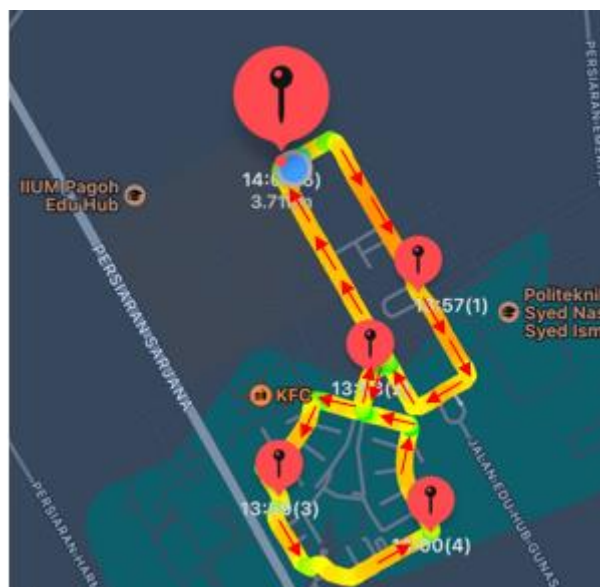


Figure 2 UTHM Pagoh road map

The chosen route is UTHM Pagoh Road. This route meets the criteria of a principal road, with minor inclines, declines, and curves. It includes linear segments, bends, and campus safety speed limits. The gold-highlighted path in the graphic shows the route the Honda Wave Alpha motorcycle will take, starting from the parking lot at Pagoh futsal shared facilities, following the gold-colored road, and returning to the starting point. According to the Cycle GPS Logger application, which uses satellite tracking to measure speed and distance, the UTHM route is 3.8 kilometers. To reach the study's target of 19 kilometers for examining the effect of tire pressure on motorcycle fuel consumption, the motorcycle must complete 5 rounds of the gold-colored route shown in Figure 2.

3. Result and Analysis

3.1 Result of Contact Surface of Motorcycle Tires on Different Inflation

Tires Conditions	Normal Inflation	Under-Inflation	Over-Inflation
Front tire pressure (Psi)	25	22	28
Average contact surface diameter (mm)	25.48	26.89	25.51
Rear tire pressure (Psi)	29	26	32
Average contact surface diameter (mm)	29.27	33.23	29.66

Table 1 Results of contact surface of tires

The experiment studied how different tire pressures affect the contact surface diameter of a motorcycle's tires, focusing on both the front and rear tires. For the front tire, three pressure conditions were analyzed. Normal inflation, under-inflation, and over-inflation. At normal inflation (25 psi), the average contact surface diameter was 25.48 mm. Under-inflation (22 psi) increased it to 26.89 mm, while over-inflation (28 psi) slightly increased it to 25.51 mm. Similarly, for the rear tire, normal inflation (29 psi) resulted in an average contact surface diameter of 29.27 mm. Under-inflation (26 psi) significantly increased it to 33.23 mm, and over-inflation (32 psi) slightly increased it to 29.66 mm. These findings demonstrate that under-inflation enlarges the contact area for both tires, affecting grip, stability, and handling, while over-inflation has a smaller effect. Understanding these changes is crucial for maintaining motorcycle performance and safety.

3.2 Results of Fuel Consumption at Varies Tires Inflation

	Under-inflation	Normal inflation	Over-inflation
Front tire pressure (kPa)	22	25	28
Rear tire pressure (kPa)	36	29	32
Load driver (Kg)	52		
Total average speed (Km/h)	35.73	35.20	36.13
Total average fuel used in 19 Km (ml)	473.33	450	483.33
Total average time taken for 19 Km (s)	356.0	363.6	352.2
Temperature (°C)	33.55	33.53	32.11
Humidity (%)	53.53	53.47	53.07

