DELIVERABLE 4.2.1[1]

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ACRONYM	**CITYHUSH**
TITLE	**Acoustically Green Road Vehicles and City Areas**
Work Package 4	**Propagation attenuation of road traffic noise**
4.2	**Air cooled tyre hoods for passenger cars – Tyre/road noise reduction by active and passive noise attenuation**
	Feasibility of passive noise attenuation within tyre hoods
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Dissemination Level

PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restrictec to a group specified by the consortium (including the Commission Services)	
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Nature of Deliverable

R	Report	✓
P	Prototype	
D	Demonstrator	
O	Other	

SEVENTH FRAMEWORK PROGRAMME

[1] see List of Deliverables, DoW – Annex I to the contract, p.32 (document 233655_CITYHUSH_AnnexI_DoW_2010-01-31_Corrections.pdf - available on the ftp-server)

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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

WP 4.2.1 aims at evaluate the concept of tyre hoods. Previous studies have fond tyre hoods to be an effective method for tyre/road noise reduction. The main drawbacks of tyre hoods have been because of excessive tyre temperatures and wear. The implementation of tyre hoods will be studied in order to evaluate the improvements that easily could be made today and what additional improvements that needs to be made to make the configuration sustainable. Due to comments received from the project reviewer the study of maintaining the temperature inside the tyre hood have been excluded. This deliverable mainly focuses on the potential noise reduction by using the concept of tyre hoods.

0.2 DESCRIPTION OF THE WORK PERFORMED SINCE THE BEGINNING OF THE PROJECT

The performed evaluation of tyre hoods was carried out using the CPX-trailer. An modifiable tyre hood was developed in the early part of the project in order to perform measurements of different tyre hood designs. The designed tyre hood was made using adjustable screens in order to shift its height relative to the road surface. Measurements was carried out with the aim of study the influence of absorption inside the tyre hood and the amount of screening required to obtain an apparent reduction of tyre/road noise.

0.3 FINAL RESULTS

0.3.1 Tyre hood screening

Improved effects are displayed as the open slit between the tyre hood and the road surface reaches less than 11 cm. The results indicate that the distance of 11 cm between road surface and lower tyre hood edge acts like a breakup distance, where the tyre/road noise are rather unchanged with slits larger than 11 cm and larger reductions are first seen using slit lengths smaller than 11 cm.

0.3.2 Tyre hood absorption

The results indicate positive effects from adding absorption to the tyre hood. Tyre hood designs that are more open show a larger influence of the added absorption, whereas the further enclosed tyre hood designs show less impact, on tyre/road noise, due to the absorptive material inside the tyre hood.

0.3.3 Source modification of tyre/road noise characteristics

The characteristics of tyre/road noise will change when implementing a hood around the tyre. The screened noise at the receiver will be more dominated by lower frequencies and for hoods with a small distance to the road surface it is likely that the characteristics will look more like the characteristics for a line source due to the small dimension of the gap between the hood and the road surface.

0.4 POTENTIAL IMPACT AND USE[2]

Introducing the screening technique in form of a tyre hood has been discussed for some time. Disadvantages have been regarding the heat problematic, where the tyre and brake discs require sufficient wind cooling to prevent overheating.

The investigation shows that the tyre hood has the potential of reducing the tyre/road noise in the range of 1 – 5 dBA-units.

0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

This deliverable was produced by ACL, being responsible for the development of a tyre hood suitable for the CPX-trailer and performing measurements and subsequent evaluation.

0.6 CONCLUSIONS

The investigation shows that the tyre hood has the potential of reducing the tyre/road noise in the range of 1 – 5 dBA-units. Further analysis show even larger potential in the specific frequency range between 800 Hz and 1250 Hz.

The implementation of the tyre hood concept holds many complications. The initial problematic regarding the overheating issue needs to be solved prior to the implementation on real vehicles.

2 *including the socio-economic impact and the wider societal implications of the project so far*

1 BACKGROUND

1.1 THE CITYHUSH PROJECT

With low drive-line noise from electric driving the tyre/road noise will dominate at speeds as low as 20 km/h. This means that if the benefit from the low electric driving noise should be fully utilized, then tyre/road noise must also be reduced by 5 -10 dBA units. The concept of need for tyre/road noise reduction for electric driving is new and has not been reported in literature up to now (except in papers and deliverables from the QCITY project).

Before 1980, tests were performed on the concept of tyre hoods (which is done by simply placing a box around the tyre). The noise reduction found was in the range of 5-10 dBA units while the tyre temperature raised by 10-12 °C. This increase in temperature causes a dramatic shortening of the tyre wear life. We believe that adding an acoustically optimised cooling air intake to the tyre hood could eliminate the problem of raised temperature. Thereby the tyre hood concept could be ready for use on real vehicles e.g. hybrid electric vehicles. Therefore, tyre hood with acoustically optimised cooling air intake is a new concept that will be studied in the frame of the CITYHUSH project.

2 METHOD

2.1 TYRE HOOD DESIGN

In order to evaluate the tyre hood impact on the tyre/road noise a tyre hood was designed to fit a CPX-trailer. The tyre hood was first designed using Google SketchUp, Fig 2.2, before built using MDF board. The tyre hood contains a semi closed space where screens are mounted round the tyre. Upon this tyre hood one extra layer of screens where mounted making it possible to shift the distance between the screen and the road surface, see Fig 2.1. The reference hood was designed with the largest distance between the lower edge of the screen and the road surface reaching 21 cm. The extra layer of hood screens where able to get as near the road surface as 5 cm, which was the maximum enclosed space tried out.

