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Temperature Gradient for Tire Pavement Noise Measurement

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Abstract

Sound pressure level (SPL) measurements were performed on a controlled test track vehicle coast-by runs of a passenger vehicle with six different sets of tires across a range of temperatures. A small but significant reduction of noise level with positive temperature increases was observed for some tires. The temperature gradient of the different tires at 80km/h ranged from -0.07 to + 0.01 dB/°C. Frequency analysis of the tire noise identified that noise content in the range of 1,300 to 1,900Hz was particularly sensitive to temperature changes. Differences in SPL due to speed and tire type were much greater than that due to temperature.

Keywords: *Temperature gradient, Tire-pavement noise, Target speed*

I. Introduction

Tire-pavement noise is a significant portion of noise coming from road vehicles and is therefore a logical focus of efforts to reduce overall traffic noise. Several publications have noted that ambient air and road surface temperature can have a significant effect on noise levels generated by moving vehicles[1 ~ 5]. However, the literatures are ambiguous and sometimes contradictory concerning exactly what the quantitative relationship is between temperature and noise.

This study is an experimental investigation of the effect of temperature on the tire-pavement noise emitted by a coasting vehicle. Tests were conducted over a span of four months with temperatures varying from a low of 4°C to a high of 34°C using six different sets of tires and coast-by runs at two different target speeds. The overall noise levels were measured and compared to identify any trends for each set of tires and any possible overall trends. The frequency spectrums of selected runs were examined to gain more insight into the variations in the noise levels due to speed, temperature and tire variations.

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II. Experiment

The goal of the experiment was to collect enough data over a large enough temperature span to determine what effect the temperature had on the tire-pavement noise level of several different passenger tires. The same test track and vehicle were used for all tests. The test track is an ISO standard pass-by or coast-by noise measurement track as shown in Figure 1 [5, 6]. The vehicle speed was calculated from the time difference of the impulses recorded from two

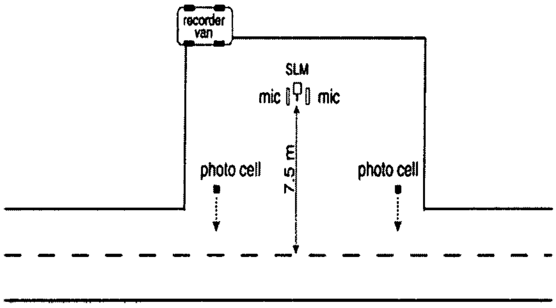

Figure 1. Diagram showing test track setup.

photocells that were 11 meters apart along the test track, on either side of the microphones. The sound level was recorded directly from a CEL sound level meter. The actual sound signal was recorded from the outputs of two 1/2″ microphones. The photocell, SLM and microphone signals were all recorded on a DAT recorder at a sample rate of 48,000 samples per second. All signals were also simultaneously recorded on a laptop computer at 20,400 samples per second and graphically displayed on screen. Vehicle speed, overall highest sound level in dBA from each microphone signal and the SLM were calculated and displayed immediately following each run. Also, an FFT of several 0.1 sec slices of each microphone signal at its highest overall level was calculated and graphically displayed in the frequency domain. The real-time data reduction allowed close monitoring of the test results.

Temperatures of the ambient air, the road surface and the tire surface were measured before and after each set of runs for each tire. Each temperature was measured with a digital heat probe thermometer, using the appropriate probe for either air or surface temperature. The thermometer was calibrated and had an accuracy of +/-0.1°C. Wind speeds were constantly monitored and noted. Testing was terminated if wind speeds exceeded 5m/sec.

The vehicle used for the pass-by runs was a Lexus GS400. The tires used for the runs were six different sets of four tires that spanned a reasonable cross section of passenger tires and sport tires. Details on the tires are listed in Table 1. The major differences in the tires were tread pattern depth, design and size of tread elements.

Data was collected in sets of 5 to 10 runs for each tire and speed. Prior to starting a set of runs, the vehicle was driven in a semi-aggressive manner for approximately 10 minutes to get the tires up to normal operating temperature. A set of 5 runs took about 5 minutes during which the starting and finishing temperatures were measured. Because of the short time required to complete a set of test runs, variation of temperatures from start to finish was small and an average temperature was used for the data. Normally sets of runs were completed at two target speeds, 53km/h and 80km/h. To capture the required temperatures and avoid windy conditions, tests were generally run from early morning till noon. During a good day six sets of tires could be tested at one temperature condition each.

Test runs were started sufficiently up-road to accelerate the vehicle, stabilize the speed, center the track, place the transmission in neutral, turn off the engine and coast by the test area. Because the test track has a slight downhill slope, speed loss while coasting in neutral with the engine off was minimal. As the vehicle entered the measurement area its rear taillight reflector triggered one of the photocells and when it exited the area the second photocell was triggered. During the entire pass the photocell pulses, the noise picked up by two microphones and the A-weighted instantaneous sound level measured by a sound level meter were recorded simultaneously on computer disk and digital tape. Immediately following the run, the peak

Table 1. List of test tires used in the study.

TIRE	SIZE	TREAD	INTENDED USE
Tire 1	P215/60R16	summer, shallow tread pattern	smooth roads, dry conditions
Tire 2	225/55R16	summer, shallow tread, high performance	smooth roads, dry conditions
Tire 3	P215/60R16	all season	dry, wet and snow traction
Tire 4	225/55R16	all season, high performance	dry, wet and snow traction
Tire 5	225/50R16	all season, high performance	dry, wet and snow traction
Tire 6	215/70R16	all season, high performance	light truck, off road capability

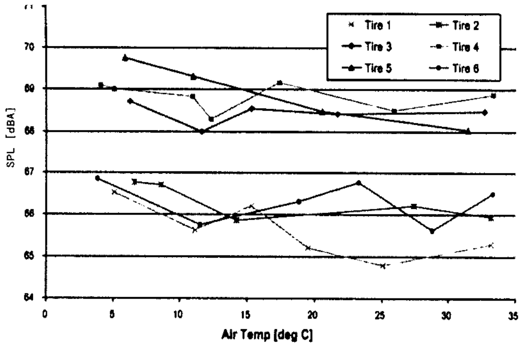

Figure 2. Graph showing sound pressure level versus air temperature at 53km/h.

