Fundamental Mechanisms of the Noise Reduction of Sound Absorbing LWRT Underbody Panels

K. Pfaffelhuber,
Röchling SE & Co. KG, 67547 Worms, Germany, klaus.pfaffelhuber@roechling-automotive.de

Introduction

Due to the CO2 reduction requirements at cars, vans and trucks, the aerodynamically optimized covering of the area below these vehicles becomes more and more important. Stiff sandwich underbody panels made from glasfiber reinforced thermoplastic layers (LWRT: Low Weight Reinforced Thermoplastics) are meanwhile established in passenger cars. By using porous layers, these LWRT-Panels have additional sound absorptive properties. So the aerodynamical and acoustical improvement could be combined [1][2][3].

At DAGA 2013 near and far field measurements of the pass by noise reduction achieved by absorptive LWRT underbody panels at a small truck and a van were presented [3]. At these vehicles an improvement of about 2-3dB(A) was obtained.

To get a better understanding of the fundamental mechanisms of absorbing underbody panels in the following investigation a simple cubic model was constructed and excited with a loudspeaker below the cube. The sound pressure around the cube was measured with and without LWRT-Panels. In parallel the same situation was simulated in a computer model.

Cubic model

Fig.1 shows this cubic model surrounded by 12 microphones. The block has a length of 3,2m and a width of 1,6m. The microphones have a distance of 750mm to the block and a height above the ground of 250mm.

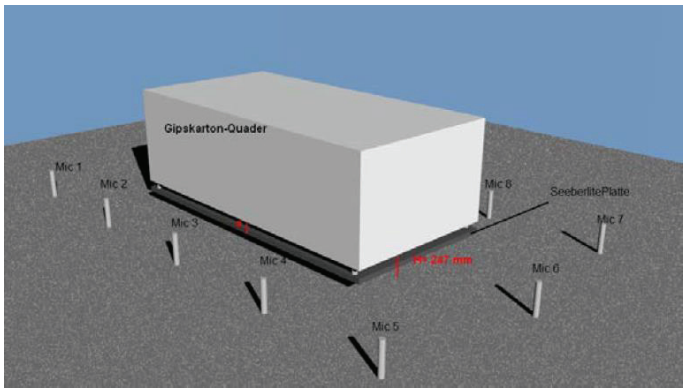

Fig 1: Modelled arrangement of block with sound absorbing LWRT plate, loudspeakers and microphones

The block has a distance to the ground of 247mm and between block and street an absorbing LWRT-plate is placed with different wall distances to the lower surface of the block (fig. 2a).

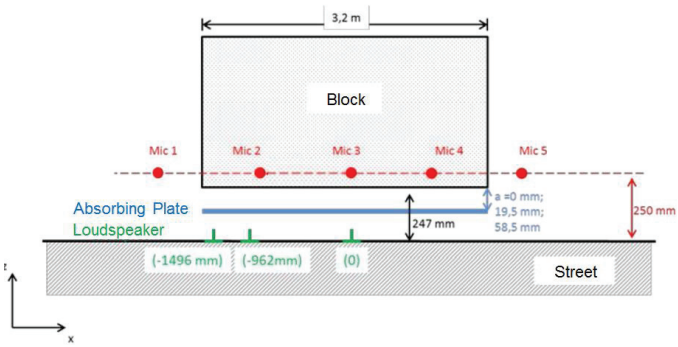

Fig 2a: Simulated arrangement of block with sound absorbing LWRT plate, loudspeakers and microphone positions

A virtual loudspeaker is placed in the ground plane at five different positions (fig. 2b): in the middle of the block (0; 0; 0), at position "engine" (-962; 0; 0), middle front position, (-1496; 0; 0), middle side position (0;-676; 0), position "wheel" (-962;-676;0)

