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## Research on Influence Mechanism of Tire Pressure on the Ride Comfort of Automobile

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# Research on Influence Mechanism of Tire Pressure on the Ride Comfort of Automobile

**Jianqiang Xiong**

School of mechanical and Electrical Engineering Xinyu College Xinyu China

Corresponding author e-mail: 544029003@qq.com

**Abstract.** Factors that affect vehicle vibration and noise are design, material, tire pressure, structure, road condition, etc. the influence of tire inflation pressure on vibration and noise of tire and whole automobile is studied. Through the experimental data and theoretical analysis show that the tire stiffness and the natural frequency increased with tire inflation pressure increase; changes of suspension and automobile vibration characteristics with the tire inflation pressure change; tire pressure has different influence on the pump noise; tire pressure has little effect on the tire noise level; tire damping performance decreased with the increase of tire pressure, increased automobile vibration feeling, reduce automobile ride comfort. Therefore, reasonable tire inflation pressure can not only reduce and improve automobile vibration and noise, but also improve automobile ride comfort.

## 1. Introduction

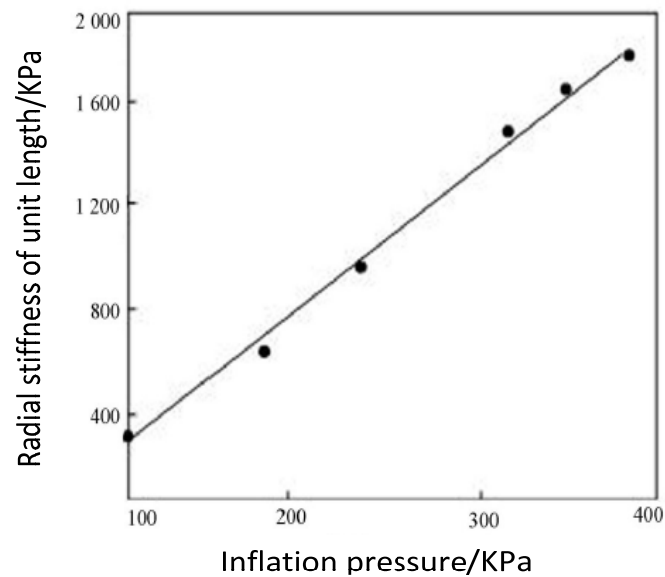
As the number of automobile increases year by year, automobile noise has become traffic major sources of noise pollution. In recent years, through the depth analysis and research of noise, the noise produced by automobile structural vibration has been got some effective control. By contrast, automobile tire noise varies with the proportion and influence of automobile speed increase in automobile noise. The extent is also increasing. Therefore, to reduce traffic noise pollution, first of all, to reduce the noise pollution of automobile, and to reduce the noise pollution caused by automobile tire. According to the relevant noise sources and the measured results show that the noise of the tire is the mainly noise of the air pump and the noise of the pump pattern block impacting road noise [1]. The factors that affect and cause tire noise include structure, material, speed, tire pressure and so on. Tire pressure is one of the important factors that affect automobile noise and vibration. Tire pressure affects not only the noise and vibration characteristics of the tire itself, but also the automobile vibration and noise characteristics. Therefore, the study of tire pressure on automobile vibration and noise is of great significance to reduce the whole automobile Vibration and noise, and improve ride comfort.

## 2. Effects of tire pressure on tire stiffness and natural frequency

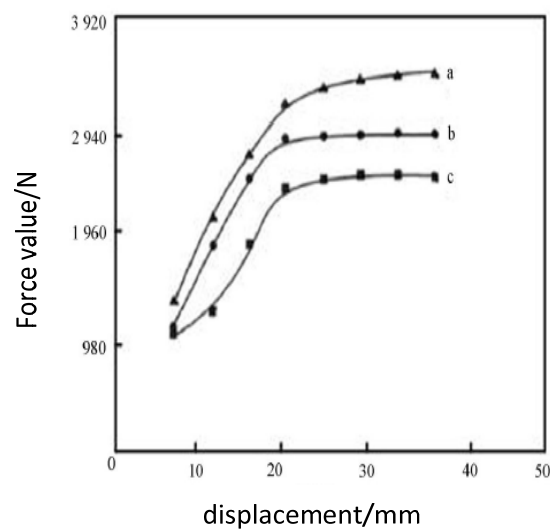
The tire stiffness characteristics have a great influence on the automobile vibration. The factors that affect tire stiffness are material, structure, air pressure, etc. In case of constant change, tire inflation pressure was performed on the tire experiment about the influence of stiffness. The same specifications of the tires are different inflating. The experiment of pneumatic force is based on the measured data. Tire stiffness increases with the increase of inflation pressure. The main reasons are as follows with the



