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Acoustically-friendly products - Sound quality as an emission related product feature

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ABSTRACT

People are permanently exposed to noise emitted by technical products in all areas of life. It is very much known that harmful noise effects are likely to occur by lower sound pressure levels as well. Moreover, residents complain about noises caused by neighbours according to the German Environment Agency with an upward trend. Moreover, acoustics is effectively one of the top product features regarding purchase decisions and it seems that consumer journals increasingly ask for more information regarding acoustic comfort and sound quality. It is already well known that massive differences in the sound quality of products on the market within the same product category exist. So far, some eco-labels have been established in the market considering noise emission, but they often work with simple noise level indicators only. But, how to reliably determine the sound quality of products representing sound perception and to widely spread this information to consumer organizations and final consumers? The paper will present some case studies on product sound quality related metrics beyond sound power and will discuss options and difficulties to use sound quality classifications for recognizing and supporting sustainable acoustically-friendly products.

Keywords: Sound quality, sound perception

1. INTRODUCTION

In everyday life, one is permanently exposed to all kind of noises. Most of the noises surrounding us are emitted by technical products. Consequently, Schwela concluded that in all societies throughout the world, the general population is increasingly exposed to environmental and consumer product noise, however defined. The health effects of these exposures constitute an increasingly serious public health problem [1].

The amount of noise we are exposed to has a great impact on well-being and quality of life. For example a survey has shown that in 2016 approximately 60 % of residents in Germany were annoyed by noises caused by neighbors [2]. Today, diverse studies have significantly proven that harmful noise effects are likely to occur even by lower sound pressure levels [3].This is particular true when health is understood as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” [4]. These statements underline the need to think about noise reduction and optimization of technical products (such as all kind of vehicles, household appliances, HVAC systems, powered tools, etc.) on a large scale to reduce noise annoyance and adverse health effects.

Besides the aspect of noise related to health effects, noise is also considered to be a relevant product feature influencing purchase decisions. According to American National Academy of Engineering, consumers rank noise as one of the top five product characteristics, when comparing product performances (among characteristics like energy efficiency, price, reliability, maintainability) [5]. It seems that different parties and stakeholders (consumer protection institutions, consumer journals, authorities, policy) increasingly demand more information regarding acoustic comfort and sound quality. In particular, in Europe over the past two decades product noise emission standards were developed (e.g., voluntary limits that have been agreed upon by a nongovernmental body), regulations (e.g., noise measurements that must be complied with and certified), and efforts to increase the amount of information provided to consumers with respect to product noise emissions, such as voluntary and mandatory product labeling requirements [5].

For example, the EU energy label established already in 1992 as mandatory for household appliances intends to indicate significant direct or indirect impact on energy consumption during use

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[6]. The European Commission concluded that by improving the efficiency of energy-related products through informed consumer choice benefits the EU economy overall [6]. Recently, the European Commission has adopted a format and visual identity of energy efficiency labels in order to make energy labels more understandable for consumers and help them make better informed purchasing choices. These new labels will be visible for European consumers in physical stores and on-line by 2021 [7]. According to the European Commission since its introduction twenty years ago, the success of the EU energy label has encouraged the development of ever more energy efficient products leading to the problem of ceiling effect of the top class rated products asking for a rescaling (the majority of products get an A++ or A+++). Noise statements in terms of A-weighted sound power levels are mandatory to be provided for most of the respective product groups. The European Commission estimations value the total final accumulated energy savings of these new labels by 2030 to an amount equivalent to the annual electricity consumption of Hungary [7]. Thus, it can be concluded that less (noise) emissions will be beneficial for all involved parties, such as consumers, manufacturers, public communities. However, it must be stated that eco-labels focusing on noise emission do only rarely exists. In most cases, product noise as an indicator for unwanted, undesirable emission during use is not primarily addressed; in most cases noise is one aspect of a label dealing with all kind of emission issues and energy consumption.

2. IDEA OF SOUND LABELS

A label is defined "as a written or printed matter accompanying an article to furnish identification or other information" [8]. In the context of noise, a label might inform potential buyers and/or users about the specific noise emission of a product. For it, different operating conditions must be considered and probably combined to a sound label to be understood by buyers and/or users.

