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INVESTIGATIONS ON AIRBORNE ULTRASOUND AT WORKING PLACES

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Due to the widespread usage of ultrasound technologies, the pollution of working places by airborne ultrasound noise has largely increased. Although there is a strong need to value the health risk of workers, the application of ultrasound noise assessment in practice lacks of measurement instruments, measurement methods and well-founded quantities and thresholds. Against this background, the EU-funded project Ears II "Metrology for modern hearing assessment and protecting public health from emerging noise sources" has started. On the one side, the project aims to raise the fundamental knowledge on human perception of airborne ultrasound to come to more validated assessment concepts and quantities. On the other side, real working places are studied statistically and in detail to develop measurement methods that are fast and still accurate in practice. First results of the project are presented as a short review on ultrasound noise at working places and visualisation of the sound field of a simulated working scene.
Keywords: airborne ultrasound, noise, working places, measurement

1. Introduction

In the last decades, ultrasound techniques have found a growing number of applications in all fields of industry. There is evidence that ultrasound can be perceived by humans and that it can lead to hearing damage or to annoyance. The knowledge on perception mechanisms and on impact on humans is small. A need has grown in the sector of occupational health to assess the risk by airborne ultrasound noise on human hearing and health. Research progress suffers from the lack of appropriate measurement techniques, rough regulations and measurement methods that do not consider the specific characteristics of ultrasound fields.

This need is the basis for the European research project “Metrology for modern hearing assessment and protecting public health from emerging noise sources”, shortly called Ears II (see project website[1]). It is funded by the European Union and the follow-up of the Ears project. Following the work done in the first Ears project [2], one of the aims is to develop measurement techniques as well as measurement methods that are appropriate to assess the risk of workers at ultrasound working places. Moreover, the new instrumentation and methods will be used for a field measurement at real working places. The results of the field tests will be complemented by a review on available data. The project shall give particular progress to the measurement of airborne ultrasound and to knowledge on the treatment of its noise in occupational health.

This paper gives a short review on ultrasound noise at working places and introduces the starting investigations in the course of the beginning Ears II project.

2. Techniques and methods for measurement

A main part of the project aims to develop measurement techniques as well as measurement methods to properly detect and assess ultrasound noise. In a first step, several participating institutes developed ultrasound level measurement systems. These systems will be used in later field tests to record and analyse noise. A unique calibration of all systems will allow quantifying the measured sound levels properly. The experiences on the realisation of different systems will be collected and published.

Since ultrasound has specific characteristics compared to audible sound, the measurement methods used to assess noise at working places has to be carefully investigated, too. Up to now, standards and guidelines such as the German guideline VDI 3766 [3] advise methods which have been mapped from equivalent methods for the assessment of audible noise and which may not be appropriate for ultrasound. Due to the small wavelength of ultrasonic waves, the increased air damping and the dependence on environmental conditions, ultrasound fields are strongly affected by reflection, directivity and interference. This is demonstrated by the visualisation of a high-frequency sound field next to an artificial head that has been performed in preparation of the project.

The artificial head and torso simulator is placed inside the free-field environment of the portal scanning system of PTB. The sound field of an ultrasonic source is simulated by use of a loudspeaker in front of the head. The high-frequency noise is simulated by a sinusoidal signal at 10 kHz. The scanning system is used to determine the sound field next to the right ear of the artificial head in an area of 10 cm in width and 20 cm in height with a resolution of 1 cm (11 x 21 points). Figure 1 shows a photo of the setup. The plot of the spatial level distribution in Figure 2 demonstrates the sound field in absence and in presence of the artificial head as a coloured map of sound pressure levels. A strong interference pattern is found when the head is present in the sound field with variations in sound pressure level of about 12 dB. This is the value that is reported by occupational health agencies on measurements at real working places. Details on that measurement can be found in [4].

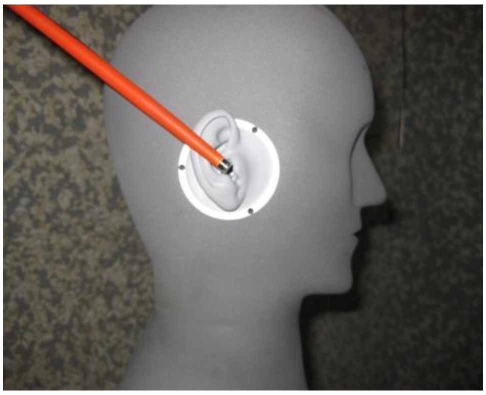

Figure 1: Photo of the artificial head and torso simulator in the free-field environment with the scanning microphone.

