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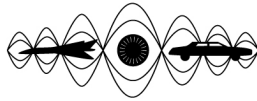
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NOISE INDUCED BY DYNAMIC CONTACT FORCES OF A RUBBER CYLINDER ROLLING ON ROAD PAVEMENT SAMPLES

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Tire/road noise, also called rolling noise, is an important part of vehicle noise. The mechanical interactions between tire pattern and the road asperities is a major contributor to mechanisms at the origin of tire/road contact noise. This paper presents an experimental study of the dependence between the dynamic contact forces and the rolling noise. A measurement campaign was carried out on asphalt pavement samples to achieve this aim. It is found that the mean value of the normal contact force, responsible of the rolling noise, remains constant and the level in dB of this force increases linearly with the logarithm of the rolling speed.

Keywords: dynamic force, rolling noise, pavement

1. Introduction

Road traffic noise has become a serious environmental pollution problem for human being problems and an important part of environmental noise [1]. It is widely known that road traffic noise has negative influences on human health [2]. Tire-road noise is a wide-band noise ranging from 100 Hz to 5000 Hz [3] and considered to be the most dominant cause of road traffic noise above 30 km/h [4]. Rolling noise arises from a complex combination of physical processes which can be categorized into three groups: mechanical mechanisms caused by tangential and radial vibrations of the tire, aerodynamic mechanisms specifically air-pumping, Helmholtz and pipe resonances, and amplification effect, also called horn effect [5]. In literature, several relationships are used to study the phenomenology of the noise induced by the rolling speed between rough surfaces. The level of the noise in dB can be investigate by physical quantities such as the sound pressure level L_p [6, 7, 8], the vibrational level L_v [9] and contact force level L_F [10].

The purpose of this paper is to measure the dynamic contact forces between a rubber cylinder and asphalt concretes samples and find the influence of the rolling speed on the normal contact force level.

The paper is structured as follows. Section 2 describes the experimental device and the procedure of measurement. In section 3 experimental results and discussion are presented. A conclusion giving the summary of the main outcomes closes the paper.

2. Experimental setup

2.1 Experimental device

The experimental device, also called LUG, shown in Fig. 1 is composed of concrete bloc with mass of 600 kg supported by four air springs. The rubber cylinder is fixed to a high precision spindle and the pavement sample is screwed at the center of top plate on the concrete bloc with its aluminum support. The rotations of the rubber cylinder and the plate are controlled with two different brushless synchronous motors with a rotational speeds ranging from 0.001 to 1000 rpm. The reactions of the spindle are measured by six cantilever strain gage force sensors which are connected to electronic amplifiers. Forces and moments can be controlled and recorded through a computer.