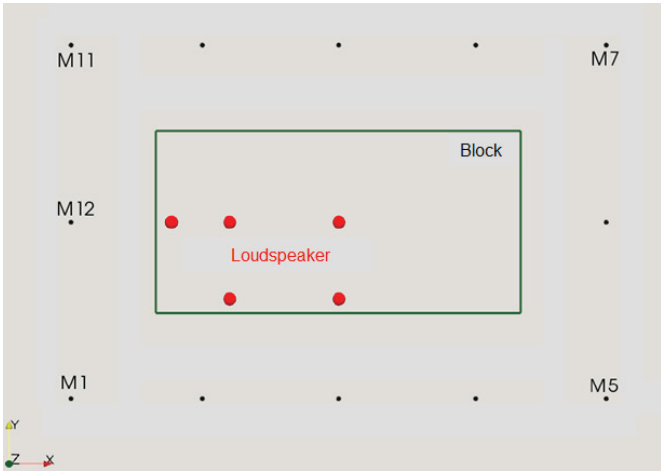

Fig 2b: Simulated arrangement of the loudspeakers and microphone positions (view from top)

With this arrangement a calculation was performed. The simulated volume around the block had the dimensions of 6,65m in x-direction, 5m in y-direction and 2,5m in z-direction. The grid was 3,25mm below the block, 6,5mm in the area of the microphones and 13mm outside. In case of the simulations with the absorbing LWRT-plate around this plate a fine resolution of 0,625mm was used. The loudspeaker was modelled as monopol source spread on 4 cells. Source signal was white noise from 25Hz to 8000Hz with a frequency resolution of 25Hz.

Fig. 3 shows the results of this simulation at the microphone positions 1 to 12 excited at the different loudspeaker positions without absorbing plate. Red is the middle of the block position, green position "engine", blue middle front position, magenta middle side position, and light blue position "wheel".

As expected, the nearer the microphone to the loudspeaker the higher is the sound pressure level.

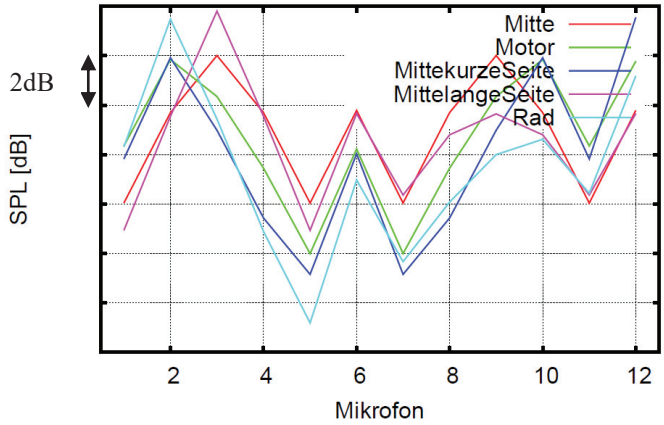

Fig 3: Simulation of sound pressure level at the microphones excited at the five different loudspeakers positions below the block

In fig. 4 the effect of the absorbing LWRT-plate (abbreviation SL for LWRT brand name Seeberlite) on the reduction of sound pressure level at the microphones can be seen in the red curve (without plate) compared to green (0mm plate distance), dark blue curve (20mm plate distance) and magenta (60mm plate distance). The assembly of the plate with different distances lowers the sound pressure level along the long sides of the block about 2-3dB (mic. 1-5 and mic. 7-11) and even about 4dB at the front and rear microphones (mic. 6 and 12). The higher the plate distance, the better is the effect in the simulation. In case of 60mm the improvement overtops even the situation without block while 0mm and 20mm are a little bit below.