Figure 2.1 Reference tyre hood mounted on the CPX trailer using the UNIROYAL, Tiger Paw AWP II reference tyre.

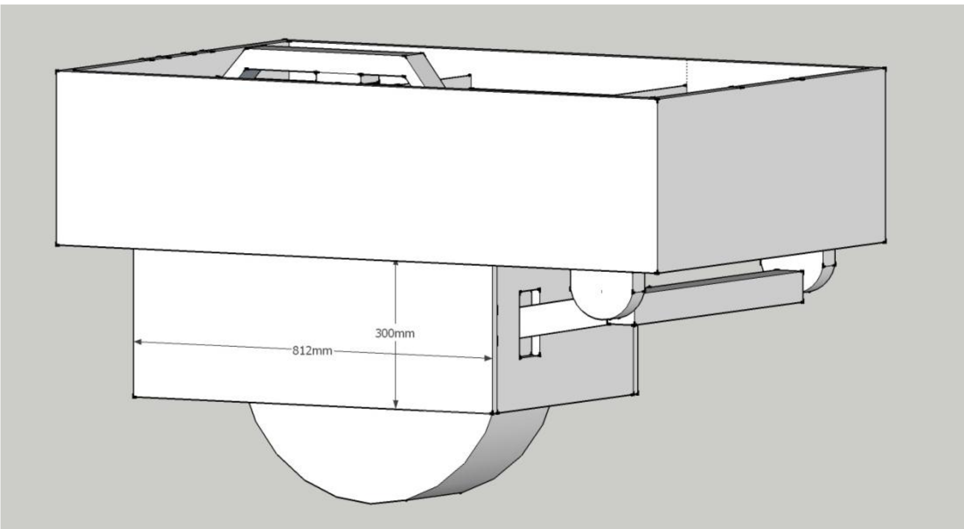


Figure 2.2 SketchUp model of tyre designed hood.

2.2 MEASUREMENTS

2.2.1 Microphone positioning

The microphone positions stated in the provisional standard CPX-method (*ISO CD 11819-2*) had to be rearranged in order to evaluate the tyre hood effect, see Figure 2.3 , since the mandatory microphone positions are located too close to the tyre. Only one microphone position was used. The microphone positioned was selected with respect to the fixed pass by microphone position according to ISO 362-1:2007, see Fig 2.4. The distance of the microphone was extended 0.9 m from the tyre edge, which was as far as possible due to traffic safety regulations since measurements were carried out on a public street.

The consequence of increasing the distance between the noise source and the receiver is reduced signal to noise ratio due to wind noise and turbulence even though a wind screen over the microphone was used. Various literature point out noise levels in the range of 70 to 60 dB SL at 1000 Hz due to the resulting wind velocities corresponding to 50 km/h.

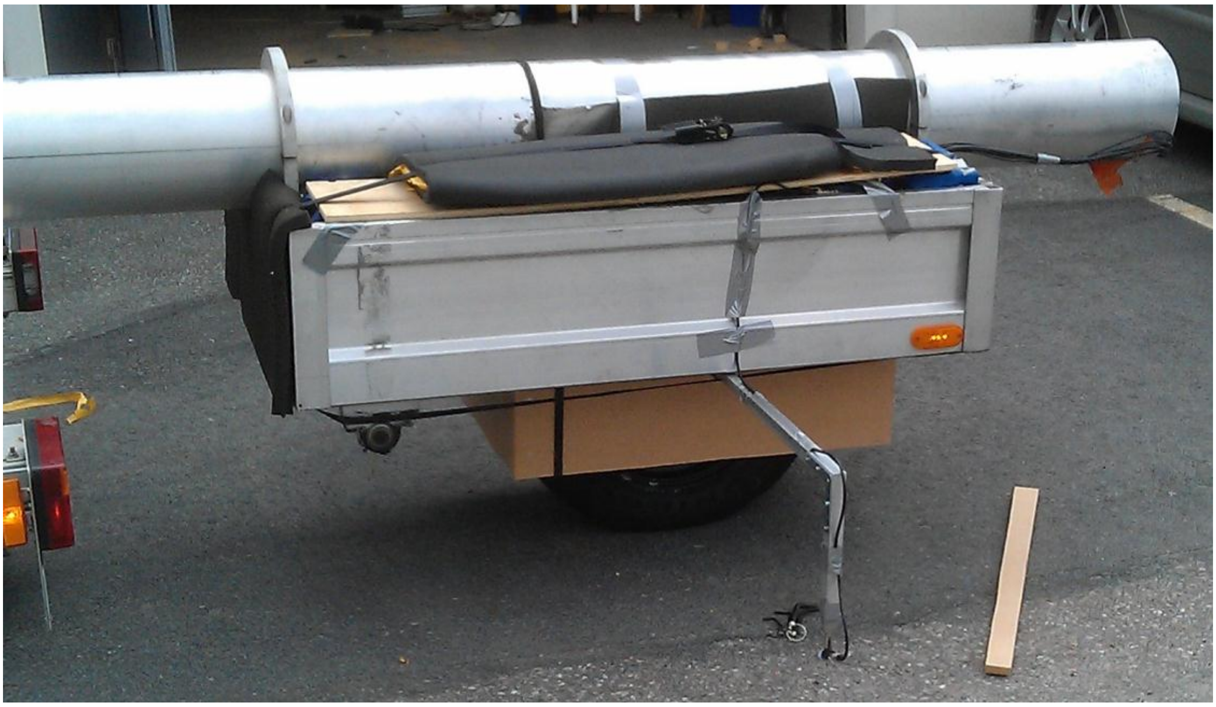


Figure 2.3

Modified microphone arm. Corresponding to the pass by measurement microphone positioning.

