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Proposal for improvement of the calculation of engine noise in the D/F proposal

1. Introduction

All proposals for ASEP data processing use a simplified model for the noise generation of a vehicle. Three proposals measure the total vehicle noise and evaluate this as function of engine speed (Japan and De Graaff) or vehicle speed times acceleration (Gerhard). The D/F proposal is a little more advanced, since it separates the vehicle in two sub sources: engine and tyre. The tyre noise is measured during a coast by event. The engine noise is determined by subtracting the tyre noise from the total vehicle noise as measured during a WOT acceleration event. In both events the maximum noise level is recorded.

The question arises whether the tyre noise as measured during the coast by event is a sufficient accurate estimation of the tyre noise during the WOT acceleration event. The back ground of this question is that we have vehicleried out measurements, where the tyre noise, as determined with the D/F proposal, exceeded the total vehicle noise. This is off course not possible. So in reality the tyre noise has to be lower than the estimation with the D/F proposal.

2. Factors influencing tyre noise

We have identified several factors that may cause a difference in tyre noise during these two events:

1. torque on the tyres
2. vehicle speed
3. propagation path
4. view angle from tyre to microphone

ad 1

The torque effect increases the tyre noise during a WOT acceleration. This effect depends on acceleration, texture of the road surface an tyre tread pattern. On high accelerating vehicles, on very smooth surfaces and/or with coarse (M+S) tyres this effect can increase to more than 5 dB(A). For a common combination of accelleration, tyre and ISO track it is typically smaller than 1 dB(A). For the moment we therefore assume that this effect can be neglected.

ad 2,3 and 4

The vehicle speed, propagation path and view angle are dependent on the place of the vehicle in the test track. We have several places in the track that can be marked: line AA', line PP', line BB' and the place where L_{max} occurs. This last place may be different for the coast by event and the WOT acceleration event. The relevance of this variance in place is discussed below.

3. vehicle positions and effect on velocities, propagation path and view angle

The layout of the test track is given in the figure below. On this test track, both coast-by measurements as well as WOT measurements are performed. For every pass-by, the maximum sound level of the vehicle is recorded between the moment that the reference point of the vehicle (around the engine of the vehicle; e.g. at the front of the vehicle if the engine is at the front) passes line AA' and the moment that the back of the vehicle passes the line BB'.

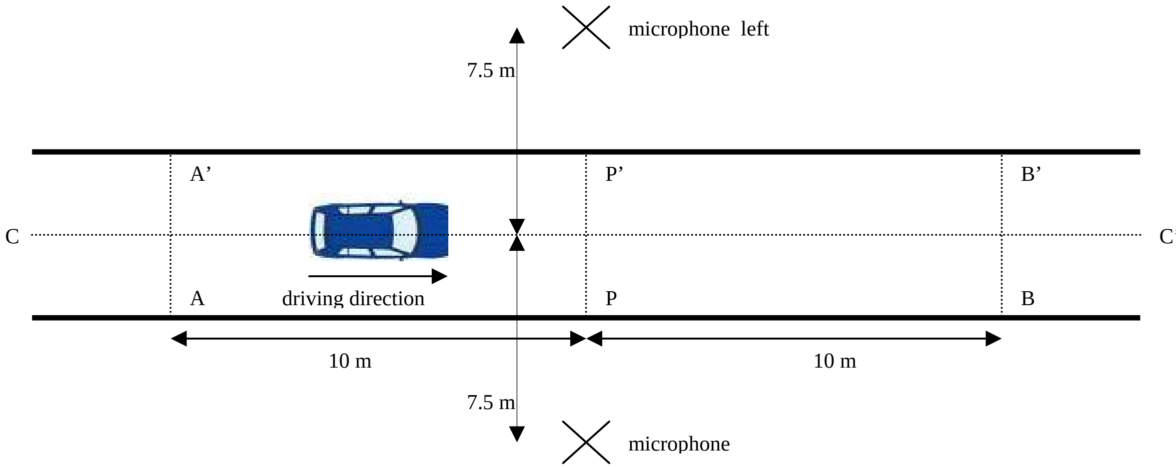

Figure 1: measurement setup

Coast-by measurement

During a coast-by measurement, the engine is shut down. The velocity of the reference point of the vehicle is 50 km/h at line PP' and remains almost constant. Assuming omni directional sound radiation, the maximum sound level (L_{tyre}) will be recorded at the moment the heart of the vehicle is closest to the microphones (7.5 meter) and this moment takes place if the heart of the vehicle will pass line PP' (i.e. this means that the reference point is around 2 to 3 meters past line PP', assuming a front engine vehicle). In some cases the tyre noise is not omni directional, which may cause a different position of $L_{max.}$ In most situations however, it can be expected that L_{max} is measured when the heart of the vehicle is close to PP'.