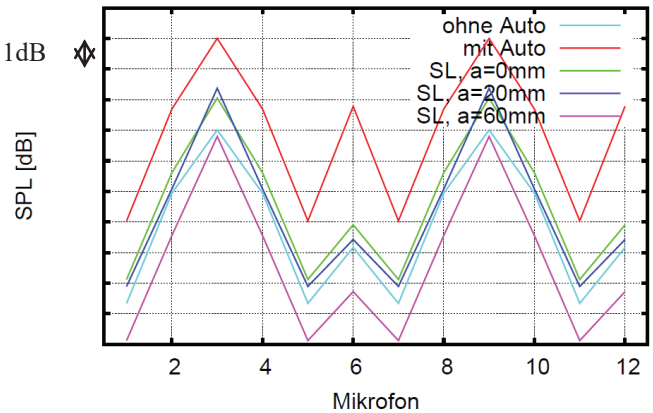

Fig 4: Simulation of sound pressure level with different positioned absorbing LWRT-plates below the block excited at loudspeaker position middle. In addition the simulation is done without LWRT-plate ("mit Auto") and without block at all ("ohne Auto").

Fig. 5 shows the simulation results in case of the loudspeaker at position "engine". Here in addition a further distance of 125mm is added, which leads in general to a further slight improvement of the SPL-reduction.

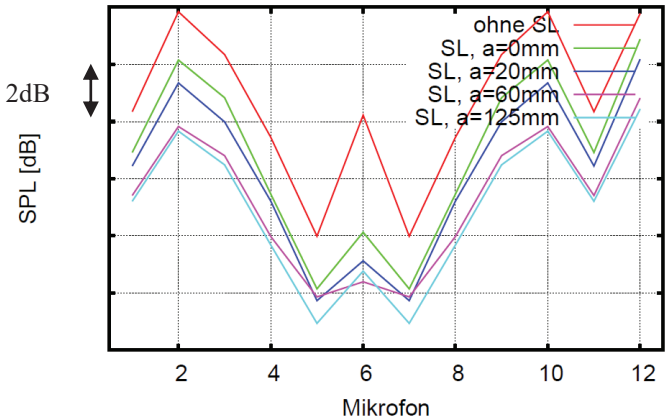

Fig 5: Simulation of sound pressure level with different positioned absorbing LWRT-plates below the block excited at loudspeaker position "engine".

Validation Measurements at Constructed Block

In Fig. 6 you can see the realized cube for the validation measurements. It was constructed with hard fiber plates and placed with the distance of 250mm above an asphalt ground.

Fig 6: Constructed block with sound absorbing LWRT plate, loudspeaker and microphone positions for validation

Fig 7: loudspeaker and microphones without the block

In this ground a fixed loudspeaker was installed (fig. 7). The relative position of the loudspeaker to the block (five different positions) was realized by moving the block.

Figures 8, 9 and 10 show the results of the measurements, which were performed in the same configuration as the simulation in figures 3, 4 and 5. Especially the measurements of the block without absorbing plate in Fig. 8 show quite good agreement to the simulated curves in Fig. 3.

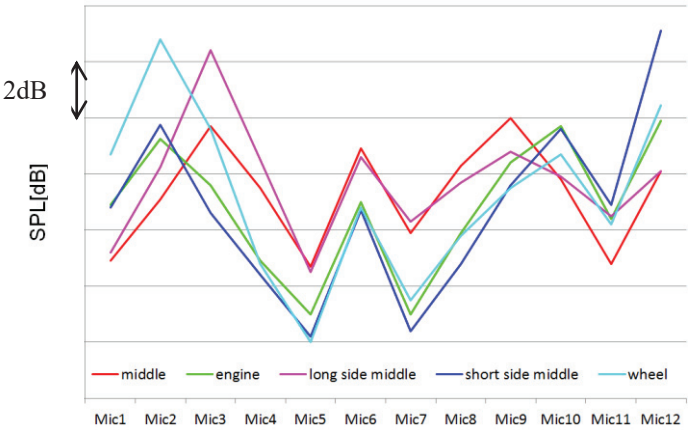

Fig 8: Measurement of sound pressure level at the microphones excited at the five different loudspeakers positions below the block

With absorbing plate below the block a difference between simulation and measurement is evident: While in the simulation the sound pressure level reduction increases with the wall distance considerably, in the measurements only a slight difference between the different wall distances can be obtained (fig. 9 and fig.10).

