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Simulation of friction system and the use of vibration force in propulsion and braking

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Abstract. First aim of this paper is to outline the rolling friction between tire and the road surface and then introduce the friction as a force transmitter. In continue, we mount the friction force between the tire and the pavement and then simulate the friction. Installing a shaker at top of the brake system, could add vertical force to the weight of the mass, that influence the friction force. changing the frequency of the shaker, could influence the friction force a lot. Braking and proportion systems could be more efficient by using this Innovation.

Keywords: Rolling Friction, Simulation, Frequency, Normal Force, Vibration.

1. INTRODUCTION

Power transmission is one of the most important issues in mechanical engineering. Vehicle's transmission system that convert and transfer engine's power to wheels contains: clutch, gearbox, power transmission shaft and the differential. The final stage of the force transmission is between the wheels and the ground that known as the friction force. Friction force often, has known as a harmful phenomenon that may cause damage mechanic equipments. Because of that researchers are in try to control and minimize it. In this particular case, has been tried to achieve the greater friction force with minimum engine power.[1,2] there are many mathematical method to simulate friction force between tire and the pavement. In this article, rolling friction method is used.

2. THE LAW OF FRICTION (NEWTON)

To study the friction law, different conditions of mass Behavior must examine. Figure 1 shows the frictional behavior of mass that placed on a flat surface. The mass pulled by increasing horizontal force. Three different stages of behavior shows up to move comes.[3]

I- Two levels do not have any slippage. (If we enter 5 Newton, friction force will be 5).

II- The mass on Threshold to move.

III- The mass slips on the surface.

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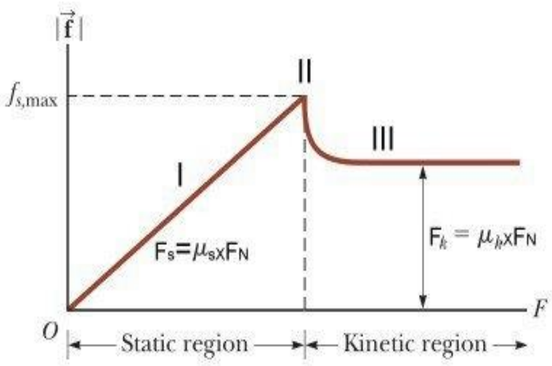

Figure 1. Incoming vertical force to friction force. kinetic friction force is fewer than maximum static friction force. [3] (page 21).

As a general formula, static friction contains two parameters, the coefficient of friction and the normal force. According to the constant friction coefficient over time, adding normal force f_t (beside the weight force F_n) can cause increase static friction force. In other words, the entered force F_t, finally appears to the friction force form. This point cause increase transferred power between tire and the pavement (friction) Figure 2.

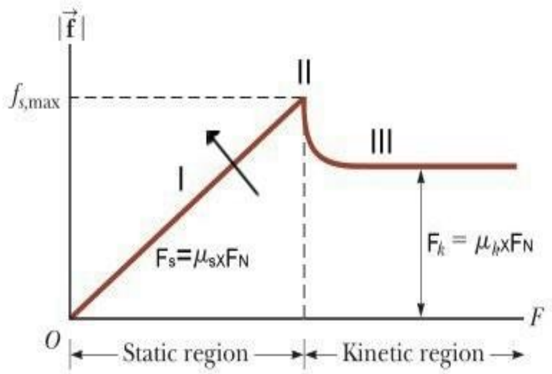

Figure 2. Increasing normal force cause increasing the friction force.

3. ROLLING RESISTANCE

The longitudinal force that created between the rotating tire and the pavement case car go ahead or make it stop. Rolling resistance force is in the opposite direction of movement and proportion of normal force. μ_r is rolling resistance coefficient which is proportionate to some causes such as temperature, tire pressure, tire wear, road conditions. Rolling resistance coefficient is proportionate to the square of the tire speed [4].

$$F_r = \mu_r \times F_N \tag{1}$$

$$\mu_r = \mu_0 + \mu_1 \times V_x^2 \tag{2}$$

The most important that affect the friction force is normal force. Figure 3 shows influence of normal force variation on the Goodyear tire in different conditions.