WOT measurement

During a WOT-measurement, the vehicle will accelerate in a certain gear, with maximum acceleration. When the reference point of the vehicle passes line PP', the velocity will be 50 km/h. Due to the fact that the vehicle will produce more sound at higher speed, the maximum noise level (L_{wot}) will be recorded past line PP' as indicated with line WW', in the figure below. Also the directivity of the vehicle sound emission may cause a difference in the position of line WW'. It is our experience that WW' is normally around 6 to 9 m past PP'

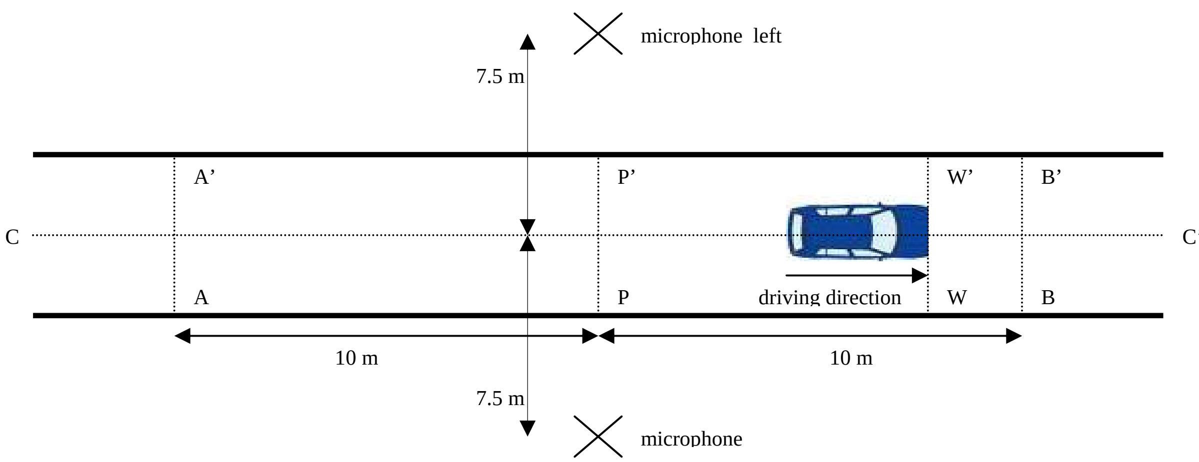

Figure 2: situation at the moment L_{wot} is recorded

Difference between Coast by and WOT measurement

This means that the position of the maximum sound level is different for the coast by and the WOT event. This has an effect on the speed of the vehicle at L_{max}, the length of the propagation path and the angle between vehicle and microphone. The effect of this on the calculation of the engine noise will be determined here after.

4. Calculation of effect of different positions on the engine and tyre noise

When calculating the engine noise of a passing vehicle using a WOT- and coast-by measurement, the following formula is used in the D/F proposal:

(1) $$L_{engine}(n_{ref}) = 10*\log(10^{(Lwot,i/10)} - 10^{(Ltyre(vBB',i)/10)})$$

(2) $$L_{tyre}(v_{BB'}) = L_{tyre}(50) + b*\log(v_{BB'}/50)$$

To demonstrate the effect of the different positions on the engine noise we assume a vehicle of 4 meter length with the reference point at the front of the vehicle. This vehicles accelerates from 46 km/h at line AA' to 50 km/h at line PP' and leaves the test track when the back of the vehicles passes line BB' with 55.6 km/h. The tyre slope b in formula (2) is assumed to be 33.

Effect of speed

In formula (1), L_{tyre} is determined at v_{BB} (55.6 km/h). L_{wot} will take place at v_{WW}, a lower speed depending on the position of the vehicle. In the graph below, the overestimation of the L_{tyre} within L_{wot} due to the speed effect is shown as a function of the position of the vehicle at L_{wot}.

