Personalized miniaturized dosimeter (PMD) for an individualized prevention of hearing loss

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Introduction

Hearing loss is becoming a disease of civilization. Many of the sounds and noises sourounding people are simply too loud and damage their auditory system. In current ergonomics there are extensive legal, technical and occupational medical measures for the prevention of hearing-loss. In spite of these measures the noise induced hearing loss is still at the top of the approved occupational diseases in germany. Present practise in the prevention of hearing-loss is an A-weighted localized (sound emission) or personalized (dosimeter) noise measurement at the workplace [1], [2]. These evaluation of the noise situation and noise sources are the basis for potential preventive measures. However, a head-related sound analysis and binaural sound recording is necessary for the precise measurement of the actual noise exposure (stress) [3]. Indeed, there are such measuring instruments (e.g. binaural head microphone), however, the application in current ergonomics is complex and in most cases not applicable. Standard devices are not portable (weight) and vibrations or manipulation by the user falsify the measuring results.

Furthermore, the determination of the beginning of a hearing-loss is only partial or hardly possible. The main reason is that the individual's hearing violability and disposition is not taken into account. Thus, in dependence on these individual factors, the same noise exposure leads to inter-individual strain responses. By chronic industrial noise (e.g. working environment or daily life), primarily the outer hair cells (OHC) are damaged. At present, there is no effective therapy of the inner ear damage respectively noise-induced hearing loss. The otoacoustic emissions (OAE) could be a possible indicator for the individual strain. OAE can be evoked specifically and be measured objectively. If a noise-induced damage of the OHC took place it comes to a failure of the otoacoustic emissions [4]. Other effects are temporary threshold shift (TTS, audiogramme) and temporary emission shift (TES, OAE). Therefore OAE can be a predictor for prophylaxis of hearing decrease. Otoacoustic emissions are very intra-individually reproducible. In principle, evidence-based conclusions should be possible with continuous controls of the noise exposure at the workplace. For the recognition of an occupational disease an sufficient quantification and an evidence-based reproducible relation of "noise-dose-effect" should be provable. This means that stress and strain have to be measured simultaneously. A precise quantification of the individual noise exposure and noise effect thereby becomes possible. Such measuring systems which are acceptable for employees under working conditions still barely exist.

Concept of the PMD device

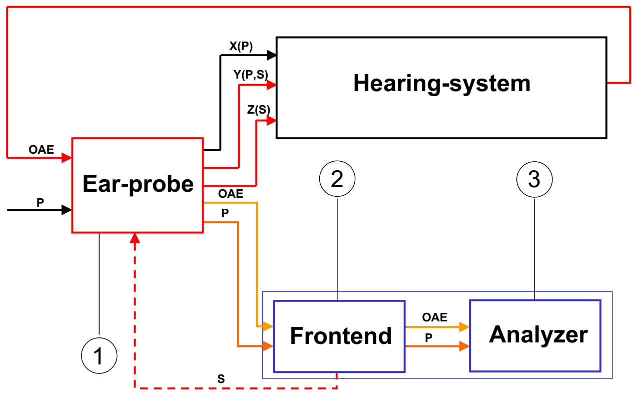

Figure 1: Concept of the personalized miniaturized dosimeter (PMD).

The three main components of the device are shown in Figure 1. The components are a sensor-actuator-unity (ear-probe) (1), a mobile signal-processing-unity (mobile frontendprocessor) (2) and an interpretation-unity (3). The ear-probe is the interface between the generate signals (mobile frontend-processor) and the sound pressure (P, X(p), Y(P,S), Z(S), OAE) in the ear-canal. The data transfer from the ear-probe to the frontend-processor is wireless. An obstruction of the user's activities is thereby avoided during the work. The measured noise exposure P (sound pressure) is stored in the mobile fontendprosessor. The signal analysis is implemented in the interpretation-unity. This unit calculates the rating level (assessment of immissions), however, also enlarged time frequency analysis is possible. The sound attenuation X(P) is attaining the ear canal. The condition for the individual and personalized noise-dosimetry is that the measurement is carried out near the ear (in situ). A possible variation is the application of ITC-probes (in the canal). A miniature microphone, sound amplifier and speaker are integrated into this ITC-probe. The probe must be an individual adapted otoplastic which does not occlude the ear canal. Beside that, inter-individual morphological differences must be taken into consideration. The adjustment of the sensors (microfone, speaker) could occur, for example, optically to the *Umbo membranae tympany.*