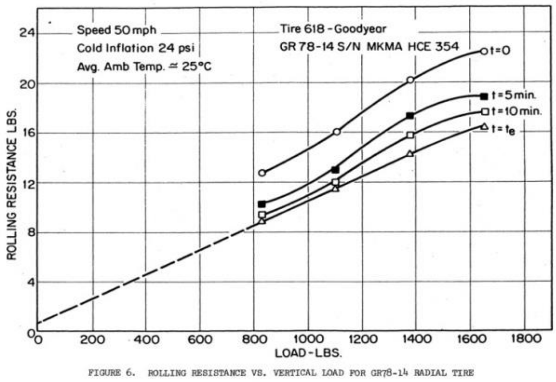

Figure 3. Rolling resistance changes by changing the Normal force in radial Goodyear tire [5](page 21).

4. FRICTION VEHICLE SYSTEM SIMULATION

A vibration system with two degrees of freedom, has used to simulate the tire model. According to Figure 4, damping and stiffness coefficient of tire hardness has assumed. By considering the Newton third law (For every action, there is an equal and opposite reaction) reaction of the vibratory force F_p which shaker inter to the tire and add the weight of tire, finally shape to frictional force between tire and pavement.

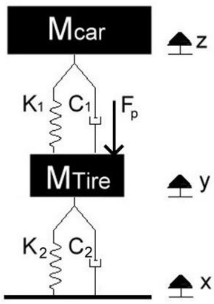

Figure 4. Tire's two degrees of freedom.

Dynamic relationships governs the vehicle and tire is equation 3 and 4.

$$M_{car} \times \ddot{q}_1 = k_1 \times (q_2 - q_1) + c_1 \times (q_2 - q_1) \quad (3)$$
$$M_{Tire} \times \ddot{q}_2 = -k_1 \times (q_2 - q_1) - c_1 \times (\dot{q}_2 - \dot{q}_1) - k_2 \times q_2 - c_2 \times \dot{q}_2 - F_P \quad (4)$$

Table 1. The values of the equations parameters.

Parameters	Element	Values
Car Mass	M_{Car}	1800 kg
Tire Mass	M_{Tire}	15 kg
Spring Stiffness	k_1	400000(N/m)
Damper Damping	c_1	3200 (Ns/m)
Tire Stiffness	k_2	100000(N/m)
Tire damping	c_2	800(Ns/m)

[6]) page (194).

Matlab software just can solve first order differential equations. In order to solve equation 3 and 4 we should convert them to four first order equations. Matrix 5 shows first order of differential dynamic movement equation. Ode45 function in matlab solve first order of differential equation with Runge-Kutta method numerically. The shaker enter absolute sine equation 6 with various amplitude and frequency to the tire's axis.

$$\begin{pmatrix} \dot{q}_1 \\ \dot{q}_2 \\ \ddot{q}_1 \\ \ddot{q}_2 \end{pmatrix} = Inv\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & M_{Car} & 0 \\ 0 & 0 & 0 & M_{Tire} \end{pmatrix} \times \left(\begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -k_1 & k_1 & -c_1 & c_1 \\ k_1 & -k_1-k_2 & c_1 & -c_1-c_2 \end{pmatrix} \times \begin{pmatrix} q_1 \\ q_2 \\ \dot{q}_1 \\ \dot{q}_2 \end{pmatrix} \right) + \begin{pmatrix} 0 \\ 0 \\ 0 \\ F_p \end{pmatrix} \quad (5)$$

$$F_p = |100 \times \sin(2\pi\omega \times t)| \quad (6)$$

The external force F_p, influence tire's damping and stiffness that cause addition force to the normal force. Equation 7 shows the normal force without external force F_P. Equation 8 shows the system's normal force behaviors with additional of external force.

$$F_{N_1} = \left(\frac{M_{car}}{4} + M_{tire}\right) \times 9.81 \quad (7)$$

$$F_{N_2} = \left(\frac{M_{car}}{4} + M_{tire}\right) \times 9.81 + k_2 \times q_2 + c_2 \times \dot{q}_2 \quad (8)$$

Equations 7 and 8 puts in rolling friction equation 1. Because of the structure of the tire that has assume such as two degrees of freedom system, Frequency changing of the external force has very effective influence on the friction force. Diagram of Figure 5 display the varying of friction force in the interval 0 to 4 Hz. According to the values of this chart, the highest transmission force, is related to the amount of 1.15 Hz.