Although the described setup is a very rough implementation of a working place environment and a non-ultrasound excitation signal of 10 kHz is used, the result clearly demonstrates that noise at high-frequency and ultrasound working places shows completely different characteristics compared to audible noise.

It is expected that ultrasound fields at real working places have much more spatial variation compared to audible sound fields. Due to air damping, noise may be concentrated near to a source. High directivity of sources may lead to ‘loud’ and ‘quiet’ areas. The combination of reflection at even small surroundings and mainly monofrequency sound emission presumably causes strongly modulated interferences. This distinction to audible sound causes measurement methods to fail when applied to ultrasound noise problems. Thus, one of the main tasks of the project is to find new methods for the assessment of ultrasound noise at working places.

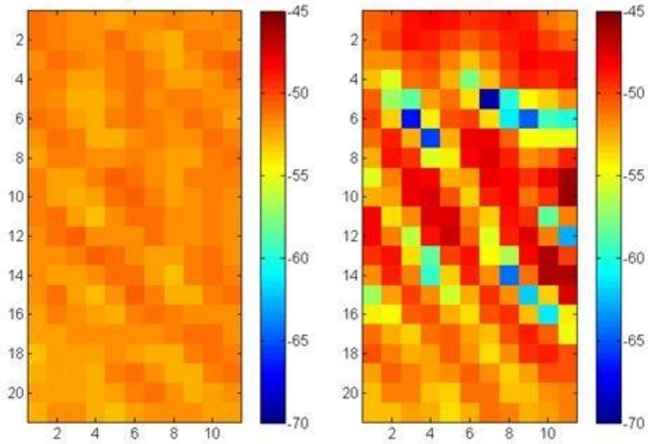

Figure 2: Distribution of sound field in an area of 10 cm x 20 cm next to the ear. The levels are given with an arbitrary reference value. The left map shows the sound field in absence, the right map shows the field in presence of the head.

The assumptions given above on the behaviour of ultrasound fields must be proven by detailed measurements at real working places. These are also necessary for the development of the new measurement methods. Unfortunately, it is not possible to do elaborated measurements in a running working line. Instead, a reference workplace which is typical for a specific field of ultrasonic techniques application can be set up in the laboratory. This is the approach of the project.

3. Ultrasound reference workplace

A revision of available data that were collected in the context of occupational health measurements at real workplaces showed that ultrasonic welding is a wide spread application with strong exposures to workers. Welding is typically performed with an excitation frequency between 20 kHz and 35 kHz. Typical spectra of such machines show strong harmonic components as well as a strong subharmonic emission at half the frequency. The sound pressure levels measured are in the range between 93 dB to 105 dB for LAeq, 76 dB to 90 dB for LAUeq and 122 dB to 135 dB for LZpeak. First information on the data review at real working places can be found in [5]. This revision of available data is valuable to demonstrate the noise immission on workers. It has to be taken into account that the revised measurements have been performed according to measurement methods that are not expected to yield reliable results and using measurement techniques that are not known to be applicable to those methods. But as the most detailed data available, it can serve to estimate the actual exposure to ultrasound and it delivers valuable information on machines and applications used in practice.

Following the outcome of the data revision, a welding machine was chosen as a reference workplace. In collaboration with a leading manufacturer of ultrasound welding machines, Herrmann Ultraschalltechnik GmbH & Co. KG, a workplace will be simulated that is typical and that can serve as a reference for detailed investigations. This reference workplace is being setup in both IFA and PTB laboratories to study sound field distribution, influence of environment and influence of the worker himself on the result of a risk assessment. The portal scanner of PTB is used to visualise the sound field around the worker in detail and to find a handy set of measurement points and a protocol that allows fast but accurate noise assessment of typical workplaces. Figure 3 shows a photo of the PTB portal scanning system. On the time this conference paper is being prepared, investigations have just started.

Figure 3: PTB scanning system with implemented free-field environment with a volume of approximately 2 m x 2 m x 2 m.

4. Summary

The need for the development of adequate measurement and assessment methods for ultrasound noise at working places was demonstrated. A review of available measurement data gave a first insight into the quantity of noise at working places. Measurements using a scanning system demonstrated the high spatial variation of high-frequency sound fields. For detailed investigations on a typical immission situation, a reference workplace is now being set up using a typical welding machine. The project work on ultrasound at working places has just started and coming results will be published.

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