<u>Technical Acoustics and Noise Control</u> *(lecture notes for self-learning)*

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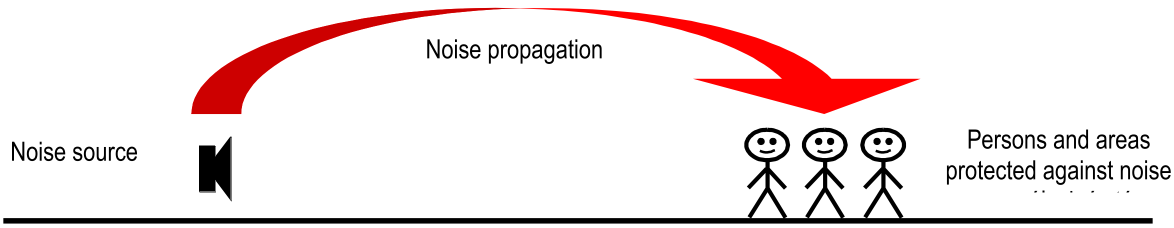
Lecture 13.

Content:

13.1. General survey of the noise control methodologies (lecture notes)

Basic exercises of the noise control are to determine the noise exposure, evaluate the results and if it is reasoned to reduce it to an acceptable level. Noise control problem can appear for example at the design of a new device, or at a noisy machine installed in urban area close to living houses.



The general process of the noise conflict formation

General methodologies of noise control: All noise conflict need noise sources, noise propagation and protected area with protected persons. This division can apply to classify noise control methodologies too.

Noise control by reducing the radiated sound power: Primary method in environmental protection to reduce the emission of the disturbing source. This is true for acoustics as well. In the following section we list some examples for the reduction of the radiated sound power,

- Modification of the base process: Generally the noise is an undesired side effect of a useful main process. Modifying or reducing the power of the main process, sometime allow to reduce the radiated noise too. For example a dull (not sharp) sheet metal cutting machine in operation need big cutting force. The big force results big deformation and at the end of the process a loud sound effect. In this case sharpen the cutting tool will result more silent operation. Traffic noise can reduce when a small portion of ware is not transported by big truck. In air conditioning to control the volume flowrate of the ventilated air the rotational speed variation of the fan is better than throttling from noise control point of view as well.

- Reducing mechanical noise sources:

- Eliminating the cause of vibrations and impulse forces
- Avoid shocks, collisions, supply smooth rolling surfaces
- Static and dynamic balancing of rotors
- Isolate from each other the excitation and radiator surfaces
- Application of high mass and rigidity construction in the design of mechanical equipment
- Application of bigger internal attenuation materials for machines

- Use appropriate lubrication and energy absorbers
- To perforate the large radiator surfaces
- To elimination the mechanical resonance

- Reducing flow noise sources:

- To reduce the characteristic speed of the flow
- Avoid the fluctuating volume flowrate
- To keep a steady, undisturbed, smoot flow along the surface of solid bodies
- Prevention of the formation of mixing zones and shear layers
- To avoid high speed free jets, throttle valve control, and high flow turbulence
- Prevent flow separation, cavitation and shock waves
- Keep out self-excited flow processes
- To avoid structural and acoustic resonances generated by periodic fluid flow

- Reducing thermal noise sources:

- Ensure conditions with steady heat release
- To keep steady fuel and air supply and appropriate mixture of them
- Prevent unstable flames and explosions
- If possible, to use a laminar flame instead of a turbulent flame
- Prevent engine knocking
- To avoid thermally excited resonances

Noise control by preventing sound propagation: If the sound power radiated by the noise source cannot be reduced, the noise protection can also be solved by preventing the propagation of sound wave. We distinguish methods that can be used in open space, in a bounded space or in pipes, but there will also be methods that are efficient in several cases. Devices and possibilities for noise control by preventing sound propagation,

Noise control in free space:

- Increase the distance from the sound source
- Select the preferential radiation direction (for spatially varying radiation direction characteristics)
- To build up noise protection wall (noise barrier artificial or natural)
- The application of noise protection cover and hood or to build up noise protection machine housing

Noise control in space bounded with walls (with internal sound sources):

- At direct sound field dominancy: Increase the distance from the source, select the preferential radiation direction, to apply noise protection screen
- At reverberated sound field dominancy: To increase the room constant (increase the internal surfaces and sound absorption) to apply noise protecting screens and extra absorbing elements
- Independent from the direct or reverberated sound field: Noise protection cover, hood and machine housing or to separate the noise source from the protected part of the room with wall

