INFRASOUND UNDER CONTROL

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SUMMARY

Infrasound emitted by some types of machines, that is sound at frequencies under 20 Hz, is not hearable by human ears but may be annoying and causing discomfort to exposed persons. As its long waves are able to pass through walls and propagate long distances, it may cause annoyance also in the neighbourhood.

This paper describes a housing technology that succeeded in reducing the infrasound of a 20m² vibrating drum for more than 20 dB in a German foundry, rendering the environment acceptable for the workers and the neighbours.

It consists of several wall parts of reinforced concrete built together in such a way that parallelity is avoided. Thus the infrasound waves reflect in different directions and eliminate one another without causing resonance.

1. WHERE IS THE PROBLEM ?

Noise is one of the most common and annoying environmental pollution in large cities and in factories, often emitting in their neighbourhood.

Audible sound may be successfully reduced by modifications at the source of its generation, as we notice for example that noise emitted from new jet engines is much less than that of older models. In industrial plants it is common to encapsulate noisy machines when it is not possible to reduce the emitted noise at its source.

A certain type of industrial equipment, vibrating screens and vibrating conveyors, may have a surface of several square meters vibrating at an acceleration of 4 to 6 times the earth acceleration "g". Moving periodically the surrounding air lets these machines act as a huge loudspeaker emitting a strong sound wave at their operating frequency in addition to their usual audible noise.

The operating frequency of such machines is usually constant and lies in the range 8 to 18 cycles per second (Hz), which means that the sound wave emitted cannot be heard by human ear as the audible sound range is 20 Hz to 20 000 Hz. The range less than 20 Hz is therefore called “Infrasound”.

Infrasound is also not recognised by sound meters using the “A” weighing curve giving a reading in decibel(A) (dB(A)), as the weighting filter “A” strongly reduces the reading of low frequency sound (and also high frequency sound).

For these reasons infrasound may be rated as harmless, however, at high intensity e.g. over 120 dB it causes discomfort, mainly nausea due to periodic movement of the stomach and other organs of the body.

Long term exposure to infrasound is till now not investigated concerning its negative influence on human health. In fact the induced discomfort is generally sufficient to call for reduction to an acceptable level.

In cases where the function of the machine in question is directly related to the generation of infrasound, as for example the case of vibrating machines, other conventional solutions to reduce immision like encapsulation proved ineffective because the relatively long wave of infrasound is able to propagate through considerable wall thickness.

The wavelength is calculated to be:

Wavelength λ (Lambda) in meters = Sound speed in meter per second / Frequency in Hz

Table 1 gives some examples for an average sound speed in air of 340 m/s

Table 1 Wavelength at different frequencies

Frequency [Hz]	Wavelength λ [m]
16.6	20.4
12.5	27.2
10	34.0
8	42.5

To ensure affectivity of encapsulation, the wall thickness shall be about one fourth of the wavelength. Obviously that is not applicable.

2. ARE THERE RECOGNISED LIMITS FOR INFRASOUND EXPOSURE ?

The German standard DIN 45680 edition of March 1997 [1] „Measurement and Assessment of Low-Frequency Noise immision in the Neighbourhood" states the threshold values of hearing for humans in the third octave bands from 8 Hz to 100 Hz, whereas the values of 20 Hz and above are similar to those of DIN 45630-2 describing the human threshold of hearing (under 20 Hz it is rather feeling than hearing).

Annex No. 1 of the a.m. standard gives guidelines for the assessment for industrial plants. It suggests limit values inside dwellings to be 5 dB over the threshold of hearing (feeling) in each 1/3 octave band during day time (6:00 to 22:00 hours) and 0 dB over that threshold in the night time. These limits ensure that during the night neighbours of industrial plants will not feel the waves emitted, while during the day they may feel some effects, which however, shall be tolerable.

The industrial standard DIN 45680 and its Annex No. 1 was taken as guideline for the governmental decree [2]"TA Laerm" 6th edition of 26th August 1998 and put in action since 01st November 1998

While the German standard and law give limits of infrasound to protect the neighbourhood of industrial plants, it did not yet issue standards to protect workers inside the plants, who are usually exposed to much higher levels and partly also for longer periods. Looking at the problem from a practical point of view, the limits within industrial plants may be considerably higher than the thresholds stated on DIN 45680; however, if annoyance is tolerated negative effects on health or even discomfort shall not be tolerated.

Similarity may be found when considering the evaluation of audible sound:

Maximum allowable within industrial plants	85 dB(A)
Mean value in residential areas in the day (outside of dwellings)	50 dB(A)
Mean value in residential areas in the night	35 dB(A)

The limit value of 85 dB(A) represents the threshold of negative effect on health and is also a threshold of discomfort because speech is only comprehensive when it is loud enough, which is combined with more effort than usual.

The negative effects of infrasound on human health were investigated by Ising [3]. Up to 120 dB, no significant effects were noticed. However, this field on both medical and physical levels is not sufficiently investigated which misleads scholars of acoustics to treat infrasound as audible sound and apply the evaluation formulae predicted for it as e.g. equivalent sound level.

