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ASSESSMENT OF THE WASHING MACHINES SOUND QUALITY BY THE BINAURAL MEASUREMENT SYSTEMS

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ОЦІНКА ЯКОСТІ ЗВУКУ ПРАЛЬНИХ МАШИН БІНАУРАЛЬНИМИ ВИМІРЮВАЛЬНИМИ СИСТЕМАМИ

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ОЦЕНКА КАЧЕСТВА ЗВУКА СТИРАЛЬНЫХ МАШИН БИНАУРАЛЬНЫМИ ИЗМЕРИТЕЛЬНЫМИ СИСТЕМАМИ

The target and goal of psychoacoustics is to understand how people perceive and experience different sounds. Psychoacoustic is joining the field of acoustic and psychology. Sound quality is a perceptual reaction to the sound that reflects the listener's reaction.

Keywords: *sound quality, binaural hearing, psychoacoustics.*

Fig.: 3. Tabl.: 4. Bibl.: 10.

Мета психоакустики – дізнатися реакцію людей на сприйняття різних звуків. Психоакустика поєднує акустику і психологію. Якість звуку – це сприйнятлива реакція на звук, тобто відображення реакції слухача.

Ключові слова: *якість звуку, бінауральное слухання, психоакустика.*

Рис.: 3. Табл.: 4. Бібл.: 10.

Цель психоакустики – узнать реакцию людей на восприятие различных звуков. Психоакустика соединяет акустику и психологию. Качество звука – это воспримчивая реакция на звук, то есть отображение реакции слушателя.

Ключевые слова: *качество звука, бинауральное слушанье, психоакустика.*

Рис.: 3. Табл.: 4. Библ.: 10.

Introduction. Psychoacoustics is the study of the perception of sound. This includes how human listen, their psychological responses, and the physiological impact of sound upon the human nervous system. Psychoacoustics is a multidisciplinary field that deals with the physical, physiological, and perceptual correlates of sound production, transmission, and reception. Sound quality is often joined with the psychoacoustic. Definition of sound quality is no definitive and there are more explanations of the sound quality. The term product sound quality refers to the adequacy of the sound from a product [4]. Another definition of sound quality is a perceptual reaction to the sound of a product that reflects the human reaction to how acceptable the sound of that product is [5].

1. Assessment methods

There are two basic methods for evaluation of the sound quality. These two methods are jury testing and objective assessment by the psychoacoustics and sound quality metrics. Jury testing consists of asking customer opinions to sounds of products. Realization of jury testing is very difficult, time consuming and is very dependent on the context [8]. Due this reason was created metrics that directly relate to subjective response. Individual metrics do not give exact indication of the sound quality of the product as a whole and indeed for different products no metrics may currently exist to adequately quantify the subjective impression. There are a wide variety of metrics for evaluations of the sound quality [1; 2; 3]. Sound quality metrics are:

– loudness,
– roughness,
– sharpness,
– tonality,
– fluctuation strength.

Once you have established appropriate metrics for evaluation sound quality, this means that quick and easy measurements of sound quality can be realized using special devices and tools. However, it can sometimes be difficult to define appropriate metrics.

2. Binaural measurement systems – artificial head

Artificial head is basic tool for evaluation of the sound quality of the products and the target of the artificial head is to get apart from the classic technique evaluation. Recordings with conventional measurement systems are not suitable for an aurally accurate evaluation of an acoustic signal, because substantial acoustic information such as the spatial array of sound sources and the selectivity of sound perception gets lost [6; 7].

Artificial heads are stand- alone measuring devices for processing aurally accurate recordings. Artificial head construction and geometry offers:

– a mathematically describable reproduction of the human head and body torso,

– an accurate reproduction of all acoustic important parts of the human outer ear.

Nowadays there is more relevant producers of the artificial head with very similar possibilities. Companies such Head Acoustic, Brüel & Kjaer, G.R.A.S., provide these binaural measurement systems as shown fig. 1.

