Noise reduction in working areas with sound absorbing baffle systems

Fabian Probst[1]

[1] *DataKustik GmbH, 86926 Greifenberg, Germany, Email: fabian.probst@datakustik.com*

Introduction

Baffle systems are applied to ensure an acceptable acoustical climate and to reduce the noise levels in rooms with noisy machinery and work places. While in offices, salesrooms and administrations in most cases closed suspended ceilings are used, baffle systems are often applied in machine halls, at production lines and in other technically complex environments.

Baffle systems are advantageous for industrial areas, because they are by far more flexible than closed suspended ceilings. The latter separate a room in two sandwich-type parts, where the upper part is thermally isolated from the lower heated part. Due to the thermal isolation of the suspended ceiling a temperature drop may occur upwards, and this again may cause humidity problems at the lower surface of the roof. This is no problem with baffle systems – even with bad isolated roofs the baffles "swim" in the air volume and no temperature discontinuities occur.

Another point is the easy way to adapt baffle systems even in rooms that can only partially be treated due to cranes, piping or other technical facilities. It is even possible to apply them only in locally restricted areas directly above noise relevant machinery. They can be arranged in any pattern so that the other installations below the roof remain accessible.

The absorption coefficient of such baffle systems is not a fixed number – or a spectrum – as it is the case for a flat absorbing plate, but depends on the spacing of the baffle elements. This spacing influences the absorption as well as the costs of such a system, therefore it is important to know the dependence of the absorption coefficient from the detailed and cost relevant construction.

These relations have been investigated and published 2008 [1]. The relation between the absorption of the basic material forming the baffles and the absorption of a plan arrangement of baffles was derived by integration of the part of the sound energy crossing the construction without being absorbed. Measurements showed good agreement with these results and therefore the method is applicable to evaluate cost-effect relations taking into account different spacing of the baffles. In the following the main results of this investigation are summarized and extended to the case where the above mentioned special arrangements are planned. This is done by modelling the baffle system in detail and with each single baffle as an own object with given acoustic properties. It is shown that this "virtual" construction opens a broad field of noise reduction measures that could not be treated in an analytic closed form and therefore not be evaluated in the planning phase.

Figure 1 shows a row-type baffle system in a bottling plant. These packaging lines are characterized by a significant air humidity due to continuous cleaning processes, by severe hygienic requirements and by noise levels just below and above the limits due to the legal requirements – a typical scenario where baffle systems are the better choice.

Figure 1: Sound absorbing baffles in a bottling plant

The absorption coefficient of a baffle construction

Baffles are generally arranged in rows – with a spacing a of the rows axes and the height h of the baffles the geometry of the construction can be described and exactly defined by the single parameter a'=a/h (related baffle spacing).

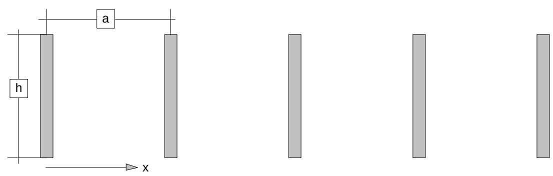

Figure 2: Cross section through baffles arranged in rows

The absorption of the baffle plate alone – being surrounded by a diffuse sound field – is the starting point to evaluate the absorption of a construction shown in figure 2. This absorption of the plate α_B can be determined in a reverberation chamber if the samples are installed with spacing large enough that all sides are exposed to the diffuse sound field.

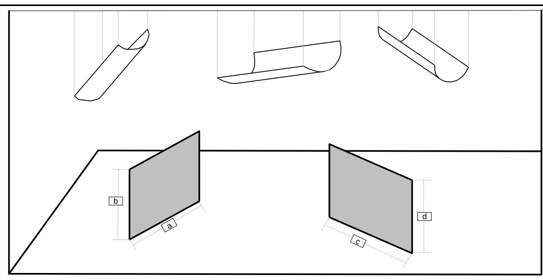

Figure 3: Measuring α_B in a reverberation chamber

If the construction shown in figure 1 is embedded in a diffuse sound field, it can theoretically be replaced by a plate with transmission $\tau = 1 - \alpha_K$, where α_K is the absorption of the baffle construction. These latter could theoretically be determined in a reverberation chamber, if the equivalent absorption area measured by differences of reverberation times is divided by the sum of both surfaces.

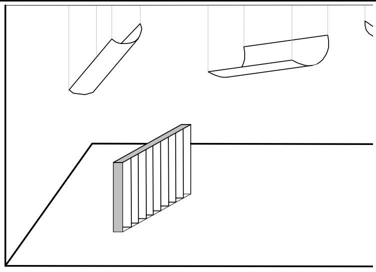

Figure 4: Measuring α_K in a reverberation chamber

Table 1 shows the dependency of the absorption of the baffle construction α_K (measured as shown in figure 4) in dependence of the absorption α_B of the material (measured as shown in figure 3).