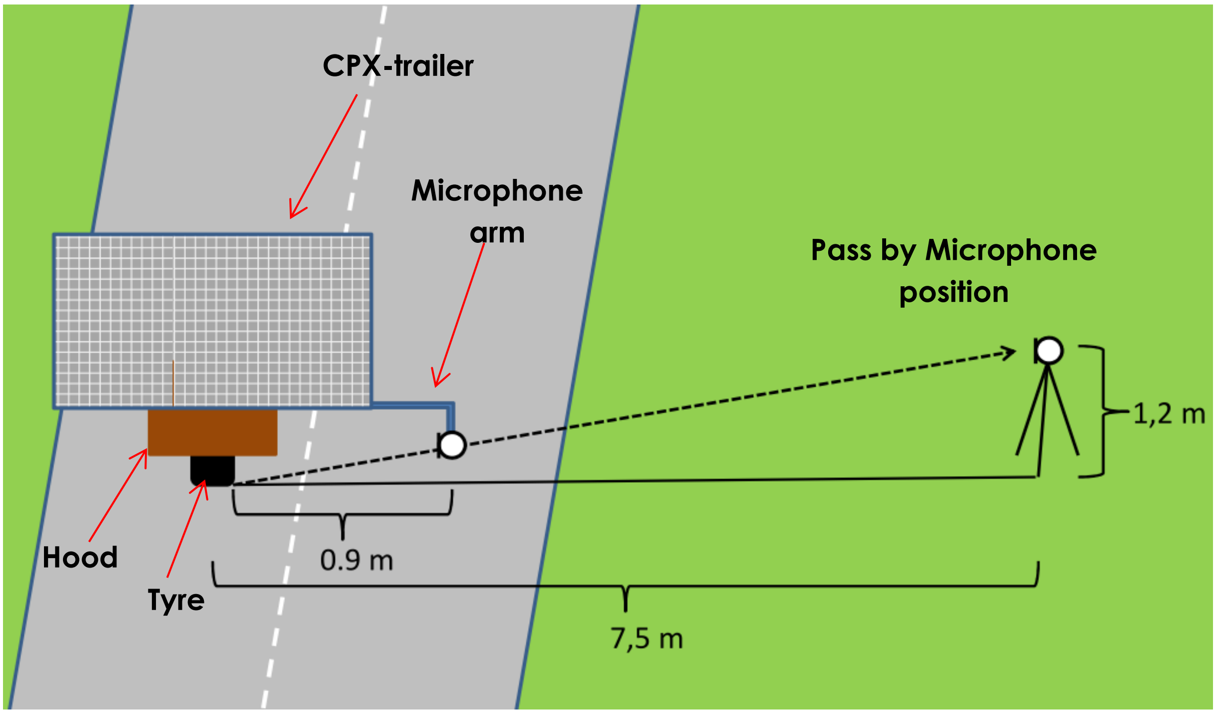


Figure 2.4
Designed microphone arm corresponding to pass by microphone setup.

2.2.2 Tyre hood modifications

The design of the tyre hood made it possible to perform modifications to the hood. The reference tyre hood starting height over the road surface was 21 cm. The outer screen shell was extended, letting the opening between hood and road surface decrease by 2 cm at a time. These extensions was made eight times reaching 5 cm distance between the lower hood edge and the road surface. Figure 2.5 show the tyre hood and the modification scheme used to increase the enclosure of the tyre. Two additional tyre hood versions where evaluated including absorption inside the tyre hood. The first additional tyre hood measurement with added absorption was carried out for the reference tyre hood and a second measurement on the maximum enclosed tyre hood design.