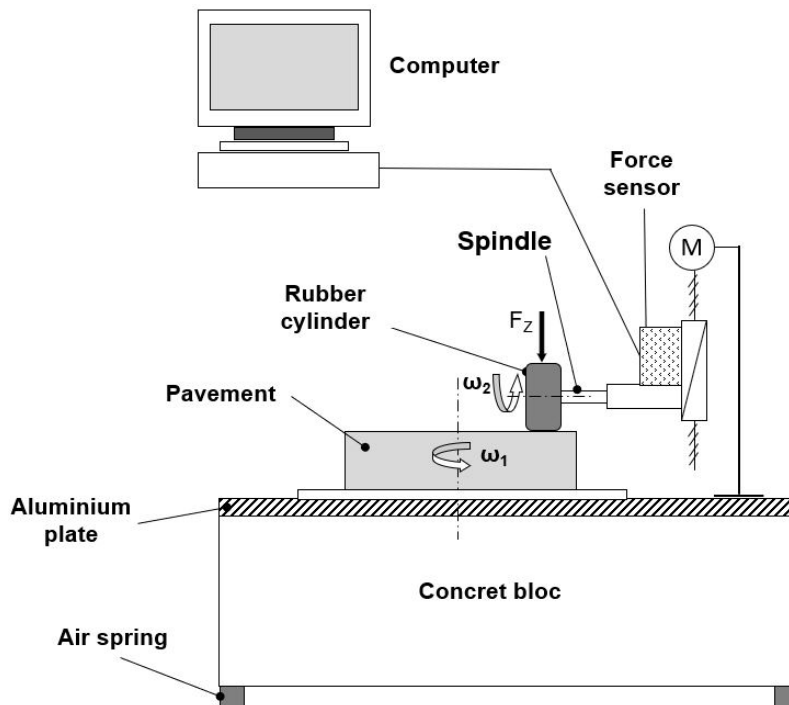


Figure 1: Experimental device. Rubber cylinder (Radius : 31.5 mm, width : 26 mm, thickness of the rubber : 5 mm), Pavement (thickness : 50 mm, radius : 49.5 mm)

2.2 Experimental procedure

The experiment consists of a freely rotating rubber cylinder in contact on the top surface of a road sample. A constant rotation speed of 20 rpm is applied onto the road sample. A wheel whose surface is made of rubber is put into contact against the upper surface of the sample with a controlled static force ranges from 0 to 100 N. The tests are realized with a normal contact force of 35 N and a sweep is set for the rotation speeds from 0 to 500 rpm. At each step, the duration of measurement is 10 s with a total of 11 steps. The dynamic forces signals are acquired with sampling frequencies of 300 Hz and 10 kHz.

2.3 Road samples

The six pavements samples used for the experiment campaign shown in Fig. 2 are porous asphalts. Five of them, labelled EN18131, EN18132, EN18133, EN18155 and EN18156, are very thin asphalts

concretes with aggregate size 0/6 mm. Thin asphalt are suitable and are known for their good acoustic performances. The sixth, labelled EN18153, is a semi grained asphalt with aggregate size 0/10 mm. This is a medium macro-texture asphalt concrete considered as a reference because this is the most used on the road network and parking. The composition of the six samples are summarized in Table 1.

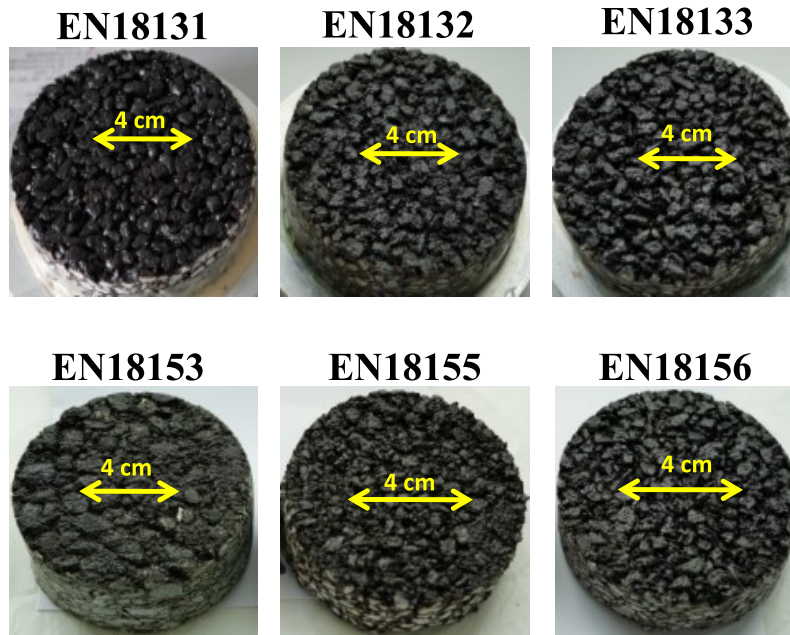


Figure 2: View of the six pavement samples used.

