Determination of Acoustic Parameters of Devices with Extensive Sound Sources

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Abstract

In most cases, while the sound power level of machines and devices is determined, it is assumed that tested objects are sound sources which can fit in a so-called reference box. Such an approach takes into account the influence of local sources. Although it does not allow their localization, separate noise measurement and evaluation. There are devices which have two or more relevant sound sources. In this paper this type of devices has been defined as devices with extensive sound sources (DESS). The tested device is a functional unit but its local sound sources are distant from each other. The results showed that determining the sound power level only is not sufficient for proper parameterization of noise emitted by DESS.

Keywords: devices with extensive sound sources (DESS), sound power level, biomedical devices

1. Introduction

The determination of acoustic parameters of devices with extensive sound sources (DESS), limited only to the sound power level (L_{WA}), may be inadequate to this kind of devices. Under the term of DESS we mean the technical object that has the possibility of various spatial arrangement of its components. In addition, these components are together a functional unit and they can not work separately. In many cases, each of the device's components could be treated as a separate sound source which usually emits sound of a different nature.

Due to the specific design of this kind of devices it is worth mentioning that:

- it is impossible to clearly define what type of measuring surface should be used in the procedure of determination of L_{WA} (see Figure 1),
- description of the acoustic features of a device basing only on one parameter, for example L_{WA}, will not fully characterize the influence of the device on the environment and it will not provide sufficient information needed for creation of acoustic maps (by numerical simulations) e.g. in the planned installation place.

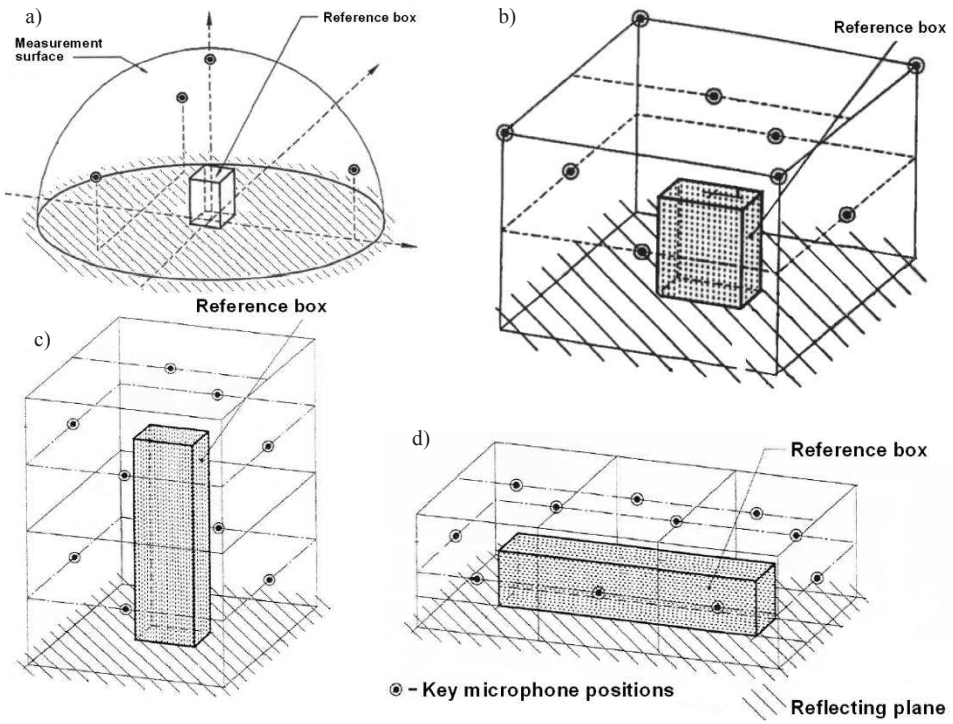

Figure 1. Examples of microphone positions and measurement surface, while determination of sound power level according to ISO 3746 : 2011; a) hemisphere, b) parallelepiped surface for a small machine, c) parallelepiped surface for a tall machine, d) parallelepiped surface for a long machine [1]

