euronoise

A single wheel trailer for tire/road noise measurements enabling both the CPX- and pass-by methods

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A single wheel trailer for tyre/road noise measurements has been developed. This new trailer concept is supplied with a towing beam, up to 8 m long, which ensures low background noise from support wheels and towing vehicle. Shielding hood is not necessary. The trailer can thus be used both for CPX-measurements with on-board carried microphones and for pass-by measurements using road-side microphones. Another advantage of using an unenclosed test tyre is that the emission frequency spectra would be almost unaffected by reflexes from suspension and loading devices. Test results can thus be more easily compared to the sound levels at the road-side. Due to the long towing beam, tyre prototypes >10 dB quieter than normal designs can be studied without disturbing background noise. The trailer has also been designed to ensure stable vehicle dynamics, even though the normally loaded measurement tyre is rolling up to 8 meters behind the support trailer. Another interesting feature is the telescopic design of the towing beam, which enable compaction of the trailer so that the measurement wheel is landed on the trailer support part, ensuring easy transportation to the measurement site.

1 Introduction

Reduction of traffic noise is one of today's more urgent issues. 20-30% of all Europeans are exposed to an equivalent sound level of at least 55 dB(A) at their façade. The dominating noise source from traffic at speeds above 35 km/h has been shown to be tyre/road noise. In order to further study the tyre/road noise generating mechanisms and/or evaluating reduction treatments a single wheel trailer has been developed. Development and manufacturing has been made with support from the EU FP6 project "Quiet City Transport" (QCITY).

2 A single wheel trailer for tyre/road noise measurements

The figure below shows a 3D model from an early design stage of the single wheel trailer. Due to the telescopic towing beam, the trailer can be compacted so that the loaded test tyre can be landed on the support trailer for easy transport to the measurement site.

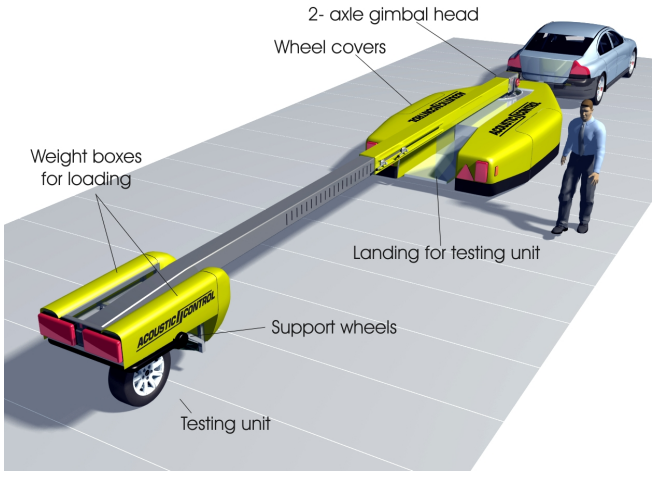

Fig. 1 Early drawing of the Single Wheel Trailer aimed both for CPX and pass-by measurements.

Why design and build a special trailer for tyre/road noise measurements? Some of the reasons are listed below:

Only one test tyre is needed. Simpler and cheaper producing and testing prototypes

When producing new low-noise tyre designs, substantial costs could be saved if only one prototype has to be manufactured. Use of only one prototype will facilitate prototype handling and tyre mounting during testing as well as storing and handling of prototype tyres

No influence from vehicle geometry such as reflexes from the wheel house etc

The wheel house often provides a partial enclosure of the tyre and may therefore change e.g. the directivity and total sound power emitted from the tyre/road system under test. Since the wheel house geometry changes from vehicle to vehicle it will be more rational to gather data from a free tyre, such as for the single wheel trailerand then if necessary calculate wheel house influence. By using the single wheel trailer the measured data would be vehicle independent thereby enabling more accurate comparison of noise data for other designs measured in the same way

Possible to study load influence in wide range

Normal vehicles offer an almost fixed loading to the tyre under test. The test tyre on the single wheel trailer is loaded "artificially" by adding weights of e.g. sand bags. The load could then be varied more freely from very low to high loadings. With aid of a trailer it is therefore possible to measure e.g. the load influence on the generated tyre/road noise from 1000 - 4000 N in small steps.

No acoustical interactions from the four wheels of the vehicle.

During pass-by or coast-by testing with aid of a normal four wheel vehicle, all tyres will contribute to the sound level in the microphone position. This will distort the directivity pattern of the emitted sound from the individual tyre. . This is in particular true if the tyre/road noise contains tonal components.

2.1 Designing the vehicle dynamics of the single wheel trailer

To ensure a stable dynamic behaviour of the single wheel trailer, extensive vehicle dynamic calculations have been performed. The trailer is designed for wheel diameters from R10 to R20 and wheel width from 69 mm to 364 mm. To guarantee the stability it is important to mount the wheel exactly in the centre of the trailer. Therefore a special spacer plate has been constructed for each set of rims.