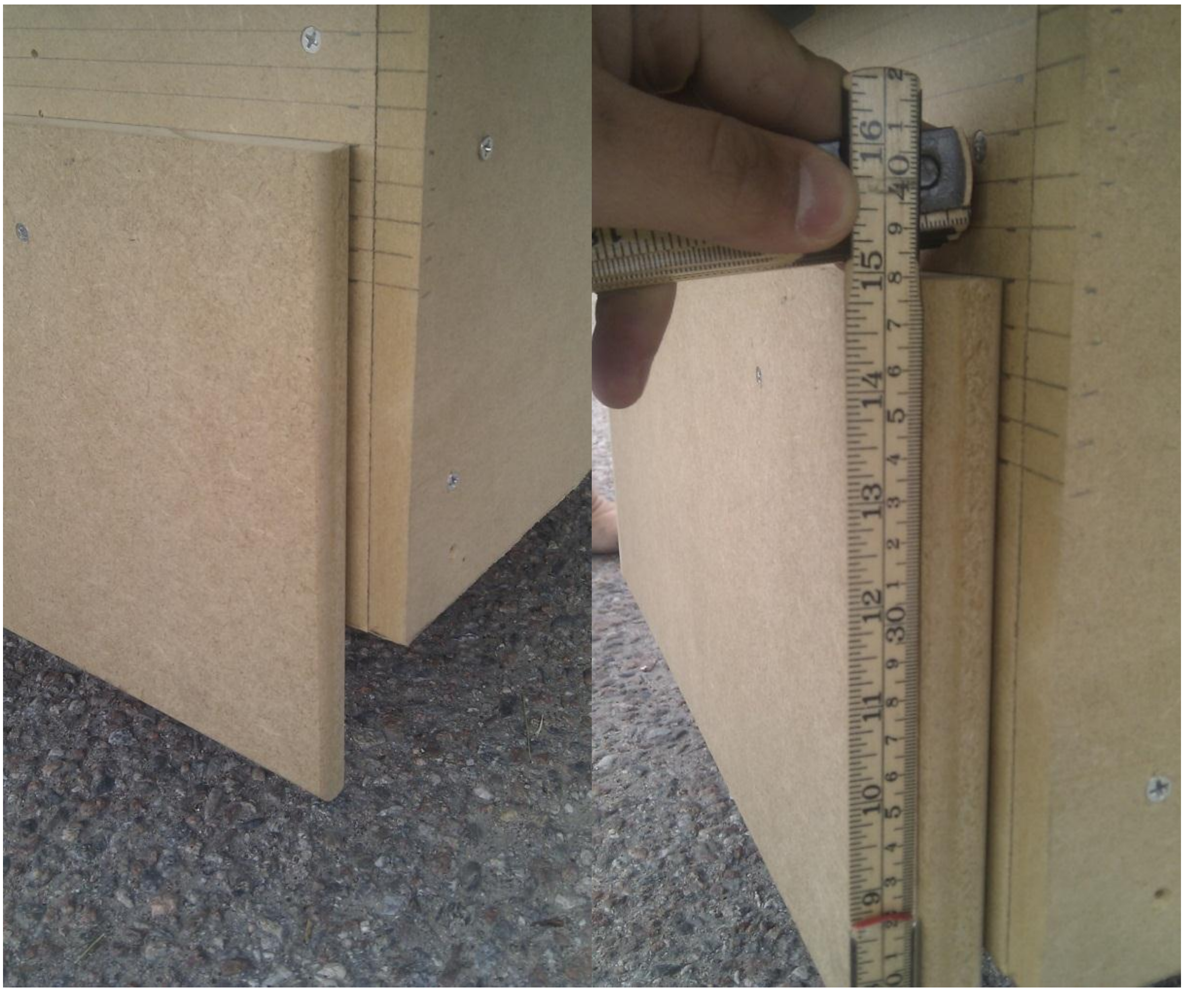


Figure 2.5

Tyre hood with the extra layer of screens.

2.2.3 Driving conditions and measurement location

The measurements were carried out in the countryside north of Stockholm in June 20012. The test segment was straight and no reflecting objects where located near the road. The tested road section was chosen in regard of its presumed noisy performance. The road surface contained a rough texture with a stone size > 11 mm. The entire measurement equipage is seen in Figure 2.6.

Each tyre hood model was measured two times with the intention of collecting a sufficient amount of data for a representative average sound pressure level. The vehicle speed and external noise interferences where monitored making it possible to exclude eventual disturbances.

Figure 2.6

The measurement equipage.

3 RESULTS

The tyre hood has only been evaluated using the CPX-trailer, leaving out the heating problematic. Table 3.1 show the measured tyre hood designs where clarifications regarding absorption and hood screen sizes are made.

Using a tyre hood does not reduce the broad band tyre/road noise frequency spectra. Result showing the total A-weighted sound pressure level reduction are consequently less due to the lack of efficiency in the low frequency region of the emitted tyre/road noise. However the largest effects are to be seen in the 1000 Hz region, since most emitted energy due to tyre/road noise are excited in that frequency region.

Table 3.1 Tyre hood modification scheme.

ID	Absorption	Distance of lower hood edge to road surface [cm]
Ref hood	No	21
Ref hood +2 cm	No	19
Ref hood +4 cm	No	17
Ref hood +6 cm	No	15
Ref hood +8 cm	No	13
Ref hood +10 cm	No	11
Ref hood +12 cm	No	9
Ref hood +14 cm	No	7
Ref hood +16 cm	No	5
Ref hood +abs	Yes	21
Ref hood +16 cm + abs	Yes	5

3.1 REDUCED TYRE/ROAD NOSE

Results showing the total A-weighted sound pressure level at the above mentioned microphone position are seen in Figure 3.1. The maximum reduction are measured using "*Ref hood + 16 cm +abs*" reaching approximately 4 dBA reduced tyre/road noise. The results only show marginal effects on the tyre road noise for the tyre hood designs with a distance between the lower hood edge and the road surface larger than 11 cm. Improved effects are displayed as the open slit between the tyre hood and the road surface reaches less than 11 cm. The results indicate that the distance of 11 cm between road surface and lower tyre hood edge acts like a breakup distance, where the tyre/road noise are rather unchanged with slits larger than 11 cm and larger reductions are first seen using slit widths smaller than 11 cm.