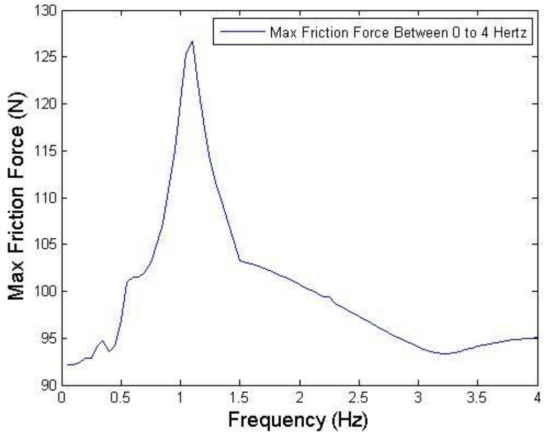

Figure 5. changing the maximum amount of friction in the frequency range 0 up to 4 Hz The force F_p.

Changes of the maximum amount of friction in the range of (0-4) Hz, are much more than the range of (4-3500) Hz. Because of that they have displayed in two separated diagrams.

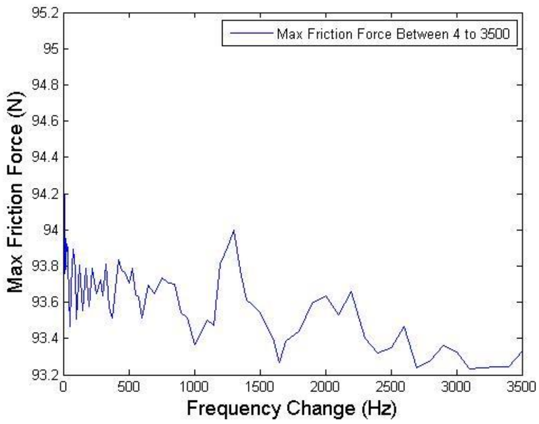

Figure 6. changing the maximum amount of friction in the frequency range 4 up to 3600 The force F_p.

With review of varying form of Figure 7, results can be achieved that at some frequencies, friction force, is less than the amount of friction in the primary friction force. At this frequency the tire is prone to slide on the surface.

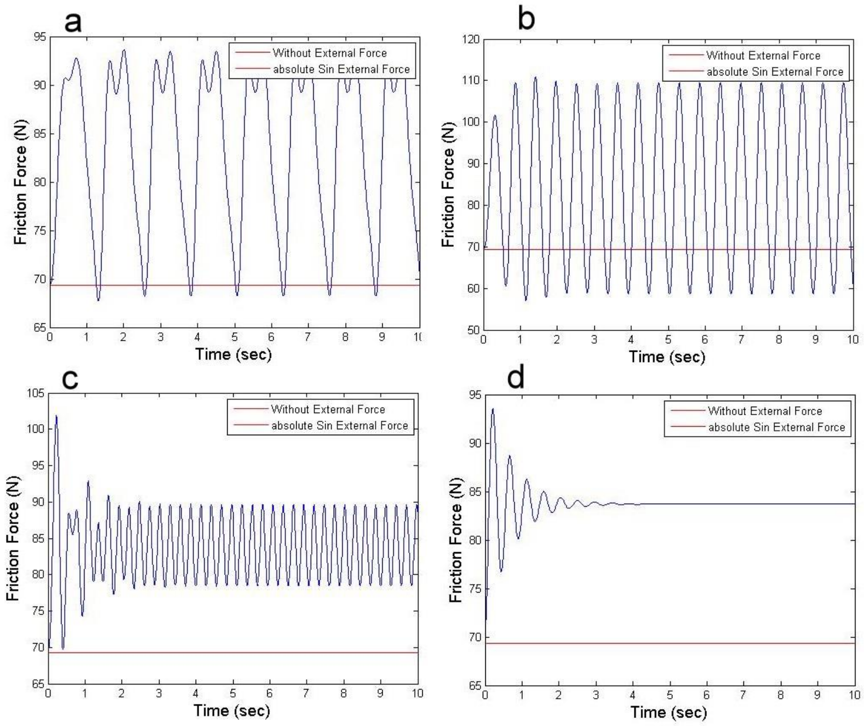

Figure 7. Oscillation of the friction force in different frequencies (a) The frequency of 0.4 Hz- (b) The requency of 0.9 kHz (c) The frequency of 1.8 kHz- (d) The frequency of 200 Hz.

5. CONCLUSION

When you start to move or stop the car, this system helps to increase power transmission rate from wheels to the ground. In other words, there will be less time needs to transfer the need force. In this method, the force that comes from shaker converts to friction force. New method help to increase friction force at the moments of propulsion or braking. This auxiliary system has not used anywhere, and we hope using this method prevent from occurring accidents.

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