Measurements of the author showed that in industrial plants an infrasound level of 115 dB is equivalent in its degree of annoyance / tolerability to the audible sound level of 85 dB(A) which is the maximum allowed in industrial plants where humans are physically working. This figure for all frequencies under 20 Hz was suggested 1988 as a limit value for a new plant in a foundry and was accepted by the local German industry supervision authority.

3. WHAT IS THE GOOD NEWS ?

High infrasound levels over 125 dB occur only in closed rooms with parallel walls reflecting the sound waves and thus causing a resonance with the known phenomena of “standing waves”. This resonance happens when the distance between the parallel walls is a multiple of half the wavelength [4]. The resonance can only take place when the source of infrasound generates a monofrequency, otherwise no standing waves occur.

It seems that it is rather a rare coincidence that the phenomena of standing waves happens, however, vibrating screens are usually installed in closed rooms with parallel walls and a roof parallel to the floor, what else is expected in industrial buildings !. This means if the operating frequency of the vibrating machine is 16.6 Hz (equivalent to 1000 rpm) which is a common operating frequency, and one of the distances of parallelism is about 10, 20 or 30 meters (see table 1), the standing wave will be established.

4. ARE THERE SOME EXAMPLES TO VISUALISE THE PROBLEM ?

A selection of typical measurements clears the occurrence forms of infrasound:

Fig. 1 Living room in the neighbourhood

Infrasound immision from a quarry including a processing plant.
The peeks show the frequencies:
49 Hz, crushing mill
19 Hz, primary screen
16.6 Hz, dust screen
12.5 Hz, sec. Screen
Peek at 19 Hz (20 Hz band) 80 dB exceeds allowable day limit

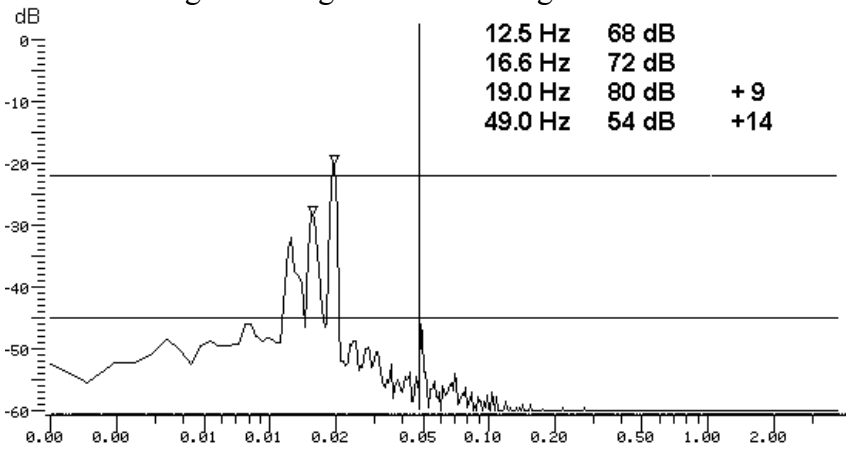


Fig. 2 Inside the screen house

Infrasound in a factory for animal food.
The peek at 12.5 Hz is originated from 3 big screens of total 15m².
Peek at 16.6 Hz originates from one small screen 1.5m² but exciting a resonance with "standing wave".
Hall length 21 m, sound pressure was 114 dB(Lin)

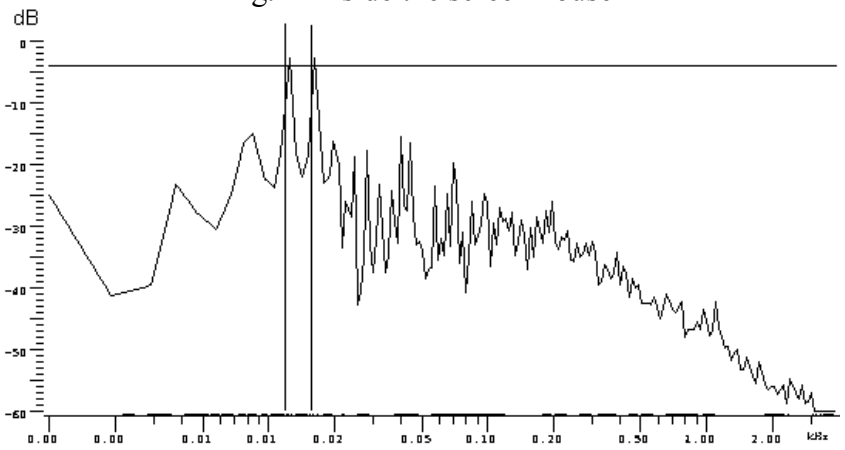
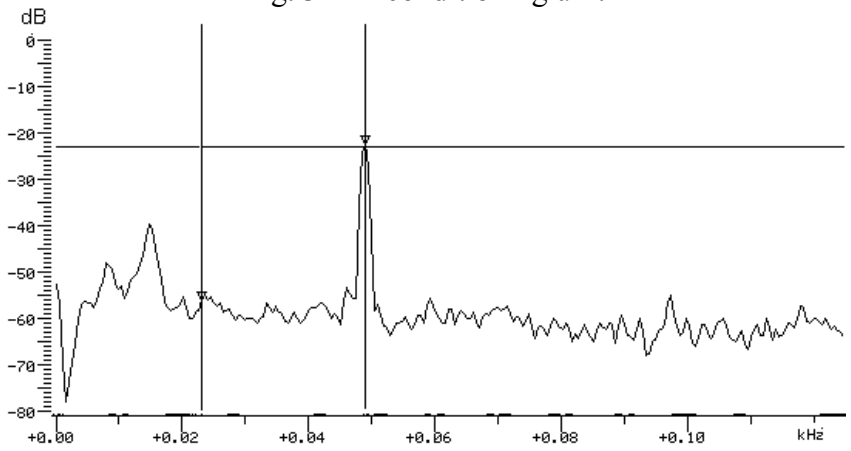