The information may be on a label affixed to the product or on the packaging, in a product brochure or user's manual, or on a manufacturer's website. If uniform labeling appears on all products, it can be a benefit to consumers, if it is not uniform, it can create confusion and be an unfair competitive advantage or disadvantage [5].

However, William Lang complained that the noise information now available on most products is neither understood by the public nor widely available to them. He concluded that there is a global lack of understanding by manufacturers, suppliers, and potential users; and we noise control engineers are partly responsible for this situation [9].

Moreover, it must be noted that there is no established and acknowledged label considering sound quality aspects so far. Almost all noise labels are focused on sound pressure/power level indicators. Only rarely, other perception-related metrics and indicators are considered to classify the acoustic comfort level. For example, product sounds can be relatively quiet but nevertheless they can be relatively annoying. The term 'sound quality' describes the perception of the suitability or desirability of a sound attached to a specific technical object emitting it. Efforts to develop an acoustic comfort related label are rarely made so far.

3. EUROPEAN ECO-LABELS

So far, most of the noise-labeling programs are not mandatory but voluntary. In Europe an increased public interest in information about products with reduced environmental impact was observed and the European Commission established the EU Ecolabel in 1992 [10]. This optional label frequently called EU flower, which was introduced by a decree, has been developed to be a reference for consumers with a focus on economic and sustainable products and services in order to reduce environmental pollution. The EU Ecolabel can be requested by manufacturers, importers, traders (etc.) at the national committee and is completely voluntary.

On a national level in Europe several eco-label programs were established over the last decades. For example, the Blue Angel (Germany), the Nordic White Swan (Scandinavia), the Milieukeur (Netherlands), the TCO (Sweden) are valuing low (noise) emission products. Products with eco-labels applying noise criteria include personal computers, printers, copiers, projectors, chain saws, garden tools, and construction machinery. The Blue Angel indicates products, which clearly damage „ the environment less " than comparable products of the same product group. The Blue-Angel awards the best in class products. The Blue Angel eco-label has been well established in the market and considers several emission criteria like noise in terms of the sound power level. The Blue-Angel eco-label is particularly preferred in public tendering procedures [11].

4. CASE STUDY – NOISE OF KETTLES

As a case study, kettles (water boilers) from 14 different manufacturers were measured, analyzed and judged with respect to sound quality assessments.

The acoustic analysis of the kettle noises revealed large sound pressure level differences between the different kettle noises (see fig.1). For example, differences of the A-weighted equivalent continuous sound pressure level L_{Aeq} were up to 10.5 dB ranging from 58.5 dB(A) to 69 dB(A). The psychoacoustic loudness according to the ISO 532-1 [12] varied almost in factor 2 between the quietest and the loudest kettle, which means that the louder product was perceived as twice as loud as the quiet kettle product (see fig. 2).

