MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Influence of mechanical wear on tyre noise

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ABSTRACT

Tyre `wear` state is an important considerations from safety point of view, since it affects passenger comfort and noise levels. The noise signature changes significantly due to mechanical `wear` and chemical `ageing` during its lifetime when it encounters the road surface. These noise can be further categorized to low (structure - borne) and relatively high frequency (e.g., approximately 800 Hz and above).

This article details the drum test rig results which allows the reproducible measurements of tyre road noise on real road surfaces at speeds up to 120 km/h. To analyze the `wear`

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state of a passenger car tyre, at first the acceleration/vibration data of the tyre tread of varying non skid depth (NSD) is recorded by an acceleration sensor. The time-series waveform of acceleration at leading, center and trailing edge region is then extracted to frequency domain by using the well known Fast Fourier Transform (FFT) technique. The vertical mode frequency data and the noise signals of worn out tyre is analyzed. Finally, the effects and mechanisms of the noise phenomena are discussed and it is concluded that tyre noise can be quantified in advance for a particular tread pattern if tyre `ageing` is ignored.

Keywords: Noise, Wear

1. INTRODUCTION

NVH stands for Noise, Vibration, and Harshness used in automotive industry for the treatment of sounds and vibration. NVH refinement has become an essential part of vehicle/product development, as it is directly related to legislative/homologation requirement, sound/ride quality, driving pleasure, and most importantly customer satisfaction. Advanced simulation tools and experimental test methods are paramount in tyre industry to ensure lowered levels of noise, vibration and enhanced product design while maintaining the performance of other components. The specific NVH test from the concept phase include the usage of for example, semi-anechoic chamber, sound source identification & intensity mapping, order Analysis, modal analysis etc.

For a tyre designer, it is important to understand the wear of tread block because it strongly affect the contact interaction between the road and the tread block. Therefore, the wear of the tread block has been considered to predict the noise spectrum under realistic tyre operating conditions. The Fig. 1 show the type of tread and wear state considered for noise analysis. The subsequent section details the specification of experimental testing

Figure 1: 245/75 R16 tyre having rated IP of 250 kPa: Wear has been measured with respect to non skid depth

mainly for modal and drum type test analysis that was used to analyze the worn out tyres.

2. EXPERIMENTAL TESTING

With respect to fresh and worn out tyres, we have considered the following testing

Modal Analysis

To understand the dynamic characteristics of worn out tyres, modal analysis has been performed. We have followed the procedure outlined in SAE standard [1]. For this particular test, the following settings are possible:

- Support system for the tyre-rim assembly (fixed or freely suspended)
- Source of excitation i.e., impact hammer or electric system
- Types of boundary conditions i.e., unloaded or loaded
- Sensors selection to minimize the effect of additional mass/stiffness

This study has a practical impact for describing the dynamical properties of tyres. We have reported the modal frequencies for loaded and unloaded condition in the next section. The test has been conducted for fixed support system using impact hammer as an excitation source.

Drum test

The drum facility or road wheel include steel drum (diameter 2 m) against which tyre can be rolled. The available facility also enables the quarter car setting noise and vibration tests in a controlled, repeatable environment with low levels of background noise (approximately 20 dB(A)). The roller is connected to a machine dynamometer, that enables the passenger cars to be tested on a wide range of vertical load and drive speed (upto 650 rpm). The drum facility can be seen in Fig. 2. Following the standard

Figure 2: Drum facility showing the position of center and trailing microphones

procedure [2], with this facility we are able to measure sound pressure level (SPL), near & Far field Noise, acoustic parameters, frequency response etc.

3. RESULTS AND DISCUSSIONS

Modal results

Under fixed inflation pressure, wear induces total weight loss of tyres. We have observed the weight reduction of worn out tyres significantly with respect to fresh conditioned. According to our results, we have observed the frequencies shift from lower to higher as tyre gets worn out for torsional, translational, radial as well as roll mode. The summarized modal frequencies can be seen in Fig. 3. Based on these results, one

Unloaded Modal Frequencies				Loaded Modal Frequencies			
Modes	**Fresh**	**50% Worn**	**90% Worn**	**Modes**	**Fresh**	**50% Worn**	**90% Worn**
Torsion	56.2	56.2	56.2	**Longitudinal**	66.0	69.0	72.0
Lateral Translational	34.5	37.5	40.5	**Lateral Tilt**	37.7	40.7	43.7
Radial	68.0	72.0	75.0	**Vertical**	72.0	75.0	78.0
Roll	44.0	47.0	50.0	**Steer**	50.0	53.0	56.0

Figure 3: Figure showing the modal frequencies of fresh, 50 % and 90 % worn out tyres

can design the tyre wear state estimation system, with the dependency on tyre inflation pressure data and modal frequencies, see [4].

