Dynamic Pressure Transducer Calibration – Traceable?

Thomas Platte*, Martin Iwanczik, and Michael Mende

SPEKTRA GmbH Dresden, 01189 Dresden, Germany

Abstract. Pressure transducers are mainly used for dynamic measurements but calibrated by means of static calibration methods. The reason is that neither a standardized method for a traceable dynamic secondary calibration of pressure transducers nor a primary dynamic calibration method for reference pressure transducers is available. The only exceptions are the calibration methods for pressure field microphones which can also be regarded as dynamic air pressure transducers for the low pressure range. This paper compares results from measurements with two different pressure exciters that have their origin in acoustics and were used for calibration of two types of pressure transducers in the frequency range 31.5 Hz to about 1 kHz at pressure amplitudes up to some 100 Pa. In both cases, a traceably calibrated pressure microphone was used as reference sensor that should provide a traceability of the pressure transducer calibration. The paper discusses the pros and cons of both exciters and if this can be considered as a traceable calibration method.

1 Method

A standardized and traceable secondary dynamic calibration method for pressure transducers besides microphones is not available yet. One important reason for the missing traceability is the lack of dynamically calibrated reference transducers. Furthermore, besides the calibration methods for microphones a general dynamic primary calibration method for reference pressure transducers is missing. Thus when the authors were asked to characterize two pressure transducers regarding their frequency response, it was decided to use acoustic methods and references in order to provide at least a certain traceability of the measurement results.

As a reference transducer a Brüel & Kjaer 4192 pressure microphone with a preamplifier MV 203 from Microtech Gefell was chosen. This reference measurement chain was calibrated in the DAkkS accredited SPEKTRA calibration laboratory by a comparison calibration with a traceable calibrated reference microphone.

Fig. 1. Acoustic coupler SQ-4.2 with reference microphone

Two different pressure exciters were chosen for the measurements. Both allow to generate sinusoidal pressure amplitudes over a certain frequency range but with quite different maximum amplitudes. The SPEKTRA acoustic coupler SQ-4.2 is basically used for the calibration of microphones. It is based on a micro-loudspeaker as pressure exciter that ‘injects’ the pressure into a small volume in the middle of the coupler device. The device has two ports where the reference microphone and the device under test can be introduced and positioned precisely (see Fig. 1). For microphone calibrations this acoustic coupler can be used over the wide frequency range 31.5 Hz up to 16 kHz but in general with pressure amplitudes below 1 Pa (94 dB). However, between 200 Hz and 2 kHz a constant amplitude of 30 Pa (123 dB) is available. Only in the range 500 Hz to 600 Hz a significantly higher pressure amplitude up to 240 Pa (141 dB) can be provided.

Fig. 2. Pressure exciter DPE-01 based on a Vibration exciter

* Corresponding author: Thomas.Platte@spektra-dresden.com

The SPEKTRA DPE-01 exciter is based on a modified calibration shaker where the shaker table is as well sealed as a lid mounted above the shaker table. Thus between shaker table and lid a small compressible air volume will be entrapped and the pressure will vary with the movement of the shaker table. The lid has two ports each for a reference transducer and a device under test transducer (see Fig. 2).

This exciter allows pressure amplitudes up to 16 kPa (178 dB) and can cover the wide frequency range 10 Hz to 2 kHz. Nevertheless, in order to stay in a pressure range comparable to the SQ-4.2 range, the pressure in the measurements was limited to only 240 Pa.

Thus the measurement method that was used for the characterization of the devices under Test (DUT) was similar to a secondary microphone calibration according to DIN EN 61094-5. However, the standard is specified for the calibration of laboratory microphones and the DUT in these measurements neither had the shape nor the working principle of a laboratory microphone. Furthermore more the exciter DPE-01 is not comparable to the equipment that is described in the standard. But evaluating the results carefully and using a traceable calibrated microphone as reference transducer, at least a certain traceability of the results can be provided.