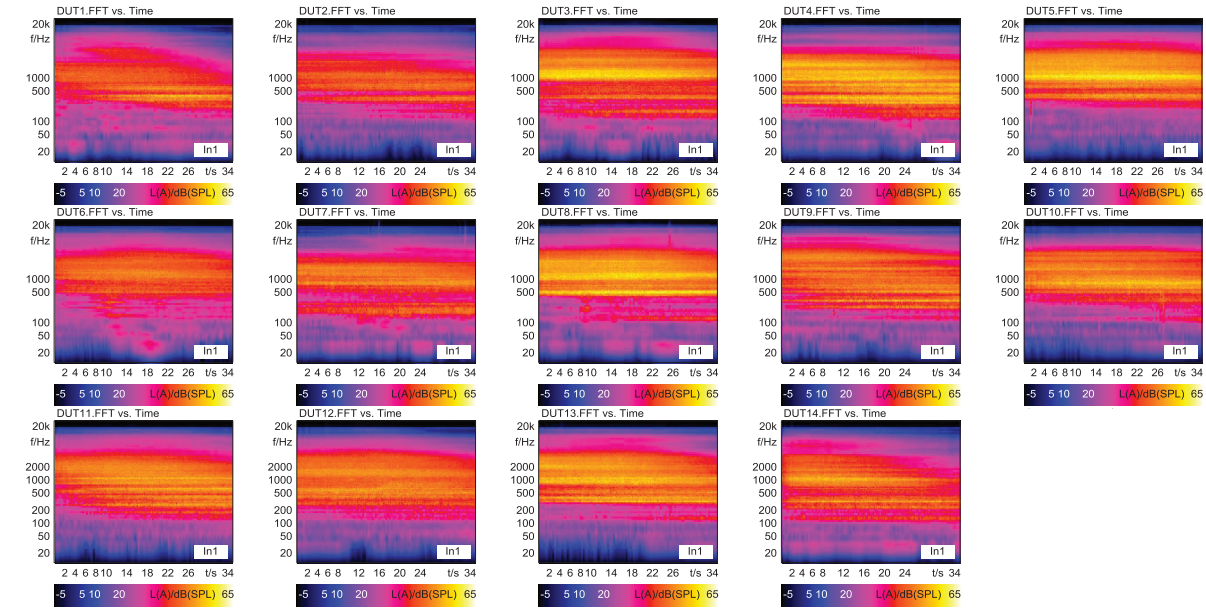

Figure 1 – Spectra of the noises from kettles boiling water. FFT vs. time (only left channel shown)

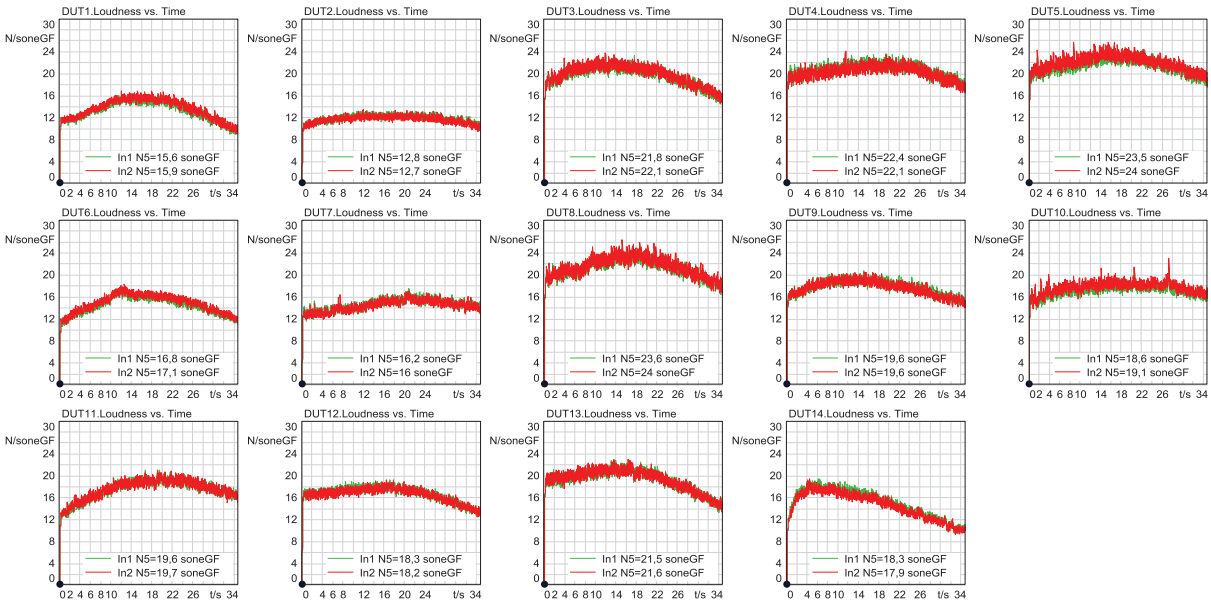

Figure 2 – Loudness of the noises from kettles boiling water. Loudness according to ISO 532-1 vs. time (left and right channel shown)

Moreover, the psychoacoustic sharpness, determined by means of the German standard DIN 45692 varied over 25% as can be seen in figure 3. These sharpness values are only related to the timbre, because the DIN 45692 does not apply an overall loudness dependency for the computation of sharpness. According to the standard, an increase of sharpness is usually associated with an increase in

annoyance [13]. The analysis specific prominence ratio illustrates some “tonal” patterns [14]. The different product noises exhibit different tonal magnitudes also varying in the respective frequency region.