α_B	Related baffle spacing a'			
	0.4	**1**	**1.2**	**2**
0.1	0.19	0.09	0.08	0.05
0.2	0.32	0.16	0.14	0.09
0.3	0.43	0.23	0.20	0.13
0.4	0.51	0.29	0.26	0.17
0.5	0.58	0.35	0.31	0.21
0.6	0.64	0.40	0.36	0.25
0.7	0.69	0.45	0.40	0.28
0.8	0.74	0.50	0.45	0.32
0.9	0.77	0.54	0.49	0.35
1	0.81	0.59	0.53	0.38

Table 1: Absorption α_K of a free suspended baffle construction (single-pass of sound energy) in dependence of α_B

Finally there is the "effective" absorption $\alpha_{K,W}$ of the lower surface of the roof, if such a baffle construction is installed below. Then all sound energy crossing the baffle construction upwards is reflected by the roof and will cross the construction again before being radiated back into the room. This effective absorption of the lower roof surface treated with such a baffle construction was derived from the absorption α_B of the plate material and the dependency is shown in table 2.

Tables 1 and 2 (for more complete presentation see [1]) can be used to evaluate the efficiency of a chosen layout and the influence of the geometry.

If a plate with "ideal" absorption of $\alpha_B = 1$ – any sound ray impacting the plate is absorbed completely – is cutted into stripes and these stripes are rotated 90° around their axes – the related baffle spacing a' is 1 and the resulting α_K of the baffle system is 0.59 according to table 1. Installed directly below the roof the resulting $\alpha_{K,W}$ is 0.83 according to table 2. Therefore the absorption of an even suspended ceiling is better than that of a baffle system with the same mass of material.

α_B	Related baffle spacing a'			
	0.4	**1**	**1.2**	**2**
0.1	0.35	0.17	0.15	0.09
0.2	0.54	0.30	0.26	0.17
0.3	0.67	0.41	0.36	0.25
0.4	0.76	0.50	0.45	0.31
0.5	0.82	0.58	0.52	0.37
0.6	0.87	0.64	0.59	0.43
0.7	0.90	0.70	0.65	0.48
0.8	0.93	0.75	0.70	0.53
0.9	0.95	0.79	0.74	0.58
1	0.96	0.83	0.78	0.62

Table 2: Absorption $\alpha_{K,W}$ of a reflecting surface treated with a baffle system (double-pass of sound energy) in dependence of α_B

Table 2 shows that it is not very effective to increase the absorption of such a baffle system with more material – increasing the tightness by a factor 2 – this means a' = 0.5 instead of a' = 1 in table 2 – increases the resulting absorption $\alpha_{K,W}$ from 0.83 to 0.94 and therefore the resulting equivalent absorption area A by about 13 %.

The presented relations are derived in [1] and can be helpful for such general considerations about the best compromise with respect to layout and costs of such a treatment.

Detailed modelling

If the calculation of sound pressure levels at work places resulting from the sound emission of machinery is performed with software programs, such baffle systems suspended from the ceiling can be taken into account in different ways. In the following the software package CadnaR [2] was applied to perform these calculations.

Direct installation under the lower roof surface

With the baffle system installed below the roof, the lower roof surface may itself be treated with absorption material with absorption α_H.

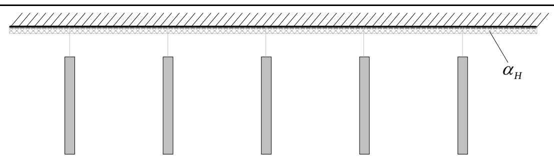

Figure 5: Baffle system with a surface with absorption α_H behind

The resulting "effective" absorption of the lower roof surface α_{comb} can be determined with

$$\alpha_{comb} = \alpha_{K,W} + \alpha_H \cdot (1 - \alpha_{K,W}) \tag{1}$$

The simplest way to integrate this in a computer model is to apply the absorption α_{comb} determined from equation (1) with $\alpha_{K,W}$ from table 2 as the final absorption coefficient of the lower roof surface. This technique is applicable independent from the calculation method – e.g. image or particle method.

Plane baffle system free floating in the room volume

If a baffle system is not installed directly with short distance below the lower room surface and may even cover only a part of the ground surface, the described method is not further applicable. In this case the construction is floating in the room volume, and it cannot be assumed that all sound energy crossing the construction will be reflected by the roof surface and will cross the system again.

This case can best be modelled and evaluated by using the sound particle model. The general assumption is that it makes no difference if the sound energy of a ray striking a baffle and not being absorbed will be reflected (left) or transmitted (right) – as a first order assumption no energy is reflected directly back and all energy not being absorbed will be transmitted through the construction.