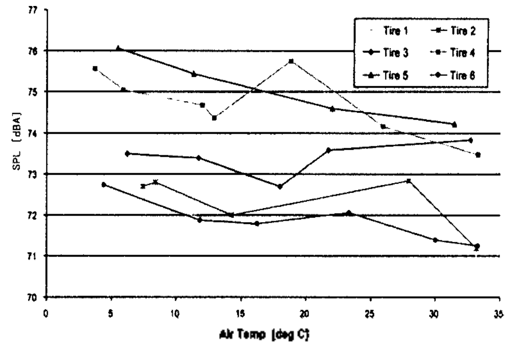

Figure 3. Graph showing sound pressure level versus air temperature at 80km/h.

in the SLM data was used to identify the time of peak noise. A 0.1 sec window around that time was used to pick the portion of each microphone signal for processing. The vehicle speed was calculated using the two pulses from the photocells. The speed was relayed to the driver so he would have direct feedback of reaching the target speed. This was essential for success at keeping the passes as close to the target speeds as possible since with different size tires, the vehicle speedometer may read either high or low depending on the tire diameter. Using that signal, an overall sound pressure level in dB and a frequency spectrum of the signal were calculated. Thus, the data was available for real-time analysis. Also, since the raw signals were all recorded, further analysis could be done at any later time.

III. Data analysis

Data was taken during five separate test periods covering one or two days each for a total of over 300 runs. The runs were grouped into 57 sets. Each set for a given tire at an average temperature and target speed was reduced to a single average value. For a given set of runs, the sound pressure level recorded had to be adjusted to the sound pressure level expected for the target speed. To do this a least squares linear regression method was used to arrive at an average sound pressure level for the target speed. Specifically, for each run the average sound pressure level from the levels measured with the two microphones along with the logarithm to base 10 of the recorded speed was

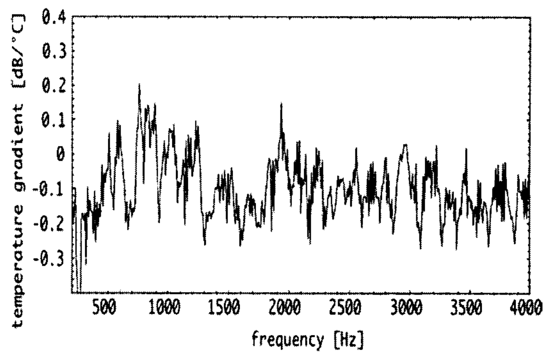

Figure 4. Temperature gradient across the frequency spectrum for Tire 1 at 80km/h.

used to determine A and B in the equation where A and B are the best fit determined by the linear regression. That equation was then used with an input speed of the target speed to calculate the adjusted average speed level for the set of runs. In all cases the runs in the set were performed at speeds both above and below the target speed and were normally within 5km/h of the target speed. The resulting linear regression returned a sound pressure level that normally had an error value of less than 0.3dB. The compiled results showing sound pressure level versus air temperature at the target speeds of 53 and 80km/h are shown in Figure 2 and 3.

Perhaps the most obvious observation of the data is that the sound pressure level due to tire-pavement noise is effected much more by vehicle speed and tire type than by temperature. Also, the results of the field tests show obvious variation from any linear relation between sound pressure level and temperature. A linear regression of the data was made. The temperature gradient of the different tires at 80km/h ranged from -0.07 to + 0.01 dB/°C.

To see more specifically what effect temperature has on the noise emitted by the rolling tire, the frequency spectrums of the recorded noise were analyzed. The frequency spectrums of the highest sound pressure levels are between 500 and 1,000Hz. Figure 4 shows the temperature gradient across the frequency spectrum. The somewhat consistently high temperature gradient between 1,300 to 1,900Hz is easily visible. The sound pressure levels below 600Hz account for only 0.3dB of the overall difference. The sound pressure levels for nearly all frequencies from 2,000 to 4,000Hz show a difference of about 3dB lower for the warm temperature resulting in an overall level difference of about 0.5dB.

Temperature does not have a general even effect on the sound pressure level of the frequency spectrums but a partially selective effect, with greatest influence on the overall sound pressure level in the region just below 600Hz and between 1,300 and 1,900Hz. Runs at 53km/h showed similar but less dramatic results. Such results could be expected since the overall temperature gradient for four of the six tires was less at 53km/h than at 80 km/h.

Ⅳ. Conclusions

Results from experimental coast-by runs on a controlled test track indicated a small but significant reduction of noise level with positive temperature increases for some tires. This SPL sensitivity to temperature was very tire type dependent. The temperature gradient of the different tires at 80km/h ranged from -0.07 to + 0.01 dB/°C. The temperature gradient was observed to be speed dependent since in these experiments the gradient was less negative at 53km/h than at 80km/h in four out of six cases. For most tires tested, the magnitude of the noise content in the range of 1,300 to 1,900Hz was particularly sensitive to temperature changes and might have a significant effect on the overall SPL. Finally, differences in SPL due to speed and tire type were much greater than that due to temperature.

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[Profile]

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