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Study of Two-wheel Vehicle's fuel consumption under the Influence of tire Inflation Pressure

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Abstract

The value of air pressure in the tire not only supports the entire weight of the vehicle, it also plays a crucial role in improving the vehicle's performance, reducing friction, providing comfort, boosting economy and enhancing safety. This study deals with the influence of tire inflation pressure on fuel consumption at various road conditions and speeds. The experimental test was performed riding a motorcycle of 180cc and using a mileage measuring kit to find the effect of tire pressure on three different road surfaces i.e., highway, earthen and graveled. The standard tire pressure for both front and rear tires recommended by the manufacturing company was also evaluated to observe the change in mileage. The results showed that the highest mileage of 55.97 km/L was obtained on the highway among the defined three road conditions and a linear drop of 5psi in tire pressure led to loss of mileage up to 6.11% in highway, 5.35% in earthen and 2.80% in graveled road. Also, the variation in speed resulted to compensation of mileage by nearly 39.9% maximum. These results highlight the importance of keeping the correct value of tire inflation pressure in relation to fuel consumption.

Keywords: Fuel consumption; Mileage; Road surface; Tire inflation pressure; Two-wheeler

1. Introduction

Driving a vehicle with inappropriate tire pressure is a great challenge. Inflation pressure is directly associated with the overall performance of a vehicle which includes handling, rolling friction, comfort, stability, safety and economy. It is a key factor for determining better mileage as there is a correlation between rolling resistance and fuel consumption [1], [2]. The higher the rolling resistance is, the more energy is required from the engine to move the vehicle forward and hence more fuel is burnt [3]–[5]. Since it is a matter of consent for saving fuel and uplifting mileage of vehicles, immense contributions have been made regarding the manufacturing of tires as well as structuring the surface texture of roads to minimize rolling resistance [6]–[8].

The manufacturer defines a correct tire pressure, owners, drivers and mechanics do not apply it in practice. They drive mostly at inappropriate pressure in every road condition neglecting the effect on mileage. As a result, filling the tire with a higher amount of pressure above the recommended level of the manufacturer (over inflation) lessens the contact area of the tire with the road leading to improper traction [7] and cause bumpier ride with uneasiness in handling [9]. On the other side, underfilling of tire pressure (under inflation) increases friction and cause-effect on life span, stability and performance while running [10]. Tire pressure fluctuates because of various factors like temperature differences due to friction, aerodynamic drag of rolling wheels[11], gradual leakage, etc. which are not noticeable to our eyes unless the tire becomes completely flat. Accurate tire pressure is required to contribute to the safety of both the rider and the road user [12]–[14]. So, systematic checkups of tire pressures and regular maintenance must be done to save hundreds of crashes and reduce fuel consumption to a greater extent.

The study is intended to observe the influence of inflation pressure on two-wheel vehicles' mileage in three major different road conditions; highway, earthen, and graveled compared to the standard nominal inflation pressure. Additionally, experimental evaluation of data is performed to dig out a proper range of tire pressure to achieve excellent mileage in those road conditions. The influence of speed over mileage is also aimed to be interpreted alongside.

2. Materials and Methodology

2.1 *Specification of vehicle and tire*

In this study, the motorcycle used was a Bajaj Pulsar 180 shown in Figure 1(a) with engine type; single cylinder, 4-stroke, 2-valve, twin spark, DTS-I Engine and displacement of 178.6 cc. The tires

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shown in Figure 1(b) and Figure 1(c), used in the motorcycle were tubeless and radial type of MRF brand. The tire notation is 90/90-17 (for Front) and 120/80-17 (for Rear) with the maximum load capacity of 185 kg at 225 KPa (Front) and 257 kg at 230 KPa (Rear). The recommended pressure by the manufacturing company is 28psi for the front and 30psi for a rear tire in single load condition.

