Twin wheels horn effect and pass-by noise

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Introduction

Similarly to light vehicles, tyre noise is the major contribution to overall noise levels for trucks at cruising speeds above 60-70 km/h. Besides different dimensions and characteristics, the main difference between truck tyres and vehicles tyres is that truck tyres can be mounted as twin wheels. In this context, this work aims at qualifying the horn effect amplification for twin wheels.

For this, a twin wheel system is built the dimensions of which are scaled with respect to the geometry of the truck tyres' mounting. Horn amplifications are determined using the reciprocity principle in and out of the plane of the wheel, using scaled positions of a pass–by situation.

Twin wheels mounting

For practical reasons, the twin wheel system built with two passenger car tyres. Tyres of dimensions 155/70R13 are chosen to have the same ratio diameter / tread width as truck tyres. The geometry is thus scaled by a factor 0.56.

The value of the distance between the two wheels is set according to two parameters. The first parameter is the ratio between the distance s between the treads of the twin wheels and the tyre diameter D (see Figure 1). The second parameter is the ratio between s and the tread width T. Experimentally, the first parameter gives s =4.15 cm and the second one gives s =4.2 cm. Therefore, a distance of 4.2 cm is set between the tyres of the scaled system by using a spacer especially made for this use (see Figure 1). The surface of the spacer is acoustically rigid, as in the case of twin wheels for trucks.

The two wheels are mounted on the same axle, which is rigidly hold (no back and forth displacements). The two rims face symmetrically as in a mirror, leaving their hollow parts towards the outside. Since the hollow part of truck wheels is "filled" by the wheel hub, an acoustically rigid protection is installed as indicated on Figure 1 (factious rim). The twin wheel system lies on an acoustically rigid plane, with no additional loads.

Measurement procedure

The system described above is characterised in terms of horn effect amplifications measured using acoustic reciprocity [1]. Instead of measuring outside the horn the noise radiated by a noise source inside the horn, we measure the noise inside the horn due to a noise source outside the horn. The source is an omnidirectional, impulse point source. The amplification factors are then obtained

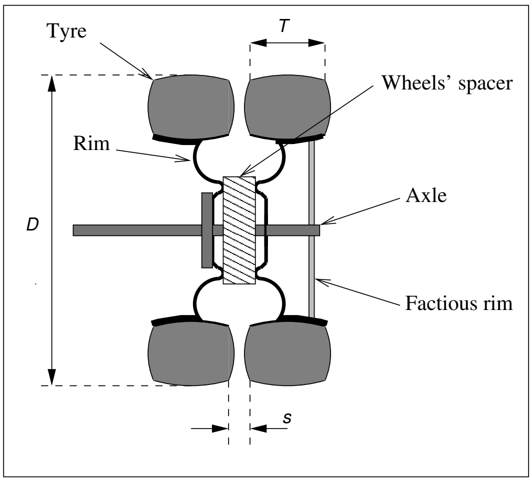

Figure 1: Schematic view of the mounting of the twin wheels.

by taking the ratio of the sound levels measured with and without the twin wheels. Averaged frequency spectra are recorded for the range spanning from 100 Hz to 10 kHz.

Horn effect amplification factors are measured for the azimutal positions indicated in Figure 2 for $\Phi = 0°$ to $\Phi = 90°$ by steps of 22.5°. The positions for $\Phi = 112.5°$ to $\Phi = 180°$ are obtained by moving the microphone on the rear side of the tyre while the sound source is placed from $\Phi = 67.5°$ to $\Phi = 0°$.

Using twin tyres, two measurement situations are possible. One can measure the influence of the exterior tyre on the noise radiated by the interior tyre or vice–versa. These two situations, respectively called "masked" and "baffled", are depicted in Figure 2. In the first situation, the second tyre has the effect of masking the sound recorded by the microphone, and in the second one the tyre acts as a baffle for the first tyre.

Sound pressure levels are measured at a distance d =75 cm and a height h =12 cm, i.e. for the same ratio h/d as for a pass–by measurement. The origin of the coordinate system is taken at the centre of the contact zone of the tyre under which the microphone is placed, as indicated in Figure 2. By doing so, the influence of the second tyre can be determined in both the masked and the baffled situation by comparisons with measurements using a single wheel.

Results and discussion

Measurement results are shown in Figure 2 for the different azimutal positions around the system. Measurements for the baffled situation (in blue) and the masked situation (in green) are compared to measurements performed with a single wheel using the same procedure (in red). The microphone (as a cross on the figure) is positioned directly on the ground surface, at 8 cm from the centre of the contact zone.

At $\Phi = 0°$, the amplification factors are very similar for the baffled and the masked situations. They show a series of three peaks between 500 Hz and 1000 Hz, i.e. before the region of maximum amplification. This would correspond to a frequency range between 250 Hz and 500 Hz for a real scale geometry. This phenomenon, not observed with a single tyre, seems associated with tyres mounted as twin wheels. At higher frequencies, amplifications are very similar that those obtained in the case of a single tyre.