Table 1: Composition of the asphalt concretes

Pavement sample code	Type of asphalt concrete	Aggregate size	Sand	Stone
EN18131	Thin asphalt	0/6 mm	0/2 mm (9.0%)	4/6 mm (82.0%)
EN18132	Thin asphalt	0/6 mm	—	1/2 mm (15.4%) 4/6 mm (73.9%)
EN18133	Thin asphalt	0/6 mm	0/2 mm (9.0%)	1/2 mm (9.0%) 4/6 mm (72.9%)
EN18153	Semi grained asphalt	0/10 mm	0/4 mm (42.8%)	4/6 mm (8.0%) 6/10 mm (41.5%)
EN18155	Thin asphalt	0/6 mm	—	1/2 mm (12.4%) 4/6 mm (73.9%)
EN18156	Thin asphalt	0/6 mm	0/2 mm (9.0%)	1/2 mm (9.0%) 4/6 mm (72.9%)

3. Results and discussion

3.1 Time fluctuation of dynamic contact forces

The time fluctuations of longitudinal, lateral and normal forces are shown by Fig. 3 for sample EN18153 at speed 450 rpm (1.2 m/s). The absolute value of mean values of longitudinal and lateral forces, respectively 1.6 N and 3 N are negligible compare to the value of the mean value of normal force which is 36 N. This result is the same for all the asphalt concretes samples and rolling speeds. The means values of dynamic forces are constant and the data confirmed that the normal contact force is responsible of the rolling noise.

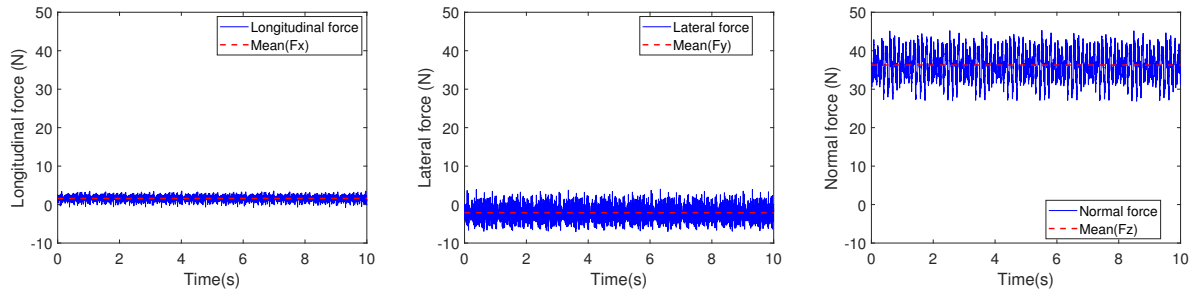


Figure 3: Time fluctuation of dynamic contact forces. F_x longitudinal force, F_y lateral force and F_z normal force.

The mean value of the normal contact force (see Fig. 4) is the same for the tested road samples and almost equal to initial load 35 N. At a given speed, the time evolution of the normal force is influenced by the texture of the pavement samples.

