RECENT STUDIES OF INFRASOUND FROM INDUSTRIAL SOURCES

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1. BACKGROUND

Infrasound from industrial equipment and its potential effects on residential neighbours has recently been the subject of discussion in the media, with infrasound from wind turbines being a particularly contentious issue on occasion. In 2007, HGC Engineering investigated infrasound at several wind power projects and prepared a summary document for the Canadian Wind Energy Association (CanWEA) [1] indicating that infrasound was not an issue at modern wind turbine installations. Following on from that study, HGC Engineering has investigated three additional situations involving the perception of infrasound by individuals. These involved the measurement of infrasound sources using refined measurement methods, determining the physical effects of infrasound at neighbouring receptors and the manner in which infrasound was perceived by the neighbours. The sources included wind turbines, a large reciprocating engine used for power generation and an industrial sieve used to sift material. The results are summarized in this paper.

2. STUDIES

Infrasound is defined as "a wave phenomenon of the same physical nature as sound but with frequencies below the range of human hearing". Generally, hearing via the auditory nervous system is considered to occur at frequencies above 20 Hz. However, although infrasound may not be "heard" based on the normal meaning of the word, under certain circumstances it can be perceived by humans. There is some degree of auditory perception below frequencies of 20 Hz and there are non-auditory mechanisms such as the vestibular balance system and the resonant excitation of body cavities by which humans can sense infrasound. As determined in these studies, humans can also perceive the effects of infrasonic excitation on structures, such as perceptible vibration in walls and windows and secondary effects such as the rattling of lightweight building components.

2.1 Wind Turbine Generators

Measuring infrasonic sound levels produced by wind turbine generators is difficult in that it is hard to separate the effect of the turbines from infrasound naturally occurring due to local wind and distant atmospheric effects. Earlier attempts by HGC Engineering measured infrasound outside at various locations near and far from wind turbines and concluded that there was no material or consistent increases noted near the wind turbines.

Additional outdoor measurements have now been conducted using refined methods, incorporating a 1" free field microphone and a large multi-layered windscreen. Infrasound measurements were also conducted inside a residence near a wind power project to eliminate the direct contribution of infrasound due to wind at the microphone, and investigate the influence in occupied spaces.

Several sets of measurements were sequentially completed with and without the wind turbine generators operating. The residence is located about 325 m from the closest of several 1.8 MW wind turbines. During the measurements the wind was blowing towards the residence from a concentration of wind turbines at a speed of approximately 5 m/s.

Figure 1 presents the two minute average sound level in the dining room of the residence with and without the operation of the wind farm. The levels of infrasound are compared to perception thresholds suggested by Watanabe and Møller [2], which is shown as a hatched line.

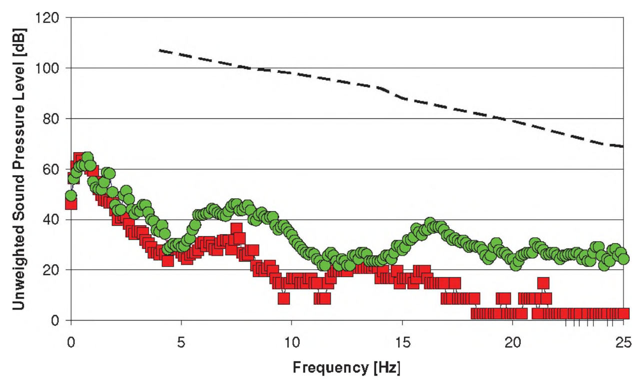

Fig. 1. Infrasonic sound levels measured in a residence, with (●) and without (■) wind turbine generators in operation.

The measurements indicate that the operation of the wind farm increases the sound levels by approximately 10 dB at selected frequencies. Regardless, if the wind turbine generators were operating, the sound levels are at least 30 dB less than the perception threshold suggested by Watanabe and Møller.

Vibration measurements were conducted on the foundation of the residence and on the foundation of several of the closest turbines to confirm that ground borne vibration was not a factor. These measurements demonstrated that in the both instances, the vibration levels are well below the perception limits discussed in ISO 2631/2 "Evaluation of human exposure to whole-body vibration Part 2".

The overall conclusion is that there is no evidence to suggest that infrasound should be a source of complaints by the occupants.

2.2 Low Speed Diesel Engine

HGC Engineering had an opportunity to investigate infrasound produced by two 30 MW low speed diesel engines used to provide electrical power for a Caribbean island. The 9 cylinder engines have an operating speed of 107 rpm. They were found to cause off-site excitation at a frequency of 10.7 Hz due to a 6th order (6 times the fundamental operation speed) "X" mode vibration of the engines. Essentially, the engines have a resonance whereby the top of the engine twists back-and-forth. The large surfaces of the engine efficiently radiate pressure pulsations which pass out through the building envelope with virtually no attenuation.