Air pumping noise

Under operating condition, there are other factors that contribute to the tyre noise, air displaced int/out of cavities between tyre tread and road surface is commonly referred as air pumping noise [5]. The effect of tread geometry on noise propagation is displayed in Fig. 4 and Fig. 5. One can directly relate the effect of tread volume reduction on sound

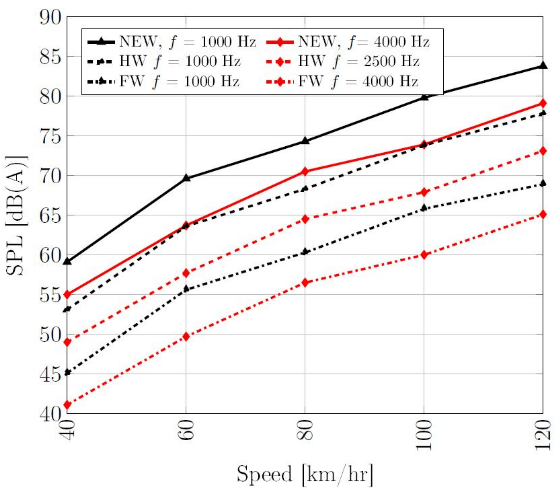

Figure 4: Sound Pressure Level vs Speed

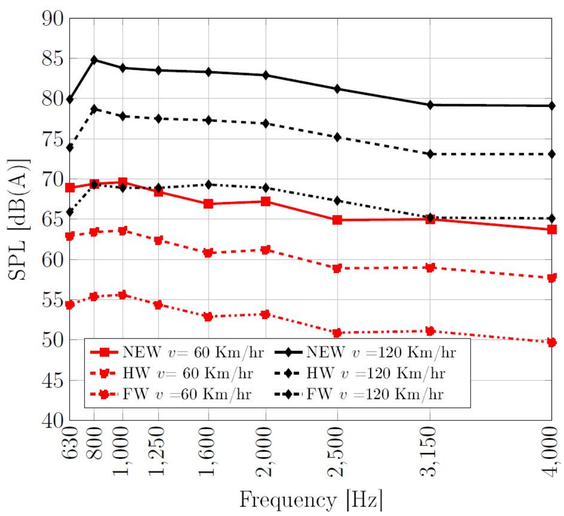

Figure 5: Sound Pressure Level vs Frequency

pressure level, that can be mathematically expressed as a SPL= f(speed,Frequency) [3]. It can be seen the nonlinear behavior of SPL with respect to speed and the magnitude increases by increasing the speed at constant frequency, however by increasing the frequency the sound pressure reduces. HW and FW are referred as half, fully worn out condition.

Drum test results

The noise measurements done using drum facility has been displayed in Fig. 6. It can be seen that noise from fresh tyre is more than worn out tyres at lower speed (40-80 kmph). In center microphone position, fresh tyre is louder by 6 -7 dB(A) than worn out tyres mainly in mid frequency range (800-1800 Hz) whereas fully-worn tyre is dominant in high frequency range (2500-4000 Hz). Furthermore, it should be emphasized that

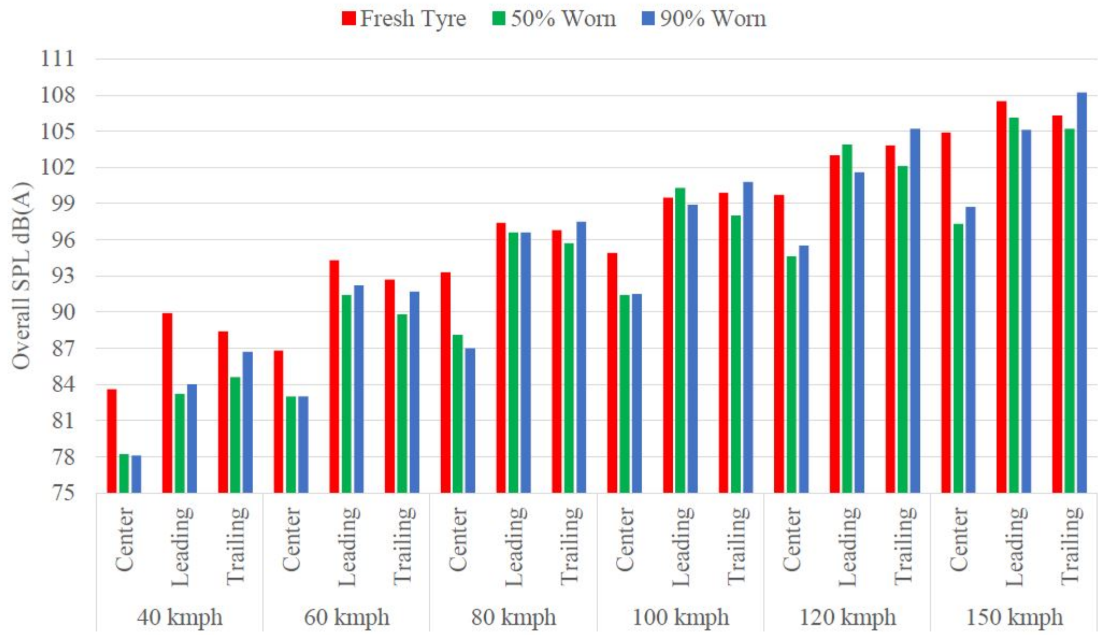

Figure 6: Figure showing overall noise level of fresh, 50 % and 90 % worn out tyres

the wear test only includes the effect of loss in tread rubber, ageing and other structural changes have not been incorporated.

4. CONCLUSIONS

The effect of artificial wear on tyre noise and vibration was investigated. It has been shown clearly that the decrease of tread thickness changes the vibrational characteristics, modal frequencies, as well as air flow through the through the grooves. The effect of wear on noise showed a decreasing trend with respect to fresh tyre. As a future problem, it would be necessary to quantify the noise levels on different textured surfaces [5].

5. ACKNOWLEDGEMENTS

The authors would like to thank Hari Shankar Singhania Elastomer and Tyre Research Institute (HASETRI) for giving us permission to utilise their research facilities.

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