2. Research methodology

Vacuum cleaners, sets of pneumatic devices or biomedical devices such as smoke evacuators can be examples of DESS. A more accurate parameterization of noise emitted by the last mentioned is necessary because of high requirements concerning the acoustic climate in areas such as operating rooms. Such devices are used to remove smoke and particles carried by it (bacteria, viruses) created during operation or electrosurgical procedures. The system typically includes a suction pump unit with air filtration system, a working tool (electrocoagulator or electroscalpel) with an air sucking tip and a flexible hose connecting the components. The pump and the working tool are usually placed in different locations within the operating room, in addition each of the components emit sound of a different character (Figure 2).

It is worth noting that due to the surgeon's necessity to maintain long-term concentration during procedures or surgeries, it is important to limit noise in the operational environment. Following recommendations from PN-N-01307: 1994 [2], relating to the performance of precision work it can be assumed that the equivalent

sound pressure level (L_{Aeq}) in this case should not exceed 65 dB. It is also worth noting that the recommendations for noise in the operating room in the United States are more restrictive. According to ANSI / ASA S12.2-2008 [3] L_{Aeq} should not exceed 44 dB. It should be emphasized that this is only a recommendation not a requirement. The results of the research presented by Kaczmarska, Łuczak and Sobolewski [4] have shown that the presence of low-frequency noise (even L_{Aeq} = 52 dB and L_{Geq} = 62 dB) while performing precision work can cause fatigue and somnolence.

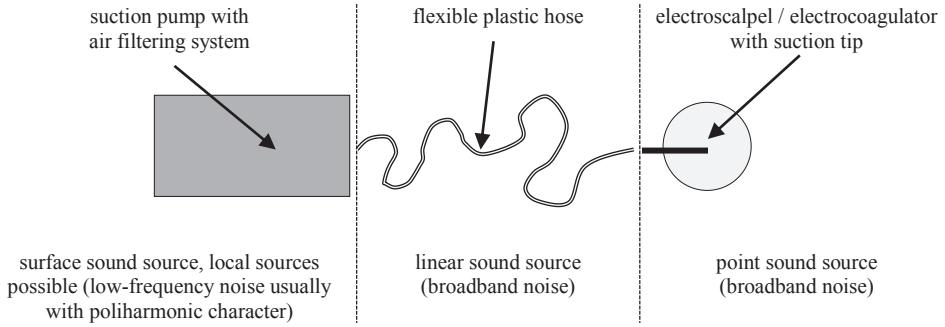

Figure 2. Components of smoke evacuator an example of DESS and specifics of noise emitted by them

For the measurement an equipment set consisting of Roga R50 microphone (ICP), data acquisition module VibDAQ 4+ and DSP structure elaborated in DASYLab® was used. An influence of environmental conditions in laboratory was taken into account according to ISO 3746: 2011 (A = 54,56 m^3/s, K_{1A} = 0,03 dB, K_{2A} = 2,13 dB).

3. Research results

The research included the determination and comparison of the L_{WA} (Figure 3) of tested device treated as:

- compact arrangement (all components were placed close to each other in a reference box in accordance to ISO 3746: 2011),
- extensive sound source; testing was carried with various configurations of the spatial arrangement of device's components, as it occurs in the real conditions in the operating room.

Figure 4 contains sound pressure levels (L_p) in octave bands. The values correspond to the levels on the measurement surface of 1m^2. The following conclusions has been drawn on the basis of comparison of the test results.

- The noise emitted by the suction pump has a low-frequency character (polyharmonic) associated with rotational frequency (and its superharmonics) of the electric motor (Figure 6). The dominant amplitude components of the noise are included in frequency range that does not exceed 500 Hz.
- The noise emitted by the suction tip is a broadband noise covering the frequency range from 4 kHz up to 16 kHz.

- An important data that should be taken into account in the parameterization of noise emitted by the device is the radial spectra of the sound emitted mainly by the suction pump unit (Figure 5).