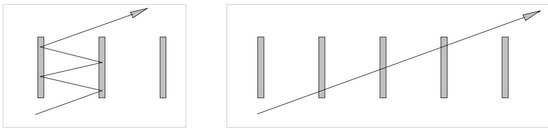

Figure 6: Acoustically equivalent models of a baffle system

Taking this into account, the floating baffle system can be modelled as a plate with $\alpha = 1$ at the upper and the lower surface and with transmission $\tau = (1 - \alpha_K)$ where α_K is the absorption related to a single pass of sound energy according to table 1.

This latter technique is generally applicable – such a plate can also be attached in short distance below a roof with surface absorption α_H. The calculation of a resulting α_{comb} as described above can be avoided in this case because the processes of crossing the construction, reflection at the lower roof surface and crossing the construction again are simulated directly in this case.

Detailed modelling of each single baffle

It may give the impression to break a fly on a wheel, but due to the power of hard- and software it is in the meantime possible to take into account each baffle element separately with its geometry, location and acoustic properties. This eliminates nearly all restrictions about the possible arrangements and even complex situations can be assessed.

The baffle itself is modelled as a vertical plate or panel with its relevant dimensions and the basic acoustic property α_B. This detailed modelling allows even to distinguish the two cases discussed above and shown in figure 6. If the transmission index of the plate material τ_B has been measured it is even possible to take it separately into account in each frequency band. With the two cases shown in figure 6 the following properties are applied for the panels:

Left side figure 6: $\alpha = \alpha_B$; $\tau = 0$

Right side figure 6: $\alpha = 1$; $\tau = 1 - \alpha_B$

Practical application

The standard situation is to “install” virtually a complete suspended baffle system above working areas.

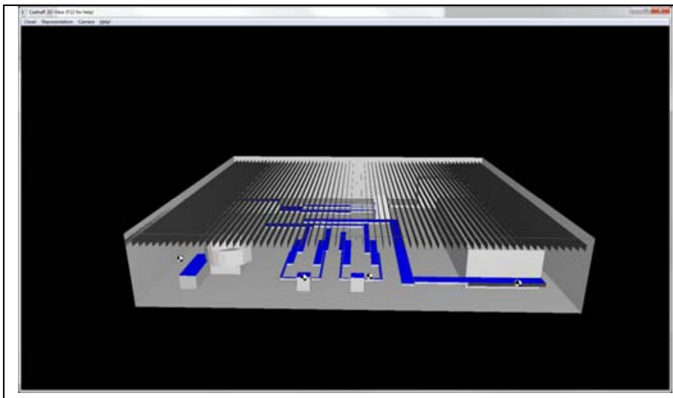

Figure 7: Virtual model of a bottling plant with baffles applied

The difference between such a detailed modelling and the simulation by a plate replacing the baffle construction is obvious – the detailed integration gives a realistic impression in 3D-views and allows avoiding any approximation in the system-layout.

But there are also significant advantages with respect to the acoustic assessment. The absorption coefficients presented in tables 1 and 2 describe only the energy-related aspects regarding the reaction on a diffuse sound field, but the directional dependencies are not represented by this description. With a modelling of the panels in detail the paths of the sound particles are calculated and therefore the directivities are conserved and will influence the result.

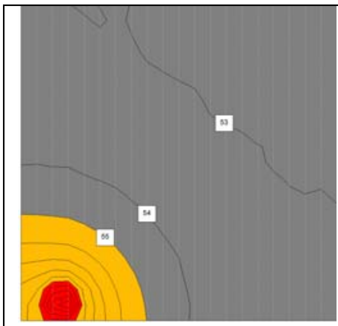

Figure 8: Level distribution in the empty room 20m x 20m

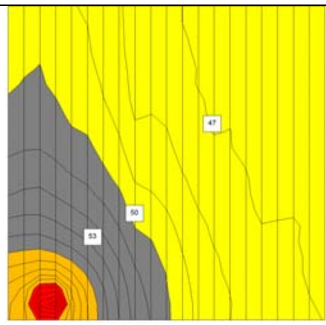

Figure 9: Level distribution in the room with baffle-system

This is shown in a simple example: a room 20m x20m x 6m with a point source – sound power level 70 dB. The distribution of sound pressure levels was calculated applying a sound particle model. Figure 8 shows the level distribution calculated with reflections up to 15 orders. Then a baffle system with a’ = 1 and α_B =1 was inserted and the resulting level distribution is shown in figure 9. The non-isotropic absorption properties of the baffle system are clearly reflected.

This detailed modelling of absorbing construction opens a wide field of application in the field of acoustic planning and noise reduction in industrial working areas, but also in open plan offices and other places where noise effects on people shall be minimized or optimized.

References

[1] Probst, W.: Sound absorption of baffle systems (Original: Die Schallabsorption von Kulissendecken). Lärmbekämpfung Bd. 3, (2008) Nr.2, pp 79 – 84

[2] CadnaR – Software for the calculation and assessment of sound in rooms. http://www.datakustik.com/produkte/cadnar