Table 2 Results of Fuel Consumption at Various Tire Inflation

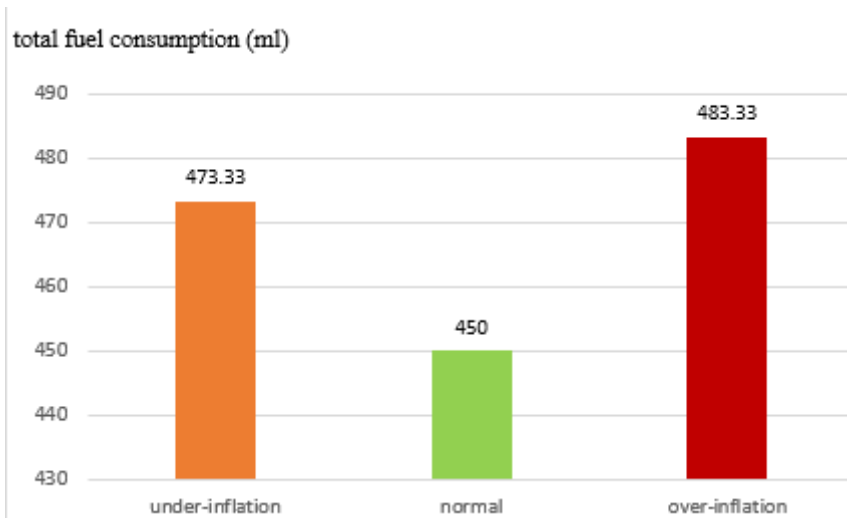


Figure 3 Comparison of Fuel Consumption against Different Tire Inflation

As shown in Figure 3 and Table 2, when the tires were inflated to the recommended pressure (normal inflation), the motorcycle achieved optimal fuel efficiency, consuming 450 ml for 19 km. This indicates that performance factors like traction, stability, and rolling resistance were most efficient under these conditions. Properly inflated tires maintain an ideal contact patch with the road, minimizing resistance and enhancing fuel economy.

Under-inflated tires increased fuel consumption to 473.33 ml for every 19 km, a 5.18% rise. This is due to the larger contact surface and higher rolling resistance, making the engine work harder and using more fuel. Under-inflation also causes uneven tire wear and can compromise handling and safety.

Over-inflated tires increased fuel consumption to 483.33 ml for every 19 km, a 7.41% rise. Though they reduce rolling resistance and use less fuel, over-inflation leads to a rougher ride, reduced traction, and uneven wear concentrated in the tire center.

The comparison highlights the importance of maintaining proper tire pressure for optimal fuel efficiency. Normal inflation provides a balanced approach, ensuring safety, performance, and moderate fuel consumption. Under-inflation increases fuel consumption and can lead to safety issues and uneven wear. Over-inflation decreases fuel consumption but may negatively impact ride comfort, traction, and tire wear. Maintaining recommended tire pressure is crucial for the best balance between fuel efficiency, handling, and tire longevity, leading to significant fuel savings and improved overall performance.

3.3 The Correlation Between the Contact Surface of Tires with Different Inflation Levels and Fuel Consumption

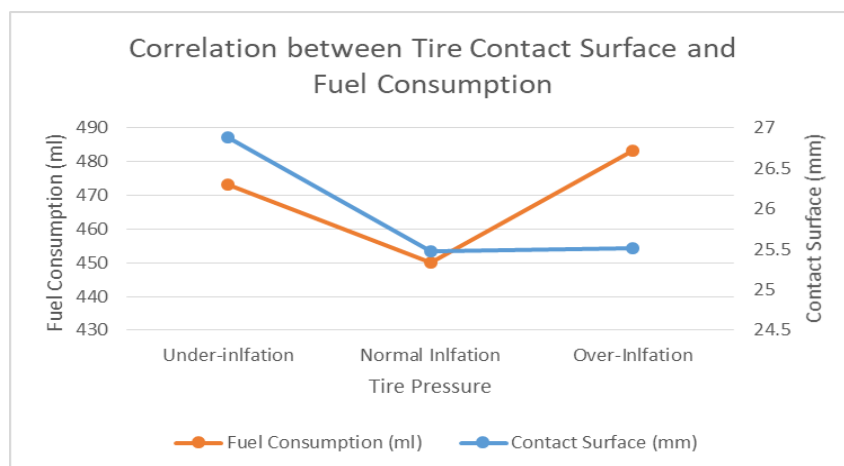


Figure 4 Correlation between Contact Surface Tire and Fuel Consumption

The graph titled "Correlation between Tire Contact Surface and Fuel Consumption" shows how different tire inflation levels affect fuel consumption and contact surface diameter.

Under-inflation leads to higher fuel consumption at about 473.33 ml and increases the contact surface diameter to around 26.89 mm, the highest of the three conditions. Normal inflation results in the lowest fuel consumption at approximately 450 ml and a balanced contact surface diameter of about 25.48 mm, indicating optimal efficiency. Over-inflation increases fuel consumption to about 483.33 ml. The contact surface diameter is slightly higher than normal inflation at around 25.51 mm, but the change is minimal.

The graph highlights that under-inflated tires consume the most fuel due to higher rolling resistance, while normal inflation offers the best balance of low fuel consumption and optimal contact surface. Over-inflation, though slightly reducing rolling resistance, still results in higher fuel consumption than normal inflation. Maintaining proper tire pressure is crucial for fuel efficiency and tire performance.

4. Conclusion

This study aimed to analyze tire contact surface areas at different pressure levels. Under normal pressure, the front tires' contact area averages 25.48 mm and the rear tires 29.27 mm. Under-inflation increases the front contact area to 26.89 mm and the rear to 33.23 mm, while over-inflation decreases it to 25.51 mm for the front and 29.66 mm for the rear. The study also found that tire pressure affects fuel consumption. Normal pressure averages 450 ml, under-inflated tires use 473.33 ml, and over-inflated tires use 483.33 ml, showing a clear link between tire pressure and fuel use. For safety, correct tire pressure is crucial. Under-inflated tires increase fuel use and risk of overheating, blowouts, and poor handling. Over-inflated tires reduce road grip, leading to longer stopping distances and less control, especially on wet surfaces.

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