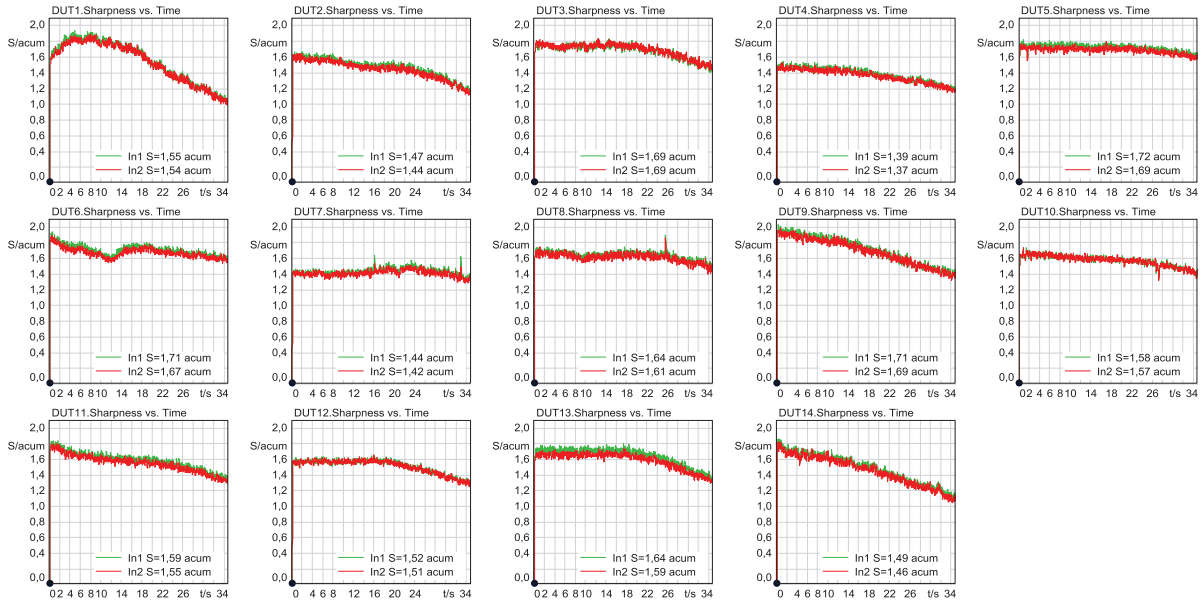

Figure 3 – Sharpness of the noises from kettles boiling water. Sharpness according to DIN 45692 vs. time (left and right channel shown)

