

Influence of tire pressure on the braking distance when driving on snow and asphalt

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Abstract. This paper studies the influence of different tire pressure values on the braking distance of a passenger vehicle when driving on different road surfaces (snow and asphalt). This was achieved by conducting experimental tests in an environmental controlled area and obtained the key parameters of the vehicle by using a GPS system. Also, by using the data obtained from the tests, the road friction coefficient was calculated and compared.

1. Introduction

Braking a vehicle on surfaces covered with snow and ice is considered dangerous because the vehicle loses control by locking the wheels and losing friction between the wheel and the road. Very dangerous situation is present for vehicles with inadequate or worn tires and for those not equipped with active safety systems (ABS, ESP) [1]. Braking on ice without ABS results in loss of control of the vehicle's direction. Vehicle deceleration may decrease by up to 90% when driving on snow covered road compared to dry road [2]. The ABS system will regulate the slip of the tire to maintain a good road adhesion [3]. The importance of ABS in these types of conditions was proven to be effective, the system assured deceleration performance but also gave directional stability [4]. On ice, it was proven that a vehicle equipped with ABS was 10% more effective when braking than a non-ABS equipped vehicle [5].

Knowing the braking parameters of vehicles on different surfaces is necessary while analysing road accidents in winter conditions [6]. Tire pressure can have an importance influence in braking distance, due to the modification of the tire contact point [7]. A modern way to assure a controlled pressure in all tires is by using a tire pressure monitoring system that monitors the pressure and alerts the driver when the tires are underinflated [8]. It is important to know the tire-road friction characteristics not only in the case of emergency braking, but also for safe spacing policies regarding the safety in traffic [9].

This paper proposes to study the dynamics of braking a vehicle on a road covered with snow and dry asphalt, and to determine the braking area by modifying the tire pressure. Thus, experimental tests were carried out on a road covered with snow and on a paved road using two tire pressures to study their influence on the braking distance. Since most cars are currently equipped with ABS, the vehicle used in these tests also has this system

2. Methods used

The method used for this study was to perform experimental braking tests using a passenger vehicle on environmental controlled areas. The areas included a shallow snow covered road and a partially dry, paved road. The velocity for the tests was 50 km/h, the maximum recommended velocity in city areas.



Two tyre pressures were considered, 1.5 bars and 2.4 bars to modify the contact pattern between the tire and the road. Four test scenarios were set, two scenarios consisted of braking on snow with the two different tyre pressures, and two scenarios were of braking on asphalt, also with two different tyre pressures. The test vehicle was equipped with a GPS system in order to measure the velocity, braking distance, and deceleration. Using the available data, the friction coefficient could be calculated for every test, using the formula:

$$\varphi = \frac{v^2}{26 \cdot g \cdot S_f} \quad (1)$$

The friction coefficient values obtained can be compared to the defined values that are presented in table 1.

Table 1. Friction coefficient values.

Road condition	Friction coefficient
Dry road	0.7 – 0.9
Wet road	0.5 – 0.7
Very wet road	0.4 – 0.5
Snow covered road	0.2 – 0.5
Ice covered road	0.05 – 0.25

To obtain the deceleration of the vehicle, the formula can be used to differentiate the velocity obtained by GPS:

$$a = \frac{dV}{dt} \quad (2)$$

3. Results

For a more accurate result, for each of the 4 scenarios tested, 3 measurements (experimental tests) were conducted for every case. The key results are presented in the next figures.

- Scenario 1 – Braking on asphalt with the tyre pressure of 2.4 bars.

In this scenario, the vehicle was accelerated at the velocity of approximately 50 km/h, the braked completely. The results are shown in figure 1 and in table 2, the maximum values are obtained for each measurement conducted.

Table 2. Braking on asphalt – 2.4 bars.