Fig. 1. Artificial heads [7, 9, 10]

3. Experimental measurements

The aim of experimental measurements was determining psychoacoustic metrics for three washing machines and comparison the psychoacoustics metrics with measurements of sound quantity emitted by the washing machines that is represented by the determination of acoustic sound power level. For measurement was selected spinning program of the washing machine. Spinning is most critical according the noise emissions. For evaluation was selected following psychoacoustic metrics: sharpness, roughness, loudness, tonality and fluctuation strength. Measurement was realized in semi anechoic chamber with reflective plate as shown fig. 2. Type of washing load was 6 kg laundry. Measurement of sound power levels was determined according to EN 60704-1; EN 60704-2-4.

Fig. 2. Measurement of the sound power level and psychoacoustic metrics in semi anechoic chamber

For measurement was selected three washing machines from different producers. Washing machines are from the same premium class with very similar technical specifications. Measured washing machines are shown in fig. 3.

Fig. 3. Measured washing machines

4. Results and discussion

Results of measurement and determination of sound power level according to EN 60704-1; EN 60704-2-4 are presented in table 1.

Table 1

Sound power levels

Wasching machine	Sound power level [dB]
Wasching machine 1	75,1
Wasching machine 2	73,1
Wasching machine 3	74,0

From the obtained results is clear that highest sound power level reach washing machine 1 and lowest sound power level reach washing machine 2.

Next table 2 presents measurement and determination of psychoacoustic metrics.

Table 2

Psychoacoustic metrics

Washing machine	Roughness [asper]	Sharpness [acum]	Loudness [soneGF]	Tonality [ton]	Fluctuation strength [vacil]
Washing machine 1	1,36	2,75	8,1	0,0785	0,0265
Washing machine 2	1,31	1,93	6,96	0,0702	0,0305
Washing machine 3	1,6	1,84	7,06	0,0345	0,0288

Evaluation assumptions

– Importance of all psychoacoustic parameters is equal,

– Lowest reached value of all psychoacoustic parameters is best and increased value of those parameters means worse psychoacoustic properties,

Evaluation methodology

– Determination of minimum and maximum measured values for each parameter,

– Calculation of relative values for each parameter,

$$p_{rel} = x_{abs}/x_{max}$$

– Calculation of overall index h_f, individually for spin,

$$h_f = w_1.p_{1rel} + w_2.p_{2rel} + w_3.p_{3rel} + w_4.p_{4rel} + w_5.p_{5rel}$$

w_x – weight of psychoacoustic parameter (same for each parameter, value=1/5)

p_{rel} – relative value of parameter

Computed standardized values for each washing machine are presented in table 3.

Table 3

Standardized relative values of psychoacoustic metrics

Washing machine	Roughness P_1	Sharpness P_2	Loudness P_3	Tonality P_4	Fluctuation strength P_5
Washing machine 1	0,85	1	1	1	0,8688525
Washing machine 2	0,81875	0,70181818	0,85925926	0,89426752	1
Washing machine 3	0,81875	0,66909091	0,85925926	0,43949045	0,8688525

For the each psychoacoustic metrics was set the same importance. According these conditions was calculated overall index of the psychoacoustic valuation for individual washers. Overall valuation of psychoacoustic metrics according standardized values is shown in table 4. Highest value means worst psychoacoustic properties.

Table 4

Overall valuation index

Washing machine	Overall valuation index h_f
Washing machine 1	0,942
Washing machine 2	0,850
Washing machine 3	0,797

Conclusions. Measurement was realized for three washing machines from different producers. Classic measurement was realized for determination of sound power level by the classic microphones. Result of these measurements presents the quantity of power emitted by the washing machine. Determination of psychoacoustic metrics was realized by the artificial head – binaural measurement systems. Result of these measurements presents the quality of the sound emitted by the washing machine. Comparison of these two types of valuation shows the different ranking of noise performance individual washing machines. By the valuation of sound power level best noise performance shows washing machine 2 and worst washing machine 1. Assessment of the psychoacoustic metrics shows that best psychoacoustic performance shows washing machine 3 and worst washing machine 1. Comparing these two methods was obtained different rankings of washing machines. That means the quantity of emitted sound is not still most important. Ranking based on the assessment of psychoacoustic metrics shows other ranking that is more similar and more accurate for human hearing. The sound of washing machine 3 is less annoying for human than sound of machine 2 and 1. But these results should be verified by the jury study that can bring new knowledge. Correlation the jury study and realized measurements can provide more objective results.

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