(a) (b) (c)

Figure 1:(a) Motorcycle used, (b) Front tire, (c) Rear tire

2.2 Measurement tools and procedure

Before starting the experimental process, a survey among 100 people was done in which 46.5% of people responded that they check the tire inflation pressure of their vehicle occasionally. Also, 87.1% of them said speed affects the mileage and 61.4% found difficulty in handling when tire pressure was underinflated. In the same way, 56% of people responded their vehicle consumed more fuel when the tire was underinflated which is shown in Figure 2. The results of the survey directly concluded that tire inflation pressure of tire plays a great role in affecting the mileage of vehicles.

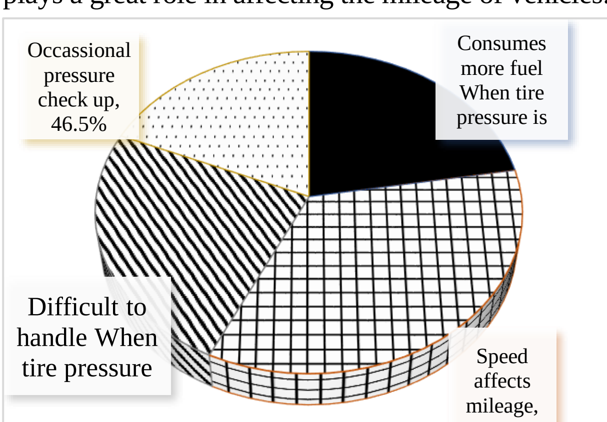

Figure 2: Result of survey

Thus, to evaluate that problem, this experimental study was carried forward in different road conditions.
To proceed with the experiment, several measuring tools shown in Table 1 were used in every section of the study. For this, a mileage kit (Figure 4 (a)) was filled with the required amount of fuel and connected to the carburetor of a motorcycle with the help of a delivery pipe as shown in Figure 5(a). Tire pressure reading was noted with the help of a pressure gauge as in Figure 5(b) and readings of distance and speed were taken from the digital speedometer of the motorcycle as in Figure 5(c). And on varying tire pressure from 34psi (max) to 10psi (min), all the data were collected for evaluation. During all these processes, the weight of the motorcycle and rider (single) was kept constant (i.e., 140kg and 65kg respectively). Distance for all the cases is kept at 10km (±100m). Data were collected by varying the road conditions as; Highway, Earthen and Gravel as shown in Figure 3. As the contact area between tire and road differs from road to road along with the variation in speed [1], the effect of tire inflation pressure on mileage was observed in all these road conditions initially.
Then further data were gathered to find an optimum range of tire pressure singly for all these three road conditions at which maximum mileage can be gained. Alongside, the effect of speed on mileage was also evaluated starting from 20km/h to a maximum speed of 80 km/h.

(a) (b) (c)

Figure 3: Road types used for study: (a) Highway Road, (b) Earthen Road, (c) Gravel Road

Table 1. List of tools and materials used

Materials/Tools	Specifications
Mileage measuring kit	300ml, plastic made
Pressure Gauge	0-110 psi range
Fuel delivery pipe	2mm ϕ, rubber
Measuring flask	100 ml, plastic made
Fuel	Petrol

(a) (b) (c) (d)

Figure 4: Measurement tools used: (a) Mileage measuring kit, (b) Pressure gauge, (c) Delivery pipe, (d) Measuring flask

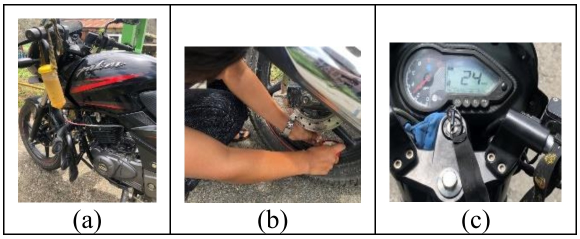

Figure 5: Glimpse of data collection: (a) Connection of mileage kit to carburetor, (b) Measuring tire pressure, (c) Running motorcycle

3. Results and Discussion

3.1 *Influence of speed on mileage*

To assess the relation between speed and mileage, data were collected at a constant inflation pressure of 28psi in Front and 30psi in Rear tires. Speed was varied from 20 km/h to 80 km/h with a range of ±10km/h. Mileage is increased by 20.9% up to 30-40 km/h and drop is faced up to 27.35% at the speed range of 80 km/h while comparing with obtained average mileage i.e.,46.79 km/L. The average mileage obtained is 3.9% higher than the standard mileage of a motorcycle (Bajaj Pulsar 180). Mileage is directly affected by speed so it is necessary to ride a motorcycle in a good speed range.