Measurement number	M1	M2	M3
Velocity [km/h]	52.2	50	51.6
Braking distance [m]	21	21.4	22
Max. deceleration [m/s ²]	-15	-12	-15.2
Friction coefficient – average value	0.55	0.51	0.52

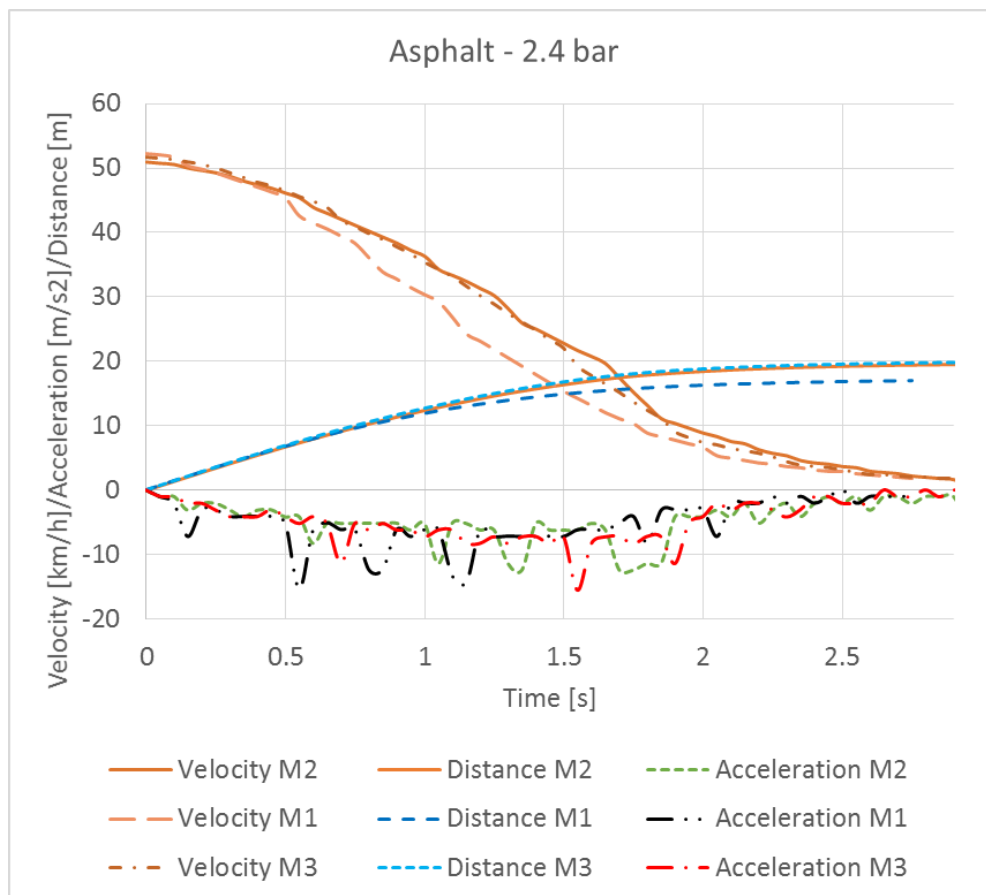


Figure 1. Braking parameters on asphalt with the pressure of 2.4 bars.

In the figure 1, it can be observed that the experimental tests were conducted in a similar way, resulting in close results for a more accurate study.

- Scenario 2 – Braking on snow with the tyre pressure of 2.4 bars.

This scenario was conducted in a similar way to the first one, only the road change from partially dry asphalt to shallow snow covered road. The results are shown in figure 2 and the maximum values are presented in table 3.

Table 3. Braking on snow – 2.4 bars.