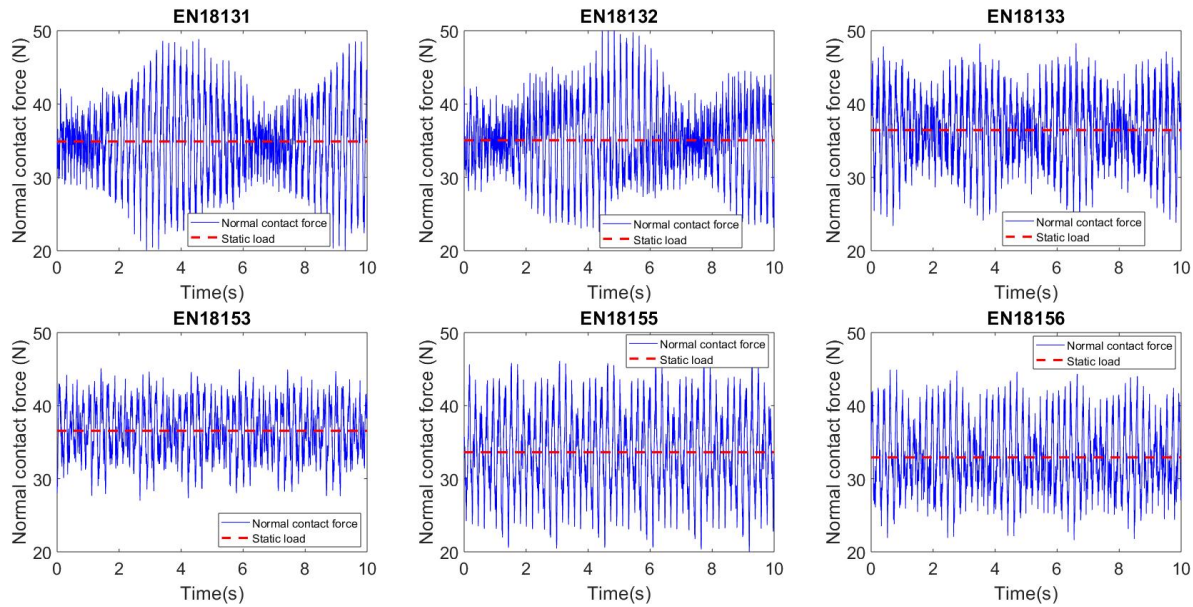


Figure 4: Time evolution of the normal force at 500 rpm (1.34 mm/s) for the six samples.

3.2 Rolling noise induced by normal contact force

In the literature, the overall noise level was largely studied. Sandberg and Ejsmont [1] proposed an empirical law between the noise level and the vehicle speed (Eq. (1)).

$$L = A + B \log_{10} V. \quad (1)$$

where L is the noise level in decibels, V the vehicle speed, A and B the regression coefficients.

In previous studies, several authors have used the same law (Eq. (1)) to predict the values of speed exponent n . Using the sound pressure level L_p (Eq. (2)), Dubois [11] has shown that $n = 1.7$ and Yokoi et al. have found that n varies between 0.6 and 1.1.

$$L_p \propto 20 \log_{10} V^n \quad (2)$$

Concerning the relation between vibrational level L_v (Eq. (3)), the values of the speed exponent found by Abdelounis at al. [9] are ranged from 0.7 to 0.96.

$$L_v \propto 20 \log_{10} V^n \quad (3)$$

The normal force level is the physical quantity used in the present study to investigate the rolling noise. We make the assumption that the values of longitudinal and lateral forces are equal to zero. From our measurement the normal force level in dB is expressed by the following relationship:

$$L_F = 20 \log_{10} \left(\frac{\sigma_F}{\sigma_{ref}} \right) \quad (4)$$

where $\sigma_F = \left(\frac{1}{N} \sum_{i=1}^N (F_i - F_z)^2 \right)^{1/2}$ is the standard deviation of normal contact force, N the number of time samples, F_i the instantaneous values of the normal force, F_z the mean value of the normal force and $\sigma_{ref} = 10^{-6}$ N. The normal force level can also be expressed as a scaling law (Eq. (5)):

$$L_F = 20 \log_{10} \left(\frac{V}{V_{ref}} \right)^m \quad (5)$$

where L_F is the level of normal force, V the rolling speed m the speed exponent and $V_{ref} = 1$ m/s.

The evolution of the level of normal force is a linear increasing function of the logarithm of the rolling speed (see Fig. 5). The tested asphalts concretes may be classified in two groups, the first group is composed of samples EN18131, EN18155 and EN18156 with high level of normal force in dB and the second group composed of EN18132, EN18133 and EN18153 with lower level of normal force. The range of the speed exponent m is from 0.38 to 1.11. The results are in agreement with the previous investigations.

