



TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics and Mechanics

Vol. 55, Issue IV, 2012

INFLUENCE OF TIRE INFLATION PRESSURE ON ROLLING RESISTANCE AND FUEL CONSUMPTION

Adrian LEU, Mariana ARGHIR

Abstract: The paper presents an analysis of air pressure variation within the tire impact on tire rolling resistance. Consequently inflation pressure variation has a certain impact on fuel consumption. This study is a part of a larger project presenting Contributions to the Study of Surface Vehicle Vibrations by analyzing Tire - Car system aiming to reduce fuel consumption and non-biodegradable waste.

Key words: Tire, Rolling Resistance, Air Pressure, Fuel Consumption.

1. INTRODUCTION

The number of vehicle in use is increasing every year and more vehicles are consuming more fuel. Vehicle manufacturers are making great efforts to develop fuel efficient engines and vehicle designs. In United States, light-duty vehicles (cars & light trucks) are responsible for about 20% of the nitrogen oxides, 27% of the volatile organic compounds, 51% of the carbon monoxide, and roughly 30% of all the carbon dioxide (the main greenhouse gas) emitted from human activities [1].

Detailed modeling conducted by the National Renewable Energy Laboratory USA concluded that a 10% reduction in tire rolling resistance should yield fuel savings of about 1 to 2%, depending on driving conditions and vehicle type. According to research for the California Energy Commission, about 1.5 to 4.5% of total gasoline use could be saved if all replacement tires in use had low rolling resistance.

2. ROLLING RESISTANCE

Rolling resistance, sometimes called rolling friction or rolling drag, is the force resisting the

motion when a body (such as a ball, tire, or wheel) rolls on a surface.

We can imagine the tire being represented by a series of independent springs which resist vertical deformation, as shown in the . As each spring element enters the contact patch, it undergoes vertical deformation. The vertical deformation of the spring reaches its maximum at the center of the contact patch and goes back to zero at the end of the contact patch [2].

$$F_r = -F_z l \quad (1)$$

$$F_r = \mu_r F_z \quad (2)$$

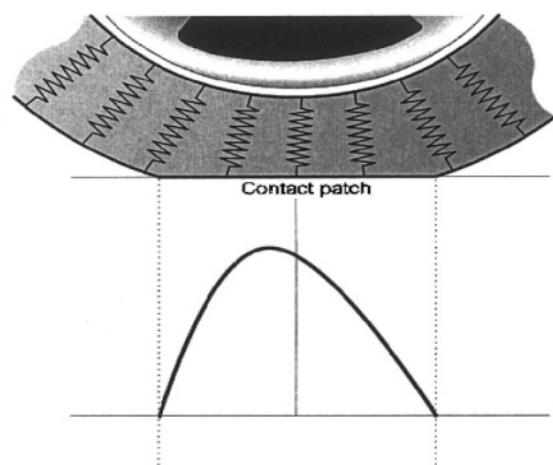


Figure 0-1. Normal Force Distribution.

The parameter μ_r is called the rolling friction coefficient. μ_r is not constant and mainly depends on tire speed, inflation pressure, sideslip and camber angles. It also depends on mechanical properties, speed, wear, temperature, load, size, driving and braking forces, and road condition ⁽³⁾.

Part of the energy that is spent in deformation will not be restored in the following relaxation. Hence, a change in the distribution of the contact pressure makes normal stress σ_z in the heading part of the tire print be higher than the tailing part. The dissipated energy and stress distortion cause the rolling resistance.

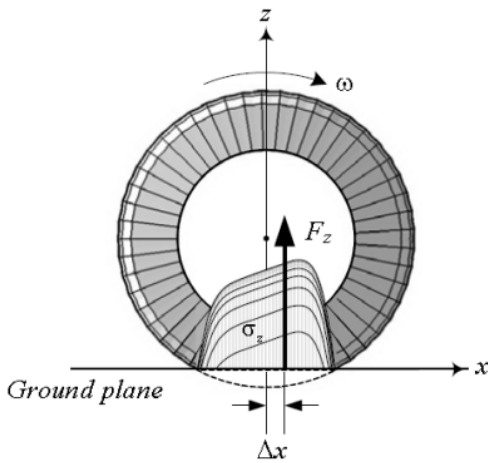


Figure 0-2. Normal Stress Distribution and Forces

Because of higher normal stress in the front part of the tire print (see Figure 0-2. Normal Stress Distribution and Forces), the resultant normal force moves forward.

Forward shift of the normal force makes a resistance moment in the $-y$ direction, opposing the forward rotation.

$$M_r = -M_r \tag{3}$$

$$M_r = F_z \Delta x \tag{4}$$

The rolling resistance moment M_r can be substituted by a rolling resistance force F_r parallel to the x-axis.

$$F_r = \frac{1}{R_h} M_r = \frac{\Delta x}{R_h} F_z \tag{5}$$

2.1. Effect of Inflation Pressure and Load on the Rolling Friction Coefficient

The rolling friction coefficient μ_r decreases by increasing the inflation pressure p . The effect of increasing pressure is equivalent to decreasing normal load F_z [3].

$$\mu_r = \frac{K}{100} \left(5.1 + \frac{5.5 \times 10^5 + 90F_z}{p} + \frac{1100 + 0.388F_z v_x^2}{p} \right) \tag{6}$$

The parameter K is equal to 0.8 for radial tires, and is equal to 1.0 for non radial tires. The value of F_z , p , and v_x must be in [N], [Pa], and [m/ s] respectively [4].