Measurement number	M1	M2	M3
Velocity [km/h]	54	53	48.7
Braking distance [m]	40	35	33
Max. deceleration [m/s ²]	-9.2	-6.2	-7.1
Friction coefficient – average value	0.28	0.31	0.29

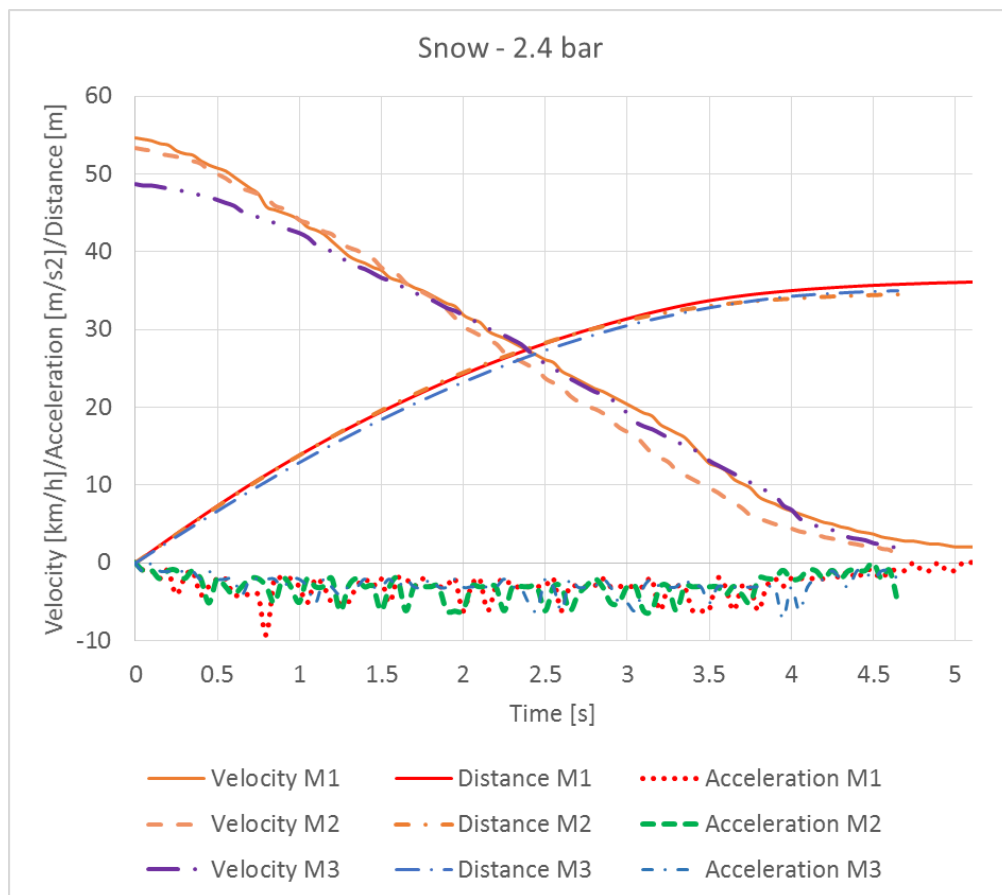


Figure 2. Braking parameters on snow with the pressure of 2.4 bars.

Similar values can be observed in the figure between the measurements, just like with the previous scenario. On snow, compared to asphalt, the braking distance is increased from 22 m up to 35 m.

- Scenario 3 – Braking on asphalt with the tyre pressure of 1.5 bars

Similar to scenario number 1, but the tyre pressure reduced to 1.5 bars. We consider this to have a positive result as it could reduce the braking distance of the vehicle.

Table 4. Braking on asphalt – 1.5 bars.