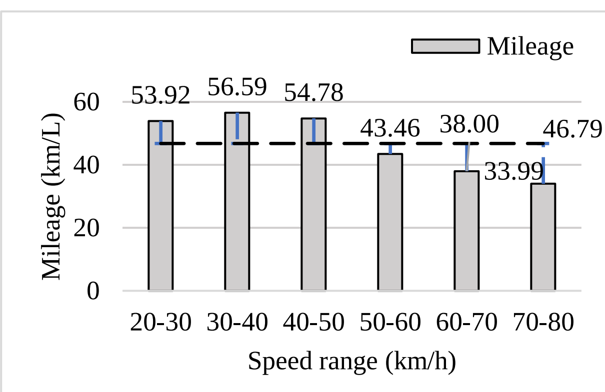

Figure 6. Mileage at different speed range in highway

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3.2 *Effect of inflation pressure on mileage*

Speed range was kept possibly slower to 20-25km/h concerning the effect of speed on mileage and safety, and pressure was filled equally in both front and rear tires. When the pressure was gradually decreased by 5psi, the mileage of the motorcycle was observed to be in decreasing as shown in Table 2. Decrease in pressure from 30psi to 25psi resulted to a drop of 6.11%, 5.32% and 2.80% in highways, earthen roads and graveled roads respectively as the low tire pressure cause increase in rolling resistance and fuel consumption [3]. The drop after 25psi showed a liner change in mileage of around 1% only. So, in order to prevent loss in mileage, tire inflation pressure must be kept around 30psi.

3.3 *Effect of road condition on mileage*

Speed range was kept possibly slower to 20-25km/h concerning the effect of speed on mileage and safety, and pressure was filled equally in both front and rear tires. When pressure was gradually decreased by 5psi, mileage of motorcycle was observed to be in decreasing as shown in Table 2. Decrease in pressure from 30psi to 25psi resulted to a drop of 6.11%, 5.32% and 2.80% in highway, earthen road and graveled road respectively as the low tire pressure cause increase in rolling resistance and fuel consumption [3]. The drop

Table 2. Mileage at different tire pressures in different roads

S.N	Tire Pressure (Psi)	Highway road Mileage (km/L)	Earthen road Mileage (km/L)	Gravel road Mileage (km/L)
1.	30F-30R	55.97	52.55	49.28
2.	25F-25R	52.55	49.75	47.90
3.	20F-20R	52.55	49.52	47.24
4.	15F-15R	52.02	48.58	47.03
5.	10F-10R	51.50	48.35	46.60

after 25psi showed a linear change in mileage of around 1% only. So, to prevent loss in mileage, tire inflation pressure must be kept around 30psi.

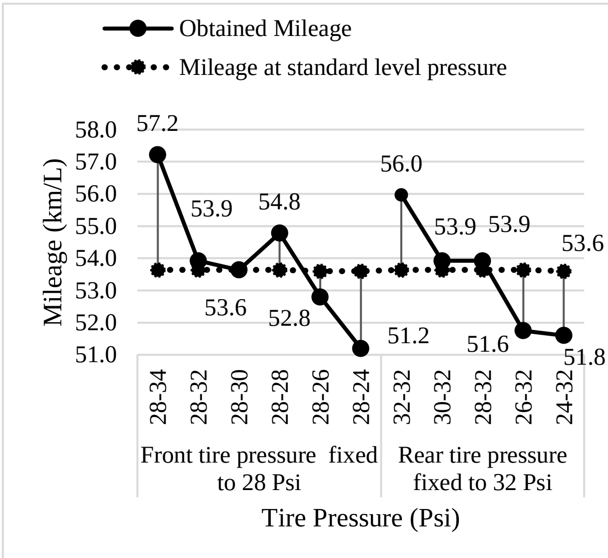

Figure 7. Mileage at different tire pressures on highway

3.3.1 Highway

To find the best inflation pressure range of tires for better mileage on highway roads, several data were collected at a speed range of 20-25km/h and changing tire pressures. The front tire is filled with maximum pressure of up to 32 Psi and a minimum of up to 24 Psi whereas the rear tire is filled up to a maximum of 34 Psi and a minimum value of 24 Psi.

