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Airborne ultrasound noise at workplaces

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ABSTRACT

Airborne ultrasound noise in the workplace is an increasing problem concerning occupational safety and health. Industry applications found most frequently are cleaning, cutting and welding. National regulations exist, often non-consistently, providing limit or guidance values and only a few give advice on the measurement procedure itself. But in general, ultrasound noise measurement has several basic problems, e.g. a lack of instrumentation, traceability, tailored procedures and even knowledge on its impact on humans. Among other issues, the EARS II project, funded by the European metrology programme for innovation and research (EMPIR) of EURAMET, has addressed the development of an appropriate measurement procedure for the assessment of noise at work sites. In the daily business of occupational health and safety engineers, there is no time for intensive studies. Thus, a reference workplace has been set up in the laboratory to examine sound fields in detail. These studies gave a detailed view into the specific characteristics of ultrasound fields and allowed to derive an adequate and practicable measurement procedure for ultrasound noise assessment.

Keywords: Airborne Ultrasound, Noise, Assessment

1. INTRODUCTION

Ultrasonic devices are used in a wide-spread area of applications in industry. The most prominent examples are ultrasonic welding of plastics such as foils or solid parts, ultrasonic cutting of cheese and cake, or ultrasonic cleaning of dirty engine parts or even sensitive electronic circuit boards. These applications usually base on a resonant sound delivering techniques leading to high acoustical amplitudes with a fundamental frequency in a typical range between 20 kHz and 50 kHz. This unavoidably leads to airborne sound which is emitted into the surrounding of the ultrasonic device with very high amplitudes. Since the ultrasonic devices or the working process in many cases have to be applied, controlled, cleaned or managed by a human, there is always a working place associated with them. The worker then moves in an area of high-frequency, tonal and loud noise.

Classical noise assessment is limited to a frequency range up to 20 kHz, due to restrictions of both, measurement instrumentation and assessment guidelines. Nevertheless, occupational health and safety agencies register a growing number of complaints at working places equipped with ultrasonic machinery. In general, any possible hazard to a worker's health must be assessed. Thus, there is a need for a practical and reliable ultrasound noise assessment.

2. ULTRASOUND NOISE ASSESSMENT IN PRACTISE

A number of national guidelines have been issued in the past decades all over the world, but a closer examination shows that these basically refer to the same limited literature basis provided in the 1970's and 1980's. The methods are widely borrowed from audible noise assessment, e.g. ISO 9612 (1). Engineers following these guidelines often run into problems due to the limitations of their instrumentation and those methods which they have to apply. This leads to inappropriate and inconsistent noise assessment at ultrasound loaded working places.

Thus, one of the aims of the EMPIR project "Ears II - Metrology for modern hearing assessment

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and protecting public health from emerging noise sources" (3) was to develop an appropriate measurement procedure for the assessment of ultrasound noise at workplaces. As a starting point for the investigations, different measurement procedures have been compared. In (2), measurement results were presented that show clear differences between stationary and spatially averaging methods to measure the sound pressure level. The stationary measurement method which is recommended in most guidelines restricts the measurement to single measurement points. This leads to a higher uncertainty in the determination of the sound pressure level. This lack of reproducibility makes it difficult for engineers to properly assess the exposure of workers at ultrasound workplaces.

3. REFERENCE WORKPLACE

The question arises why the methods borrowed from procedures for audible noise measurement lead to inconsistent results. How does ultrasound noise differ from audible noise? An observation by measurement engineers is that the sound level strongly varies when moving the microphone through the sound field. Level differences of more than 12 dB are reported during movements of just a few centimeters. This triggered to study the sound field of a working place in more detail. Unfortunately, such working places usually are integrated in a complex industrial production process giving no chance at all for time-consuming and extensive scientific studies.