increase of air pressure, the internal stress of the tire profile increases accordingly plus, tire stiffness is also increasing [2-4]. Obtained by experimental data Radial stiffness, longitudinal stiffness and lateral stiffness of tire vary with inflation pressure As shown in figures (1)、(2)、(3), a, b, c, three curves are separately at the pressure of 180kPa, 250kPa, 300kPa, the tires are vertical and horizontal curve of stiffness change.

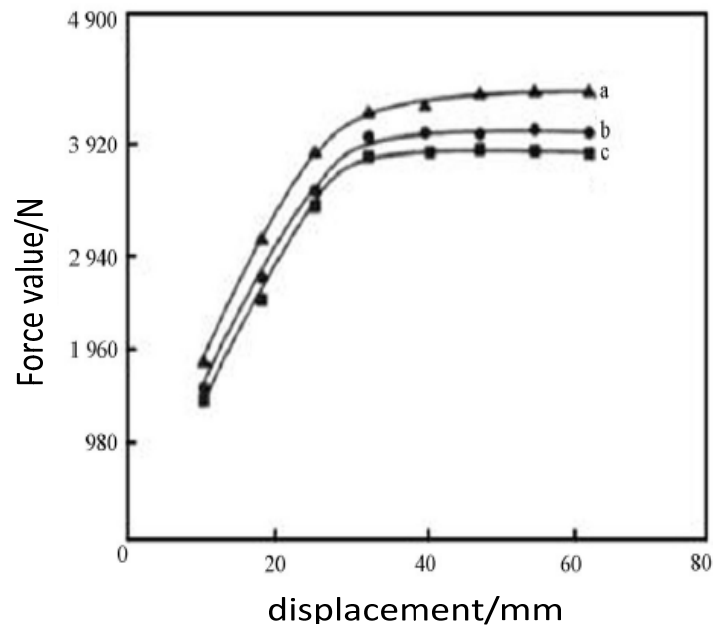


**Figure. 1** Relation curve of radial stiffness and tire air pressure



**Figure. 2** Relation curve of longitudinal stiffness and tire air pressure

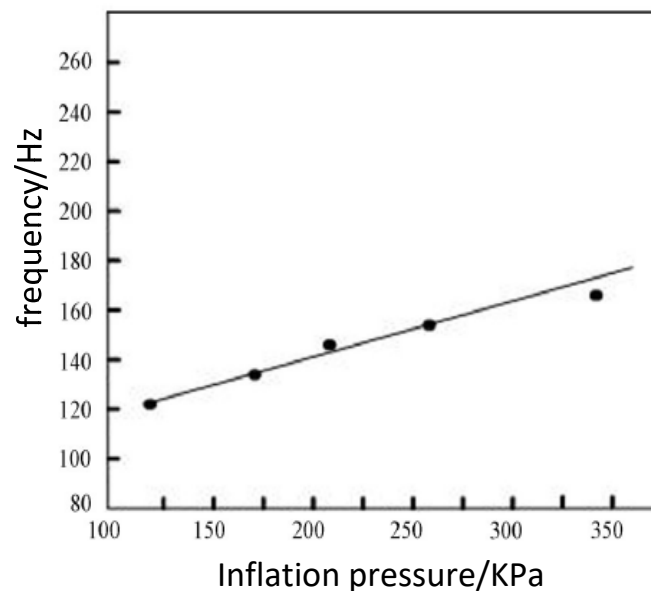
Inflation pressure (KPa):a-180; b-250; c-300



**Figure. 3** Relation curve of lateral stiffness and tire air pressure

Inflation pressure (kPa): a-180; b-250; c-300

The tire stiffness varies with tire inflation pressure, which will affect the inherent characteristics of tire vibration. The frequency is one of the changes, and the natural frequency of the tire is measured according to the experimental data. The rate varies with the tire inflation pressure as shown in figure 4.