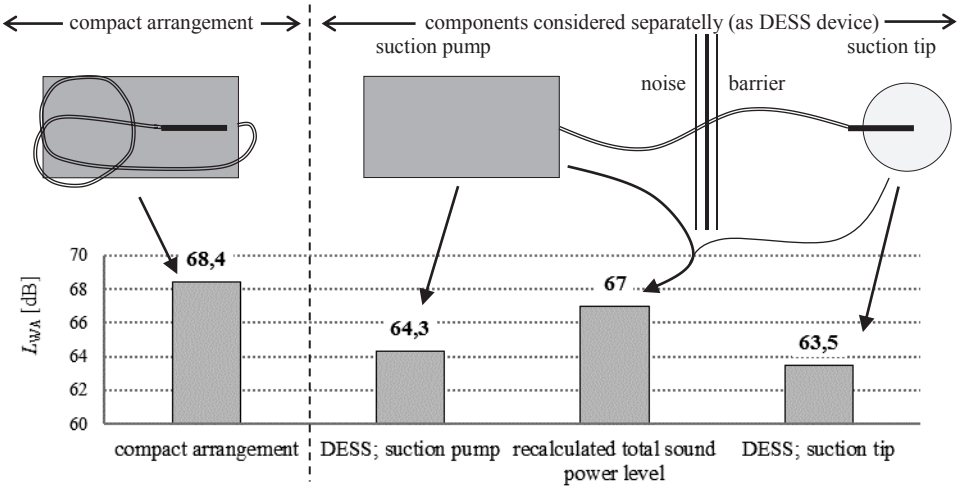

Figure 3. Spatial arrangement of components during testing and theirs L_{WA}

Taking under consideration that components emit noise of different character, reduction of the level of emitted noise require an individual approach to each source. Another problem is the determination of L_{WA} of device that is characterized by various regime of work. Testing should include all operating modes that can occur during surgery or chirurgical procedures. This is connected with the necessity of using a relatively long averaging time and/or determining the duration of each operating mode such as suction, choking airflow, idle.

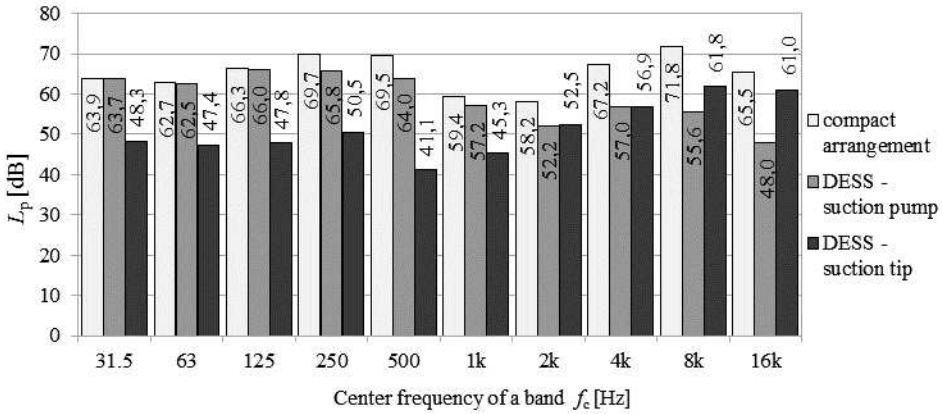

Figure 4. Noise emitted by tested device treated as compact arrangement and as DESS (average acoustic pressure level correspondent to measurement surface of 1m^2)