Thus, a reference workplace was set up that simulates a typical industrial working place equipped with an ultrasonic device. The setup consisted of a typical industrial welding machine with a driving frequency of about 20 kHz. For better control, the machine was mounted in a free field environment in laboratory. The setup was incorporated into the large PTB portal scanner. The scanner had three moving axes in X, Y and Z direction and allowed computer-controlled positioning of a microphone in the sound field with a precision of about 50 µm. The scanning area was nearly 2 m on each axis and gave the opportunity for large and highly detailed sound field studies. Extensive pretests and examinations were performed with the sound source to ensure reliable scanning results. See (4) for more details. Figure 1 gives a photograph of the scanner.

Figure 1 – Portal scanner of PTB with a scanning volume of about 2 m x 2 m x 2 m with three axes in X, Y and Z direction with a minimum spatial resolution of about 50 µm. (4)

4. A TYPICAL ULTRASOUND FIELD

The reference workplace was used for detailed recordings of the sound field around the reference source. The scans were performed in areas where the worker typically moves. This included standing working positions, sedentary working positions and positions in the far field and on the sides of the machine. Figure 2 shows an example of a scan of the ultrasound field. More details can be found in (4).

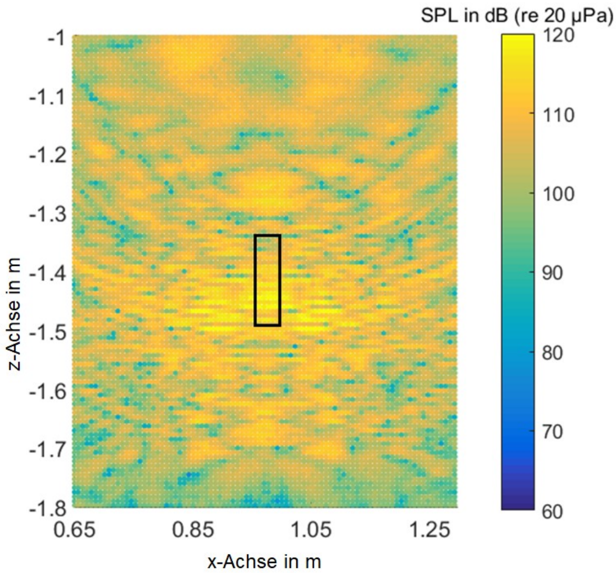

Figure 2 – Measured sound pressure levels in front of an ultrasonic welding machine in an area of about 0.65 m in width and 0.8 m in height. The black rectangle marks the position of the driving sonotrode. (4)

The scanning picture shows a highly non-uniform sound field with distinctive interference patterns. The level differences are up to 35 dB between points with a distance of a few centimeters. The characteristics are similar in areas at all sides of the machine. The various scans have been analyzed to find significant parameters for the characterization of ultrasound fields. This will be used to derive a proper and applicable measurement method for noise assessment.

The scans clearly show that ultrasound fields differ from the more uniform audible sound fields. Specific measurement methods are required to reproducibly obtain sound pressure levels that are representative for the workplace and that allow to properly assess the noise exposure of the worker even in non-uniform ultrasound fields.

5. INFLUENCE BY THE OPERATOR

The non-uniformity of ultrasound fields is not the only difference to audible sound fields. The field structure is quite more sensitive to any change in the acoustic properties of the surrounding or structure incorporated in the sound field. This includes not only the machine housing but also the operator himself. The standard procedure for audible noise assessment is to measure the noise in absence of the operator. In fact, the sound level difference measured with and without him present is usually neglected in practice. This may not be appropriate for ultrasound fields.

In preliminary studies, it was observed that the operator influences the sound field. In (5), an artificial head was placed in front of a loud speaker and a sinusoidal sound signal of 10 kHz was played. The sound field was scanned next to the right ear of the head in rough steps with and without the artificial head present. Instead of the sound pressure level, the impulse response was determined at each point which resulted in complex information about the sound field. The phase angle at each measurement point was plotted for both situations and is shown in figure 3. In the situation with the head present, an interference pattern can be observed that is not seen in the situation without the head. The corresponding local level differences were about 12 dB.