Measurement number	M1	M2	M3
Velocity [km/h]	51.6	51	55
Braking distance [m]	16	15.6	20
Max. deceleration [m/s ²]	-18	-22.6	-19.5
Friction coefficient – average value	0.61	0.68	0.67

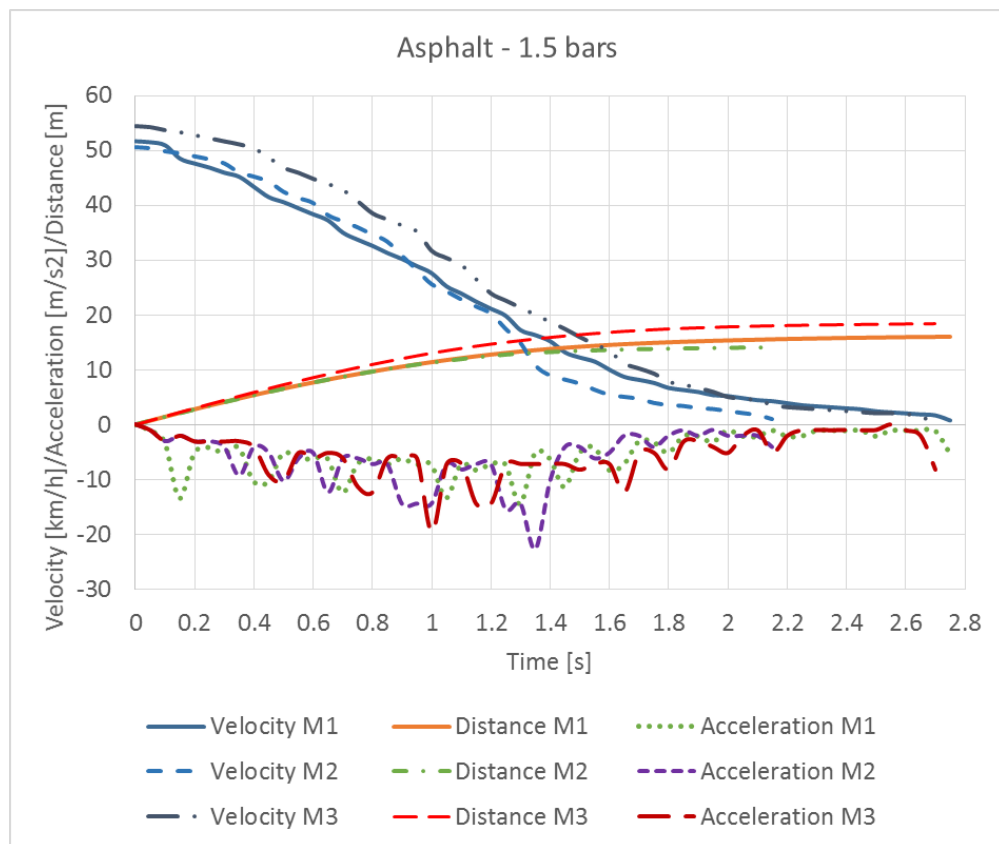


Figure 3. Braking parameters on asphalt with the pressure of 1.5 bars.

From the data obtained in this scenario, compared to the first, it can be observed that the braking distance is improved, decreasing by 20%, as it can be seen in figure 4. Also, as a result of an improved braking distance, the vehicle's deceleration is increased, by 27%.

