Analysis of Pass-by noise using Nearfield Acoustic Holography

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Introduction

Traditional Pass-by noise (PBN) measurements acc. to DIN 362 has been the only way to determine the contribution of different noise sources to exterior noise emission of vehicles during operation. This method involves efforts for shielding each noise contributing area. The noise contribution is determined by the difference of the measures PBN level w/o and with shielding, figure 1.

Figure 1: Standard analysis of pass-by noise

The paper describes an indoor testing for noise contributions of different vehicle areas by means of Nearfield Acoustic Holography (NAH).

Theory of NAH

The Nearfield Acoustic Holography (NAH) is based on a two dimensional spatial Fast Fourier transformation (DFFT) of the measured pressure distribution at fixed temporal frequencies. Each arbitrary wave can be transformed to plane and evanescent waves.

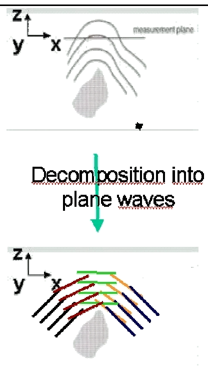

Figure 2: Decomposition into plane waves

These fundamental waves can be transformed into propagation direction or towards by changing the phase term (in case of plane waves) or the amplitude term (in case of evanescent waves), figure 2. For the transformation in the new plane it is necessary to make an inverse two dimensional Fourier transformation. Using this method a sound pressure distribution can be calculated in planes close to the structure (source plane) and far away to the far field.

The dimensions of the measurement plane define the lower frequency limit, because λ is the shortest dimension of the measurement plane:

$$c = \lambda \bullet f ; => f = \frac{c}{\lambda}$$

The highest measurement frequency is defined by the distance between the microphones together. The Shannon theorem explains that 2 points per wavelength are necessary for a Fast Fourier Transformation.

$$f = \frac{c}{2\lambda}$$

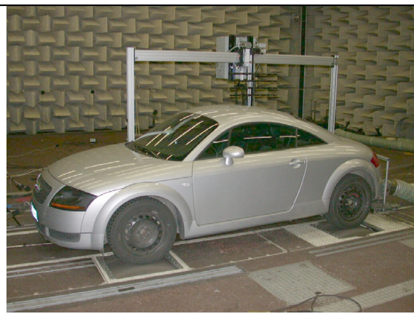

Figure 3: NAH measurements with standard microphone array on an acoustic 4-wheel-drive roller-bench test cell

With NAH the distance of two microphones in the array is is limiting the upper frequency, while the smaller dimension of the array gives the limiting lower frequency. According to the microphone distance of 10 cm and the height of the array of 1,45 m transformations with the existing array can be carried out between 234 Hz and 1700 Hz.

The measurements must be carried out under stationary conditions and at least one reference point must be used to get the phase information

Measurement procedure of NAH

As described before NAH measurements need stationary conditions. Nonetheless, they have to mirror the PBN conditions correctly, i.e. they have to represent the highest noise level and the correct microphone position of the non-stationary PBN measurements. E.g., the highest noise level is measured at a speed of 56 km/h and with the car front 2 meters past the reference microphone. In this case, the stationary NAH measurements on the acoustic roller-bench have to be done at the same vehicle speed with the reference microphone positioned 2 meters from the vehicle front.

In the next step areas relevant for the noise sources have to be defined. The measurements are carried out on an acoustic 4-wheel-driven rollerbench in the near field (typically in a distance of about 20 cm from the car), figure 3.

Analysis and results for NAH

The first step of the analysis is a transformation to the source plane, figure 4. For detecting the source contributions, this near field plane is subdivided in areas, figure 4.

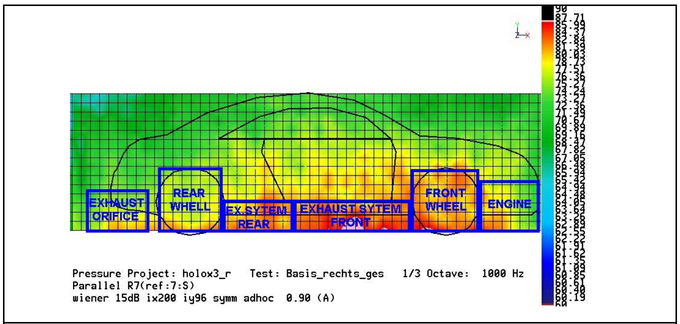

Figure 4: Noise contribution in the source plane and subdivision of contributing areas.