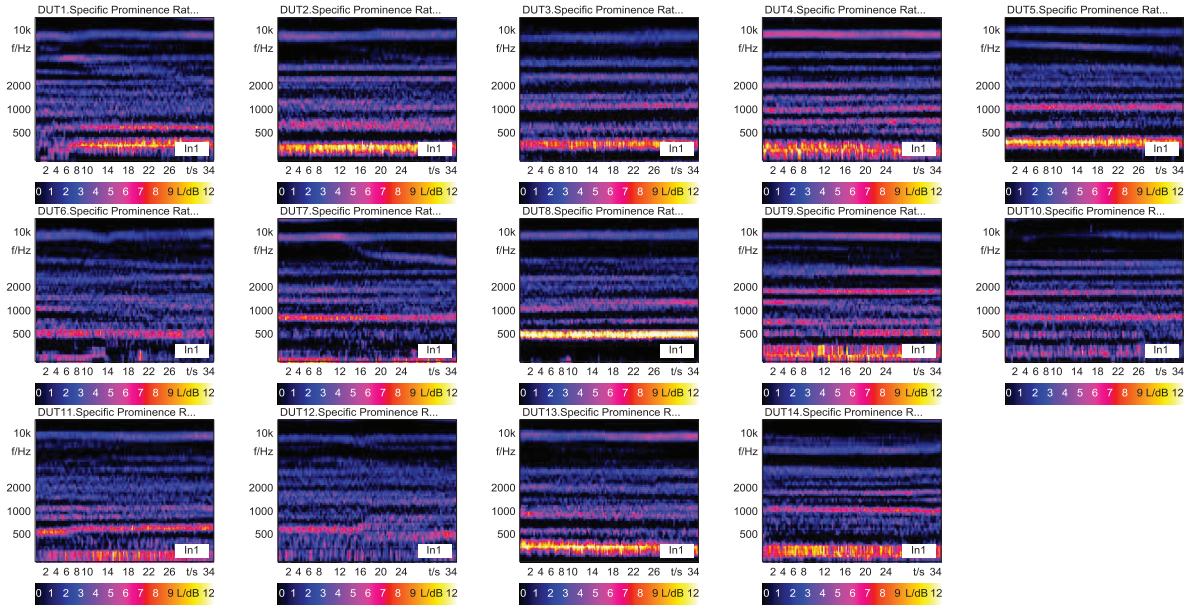

Figure 4 – Specific prominence ratio analysis of the noises from kettles boiling water. Spec. prominence ratio vs. time (only left channel shown)

Fourteen participants (9 male and 5 female) took part in the experiment and listened to kettle product sounds, which were binaurally measured with a calibrated head measurement system (HMS IV) under controlled conditions. The sounds were presented via a programmable equalizer (PEQ V) and headphones (HD 650) in a quiet listening room. The complete playback chain was calibrated and equalized.

In order to provide an associative context and to illustrate the design and size of the kettles, few sounds were played back first and at the same time pictures of the different products were shown. After this instruction providing a context for assessing kettle sounds, a short ‘training session’ took place, where participants familiarized with the evaluation tasks and provide first ratings, which were not considered for later analysis. In order to avoid sequence effects the anonymized sounds were played

back randomly. In agreement with ethical procedures, written consent was obtained from all of the participants.

In the first part of the experiment, the product sounds were judged by means of an 11-point unipolar category scale with respect to 'sound quality'. The category scale ranged from 'excellent' (10) to 'unbearable' (1). In the second part of the experiment, the participants were requested to provide assessments on multiple 9-point category scales with respect to attributes like 'powerful', 'acceptable', 'expensive', 'tonality' or 'sharpness'.

Several product noises were assessed an acceptable or fair sound quality, however a significant part of the kettles obtained only poor, very poor or even unbearable sound quality ratings (see fig. 5). As indicated by the non-overlapping confidence intervals, as expected the different product noises were statistically significant judged regarding sound quality. The same applies to other evaluation dimensions as displayed in figure 6.

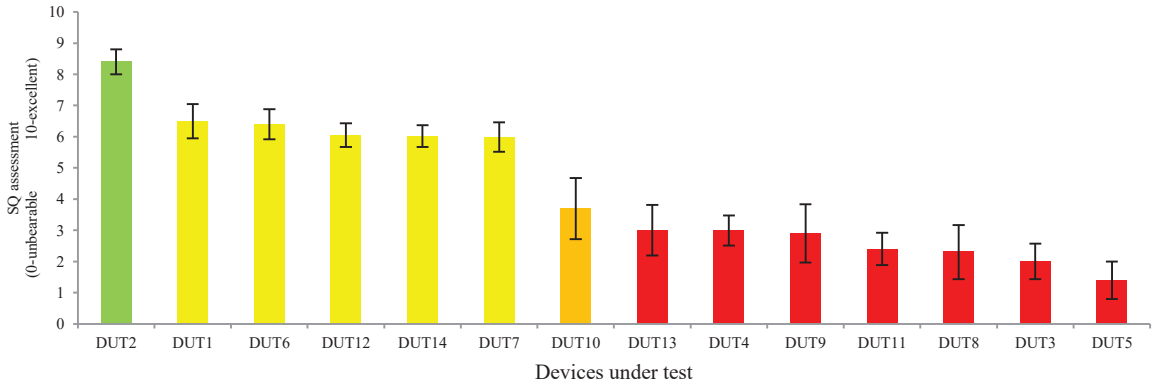

Figure 5 – Sound quality assessments (average, 95% confidence interval) of kettles emitting noise during boiling water (colors indicate quality classes: green: good, yellow: acceptable, orange: insufficient, red: poor)