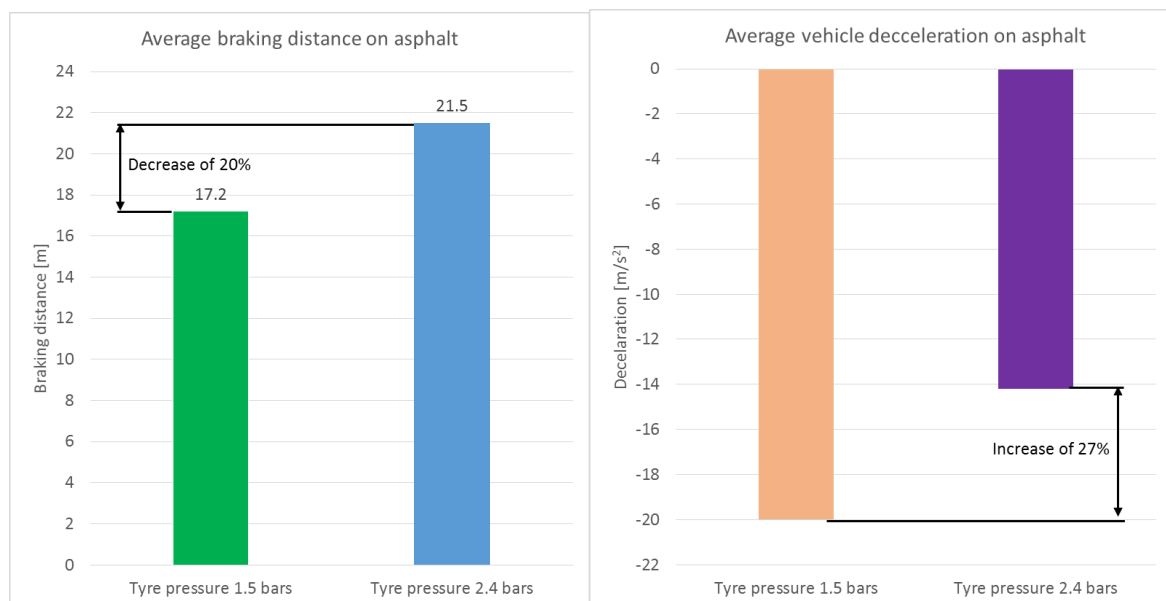


Figure 4. Average braking distance and deceleration on asphalt.

- Scenario 4 – Braking on snow with the tyre pressure of 1.5 bars

This scenario was done in the similar way as scenario number 2, but with the modification of the tyre pressure.

Table 5. Braking on snow – 1.5 bars.

Measurement number	M1	M2	M3
Velocity [km/h]	51.4	48	50
Braking distance [m]	31	28.2	28.8
Max. deceleration [m/s^2]	-10	-8.2	-13
Friction coefficient – average value	0.33	0.3	0.34