The obtained data in Figure 7 shows that the highest mileage of 57.22 km/L is achieved at a tire inflation pressure of 28 Psi in the Front tire and 34 Psi in the Rear tires followed by mileage of 56 km/L at the pressure of 32 Psi in both front and rear tires. These data portray that, the best mileage can be achieved on highway roads when inflation pressure is slightly increased from the recommended value i.e., from 28 Psi to a maximum of 32 Psi in the front tire and from 30 Psi to a maximum of 34 Psi in the rear tire. The mileage at a standard tire pressure of 28 Psi in front and 30 Psi on highway road is calculated to be 53.64 km/L.

3.3.2 Earthen Road

Testing of mileage on varying tire pressure in earthen roads revealed that appropriate inflation pressure for the finest mileage is from 28psi to a maximum of 30psi in the front tire and from 30psi to a maximum of 34psi in the rear tire. From the interpretation of collected data in Figure 8, we can see that, at the recommended level of inflation pressure (28F-30R), the amount of fuel consumed is 200 ml which gives a mileage of 51.50 km/L only. When the pressure is increased from the recommended level, the mileage is also seen increasing and reaches up to 53.1 km/L while on the other hand, the decrement in tire pressure showed the fall of mileage up to 47.2 km/L.

It was observed that if the tire pressure of the rear tire is increased above standard level by 4 Psi and 2 Psi, then there was an increment in the mileage which resulted in mileage of 53.09 km/L and 51.8 km/L respectively. But when the pressure was decreased by 2 Psi below standard level then mileage decreased to 48.8 km/L. Also, the variation in pressures of the front tire didn't obtain good mileage as all the obtained data were below the mileage of the standard pressure level. Analysis of collected data concluded that a peak mileage of 53.1 km/L is gained at an inflation pressure of 28 Psi in the front tire and 34 Psi in the rear tire. The tire pressure of the front tire shouldn't be increased or decreased from the standard level on earthen roads to prevent loss of mileage.

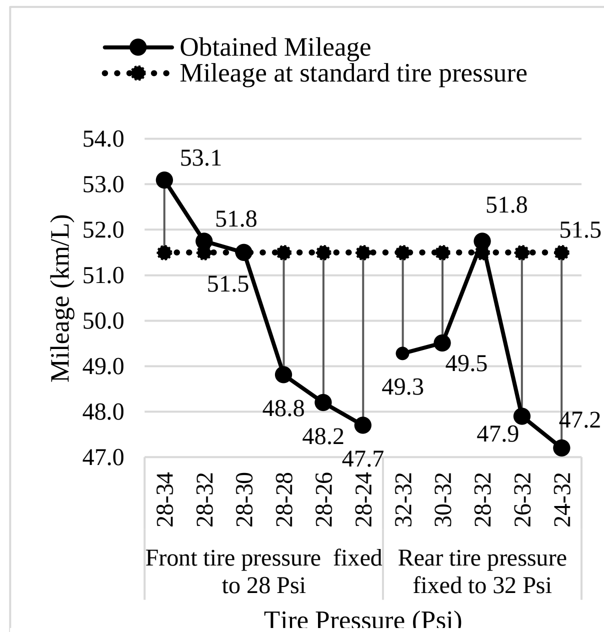

Figure 8. Mileage at different inflation pressure on earthen road

3.3.3 Gravel Road

The rough surface and uneven land structure of the gravel road led to the consumption of fuel of 208 ml at the recommended tire pressure (28F-30R) which gives the mileage of 49.51 km/L as shown in Figure 9. Maximum mileage of 51.5 km/L was obtained at the inflation pressure of 28 Psi in Front and 34 Psi in the rear tire followed by 50 km/L at 28 Psi in front and 28 Psi in the rear tire. And minimum mileage of 48.8

km/L was obtained at a tire inflation pressure of 28 Psi in front and 32 Psi in rear tire.