Figure 3.2 show the reduced tyre/road noise for the different tyre hood designs using a selected frequency range. The selected frequency range are made with respect to the energy characteristics of tyre/road noise, which mostly contain energy in the range of 800 Hz to 1250 Hz. A similar pattern is displayed, where larger effects are visible for opening slits smaller than 11 cm. Greater improvements are visible selecting the more narrow frequency span, since disturbances due to wind and turbulence are in some extent left out. Two tyre hood designs show reduced tyre/road noise levels larger than 5 dBA and the more open enclosure designs display reduced noise levels by in the region of 1 dBA.

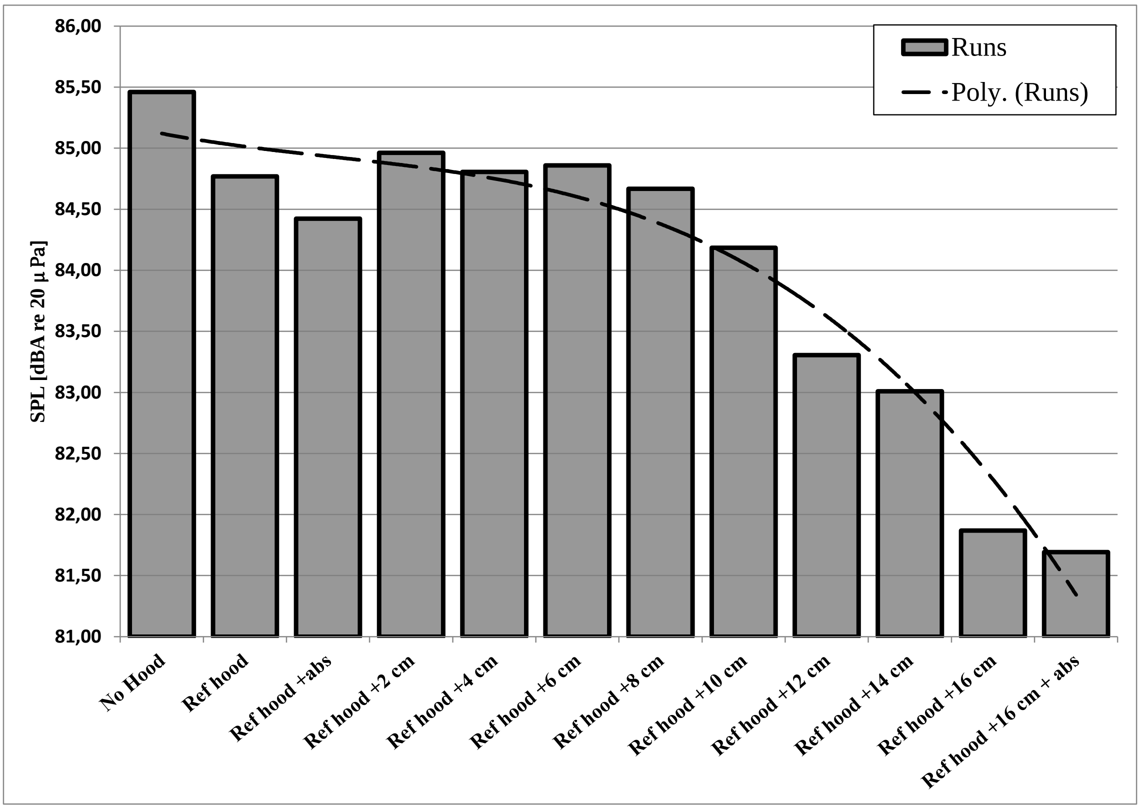


Figure 3.1 Total A-weighted sound pressure level for the various tyre hood designs.