Fig. 3 Air conditioning unit

A small unit in the bottom floor of an office building. Its vibrations at 49 Hz are transmitted to an aeration duct then to a corridor in the building, 35 m long i.e. 5 times the half wavelength of 49 Hz, causing a standing wave with 77 dB well above hearing limit



5. WHAT ARE THE POSSIBLE SOLUTIONS ?

Assuming that the function of the machine in question depends mainly on vibration and thus it moves the surrounding air periodically causing infrasound waves, the solution cannot be found in reducing the emitted sound at the source.

5.1 CHANGE OF OPERATING FREQUENCY ?

This seems to be the most elegant solution. However, small changes of about ±10%, which may be easily performed by means of frequency converters, are usually insufficient because the long waves accept reflection areas up to about 10% differing from their half wavelength. Therefore frequency shall be changed at least 1/3 octave, which means about ±25%. Under these circumstances the functionality of the machine may be affected, therefore this method is not always applicable.

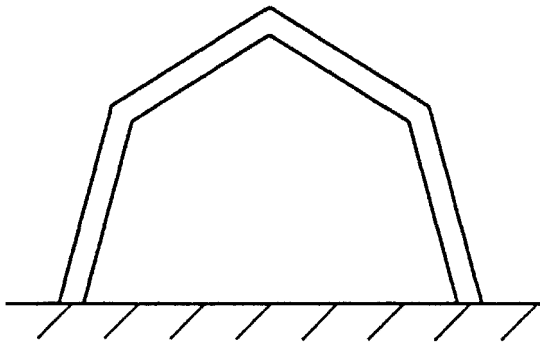
5.2 HELMHOLTZ RESONATOR AS VIBRATION DAMPER ?

This was successfully used in concert halls for audible sound to reduce echo effects. It was suggested for frequencies under 100 Hz in a modified form [5]. However, its use with 16.6 Hz and 12.5 Hz did not yield the desired results. As the costs of such a solution are relatively high, it shall not be considered as an applicable alternative.

5.3 INFRASOUND HOUSING ?

To solve the problem expected in a foundry installing a new plant including a vibrating drum of 2 m diameter and 10 m length, giving a vibrating area of 20 m² and an expected infrasound at 17 Hz of 130 dB, it was suggested to build a special housing (Fig. 4) consisting of rigid reinforced concrete walls. The walls to be inclined to one another at an angle of at least 15°. These reflecting the infrasound waves in random directions thus causing neutralisation of the sound pressure peeks. To ensure rigidity of the walls each section shall not be longer than 1.8 m with rigid connections and at least 14 cm thick

Fig. 4 The Infrasound Housing



The results found after putting the machine in operation were:

Inside the Infrasound housing	128	to	132	dB
Outside the infrasound housing 1m	110	to	115	dB
Outside the infrasound housing 5 m	105	to	107	dB

Also in the working hall no standing waves occurred.

The environment inside the foundry was acceptable for the workers spending 8 hours a day there, in fact, when visiting the site, it was not possible to recognise whether the drum was working or not. Also measurements in the neighbourhood proved that the limits recommended by DIN 45680 were not exceeded

LITERATURE

[1] DIN 45680 edition of March 1997 „Measurement and Assessment of Low-Frequency Noise immision in the Neighbourhood" including Annex No. 1 " guidelines for the assessment for industrial plants"

[2] TA Laerm, Technische Anleitung zum Schutz gegen Laerm "Technical directive for protection against noise", 6th edition dated 26th August 1998.

[3] ISING, Hartmuth; MARKERT, Baldur; SHENODA, Fathy; SCHWARZE, Christiane: Infraschallwirkungen auf den Menschen "Effect of Infrasound on humans". VDI-Verlag 1982

[4].VEIT, Ivar: Technische Akustik, Grundlagen der physikalischen, physiologischen und Elektroakustik "Technical Acoustics". Vogel-Verlag., 1996

[5] FASHOLD; SONNTAG; WINKLER: Bauphysik Entwurfsempfehlungen f. Bau- und Raumakustik "Physics of buildings, recommendations for planing, building and room acoustics". VEB Verlag