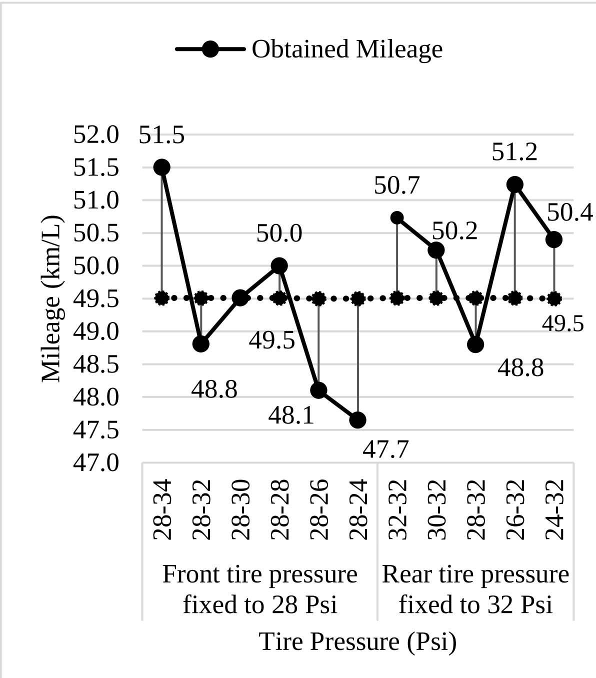

Figure 9. Mileage at different inflation pressures on gravel road

Evaluation of data showed that leading mileage can be achieved in gravel roads if the front tire is filled with a variation of ±2 Psi at recommended standard pressure (28 Psi) as mileage of 51.2 km/L is gained at 26 Psi in the front tire. When the rear tire is filled with a variation range up to 34 Psi from standard pressure (30 Psi), better mileage can be achieved on gravel roads.

Note: Higher tire pressure on gravel roads gives a bumpier ride, so it depends upon the rider whether to focus on the economy of the vehicle or the comfort of riding and it is suggested to keep the tire pressure of 26 Psi in front and 32 Psi in rear tire rather than higher

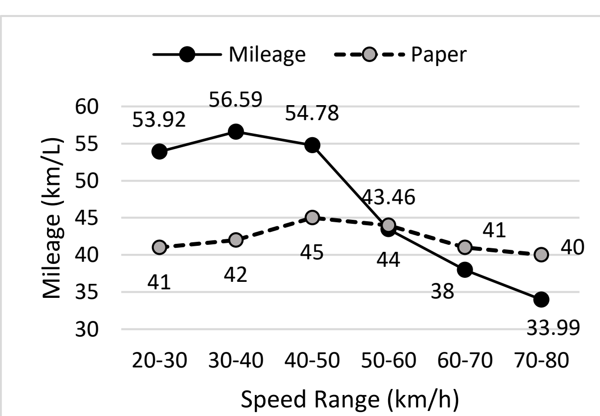

Figure 10. Comparison of experimental data and data from [11]

value of 34 Psi or 32 psi to experience less jerk.

3.4 Validation of Obtained Data

The experiment for the influence of speed on mileage is performed at different speed ranges at standard tire pressure (28 Psi in front tire and 30 Psi in rear tire). Obtained data are compared with the recent experiments performed by other researchers for the validation of those obtained data.