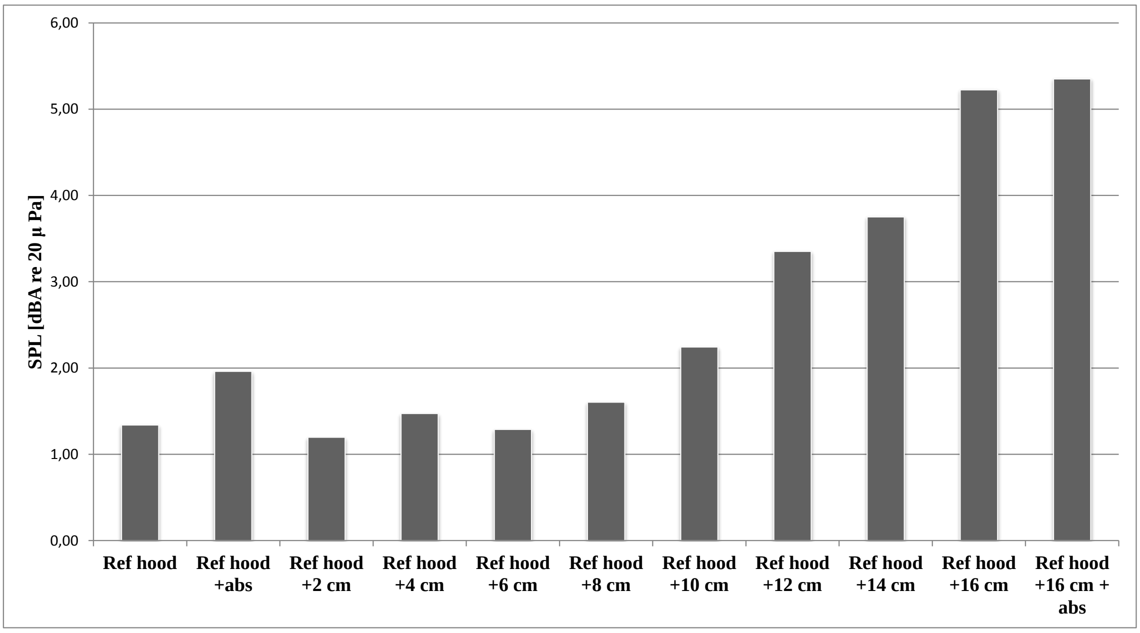


Figure 3.2
Reduced tyre/road noise compared to no tyre hood. Only 1/3 octave band 800 Hz to 1250 Hz.

The tyre hood designs with added absorption are compared in Figure 3.3. The two measured designs with absorption are compared to its corresponding design without absorption. Figure 3.3 shows that when adding absorption inside the reference hood the tyre road noise reduction improves by 0.7 dBA between 500 Hz and 2000 Hz and the narrower frequency range between 800 Hz and 1250 Hz improvements are in the range of 1,3 dBA. Similar range of improvements are not seen for the comparison between "*Ref hood +16 cm*" and "*Ref hood +16 cm + abs*" as the improvements in both frequency range selections show progresses of less than 0.2 dBA.

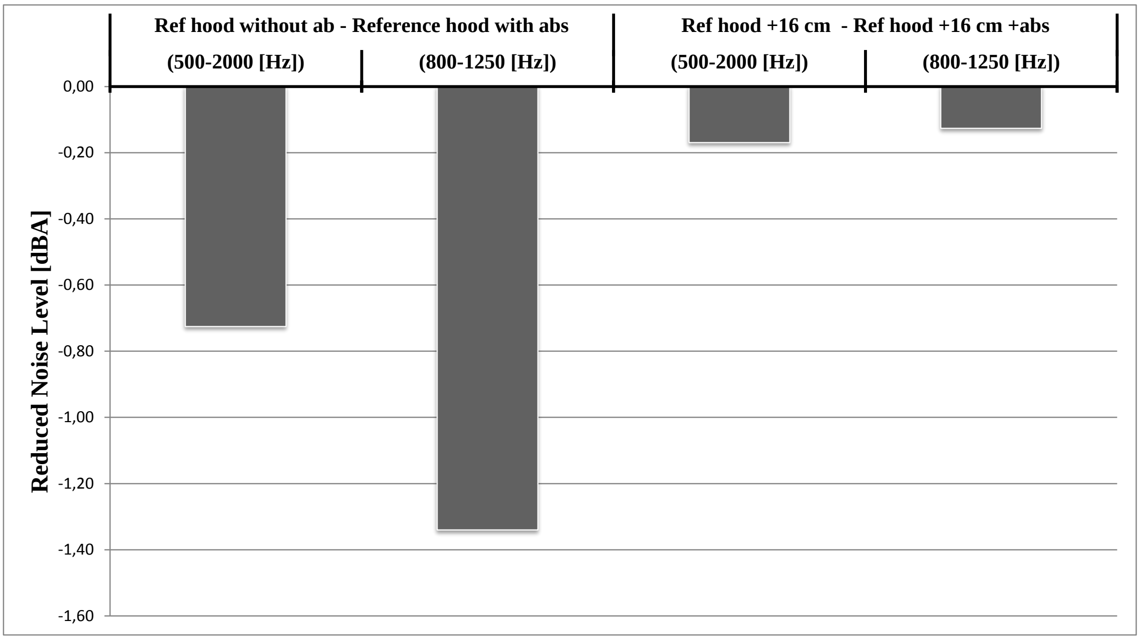


Figure 3.3
Reduced noise level due to added absorption inside the tyre hood.

3.2 SPECTRAL BEHAVIOUR

The measured sound pressure level spectras are showed in 3D line plot in Figure 3.4 and 2D line plot in Figure 3.5. Effects of the tyre hood are mainly seen inte frequency region between 1/3 octave band centre frequency of 500 Hz to 1250 Hz, on the basis of the low tyre/road noise excitation in the frequncies above and below this region.