Noise control in space bounded with walls (with external sound sources):

- To increase the transmission loss of the wall between the source and the protected area
- To increase the room constant (internal surfaces and sound absorption) in the receiver room

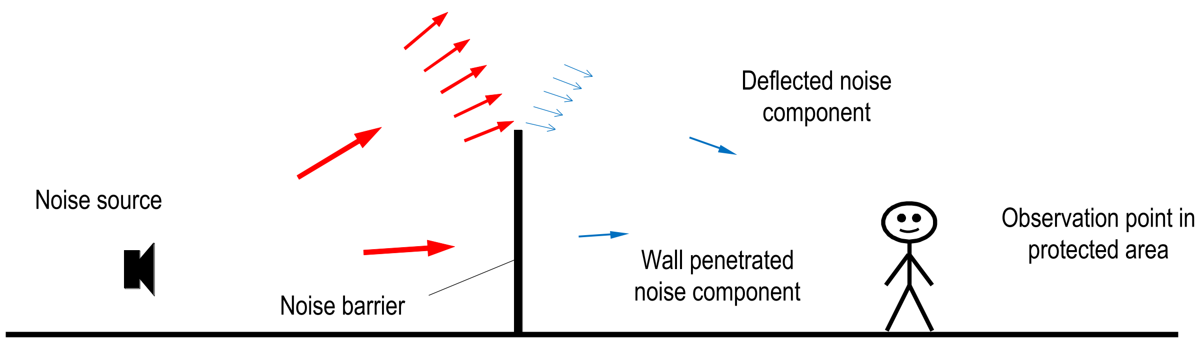
Noise control in ducts and channels:

- To increase the distance from the source (in the case of sound absorbing wall ducts) at low flow speed
- Insert duct elements to block sound propagation (e.g.: elbow, filter) at low flow speed
- To insert absorber or reactive type duct silencer
- To insert duct compensator to reduce the structure borne sound propagation in the duct wall

Noise control with personal protection: There are some cases when to reduce the radiated sound power and to prevent the noise propagation is not possible within acceptable technical circumstances. In this case the noise control will be ensured by personal protection. For example in a turbine hall of a power station during the daily periodic inspection, the radiated sound power of the turbines cannot be reduced, and it is impossible to insert a noise protecting hood between the source and observer. The noise protection for the persons, participating the inspection will be ensured by ear protecting pug or muff. Tools and possibilities for personal noise protection,

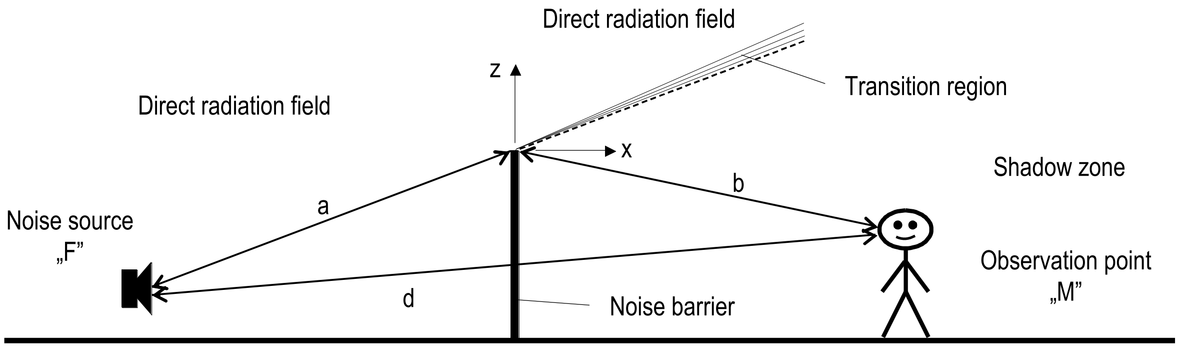
- Personal noise control devices (ear plug and ear muff)
- The limitation of the noise exposure by time schedule (appropriate long silent and noisy periods during working time)
- Noise isolated control rooms, and rest room.