As obtained from [12]'s experiment data and the experimental data obtained for the speed range from 20 km/h to 80 km/h are approximately similar and both the experiments show a declining nature of

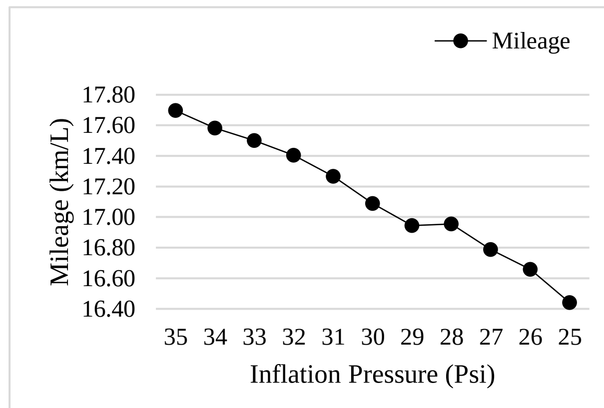

Figure 11. Mileage data from experiment of [13]

mileage when there is an increment in speed, they are compared below where the experimental data of this study is shown in Figure 10. From the graph, we can see that mileage has increased up to the speed range of 30-40 km/h and started declining onwards.

From both experimental data we can see that, the highest mileage can be achieved at the speed range of

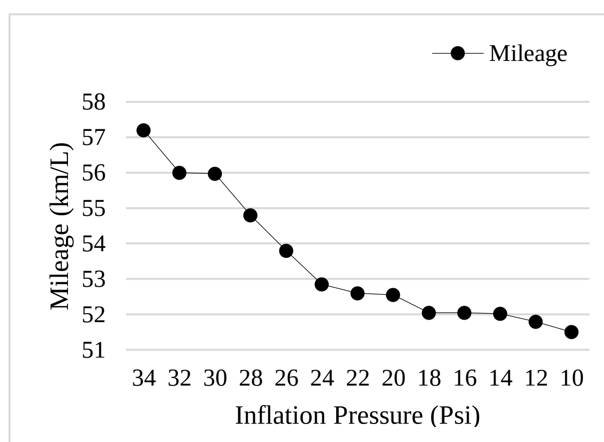

Figure 12. Mileage data obtained through study

30-40 km/h.

The experimental data for the effect of inflation pressure on mileage is also compared with the

simulation results of the experiment performed by [13], which is shown in Figure 11. It shows that the mileage of the vehicle decreases as there is a decrease in the inflation pressure of the tire. The experimental data of this study is also shown in Figure 12 which also shows a similar trend of decrement in mileage of two-wheel vehicle with the decrement in tire inflation pressure.
Both the figures show a similar pattern for mileage with a decrement in the inflation pressure of tires. So, it is necessary to keep the tire pressures around the recommended level to obtain better mileage.

4. Conclusions

The study is focused on figuring out a range of tire inflation pressure at which comparatively less fuel will be consumed and higher mileage can be secured. The motorcycle of 180cc was ridden by varying speed ranges and tire inflation pressure in three different road conditions; Highway, Earthen Road and Graveled Road. The evaluation of data finalized the following findings:

- Mileage is increased by 20.9% up to the speed range of 30-40 km/h and drop is faced up to 27.35% at the speed range of 70-80 km/h while comparing with average mileage obtained i.e., 46.79 km/L. The average mileage obtained is 3.9% higher than the standard mileage of a motorcycle (Bajaj Pulsar 180).
- Decreasing tire pressure from 30 Psi to 25 Psi caused a maximum reduction of mileage by 6.11% on highways, 5.35% on earthen and 2.80% on gravel roads.
- Riding the motorcycle is almost every inflation pressure range from 10 Psi to 34 Psi found an optimum range of tire pressure for better mileage in three different road conditions as: 28-32 Psi in front and 30-34 Psi in rear for Highway, 28-30 Psi in front and 30-34 Psi in rear for Earthen Road and 26-30 Psi in front and 30-34 Psi in rear for Gravel Road.

The present study is only limited to single load conditions with a fixed distance of 10 (±0.1) km and a minimum speed range of 20-25km/h. Further study may include the variation in speed and distance with diversified road conditions as; mixed roads, concrete roads, sandy roads, etc. The problem of handling and steerability under the influence of inflation pressure can also be stated in future studies as it is considered a problem according to the survey campaign.

Acknowledgment

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