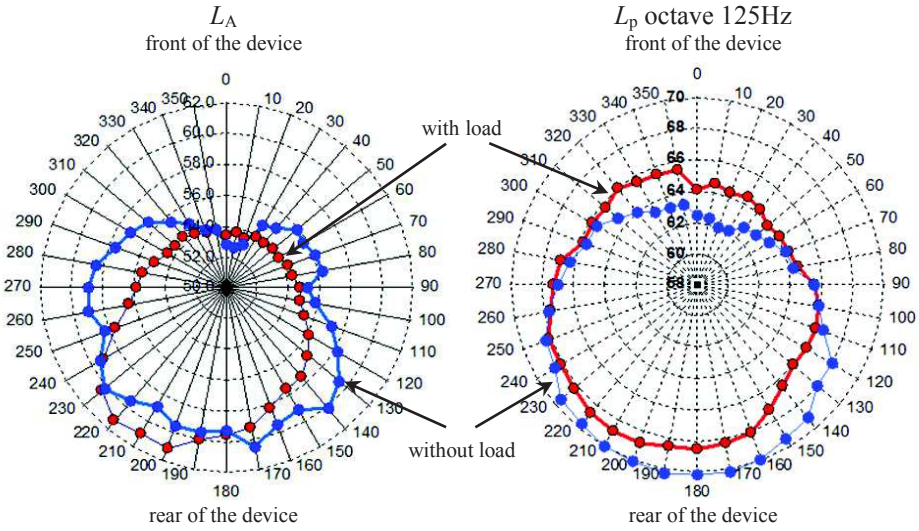

Figure 5. Radial spectra of noise emitted by suction pump; without load (hose not connected), with load (hose and tool connected)

Sound power level of the tested device (compact arrangement case) determined in accordance to ISO 3746 : 2011 is equal to 68.4 dB. In the case of the machine's components tested separately L_{WA} of suction pump equals 64.3 dB and L_{WA} of suction tip equals 63.5 dB. While the total sound power level of both components after recalculation would be 67 dB. The difference between the device's L_{WA} (compact arrangement case) and the recalculated total L_{WA} (separated sound sources case) probably results from that a part of acoustic energy emitted by the hose is not included. In comparison to other potential sources of noise in the operating room [5-8] it can be stated that the noise emitted by the tested device can have a significant influence on the acoustic climate in the operating room.

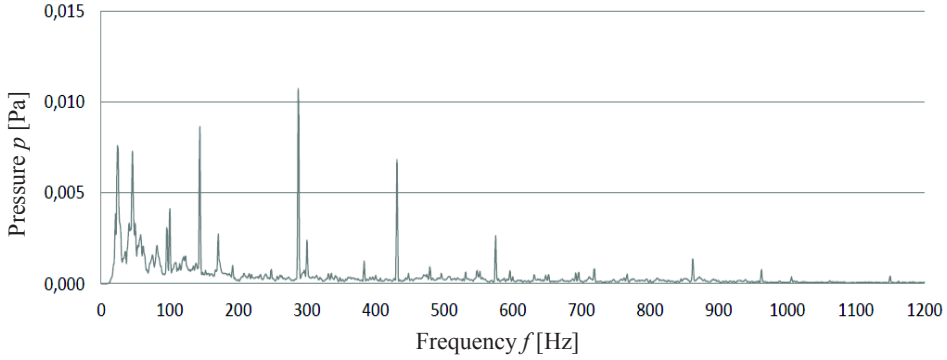

Figure 6. Narrowband spectrum of acoustic pressure measured 1m above the suction pump unit

4. Conclusions

- Treating components as autonomous but simultaneously influencing sound sources allows obtaining data helpful at the prototype research stage and minimize the noise emitted by the each device's component. Finally, this approach gives the possibility of noise reduction in the area of surgeon's operation. As well as, it allows meeting the noise requirements in areas of such a kind. It can be done by e.g. the appropriate placement of the device's components within the operating room.
- An extended data set should include among others:
  - L_{WA} (total and individual for device's components, which can be treated as local noise source),
  - radial spectra of noise emitted by device's components,
  - typical arrangement of components and operator in installation place (e.g. operating room),
  - duration of typical tasks performed using the device.

  That parameters may allow the creation of reliable acoustic maps of operating rooms at the design stage using simulation software.
- The results of the carried out research may be helpful in developing the methodology of L_{WA} determination for DESS.

Acknowledgement

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