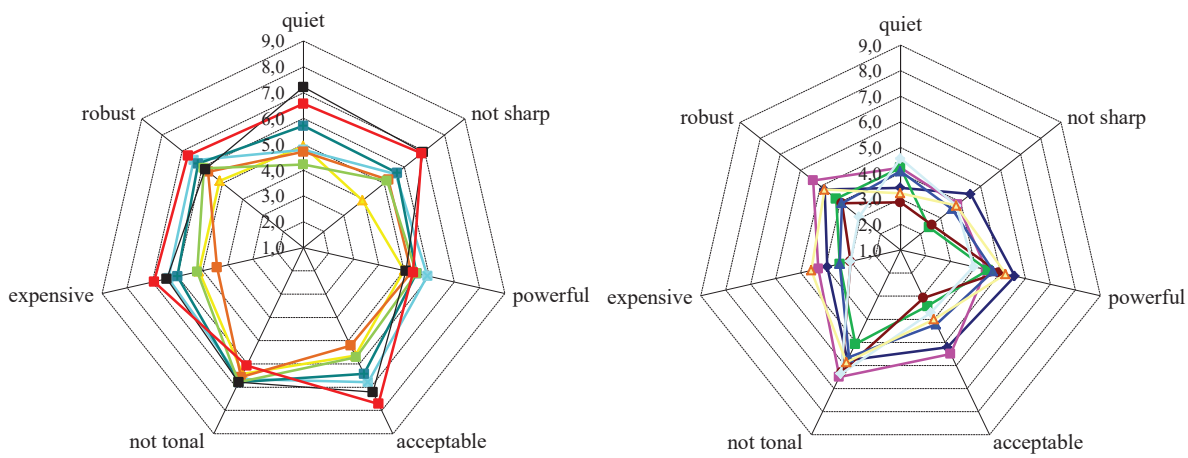

Figure 5 – Assessments (average) with respect to different evaluation criteria of kettles emitting noise during boiling water (left: good devices under tests, right: poor devices under test)

The case study illustrated that the acoustical and perceptual differences of consumer products on the market (like kettles) can be great. It has to be pointed out that the noise of kettles judged as poor did not universally possess more power reducing the time needed to boil the defined amount of water. By means of additional (psychoacoustic) parameters the sound character can be predicted. The term 'sound character' refers to the perception related to basic sensory attributes of auditory events without considering context effects (like influences like design, haptics, brand name, etc. on the assessment of

product sound). The detailed description of the sound character of a product noise might be more a more meaningful information related to perception than sound power level information only. However, it is challenging to develop a format which will be understandable for consumers and help them to make better informed purchasing choices.

5. CONCLUSIONS

It is evident that noise emissions are an issue in industry, in communities, in buildings, and during leisure activities [5]. In the context of products noise classification several national and international activities are evidence of the increasing social interest in environmentally-friendly products and technologies. So far, motivation to purchase environmentally-friendly products is only partially achieved by recent action and initiatives. In most cases, only some minimum requirements are defined, which are not stimulating more extensive sound design efforts. In most cases, only the emission is considered instead of the typical receiver/operator perspective (immission). Unfortunately, several eco-labels are not enforced and companies can voluntarily apply for. It is expected that it is even not necessary to enforce quiet product noises by law, in case a sound (quality) label indicating quiet recommendable products is acknowledged by consumers. In this case, it will be attractive for manufacturers to optimize sound quality and to highlight the respective acoustic comfort level of the product, which will influence purchase decisions.

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