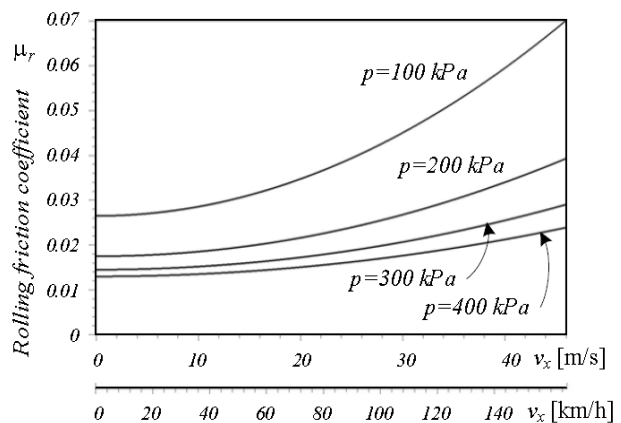


Fig. 2.1-3. Rolling Friction Coefficient

2.2. Reducing the Rolling Resistance

Factors that contribute to rolling resistance

- The amount of deformation of the tire
- The deformation of the surface
- Movement below the surface

Lower inflation pressure in tires results in more flexing of sidewalls, increases of the contact patch area and higher rolling resistance [5]. The magnitude of the effect of inflation pressure on tire rolling resistance is dependent upon tire size and type. The decrease in rolling resistance per PSI inflation pressure increase is 2.3% - 2.5% for radial tires [6].

According to the National Academy of Sciences USA, about 80 to 88% of the energy in a vehicle's gasoline tank is wasted in various thermal, frictional, and standby losses in the engine and exhaust system. This leaves only about 12 to 20% of the potential energy actually converted to vehicle motion. One of the key ways to improve that efficiency is to reduce the rolling resistance of vehicle tires.

This is not a measure of a tire's traction or "grip" on the road surface, but rather simply indicates how easily a tire rolls down the road, minimizing the energy wasted as heat between the tire and the road, within the tire sidewall itself, and between the tire and the rim.

Good air pressure maintenance is the most efficient way to control energy loss on tires. By checking (and adjusting if needed) air pressure we can insure optimal level of rolling resistance on tires and consequently lower fuel consumption.

3. CONCLUSIONS

A tire's overall contribution to vehicle fuel consumption is determined by its rolling resistance averaged over its lifetime of use.

10% reduction in tire rolling resistance should yield fuel savings of about 1 to 2%, depending on driving conditions and vehicle type.

A reduction in the average rolling resistance of replacement tires in the fleet can occur through various means. Consumers could purchase more tires that are now available with lower rolling resistance, tire designs could be modified, and new tire technologies that offer reduced rolling resistance could be introduced. More vigilant maintenance of tire inflation pressure will further this outcome. Air pressure in tires has a direct impact on rolling resistance.

One of the easiest and most practical way to optimize the rolling resistance in tires is to control the air pressure on a periodical basis.

We recommend checking (and adjusting if needed) the air pressure to the vehicle manufacturer's cold tire pressure(s) recommended on the vehicle's tire placard or in

its owner's manual at least once a month, at cold (internal temperature of tires equals the ambient temperature).

Please note that the air pressure in the tires can be influenced by ambient temperature variation and other factors. For any questions related to the best air pressure value adapted to different application is better to consult a tire specialist.

4. REFERENCES

1. **Green Seal.** *Choose Green Report - Tire Rolling Resistance.* Washington, DC : Green Seal, 2003.
2. **Rajamani, Rajesh.** *Vehicle Dynamics and Control.* Troy, NY : Springer, 2006. ISBN 0-387-26396-9.
3. **Jazar, Reza N.** *Vehicle Dynamics: Theory and Application.* New York : Springer Science+Business Media, 2008. ISBN: 978-0-387-74243-4.
4. **Cossalter, V.** *Motorcycle Dynamics.* Greendale : Race Dynamic Publishing, 2002.
5. **US Department of Transportation. National Highway Traffic Safety Administration.** *NHTSA Tire Fuel Efficiency Consumer Information Program Development: Phase 2.* Springfield, VA : NHTSA, 2009.
6. **Burgeson, Richard N.** *Tire Rolling Resistance Measurement at Initial Inflation Pressure of 45PSI and 26 PSI.* s.l. : US Environmental Protection Agency, 1978.

INFLUENTA PRESIUNII AERULUI ASUPRA REZISTENȚEI LA RULARE ȘI A CONSUMULUI DE COMBUSTIBIL

Rezumat: Lucrarea prezintă comentarii asupra legăturii între presiunea aerului în pneuri și rezistența la rulare, respectiv asupra consumului de combustibil. Una din metodele cele mai simple și practice de a reduce rezistența la rulare este de a controla presiunea aerului în pneuri pe o bază regulată. Un program experimental condus de către National Renewable Energy Laboratory USA arată că o reducere a rezistenței la rulare poate duce la o reducere de 1% – 2% a consumului de combustibil. Această lucrare face parte dintr-un proiect mai larg intitulat Contribuții la studiul vibrațiilor vehiculelor de suprafață prin analiza sistemului pneu - mașină în vederea reducerii consumului de materiale non-bio-degradabile și de combustibil.

Adrian LEU, PhD. Stud. Eng., Department of Mechanics and Computer Programming, Faculty of Machines Building, Technical University of Cluj-Napoca, Tel: (+) 40.264.401.759;
Mariana ARGHIR, Prof. Dr., Mech. Eng., Department of Mechanics and Computer Programming, Faculty of Machines Building, Technical University of Cluj-Napoca, Tel: (+)40.264.401.657.