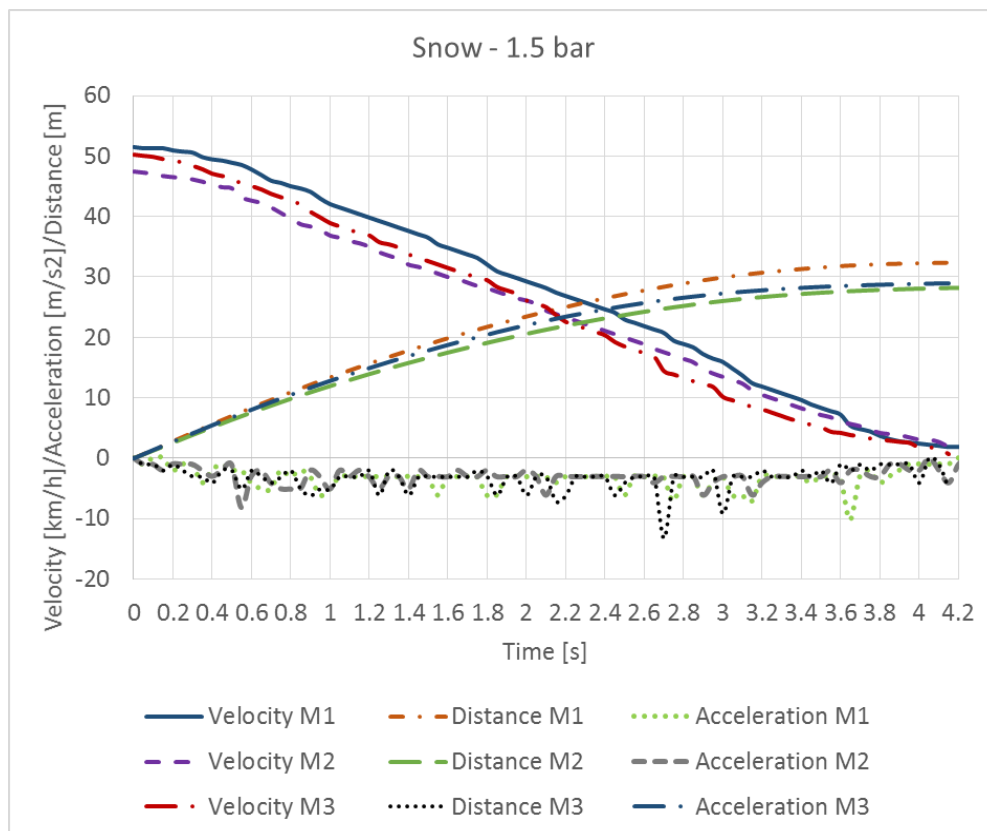


Figure 5. Braking parameters on snow with the pressure of 1.5 bars.

The data obtained in this scenario can be compared to braking on snow with the tyre pressure of 2.4 bars. As such, in figure 6, a comparison of the braking distance and deceleration was calculated.

In this figure can be observed that by decreasing the tyre pressure from 2.4 bars to 1.5 bars, the braking distance was improved with approximately 20% not only on snow, but on asphalt as well. Also, the deceleration was increased by 27 – 28% for both snow and asphalt. This result is conclusive and it is recommended that in winter driving, the tyre pressure should be decreased to improved braking performance.

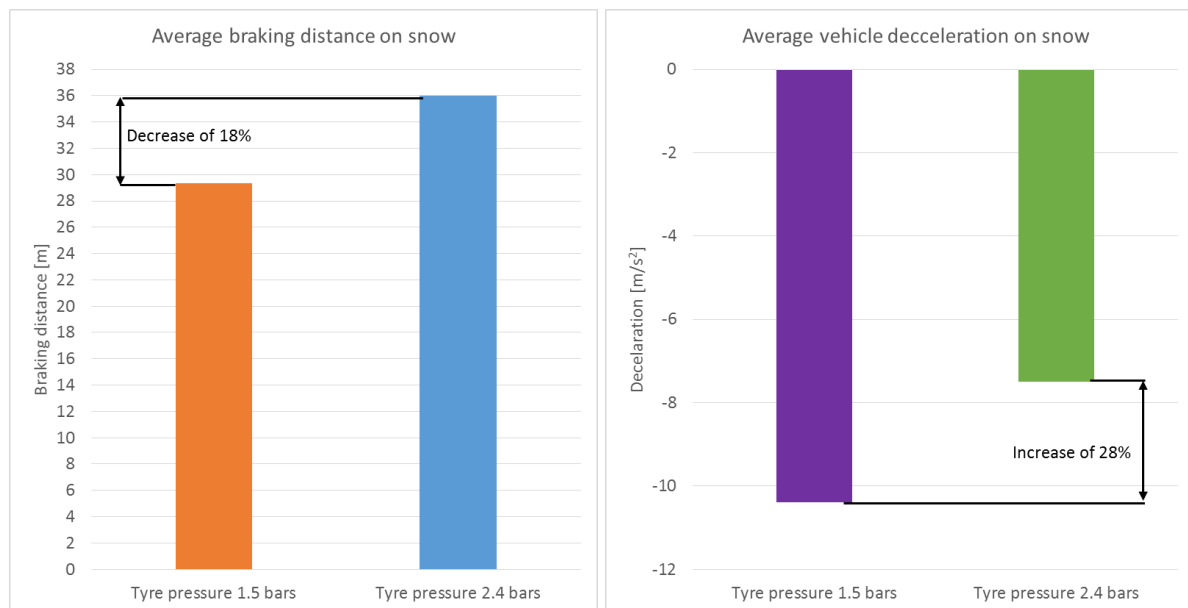


Figure 6. Average braking distance and deceleration on snow.

Also, by using the data from the GPS, the friction coefficient was calculated and presented in figure 7.