13.2. Noise barrier: A wall placed between the noise source and the protected area that prevents optical transparency is called a noise barrier. The wall structure of the noise barrier is always soundproofing (preventing sound propagation). The noise barrier does not airtight separate the noise source from the outside environment. The construction of a noise barrier is intended to reduce the noise of large or spatially distributed noise sources (industrial area), indeterminate position vehicles (road vehicles, railway trains,…) or equipment that cannot be closed for safety reasons (petrochemical plant pumping station, gas receiver,…). . Noise shielding can be created not only with a specially built noise barrier wall, but also with the use of an existing object (building, solid reinforced concrete fence, embankment,…). The most important property of a noise barrier wall is the insertion loss (ΔL_{in}), the difference of sound pressure levels determined at the same observation point without the wall and in the presence of a wall. The ability of a noise barrier to impede sound propagation is determined by two acoustic phenomena, deflection and wall across propagation (see the following figure). In order to achieve the required insertion loss, the length and height of the wall can be calculated from the sound deflection, the wall thickness and the layer structure based on the sound transmission through the wall.



Noise components passing to the protected area by deflection and wall penetration in the presence of a noise barrier

First, the magnitude of the insertion loss (ΔL_{in}) for the noise component passing through the protected space by deflection is determined. The protected side is located on the other side of the noise barrier relative to the noise source. On the protected side, the part below the straight line connecting the noise source and the highest point of the wall is the shadow zone. The narrow band directly above the straight line is the transition region, and the part above the transition region is the direct radiation field (see the following figure). The magnitude of the insertion loss depends on which part of the observation point is located in the protected side, in the shadow zone, in the transition region, or in the direct radiation field.



Typical sections behind the noise barrier on the protected side

The insertion loss can be determined by the Helmholtz-Kirchoff diffraction integral solution. The simplifications used for the calculation, the layout is located in free space, the noise source is point-like, the sound insulation of the wall layer is infinite and the noise shielding wall is infinitely long. Depending on the location of the observation point, the installation loss of the noise barrier (ΔL_{in}),

In the shadow zone, if $\frac{z_F}{x_F} \geq \frac{z_M}{x_M}$, where x_F and z_F are the coordinates of the noise source, x_M and z_M are the coordinates of the observation point in the x-z coordinate system fitted to the top of the noise barrier (see previous figure).

$$\Delta L_h = 20lg\frac{\sqrt{2\pi N}}{tgh\sqrt{2\pi N}} + 5 \quad \text{[dB]}$$

In the transition region, if $\frac{z_F}{x_F} < \frac{z_M}{x_M}$ és $0 < N \leq 0{,}2$

$$\Delta L_h = 20lg\frac{\sqrt{2\pi N}}{tg\sqrt{2\pi N}} + 5 \quad \text{[dB]}$$

In the direct radiation field, if $\frac{z_F}{x_F} < \frac{z_M}{x_M}$ és $N > 0{,}2$ $\qquad \Delta L_h = 0$ [dB]

where the Fresnel-number is: $\quad N = \frac{2}{\lambda}(a + b - d)$

Comments:

- In the case of a perfect sound-insulating (infinitely sound-proof) wall layer, the insertion loss is a function of the Fresnel number (N). An increasing Fresnel number has an increasing insertion loss.

- The Fresnel number is twice the ratio of the difference between the flanking and the direct sound propagation path length (a+b-d) and the wavelength (λ). A large difference in sound propagation path length occurs when, in the presence of a wall, the difference between the sound propagation distance (a+b) by the shortest path in the air between the noise source and the observation point and the direct distance between the noise source and the observation point (through the wall) is large. Weak deflection and high insertion loss occur when the wavelength (high frequency) of the propagating sound is small compared to the characteristic size of the object blocking sound propagation. This finding also applies to other wave phenomena.

- In practice, the wall structure of the noise barrier must be compiled in such a way, that at the tested frequency the transmission loss of the wall (R_{wall}) is ~ 10 dB higher than the insertion loss (ΔL_{in}) of the noise component passing by sound deflection.

- The soft-surfaced wall is covered with sound-absorbing material on the source side, and the hard-surfaced wall is covered with sound-reflecting material. Hard-surfaced noise shielding walls have greater environmental resistance and longevity than soft-walled walls. In an installation site where there is a protected space on both sides of the noise barrier, a soft wall must be used to avoid harmful sound reflections that impair installation losses.

- In the case of long-range sound propagation, sound propagation anomalies due to atmospheric wind and inverse temperature stratification may reduce the effectiveness of noise barrier walls.

- The outdoor noise barrier must be designed to be environmentally friendly. In the case of noise barriers, the effect of loads due to atmospheric wind and the soil mechanical conditions at the foundation must be given special attention.

13.3. Test questions

T.Q.1. Describe the three most important methodological principles of noise reduction, give examples of each method! (see lecture notes)

T.Q.2. Describe the means of personal noise protection! (see lecture notes)

T.Q.3. What is the difference between soft and hard surface noise protection walls, give an example of their application areas! (see lecture notes)