For all azimutal positions, the overall maximum amplification reaches 16 dB. For a single tyre, it is observed at $\Phi = 0°$. For twin wheels, it is obtained at $\Phi = 22.5°$ and $\Phi = 45°$. From $\Phi = 0°$ to $\Phi = 45°$, the frequency of maximum amplification shifts from 1700 Hz to 2000 Hz. For a geometry of truck tyres, this would correspond to a frequency of around 1000 Hz, region of maximum contribution to A–weighted noise levels.

At $\Phi = 90°$, amplification factors for the baffled situation are very similar to that measured with a single tyre ; there is not significant influence of the second wheel. Amplification levels reach 10 dB and are almost always positive up to 10 kHz. On the other hand, amplifications for the masked situation are almost always negative on the same frequency range. As could be expected, the masking tyre has a maximum influence on the measurements at this position. A similar observation may be made at $\Phi = 112.5°$.

At $\Phi = 135°$, measurements for the baffled position show a series of large interferences which are not observed for the masked situation nor in the case of a single wheel. The periodicity of these peaks is about 2000 Hz. At this frequency, the quarter wavelength corresponds to the distance s between the wheels. It should also be noted that the maximum amplifications reach 8 dB at 2 kHz and 9 dB around 6 kHz.

For both $\Phi = 157.5°$ and $\Phi = 180°$, the amplification factors for twin wheels are positive at frequencies below 2000 Hz, corresponding to frequencies below 1000 Hz for a real scale geometry. They reach 5 dB to 7 dB at these two azimutal positions. This is quite different from single wheel measurements for which the amplification factors are negative on the entire frequency range.

Conclusions

Horn effect for twin wheels appears to differ in many ways from horn effect for a single tyre. Moreover, most of the deviations occur in the frequency range around 1000 Hz in the real scale geometry. This deserves to be confirmed by measurements on real twin truck tyres.

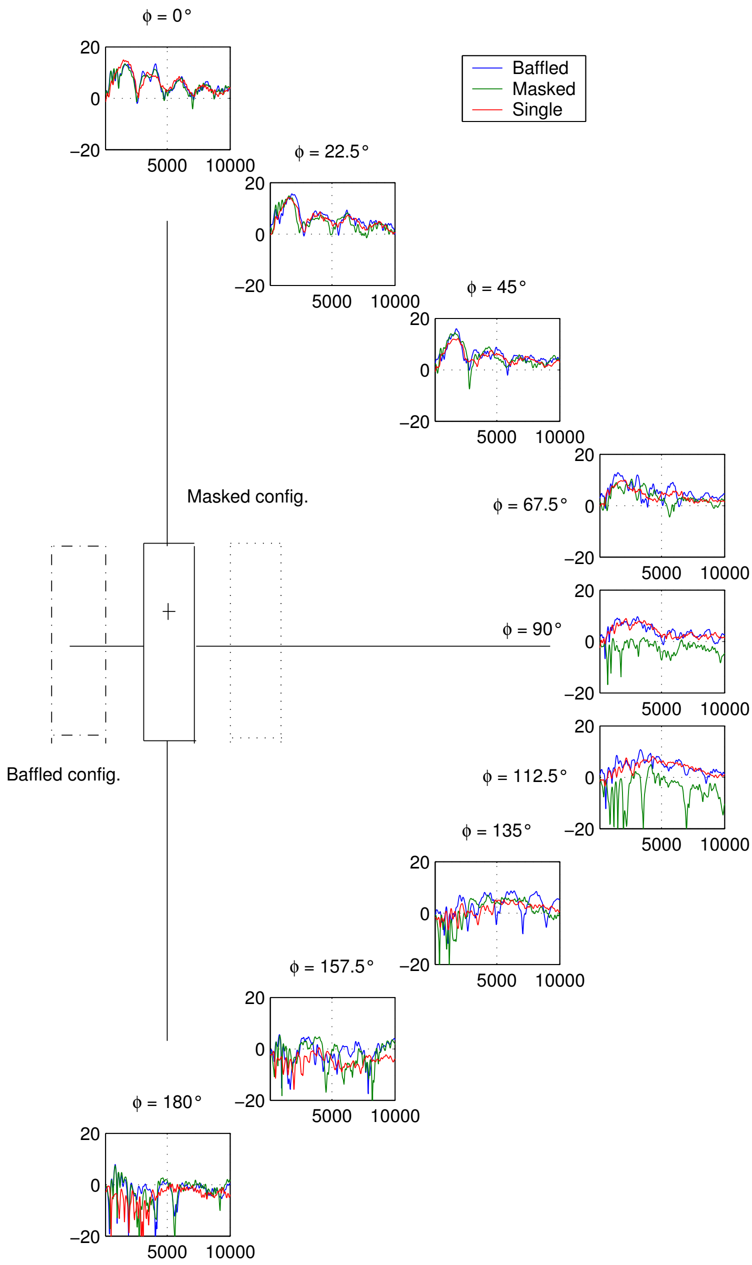

Figure 2: Directivity of the horn amplification for azimutal positions ranging from $\Phi = 0°$ to $\Phi = 180°$.

Acknowledgements

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References

[1] On the sound radiation from tyres. W. Kropp, F-X. Bécot, S. Barrelet, Acta Acustica united with Acustica **86** (2000), 769-779