Final Publishable JRP Summary for SIB56 SoundPWR Realisation, dissemination and application of the unit watt in airborne sound

Overview

Sound power is the rate at which sound energy from a source or object is emitted per unit time, and is measured in watts (W), the SI unit of power. Until now, the sound power was considered to be independent of the environment and of the distance from the source, and could therefore be used to describe the acoustic output of both domestic and industrial technical products. But in practice, sound power can only be determined from other measurements such as sound pressure at a certain position, which is measured in pascals (Pa). There are many different ways to determine the sound power of a particular source, but results can vary widely. Even worse, uncertainties can only be compared if the measurement procedures were the same, and not for an individual measurement result. This makes it difficult to compare the measured sound power levels for regulatory compliance with noise protection legislation.

Within this project, primary sound power sources and measurement techniques were developed to reduce measurement uncertainties. Measurements for low frequency sounds were also carried out, for which there is little guidance at present. It was found that the assumption that the sound power is independent of surroundings is not the case for low frequencies, which is a completely new concept for airborne sound. Improvements to sound power measurements will be beneficial in both industrial and domestic environments.

Need for the project

Measuring the sound emitted from an object is required for consumer information on domestic and industrial products. It enables potential purchasers of machines to compare products of the same type, and take the sound emissions into consideration. As a result, manufacturers should be able to demonstrate that their product complies with European legislation on noise emissions and fewer people should be affected by hearing impairment. The three primary directives of interest are the Machinery Directive 2006/42/EC, the Outdoor Noise Directive 2000/14/EC and the Eco Design of Energy Related Products Directive 2009/125/EC; which cover noise emission. Manufacturers are not allowed to market their products in Europe if they do not meet these noise emission requirements. Therefore, manufacturers as well as notified bodies which carry out or supervise the conformity assessment procedures require traceable results with small uncertainties.

The measurement of sound power is currently based on the measurement of field quantities like sound pressure, which is measured under specified conditions. This approach and the lack of a reference procedure are the basic reasons why the currently 10 different standardised procedures give different results and why uncertainties easily reach several decibels (dB).

A further need arises from the replacement of centralised large fossil fuel power stations by decentralised energy conversion devices like heat pumps or small combined heat and power plants. These sources emit low frequency sounds (< 100 Hz), which are not covered by measurement guidelines at present.

To address these needs, this project aimed to develop primary sound power sources, measure the acoustic field generated by these sources, develop calibration techniques and make practical recommendations for the use of these standards for measuring sound power.

EMRP
European Metrology Research Programme
Programme of EURAMET

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Scientific and technical objectives

The project addresses the following scientific and technical objectives:

1. To develop a reference sound power source with a calculable sound power based on measurements of vibration velocity, dimension and the environmental properties of air with an uncertainty of 0.5 dB.
2. To measure the output of this reference sound power source with sound intensity instruments calibrated in accordance with IEC 61043 and explain any deviations from the predicted behaviour. This is necessary to distinguish the phase shift between the sound velocity and the sound pressure on the enveloping surface.
3. To develop methods for the calibration of non-calculable sound sources by comparison with the reference sound power source. One major focus will be on broadband sources, which generate sound aerodynamically. Another aspect addressed is the development of a new concept for tonal sound power sources.
4. To develop qualification procedures for measurement setups, analyse uncertainties of sound power determinations in practice and develop a substitution method using sound intensity for machinery noise.

Results

To develop a reference sound power source with a calculable sound power based on measurements of vibration velocity, dimension and the environmental properties of air with an uncertainty of 0.5 dB.

Primary reference sound power sources consisting of a vibrating plane solid body in a rigid surrounding have been developed by different partner institutes. All four institutions developed individual technical solutions and successfully tested the reference sound source devices. The main topics to be addressed turned out to be the friction between the moving part and the supporting structure and the reaction forces. Both processes lead to vibrations in the supporting structure which influences the radiated sound power. These primary reference sound power sources are the first in the world.

To perform measurements of the acoustic field, dedicated scanning apparatuses were developed which can measure sound field quantities, like sound pressure or sound intensity. These measurements were performed to understand the sound field generated by the reference sound power sources.

Even though all four reference sound power sources met the major design goals with respect to linearity, stability and directivity, they were further optimised. The main parameters to be optimised were the small vibrational excitation of the surrounding structure, a sufficient airtightness and a sufficient sound power emission. The uncertainty goal of 0.5 dB was met by the individual reference sound power sources in different frequency ranges and therefore the objective was achieved.

To measure the output of the reference sound power sources *with sound intensity instruments calibrated in accordance with IEC 61043 and explain any deviations from the predicted behaviour.*

The sound intensity levels emitted by the primary reference sound power sources (from objective 1) into a hemianechoic environment were measured using a newly developed scanning apparatus. A hemianechoic environment has the source on a reflecting plane surrounded by an anechoic chamber, anechoic means that sound waves are absorbed. From the intensity levels measured with the new scanning apparatus, sound power levels were calculated and compared to the sound power levels calculated from the vibration velocity and to the sound power levels determined by sound pressure measurements.

In the frequency range between 125 Hz and 1.6 kHz, all sound power levels agreed within typically 0.5 dB. At frequencies below 125 Hz, a systematic behaviour was observed which could only be explained by different sound power emissions of the source in different environments. This is a major result since it changes the current philosophy that the sound power output of an airborne source is independent from the environment. Therefore, at low frequencies (below about 100 Hz), a field dependent sound power output of sound sources should be taken into consideration in the future research.