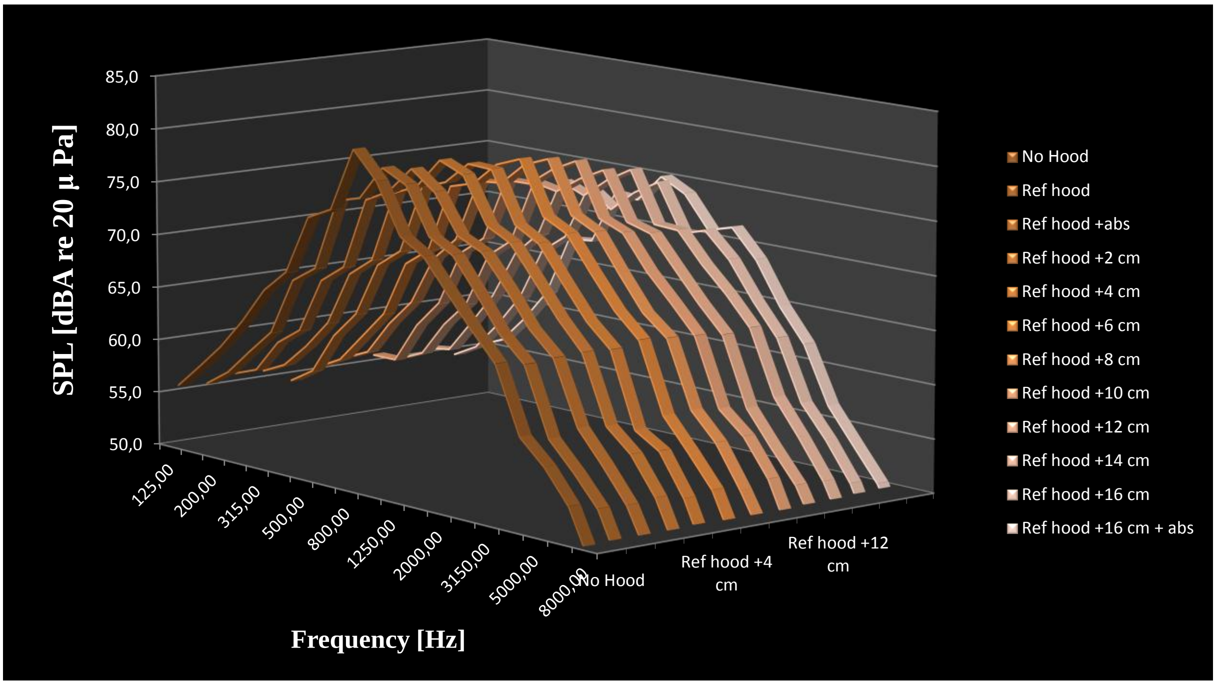


Figure 3.4 3D line plot showing the effect of varying the tyre hood design in 1/3 octave band.

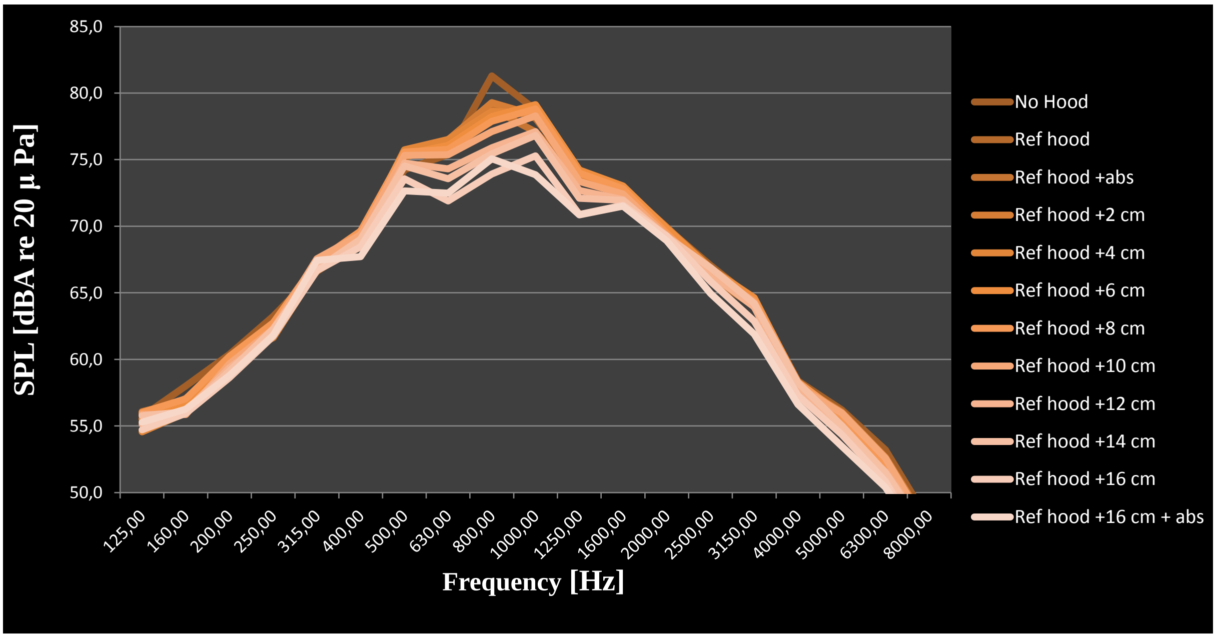


Figure 3.5 2D line plot showing the effect of varying the tyre hood design in 1/3 octave band.

The results in Figure 3.6 show the effects of different tyre hood designs and its screening efficiency regarding various frequency bands. Effects that have been mentioned in previous sections are once again visible, where noise reduction due to the tyre hood distinctively increases once the tyre hood reaches 11 cm distance between the tyre hood and the road surface. Frequencies above 1600 Hz and below 400 Hz show effects that are more or less neglectable, whereas screening effects are visible for frequencies between 1250 Hz and 800.