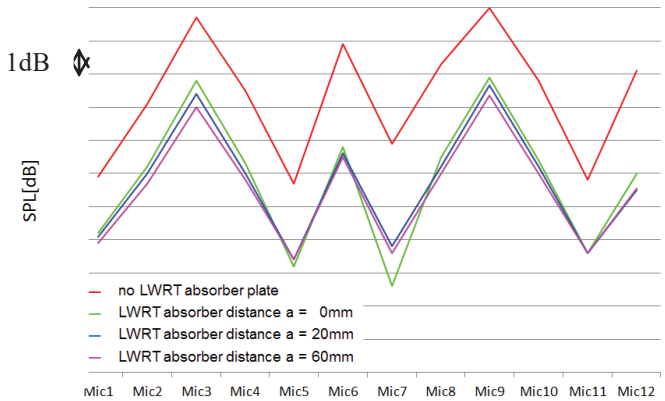

Fig 9: Measurement of sound pressure level with different positioned absorbing LWRT-plates below the block excited at loudspeaker position middle. The red curve shows the measurement without LWRT-plate

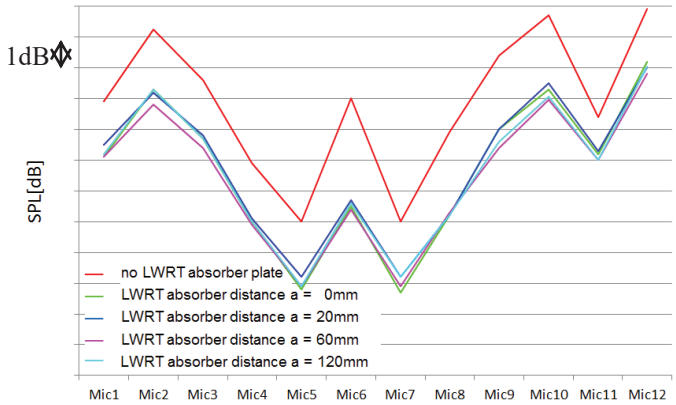

Fig 10: Measurement of sound pressure level with different positioned absorbing LWRT-plates below the block excited at loudspeaker position "engine".

Conclusion

Measurements and simulations at a model block with dimensions comparable to a passenger car (3,2m*1,6m) and a sound source below the block show:

The existence of the block on top of a central source increases the sound pressure level besides the block at about 2,5-3dB and in front of and behind the block nearly at about 4,5dB.

Installation of a sound absorbing plate between block and street reduces the sound pressure level nearly to the level without block.

In case of simulation the reduction increases with wall distance, in case of measurement there is nearly no effect of the wall distance.

Acknowledgments

This project was part of a subproject of the LeiStra3 (Leiser Straßenverkehr 3) german state funded research project. It was funded by the german Minsterium für Wirtschaft und Energie and the Ministerium für Verkehr und digitale Infrastruktur and was coordinated by the german Bundesamt für Straßenwesen.

Thank you very much for support and realisation of these results especially to Johannes Kreuzinger, KM Turbulenz GmbH, Dorothee Sauer und Thomas Beckenbauer, Müller BBM, Ulrike Stöckert, Bundesamt für Straßenwesen

References

[1] Uhl, F., Pfaffelhuber, K.: Akustisch wirksame Unterbodenverkleidungen: Außen- und Innengeräusch In: Fortschritte der Akustik (DAGA'06) Oldenburg 2006.

[2] Pfaffelhuber, K., Uhl, F.: Neue Möglichkeiten zur akustischen Gestaltung von PKW-Klimakanälen In: Fortschritte der Akustik (DAGA'08) Dresden 2008

[3] K.Pfaffelhuber, F.Uhl, C.Riewe: Tyre/Road Noise Reduction at Trucks and Vans with LWRT Underbody Panels In: Fortschritte der Akustik (DAGA'13) Meran 2013