The infrasound was creating complaints at a neighbouring office building and hotel. The principal complains related to obvious rattling and visual motion of ceiling tiles and various lightweight fixtures. There were no complaints about physical perception per se.

To address the vibration, it would have been prohibitively expensive for the manufacturer to modify the engine to avoid the 6th order excitation. Rather, tuned mass dampers (TMDs) were originally installed at the ends of the engine block to reduce the vibration. Unfortunately, the tuning of the original TMDs was found to be unreliable; the spring elements failed due to fatigue, shifting the resonant frequency dramatically. The situation was finally solved by installing powered vibration compensators at the top of each end of the engine. These compensators are rotating eccentric masses which are adjusted to provide a force out of phase and equal to the inertia force of the vibrating engine.

Figure 2 presents the frequency spectra of the sound pressure level measured in the conference room of the office building located approximately 80 m from the building that houses the two engines. The levels were measured while both engines were running at full load, with and without the powered vibration compensators operating.

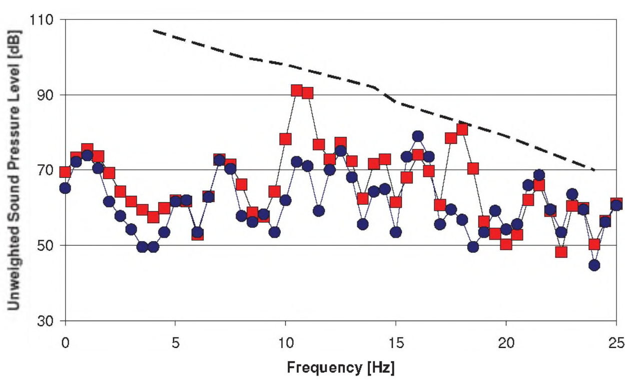

Fig. 2. Infrasonic sound levels measured indoors at 80 m from a 30 MW low speed diesel engine, with a powered vibration compensator (■) and without (●).

The compensators are extremely efficient at controlling the infrasound, reducing the sound pressure levels in the office space by 19 dB at a frequency of 10.5 Hz. Subjectively, the rattling of the ceiling and various fixtures within the offices was essentially eliminated as a result of the compensators, although there remains some residual low frequency air-borne excitation created by the firing of the engines at a frequency of 16 Hz.

It is interesting to note that the infrasound levels due to the engines were initially almost identical to the perception limits defined by Watanabe and Møller, and yet the complainants did not express concerns related to perception.

2.3 Vibrating Screens and Sieves

Infrasound proved to be a potential issue for a manufacturing plant that produces a foamed glass bead insulation product. The manufacturing process utilizes a number of large vibrating screens and sieves to classify the product by size. HGC Engineering completed extensive measurements at a plant in Germany, in order to aid in the design of a similar plant in Canada.

The screens operated at a frequency of 16 Hz. Vibration transmitted via the structure to the building shell was the principal source of infrasound noted off the property. Occupants of an office located approximately 75 m from the main processing building experienced visual vibration of its windows and light building components. One-third octave sound levels outside the windows were 87 dB at 16 Hz. Physically, the infrasound was not otherwise noticeable by the occupants in the building.

There were residential uses at approximately 150 m from the process. At this distance, the 16 Hz sound levels were reduced to 77 dBA. With these levels measured in one-third octave bands, it may not be precise to compare them to the aforementioned studies, but nonetheless: no complaints from the residents were noted even though the levels are approaching the perception limits as defined by Watanabe and Møller.

In designing the new plant in Canada, the frequency of the vibrating sieves was increased to 20 Hz, not to simply move the frequency of excitation above the infrasonic region, but to increase the efficiency of the vibration isolation systems supporting the sieves. In addition, the sieve building was designed to provide additional noise reduction at 20 Hz. This reduced the 20 Hz sound pressure level to 70 dB at the equivalent distance of 75 m.

3. CONCLUSION

HGC Engineering has recently conducted several infrasound studies using refined measurement methods to isolate the infrasound energy produced by industrial sources from naturally occurring infrasound in the environment. The results confirm a previous study prepared for the Canadian Wind Energy Association, concluding that infrasound from wind turbine generators is well below any realistic human perception limits.

The results also show that the effects of infrasound generally manifest themselves as the visual movement of lightweight building components and fixtures before human perception becomes an issue. This is particularly evident in instances when the infrasound is produced in a narrow frequency range where the probability of matching the resonant frequency of a component increases.

REFERENCES

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[2] Watanabe and Møller, "Low frequency hearing thresholds in pressure field and free field", Journal of Low Frequency Noise and Vibration, 1990b