Other important features of the trailer are to get the frame of the trailer and the 8 m long pulling girder stiff enough. Slip angles between the wheel and the ground, generate side forces. Therefore the trailer must be stiff enough to limit the rotation around the axis of the pulling girder. A large rotation could cause an unstable wobbling motion of the trailer.

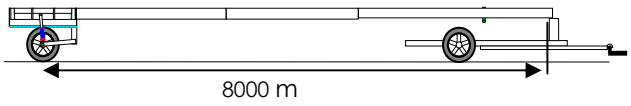

Fig 2. Simplified drawing of the single wheel trailer with the support trailer.

To avoid unstable wobbling motion, the whole trailer has been optimised regarding its torsion stiffness so that the lowest torsional resonance frequency is well above 2 Hz which gives a stable dynamics of the test wheel even 8 meters behind the trailer.

2.2 Measurements according to the CPX-standard ISO CD 11819-2

One of the requirements to be considered when developing the Single Wheel Trailer was that measurement of tyre/road noise according to the Close Proximity Method (CPX) standard ISO CD 11819-2 should be possible. In fig 3 the microphone positions close to the test tyre is shown. The distance to the support trailer is also shown.

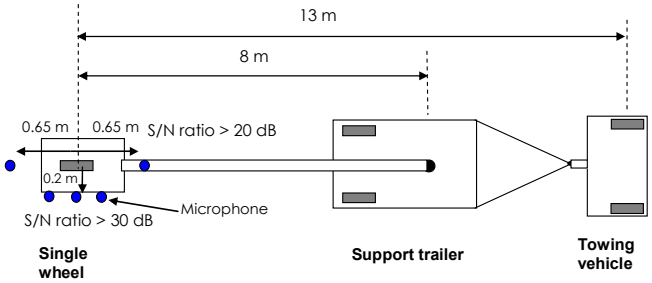

Fig 3. Distances between noise sources and microphones for CPX-measurements.

By ensuring an enough big distance between the measurement tyre and the support trailer, the S/N-ratio will be satisfactory both for CPX and Pass-by measurements. With the used dimensions of the trailer (Fig 3), the S/N ratio will be 35 dB-units for the 0.2m microphones and 25 dB-units for the 0.65 m microphones. This will enable measurements unaffected by background noise even for very quiet tyre designs. By using the single wheel trailer the measured frequency spectra will be unaffected by reflections from details of the test unit, which will enable to more accurately relate CPX-data and data from road-side measurements.

With possibility to carefully control parameters like load, and tyre pressure comparison of measurement results performed at different dates, locations and meteorological conditions is facilitated.

Fig 4. Free field mounted microphones on the test tyre unit of the trailer according to the CPX standard. The hood on the support trailer was not yet mounted at these measurements.

As can be seen in fig 4 above the microphones, mounted close to the test tyre, are in the direct sound field relative the sources primarily at the leading and trailing contact edge. The bottom side of the test unit is supplied with sound absorbing material in order to further ensure the free-field non-reflective acoustical environment. .

2.3 Measurements using roadside microphones

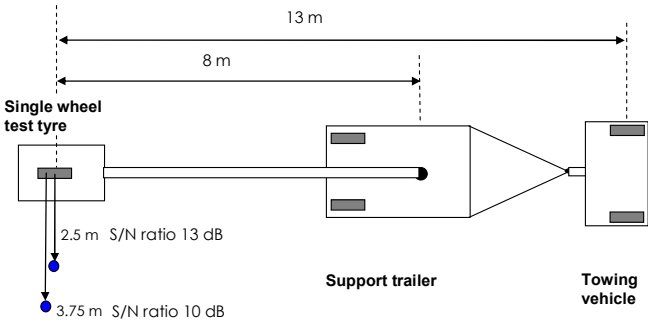

Fig 5. Distances between noise sources and microphones for measurement with road side microphones.

For road side measurements an S/N-ratio of 10 dB-units can be achieved at a microphone distance of 3.75 m from the tyre under test.

2.4 High accuracy measurements of the vehicle speed

The speed of the test tyre is monitored during the whole measurement procedure with aid of a GPS-system that stores the speed and position together with a time code (synchronized with the sound measurement system) on a flash memory. Due to the internal GPS accelerometers the accuracy of the speed data is further improved. The uncertainty of the speed measurement is ±0.2 km/h. Data is sampled every 10 milliseconds (sampling frequency is 100 Hz).

3 Trailer Applications

3.1 Evaluation of low noise road surfaces

The single wheel trailer has been used to study the noise reduction for several different low noise pavements. In the figure below one example is presented. From the figure it can be seen that the low noise road surface is up to 9 dB(A) less noisy compared to the reference pavement (Section 3).