**Figure. 4** Relation curve of natural frequency and tire air pressure

According to the diagram of tire stiffness and natural frequency with pressure change, the radial, longitudinal and lateral stiffness and natural frequency of tire are proportional to the variation of tire inflation pressure.

### 3. Effect of tire pressure on tire vibration and noise

#### 3.1. Noise and vibration of tread block impacting on road surface

In the process of cyclic rolling, the tread block will hit the road surface, especially when the slope of the road is large, it will cause a certain impact vibration and noise. When the tire inflation pressure is small, the tire stiffness is correspondingly low. When the tire bumps, the tire deformation and vibration energy can be increased and will absorb more impact vibration energy, which makes the impact vibration noise less, and the performance of vibration and noise reduction is better. with the tire inflation pressure increases, the tire radial、longitudinal and lateral stiffness increases, the impact of tire bump deformation is reduced, the impact of vibration absorption or buffer capacity is poor, so that the damping performance of tire decreased, the impact of vibration and noise enhanced, ride comfort is greatly reduced.

#### 3.2. Tire vibration

Tire vibration and noise includes sidewall and tread vibration, forced vibration and noise of tread relative pavement sliding, vibration and noise of tread hit pavement <sup>[5]</sup>. When the tire pressure increases, the tire stiffness and the natural frequency of tire increase, while the vibration amplitude of the tire in the high modal is greatly affected by the change of the pressure. As a result, the increase in tire pressure results in higher modal amplitude of the tires.

According to the experimental data, the natural frequencies of the 5 order radial free vibration of the tire at different pressures are obtained, as shown in table .1.

**Table. 1** Natural frequency value of different tire air pressure (Unit: Hz)

Inflation pressure/MPa	1 order	2 order	3 order	4 order	5 order
0.12	44.56	59.50	75.62	94.07	114.37
0.24	53.74	74.64	96.43	120.19	145.36
0.36	61.16	86.65	112.94	140.97	169.91

From the above data, it can be seen that the influence of the change of the inflating pressure on the natural frequency of the higher order free vibration of the tire is greater than the influence of the natural frequency of the low order free vibration.

The experimental and theoretical analysis, the natural frequency and the stiffness of the tire with increasing air pressure increased, therefore, the enhanced tire pressure will increase the wheel acceleration at the resonance frequency, thereby reducing the ride comfort.

#### 3.3. The effect of tire noise level

Above the position of the same type of tire rolling, the noise level of the same level of experimental load, the same speed under different pressure, according to the experimental data are shown in table (2) .

**Table. 2** Noise level of different tire air pressure

air pressure/KPa	210	260	300
The average sound pressure level/dB	90.2	90.7	88.7

From the experimental data in Tab.2 can be seen on the experimental tire noise level with the pressure does not change, or that the tire noise level with the pressure does not change with regularity, therefore, The tire pressure has little effect on the tire noise level.

### 3.4. Air pump noise

Pump noise is due to contact with the ground tread, in radial, longitudinal and lateral will produce compression deformation, volume of the tread groove is reduced, the trench contained in the air out, tread off the ground, ditch volume recovery, air flows into the trench. The continuous flow of air between the tread elements or the air in the convex and concave of the pavement causes the pressure to fluctuate and make sound, thus forming the noise of the air pump.

According to document [6], a prediction model of noise pressure level for tire pump noise is presented:

$$L_m = 20 \lg \frac{\rho_0 m S l_3 v^2}{4 p_0 \pi l_1 l_2^2} \quad (1)$$

Where  $\rho_0$  for air density; m block number;  $P_0$  as the reference pressure ( $2 \times 10^{-5}$  Pa); V for speed,  $l_3$  is the horizontal length of pattern block,  $l_2$  is the circumferential length of the pattern block; S for area block siege;  $l_1$  for between the source region and the distance from the observer.