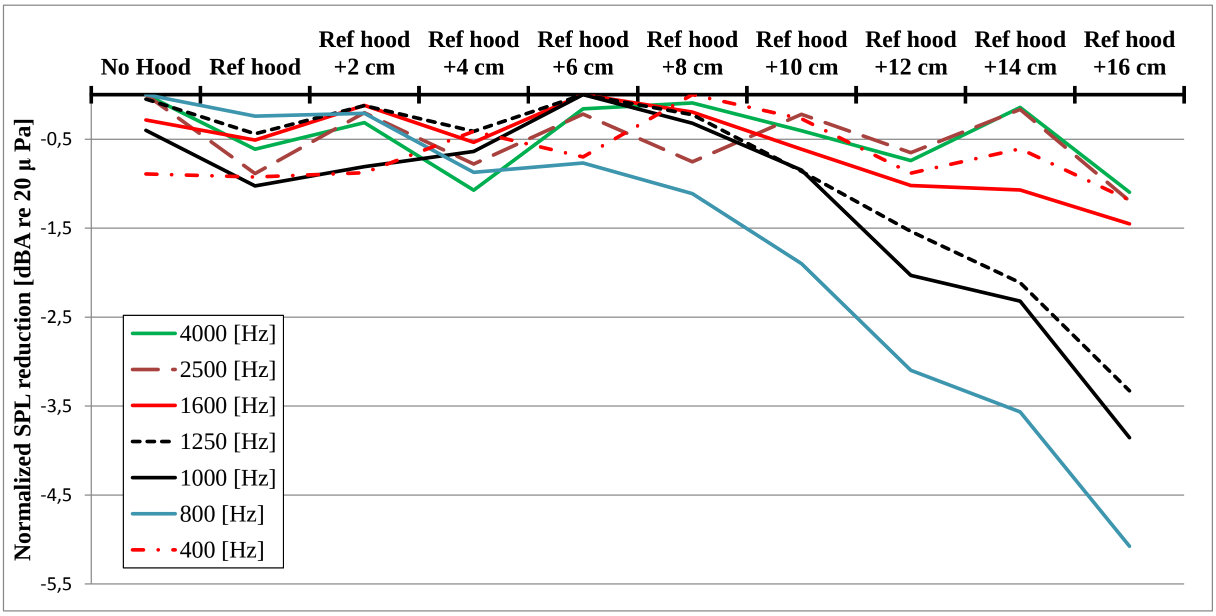


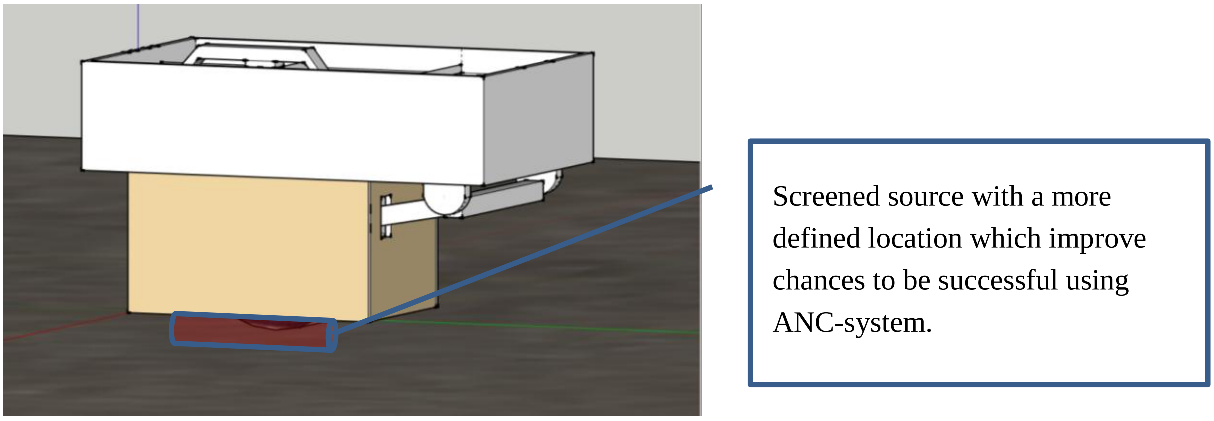
Figure 3.6

Comparison of tyre hood effects at various 1/3 octave bands.

4 GENERAL DISCUSSION

Dealing with the overheating problematic using a tyre hood with acoustically optimised cooling air intake needs further analysis. The implementation of tyre hoods have been tested using the CPX-trailer and evaluation of cooling air intake on the wheel arch is still to be evaluated with respect to the concern of overheating.

The tyre hood generates a change in tyre/road source characteristics. The capsulation of the source improves the possibility to absorb the tyre/road noise. The capsulation also improves the chances to be successful using an ANC(Active Noise Cancelation) system to further reduce the tyre/road noise. The reasons for this are mainly due to that the remaining noise are low frequent and the characteristics of the reduced noise look more like a line source due to the small gap between the road surface and the tyre hood. Also the location of the source to be cancelled out is more defined.



The tyre hood concept has a potential to reduce the noise from the tyre/raod contact with up to 5 dB(A)-units. The efficiency of the tyre hood are within the frequency range of 500Hz to 16oo Hz. The gap between the surface and the hood determins the upper frequency range of the noise reduction.

5 REFERENCES

1-1996, Technical Review, Windscreening of Outdoor Microphones, Brüel & Kjær