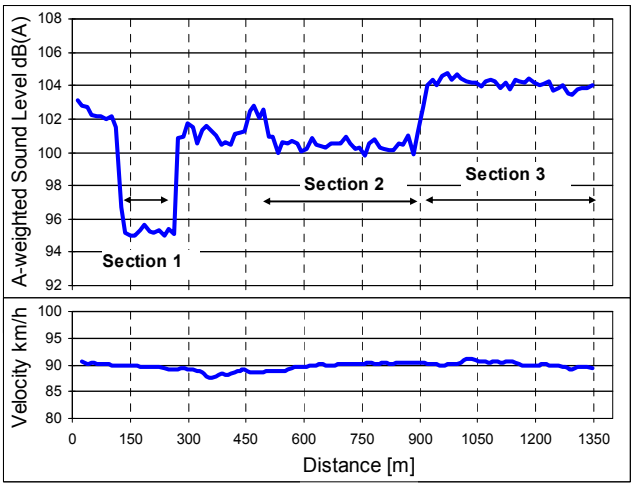

Fig 6. A-weighted sound level and vehicle velocity as a function of tyre position.
Three types of road pavement have been tested.

In Fig 7 below, the sound pressure levels are presented as 1/3 octave band spectra for the three road sections.

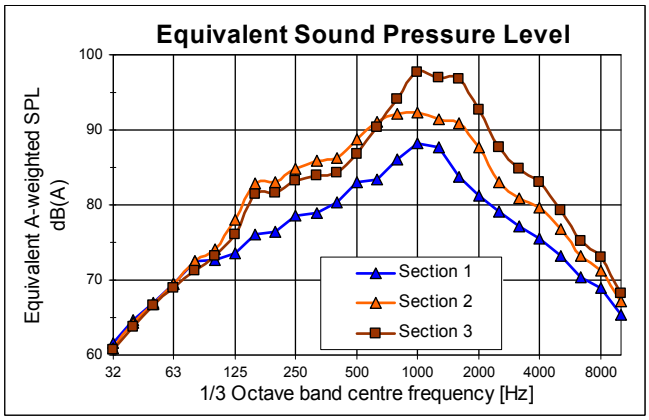

Fig 7. Equivalent sound pressure level, in 1/3 octave band, for the selected section according to fig 6.

3.2 Evaluation of low noise tyres

The single wheel trailer can be conveniently used to study the effects of

- different tyre tread patterns
- new tyre designs
- the tyre width dependence on different road pavements
- combinations of low noise tread designs and very smooth road surfaces.

3.3 - Updating of noise maps with road surface source emission data

Another interesting usage of the Single Wheel Trailer is to map the noise generation related road surfaces (standard reference tyres are used). The trailer would easily enable mapping of an entire road network with respect to its source strength.

Poorly maintained older worn road surfaces would display high surface roughness and thereby higher noise emission. On the contrary, well maintained newly paved, smooth road surfaces would give lower noise emission.

Data from the Single Wheel Trailer measurements could be used as input in the noise mapping calculation model software to adjust the emitted sound power from the different road sections.

Due to the synchronisation between the GPS system and the sound measurement system it is possible to relate CPX-levels to accurate geographical positions. In this way precise information on the source strength related to the road surface could be provided as input to the software.

In this way the single wheel trailer data could drastically improve the accuracy of the noise maps so that it would reflect the actual status of the road pavements in the area.

A noise map updated with respect to the current status of the road network can thus be created.

The excessive noise produced by poor road maintenance seen on the noise map, could even serve as an indicator to which areas that should be on the priority list for repaving.

4 Conclusions

A single wheel trailer for tyre/road noise measurements has been designed and built. The achievements are summarized below:

- The design permits the use of the trailer both for onboard carried microphones using the CPX method as well as for stationary road-side microphones employing the pass-by or coast-by measurement technique.
- The telescopic towing girder will enable different girder lengths allowing adaptation of the trailer configuration to the current test site.
- The telescopic towing girder will also permit that the test tyre unit is landed on the support trailer platform
- Tests reveal that the trailer is extremely stable and free from wobbling even for the maximum length of the towing girder
- Experience reveal that the background level from support wheels are very low and permits undisturbed CPX measurements of tyre/road noise emission levels at least 10 dB(A) lower than normal .
- The trailer could be conveniently used for monitoring the noise status of an entire road network.

Acknowledgments

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This support is gratefully acknowledged.

References

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[2] ISO CD 11819-1. Acoustic – Measurement of the influence of road surfaces on traffic noise – Part 1: Statistical Pass-By method

[3] ISO CD 11819-2, Acoustic – Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method