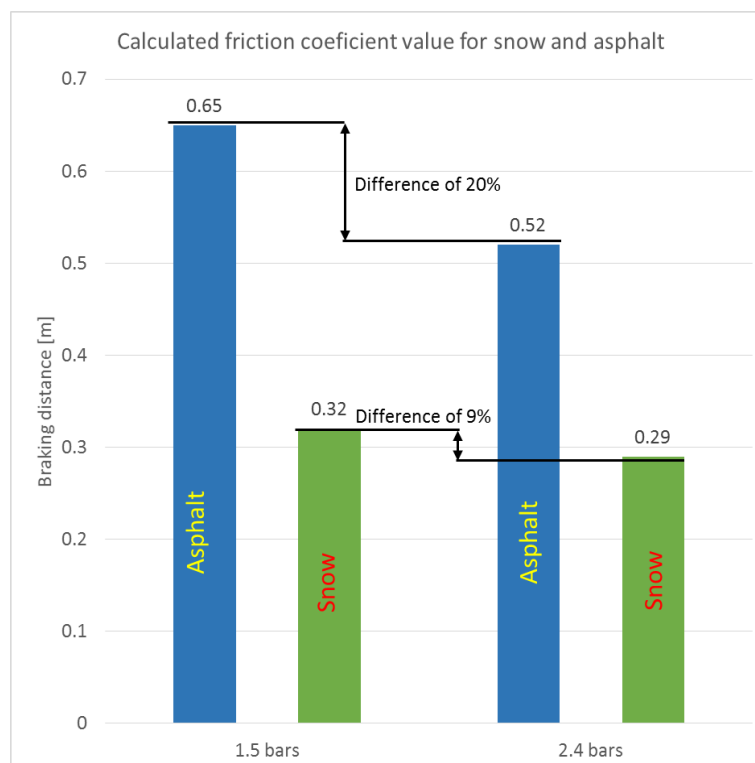


Figure 7. Friction obtained by calculation for snow and asphalt.

The calculations show that for asphalt the friction coefficient was 0.65 – 0.52, which corresponds with wet asphalt, from table 1. The values of the coefficient were accurate and describe the type of surface the vehicle was braked on. There was a 20% in the values to the different tyre pressures used.

Because the road was wet, there was room to improve the friction, similar to dry road. This proves that the adhesion is increased between the tyre and the road when the pressure is lower.

In the case of snow, the coefficient was calculated as 0.32 – 0.29, that corresponds to snow covered road from table 1. The difference here is only of 9%, which would suggest that on a snow covered road, the friction coefficient doesn't change that much.

4. Conclusions

It can be concluded that by reducing the tyre pressure from 2.4 to 1.5 bar, the tyre-to-road contact point increases, thus increasing the grip and therefore reducing the braking area by approximately 20% for both snow and asphalt at the traveling velocity of 50 km/h. By increasing the grip of the vehicle on the road, the deceleration also increases by 28% in order to stop the vehicle in a shorter distance. By using only GPS data, key parameters could be obtained such as velocity, deceleration, and travel distance. Using this information, the road friction coefficient could be calculated to accurately describe the type of surface the vehicle is traveling on.

The diagrams obtained after the tests show that all three measurements for each test are similar in order to successfully verify the conclusiveness of the data. In the diagrams it can also be observed that when braking on asphalt for both tire pressures, the deceleration of the vehicle is similar with an average of 10 to 15 m/s² with a travel time of 2.6 to 2.8 seconds. On snow we can see that the deceleration on average was 6 m/s² for both tyre pressures and a braking time of 4.2 to 4.5 seconds. The time it take to brake on snow is almost double compared to the time it take to brake on asphalt.

The theoretical results confirm the positive influence of tire pressure reduction in winter condition as it was observed in the experimental tests conducted. In winter conditions, on shallow and deep covered snow roads, the tyre pressure of all the wheels should be lowered in order to increase braking performance, however, on wet or dry asphalt roads, lower tyre pressure can increase fuel consumptions and also tyre wear.

5. References

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