To develop methods for the calibration of non-calculable sound sources by comparison with the reference sound power source.

Non-calculable sound sources in the sense of this project are sound sources where the sound power emission cannot be calculated from the source properties directly. Nevertheless, these sources can be used as transfer standards for the dissemination of the unit watt. Within the project it was investigated whether aerodynamic reference sound sources can be used as transfer standards. Aerodynamic sound sources are fan-like devices which produce sound by the interaction between the moving fan blades and the air. Their advantage is that they are easily moved. The influence of temperature and rotational speed on the sound power output of such sources was measured and empirical corrections to account for these effects were derived. The directivity of aerodynamic reference sound sources was also measured at different partners. The results from the partners agreed very well and demonstrated a rotational symmetry in the horizontal direction whereas the influence of the reflecting ground plane lead to considerable directivity in the vertical direction. This information is necessary for the use of the sources as transfer standards.

The possibility of developing tonal sound power sources was also investigated. It was discovered that aerodynamic sources may be used for this purpose if the frequency analysis is performed in narrow bands. Other concepts for tonal sources like measuring the volume flow of the source with a two microphone setup or using commercial speakers were investigated but require further development.

In conclusion, methods for calibrating non-calculable sound sources were developed by the project and empirical corrections were derived to predict the sound power level of these sources under conditions different to those experienced during calibrations.

Qualification procedures and applications for machinery noise

This part of the project focused on using the project's newly developed methods for the determination of sound power using sound sources. The key feature is the traceability to the SI unit of power – the watt – which is ensured by the use of transfer sound sources. These are mobile devices with a sound power level which is determined by comparison to the primary standard. The transfer standard is then used to insert a known sound power into a measurement setup which consists of the acoustic environment, sound measuring devices and a dedicated choice of spatial positions for the measurement of sound pressure or sound intensity levels. The determined sound power level is then compared to the sound power level injected by the transfer standard. At partners SP and PTB, these investigations were performed using realistic sound sources and a large range of acoustic surroundings. The results showed that the ratio between the free-field sound power and the sound pressure measured on an enveloping surface or in the diffuse field is constant for a particular setup whichever source is used. This is a very important result since it demonstrates the general applicability of the traceability concept in sound power measurement, especially at frequencies below 100 Hz where current methods fail.

Furthermore, a large number of sound power levels from different sound sources were measured in a wide range of acoustic fields. Various enveloping surfaces were applied using sound pressure or sound intensity. Results show that the sound power levels determined from sound intensity were on average 1 dB below the sound pressure based sound power levels.

These results were very promising since they indicated that the proposed concept of traceability for sound power is capable of addressing the current needs for sound power measurements.

Actual and potential impact

Dissemination

Altogether 30 presentations on the project were given, 14 of them at leading international conferences. 23 proceedings have been published and two peer-reviewed papers are in preparation, one on the concept of characterising sound sources by a sound power level including the question of traceability and one on the use of aerodynamic reference sound sources as transfer standards for the quantity sound power. Two more peer-reviewed papers are planned about the primary realisation of the unit watt and about the numerical models describing the primary sound source.

A project workshop was held as a structured session at INTER-NOISE 2016 a leading international conference to disseminate the results to the stakeholders from industry, authorities and testing institutes. The standardisation committees ISO/TC 43 Acoustics SC 1 (Noise) and ISO/TC 188/ WG 28 (Measurement of airborne noise) were also at that conference and members were able to take part.

Impact on standards

The project has contributed presentations to the committees ISO/TC 43/SC 1 and ISO/TC 188/WG 28, AFNOR S30B (Acoustique, sources fixes, mesurage et déclaration du bruit) and NA 001-01-04 AA "Geräuschemission von Maschinen und Anlagen, Messung, Minderung, Datensammlung" (German standardisation committee on sound emission of machinery).

The development of a primary sound power standard and to derive secondary (transfer) standards has been discussed in the standardisation community, particularly with ISO/TC 43 SC 2, where power based methods for source characterisation have been implemented for structure-borne sound sources recently.

Future work also includes a new international standard for the primary realisation of the unit watt and proposed changes to the existing ISO 6926 on the calibration of reference sound sources, both of which will include results from this project. Furthermore, the results of the project will be considered in future revisions of the ISO 3740 series of standards covering the determination of sound power levels of noise sources.

Actual impact

A core group of European NMIs was established which are willing to develop a metrological system for the quantity sound power. A supplementary comparison within TC-AUV (the Technical Committee for Acoustics, Ultrasound and Vibration in EURAMET) is the next step. This comparison within TCAUV will be based on the primary sound power sources and calibration techniques developed in the project.

Potential impact

The project has led to a new level of understanding about sound power within the acoustic community. Previously, sound power was considered as a unique quantity describing the ability of a source to emit sound, but it is now clear that the sound power emitted by a source depends on the surrounding sound field. The assumption that the sound field does not influence the emitted sound power holds for broadband sources above 100 Hz. But for tonal frequencies below 100 Hz, this assumption is not true. This is a complete change in philosophy in sound power metrology and means that sound power levels at frequencies below 100 Hz can now be accurately determined in the future. This is particularly important as it demonstrates that the discrepancies currently observed between different measurement methods are not caused by systematic deviations between the methods, but by changes in the measured quantity itself.

In a wider perspective, the project results will be the starting point for a change of philosophy for the experimental determination of those quantities in applied acoustics which are directly linked to sound power. These include sound insulation, sound absorption or impact noise levels This will have major consequences for sound emission and building acoustics as major quantities in building acoustics are sound powers or sound power ratios.

List of publications

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