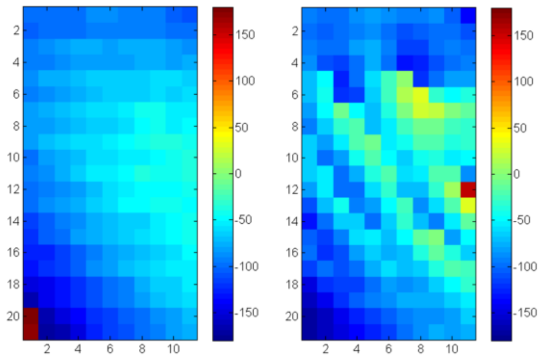

Figure 3 – Phase of the impulse response, left panel without an artificial head in the sound field, right panel with head. Both plots show the phase in degrees as colors over an area of about 12 cm in width on axis *X* and 22 cm in height on axis *Y* next to the right ear. (5)

Motivated by these findings, the reference workplace studies were extended by the situation that an operator was simulated sitting or standing in front of the welding machine. Again, an artificial head was used as a representation of the operator. The sound field was scanned for sound pressure levels in areas around both ears. As an example, figure 4 shows a plot of a preliminary analysis of these scans.

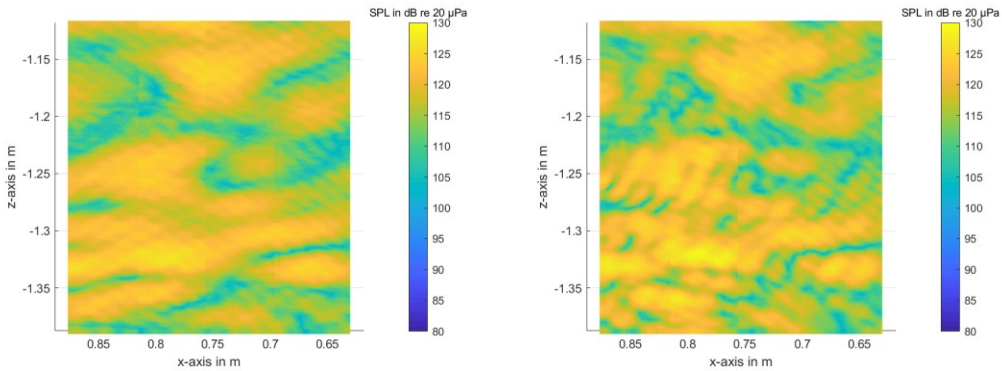

Figure 4 – Measured sound pressure levels coded by colors in front of an ultrasonic welding machine without (left) and with (right) the head present. The scanned area is next to the right ear and has a width of about 25 cm and a height of about 29 cm.

The analysis of these measurement series is still in progress. But the first results show that there is a strong influence of the head and the torso of the operator on the sound field. The influence may affect the level as well as the structure of the sound field. Both parameters must be accounted for when assessing the exposure.

The minimal conclusion from these findings is that an ultrasound noise measurement is only valid when the operator is present in the sound field. Further conclusions will be drawn when the analyses will be finished.

6. CONCLUSIONS

The sound field at workplaces that involve ultrasonic machinery has been studied. Since real workplaces do not allow extensive scientific studies, the investigations were performed using a reference workplace that simulates a typical welding working station under controlled laboratory conditions. Spatial high-resolution scans of the sound field were performed around the source. Moreover, an operator was simulated using an artificial head being placed in front of the machine. First results showed that the operator himself strongly influences the sound field and thus the result of a noise measurement. Further analysis of the data is in progress.

The aim of these studies was to derive a measurement procedure that allows the practical and reliable assessment of the ultrasound noise exposition of a worker. The method should include the specific characteristics of ultrasound fields and should be applicable even on a running industrial production line.

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