Where  $S l_3$  is the block and the ground between the extrusion or inhalation volume, with the increase of tire pressure, tire radial stiffness, axial stiffness and lateral stiffness are increased; the tire deformation reduced, the cavity volume changes of  $S l_3$  also decreased. By the formula (1) can be inferred, unchanged in the context of other variables, tire pressure increased and the molecular formula is reduced, because the denominator does not change, so the pump noise level decreased. Therefore, the same in other variables, according to the pump noise prediction model can be learned: the increase of tire pressure, the pump noise is reduced; the tire pressure is reduced, the pump noise increased [7-8].

### 4. Analysis of effects of tire pressure on automobile vibration

Because of dynamic interaction between tire suspension and chassis, the change of tire stiffness is bound to affect the dynamic interaction between them. According to the literature, the radial stiffness of the tire increases, and the greater the radial vibration caused by the roughness of the road, the greater the vibration to the body. The tire pressure will directly affect the tire vibration transmissibility, and eventually affect the vibration characteristics of the automobile. Therefore, the tire pressure has a greater impact on the suspension, chassis and car vibration. According to the relationship between suspension and automobile vibration frequency, the vibration frequency of car can be determined by the following formula [9], that is

$$n = 300 / \sqrt{f_a} \quad (2)$$

The  $f_a$  is suspension deformation, and

$$f_a = \frac{G}{C} \quad (3)$$

The G is the suspension load, and the C is the suspension composite stiffness, and

$$C = \frac{C_s * C_t}{C_s - C_t} \quad (4)$$

In the formula,  $C_s$  is spring stiffness,  $C_t$  is tire stiffness, and

$$C_t = \frac{Q}{f} \quad (5)$$

In the formula,  $f$  is radial deformation of tire, and  $Q$  is tire load.

Radial deformation of the tire can be obtained by the following formula.

$$P = \frac{Q}{F} K_1 P_w \quad (6)$$

$$F = K_2 b S = 2 K_2 S (2 R_0 f - f^2)^{\frac{1}{2}} \quad (7)$$

$F$  is the floor area of the tire;  $S$  is the section width of the tire;  $B$  is the length of the tire ground area;  $K_2$  is the ratio of actual ground area to  $B \times S$ ;  $f$  is the tire deformation;  $R_0$  is the tire free radius.

The radial deformation of the tire can be obtained by substituting (7) in the formula (6):

$$f = \left[ 1 - \sqrt{1 - (\alpha\beta)^2} \right] \times R \quad (8)$$

$A$  is a parameter factor,  $\alpha = \frac{Q}{P_w R_0 S}$ ;  $\beta$  is Radial stiffness factor of tire, and  $\beta = \frac{5}{K_1 K_2}$ .

From the above several formulas can be inferred from the tire stiffness influence of suspension combination stiffness, suspension combination stiffness effect of automobile vibration frequency. When the automobile load is fixed, with the increase of tire pressure, tire stiffness increases, with the increase of tire stiffness, changing the suspension stiffness, suspension stiffness change will influence the automobile vibration frequency and characteristics.

## 5. Conclusion

The tire is one of the main vibration and noise sources of the automobile, and the tire is also an important factor affecting the vibration and noise of the automobile. Therefore, the study of the effects of air pressure on the vibration and noise characteristics of tires is of important guiding role in reducing the vibration and noise of automobiles and improving the riding comfort of automobile:

(1) The natural frequency, tire stiffness and vibration frequency of the tire increase with the increase of tire pressure, which is directly proportional to the tire frequency;

(2) The increase of the tire pressure reduces the vibration absorption ability of the tire, enhances the vibration intensity and reduces the riding comfort, the influence of the inflated pressure on the higher order free vibration of the tire is greater than that of the low order free vibration.

(3) According to the prediction model of the tire air pump noise, the noise of the air pump is proportional to the change of the tire pressure, the tire noise level has little relation with tire pressure, and the change is not regular.

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