The first upgrade of the system is the integration of a communication channel Y(P,S). This channel is available for the bidirectional transfer of audio-signals and is controlled (S) by the frontend-processor. The following advantages are thereby reached:

- Relevant information about the noise exposure ("noise-dose") or security at the workplace can be transferred to the user (earprobe).
- Other senses can be compensated (e.g., sense of touche, visual sense).
- The personal noise control is preserved at all times, because the user doesn't have to take out the earprobe during the work.

The next expansion level will be the implementation of components for an integrated provocation analysis (otoacoustic emissions OAE). The frontend-processor generates the stimulation pulse for the OAE-measurment Z(S). The ear-probe extracts the cochlear response (OAE) to an acoustic stimulation pulse Z(S) and sends the signal to the frontend processor.

Figure 2: First Prototype of the Personalized Miniaturized mechatronic Dosimeter (PMD).

First prototype

Wireless headsets with ear-probe are particularly suitable for the first prototype. Based on a combination of work of the Audia Akustik GmbH Sömmda with current work at Ilmenau on the noise induced hearing loss an active and individual adaptable otoplastic (ear-probe) was developed. The prototype is shown on the top right of Figure 2. In collaboration with the IMMS gGmbH Ilmenau the prototype of the fontend was implemented as a subsystem ”‘Hearing protection, dosimeter and communication”’. After the design and construction phase of the application (hardware and software) the following functionalities are supported:

- Wireless bidirectional connection with two different ear-probes via BluethoothTM (left ear and right ear)
- Calibration cycle for each ear-probe
- Recording the audio data from the ear-probes on a flash-memory for a period of at least eight hours
- Play a wave file (e.g. sending an alarm dosage signal or relevant information about the noise exposure)

The following values are calculated or displayed:

- Equivalent continuous sound level (Leq), rating level and noise doasage for two audio channels
- Charge of battery, available memory, show settings

The ear-probe prototype in cojunction with the frontend are currently in a functional test.

Results and preventive perspectives

Employers as well as employees have great interest in the availability of technical possibilities for the measurement and control of individual "noise-dose-effects". Aiming at the indivuidual prevention of hearing loss caused by noise exposure, methods which deliver impression proportional results must be used or developed. Thus, supplementary examinations are necessary to quantify the relation between noise exposure and the hearing perception caused by them. Implementation of measuring the oto-acoustic emissions promises better information about the individual's hearing violability.

PMD gives the first possibility of extensive studies for questions of preventive effectiveness. In the application the following advantages arise:

- PMD has features to determine objective parameters with which the physiological reaction (strain) to the physical load (stress) can be described.
- For individualized prevention of hearing loss, PMD enables a perspective for prophylactic identification of employees with especially sensitive hearing (violability).
- In the context of longitudinal analysis, the technical and organizational complexity and financial expenditure can be reduced.

References

[1] Hoffmann, H. ; von Lüpke, J. ; Maue, J.: 0 Dezibel + 0 Dezibel = 3 Dezibel – Einführung in die Grundbegriffe und die quantitative Erfassung des Lärms. Erich Schmidt, Berlin, 2003

[2] Ermittlung von Beurteilungspegeln aus Messungen – Teil 2: Geräuschimmission am Arbeitsplatz, Deutsche Industrienorm DIN 45 645-2: 1997

[3] Genuit, K.: Gehörgerechte Schallmesstechnik. Chap. 6, Taschenbuch der angewandten Psychoakustik, edited by M.T. Kalivoda and J.W. Steiner, Springer, Wien New York, 1998

[4] Hoth, S. and Neumann, K.: Das OAE-Handbuch – Otoakustische Emissionen in der Praxis, Georg Thieme, Stuttgart New York, 2006