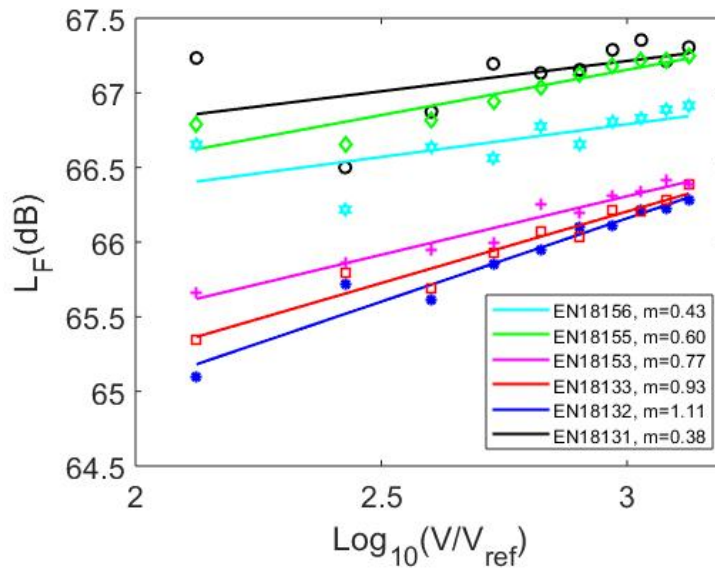


Figure 5: Relationship between L_F , the level of normal force and the logarithm of the rolling speed of the rubber cylinder.

In previous studies, the exponent of the rolling speed is ranged from 1 to 2.5 [5, 4]. These values of the slope take into account mechanical vibrations and aerodynamical phenomena [1]. The difference between the values expected for the slope n and our results is due to the fact that in the present study, only the mechanism of vibrations is highlighted.

4. Conclusion

In this paper, an experimental study has been performed to measure the dynamic contact forces between a rubber cylinder and pavement samples. The results show that the normal force is responsible of the rolling noise and the mean value of this force is the same for the tested samples. The normal contact force level is a linear increasing function of the logarithm of the rolling speed.

REFERENCES

1. Sandberg U. and Ejsmont, G. *Tyre/road reference book*, Informex, Sweden, (2002).
2. Lambert, J., Lelong, J. and Philipps-Bertin, C. European Network on Noise and Health, (EU Project no.226442), (2013).
3. Iwao, K. and Yamazaki, I. A study on the mechanism of tire/road noise *JSAE Review*, **17**(2), pp. 139–144, (1996).
4. F. Anfosso-Lédée and J. Cesbron. Bruit de roulement automobile : influence du revêtement de chaussée. *TECHNIQUES DE L'INGENIEUR*, Réf.: BR2060 V2, (2019).
5. Kuijpers, A. and Blokland, G., Tyre/road noise models in the last two decades : a critical evaluation, *Proceedings of Inter-Noise 2001, the 2001 International Congress and Exhibition on Noise Control Engineering*, The Hague, The Netherlands, 27–30 August (2001).
6. Yokoi, M. and Nakai, M. A Fundamental Study on Friction Noise(5th report, The influence of random surface roughness on frictional noise), *Bulletin of the JSME*, **25**(203), pp. 827–833, (1982).
7. Othman, M. O and Elkholy, A. H. Surfaces roughness measuring using dry friction noise, *Experimental Mechanics*, **47**, pp. 309–312, (1990).
8. Stoimenov, B. L, Maruyama, S., Adashi, K. and Kato, K. The roughness effect on the frequency of frictional sound, *Tribology International*, **40**, pp. 659–664, (2007).
9. Abdelounis, H. B., Le Bot, A., Perret-Liaudet, J. and Zahouani, H. An experimental study on roughness noise of dry rough flat surfaces, *Wear*, **25**(268), pp. 335–345, (2010).
10. Cesbron, J., Anfosso-Lédée, F., Duhamelc, D., Yinc, H.P. and Le Houédec, D. Experimental study of tyre/road contact forces in rolling conditions for noise prediction, *Journal of Sound and Vibration*, **320**(1-2), pp. 125–144, (2009).
11. Dubois, G., *Modèle de contact dynamique pneumatique chaussée par approche multi-aspérités: application au bruit de roulement*, Ph.D. thesis, Ecole Centrale de Nantes, France, doctoral Dissertation. <https://tel.archives-ouvertes.fr/tel-00755561>, (2012).