The following three methods have been analysed :

Method (1): Principle component analysis (PCA)

The principle component analysis looks for incoherent sources in the source plane. According to the fact, that many sources are correlated to the engine orders, the PCA does not allow a separation of engine and exhaust noise and is not sufficient for a detailed noise source detection.

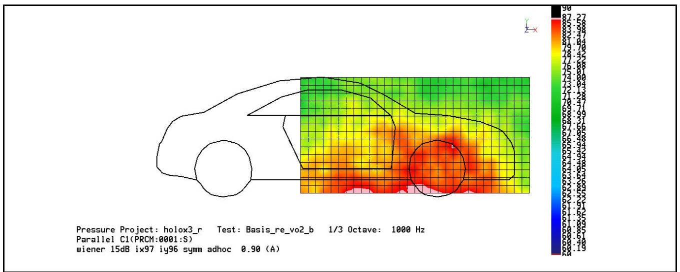

Figure 5: Result of method (1) - principle component analysis (PCA). Noseparation of correlated sources.

Method (2): Farfield calculation

A good method for visualization is the farfield calculation method by means of Fourier transformation. This method gives a good desciption of the noise propagation, but no quantitative results of different sources can be derived.

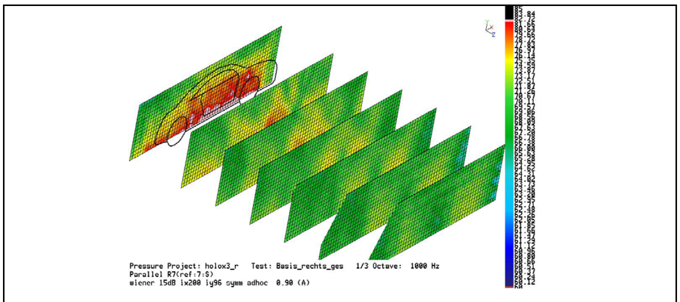

Figure 6: Result of method (2) - Farfield calculation: Transformation of test results in the farfield

Method (3): Covering sources by software

The covering of noise sources is simulated by the software similarly to the real cover in the standard PBN analysis., In case, the influence of the engine noise is investigated, the noise level of this part is covered in the source plane, i.e. the pressure values of this area are significantly reduced, e.g. by 20 dB. The difference between the integral noise level w/o and with the simulated cover gives the contribution of the engine noise. Thus, the noise contribution of each source represented by a specific sub-area can be determined with method (3).

Summing up the contributions from all different noise sources (sub-areas) measured with NAH method (3) the integral level of 71,2 dB was obtained. The result is confirmed by the PBN measured in 7,5 m with 71,4 dB.

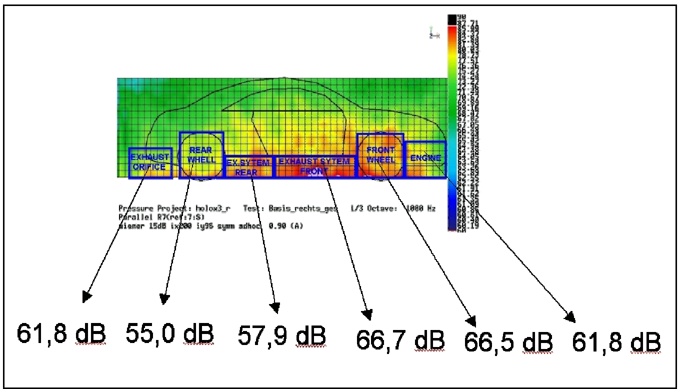

Figure 7: Method (3) - Sources covered by the software, in integral noise level of 71,2 dB results

Conclusions

A specific NAH methodology was described to replace expesive PBN tests for noise source contribution analyses. The corellation of integral noise level from PBN test and simulated covering of sub-areas is very good.

In case, two or more close-by noise sources are located in one plane (e.g.: engine and gearbox in the engine compartment) further methods to seperate these sources have to be used in addition.

Acknowledgements

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References

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