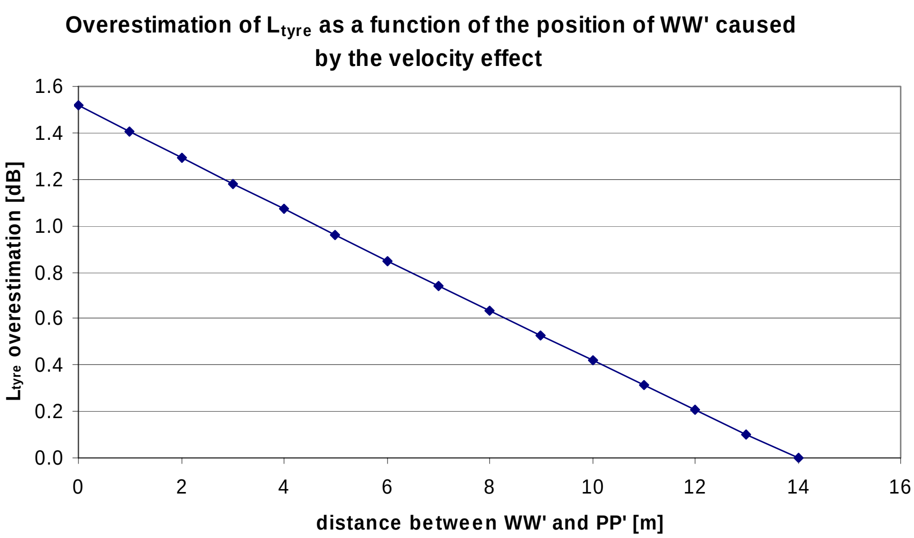

Figure 3: overestimation of L_{tyre} caused by the difference in velocity at BB' and WW'

Effect of different length of the propagation path

L_{wot} takes place when the vehicle is further away from the microphone than when L_{tyre} is recorded, so a distance effect is introduced. When assuming a omni directional point source model at the centre of the vehicle, this causes a difference in the measured noise level according to:

(3) $$20*\log\frac{\sqrt{7.5^2 + PW^2}}{7.5}$$

Where PW is the distance between the line PP' and WW' in figure 2. In the graph below this effect is shown.

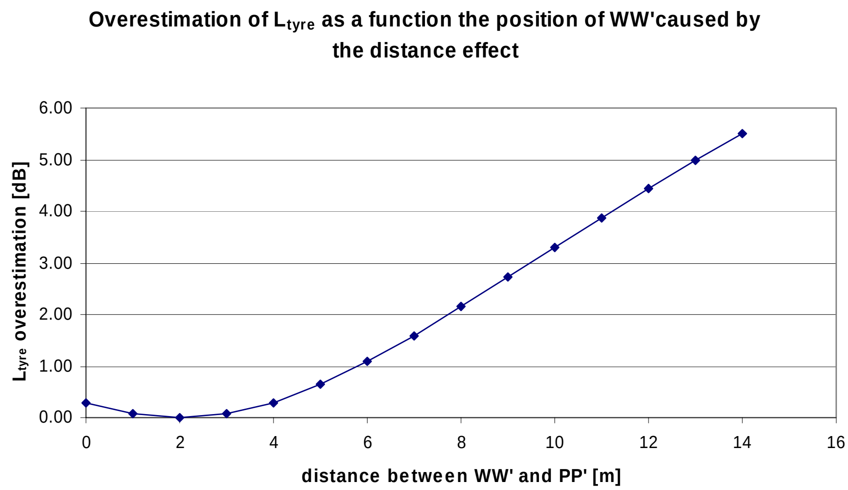

Figure 4: overestimation of L_{tyre} caused by the difference in propagation path length

Effect of different angle (directivity)

Due to the Horn effect a tyre will radiate its noise more efficiently in for- and backward direction than perpendicular on the driving direction. This Horn effect is more pronounced on smooth road surfaces and non profiles tyres and can reach a value of +6 dB(A) in for- back ward direction during near field measurements. When L_{tyre} is measured during the coast by measurement, the radiation angle from the tyre to the microphone is perpendicular (90°) to the driving direction; the radiation angle at the moment that L_{wot} is measured is between 90° and 32°, depending on the size and the position of the vehicle. The Horn effect on profiled tyres and 45° is less than +2 dB(A). The result of this effect is that in the D/F proposal, the tyre noise is likely to be underestimated.

However the propagation of this directivity from near field measurements to far field effects is not clear yet. Furthermore it is dependent on the tyre type. Therefore we do not take it into account for the moment.

5. Example
Measured:
L_{tyre} = 71.0 (at 50.0 km/h; reference point 2 meters from line PP')
L_{wot} = 74.0 (at 53.6 km/h; reference point 9 meters from line PP')

Calculated according to formula (1) and (2) from the current D/F proposal determines
$L_{tyre(vBB)} = 71 + 33*\log(55.6/50) = 72.5$
$L_{engine} = 68.6$

Improved estimation of L_{tyre} within L_{wot}:
If L_{wot} is recorded 9 meters from line PP', this causes the following effects:

Overestimation of L_{tyre} due to the higher velocity at BB' than at WW':	0.5
Overestimation of L_{tyre} due to the larger distance to the microphone at WW' than at PP':	2.7

So, if L_{tyre} is determined at the position of L_{wot}, L_{tyre} will be 72.5 - 0.5 - 2.7 = 69.3, which gives:
L_{tyre}= 69.3
L_{engine} = 72.2

6. Conclusion and recommendation
We recommend that the calculation of the engine noise in the D/F proposal will compensate the tyre noise for both the speed and vehicle position where $L_{wot,i}$ occurs. This implies the use of continuous measuring equipment.