2 Device Under Test

Two very different DUT were investigated for this paper. DUT A is a piezoelectric pressure transducer where the pressure acts directly on the piezo-element and generates a charge output with a nominal sensitivity of 0,870 pC/kPa. The nominal measurement range is up to 690 kPa. An external charge-amplifier, belonging to this transducer, was used to transform the charge output into a voltage signal. The voltage output of this measurement chain was recorded with an A/D-converter and the sensitivity was determined by comparison to the output of the calibrated microphone.

DUT B was a piezo-resistive transducer which is based on a measurement bridge and had a measurement range up to 1000 kPa. A signal conditioner that belongs to the transducer was used to supply the measurement bridge with a defined excitation voltage and to amplify the output signal. The output voltage of this measurement chain was fed into the A/D-converter and thus again the whole measurement chain was characterized by comparison to the output signal of the reference microphone.

3 Measurement Results

Besides the mechanical adaption of the transducers, the major challenge for these measurement was the low sensitivity of both measurement chains. The transducers were designed for the measurement of pressures up to 4000 times higher than the pressure that could be provided with the DPE-01 exciter and even more than 30 000 times higher than the pressure that could be provided with the SQ-02 exciter. In fact the noise floor

of the measurement chains had a big impact on the results.

Fig. 3. DUT A measured with the SQ-4.2 acoustic coupler with a pressure amplitude of 30 Pa peak

As an example DUT A was calibrated over a frequency range from 100 Hz to 2 kHz. The amplitude was kept at 30 Pa since this was the maximum amplitude that could be provided constantly over the whole frequency range. Although a relatively flat frequency response was expected from the data sheet data, quite big deviations of the sensitivity of about 4% around 650 Hz were observed. However, the SQ-02 has a resonance around 650 Hz that could be used to repeat the measurement with a significantly higher amplitude around this resonance frequency. The results in Fig. 4 show the much flatter expected frequency response. At an amplitude of 30 Pa the signal was too close to the noise floor for stable measurement results while at 240 Pa the signal to noise ratio improved sufficiently for a stable measurement.

Fig. 4. DUT A measured with the with the SQ-4.2 acoustic coupler at a higher amplitude.

The results could be verified with measurements using the DPE-01 exciter. With this exciter it was possible to keep the amplitude over a wide frequency range constantly at 240 Pa and thus the expected flat frequency response over the whole frequency range up to nearly 2 kHz could be observed (see Fig. 4). Furthermore the comparison of the results that were obtained at 650 Hz and 240 Pa on both exciters showed a deviation of just 0.31 %. These results made us confident that the method is reasonable as long as the amplitude that can be generated with the exciter is sufficient for the particular DUT.

Fig. 5. DUT A calibrated on Exciter DPE-01

However, the low sensitivity of DUT B showed the limits of this method using these pressure exciters. It was not possible to get any calibration results from DUT at an amplitude of 30 Pa because the signal was disappearing in the noise floor. Thus, the only measurement results could be achieved at an amplitude of 240 Pa on the DPE-01 and at 540 Hz at the resonance point of the SQ-4.2. The resonance frequency was lower than in the measurements with DUT A because DUT B added a bigger volume in front of the membrane to the pressure exciter volume.

The comparison of the results determined with both exciters at 540 Hz and 240 Pa showed again a low deviation of just 0.89 %. But the frequency response measured with the DPE-01 was not flat as expected but was increasing significantly with the frequency (see Fig. 6.). The reason for this behaviour of DUT B is not yet clear and further investigations together with the manufacturer are necessary to clarify this result.

Fig. 6. Frequency response of DUT B calibrated by means of exciter DPE-01.

4 Summary and Outlook

Acoustic couplers or pistonphone-like pressure generators together with a pressure reference microphone offer the chance of a traceable dynamic calibration of pressure transducers. However, the pressure amplitude is far too low for most DUT. Thus, hydraulic dynamic pressure generators are necessary for these DUT that offer higher amplitude ranges.

Nevertheless, currently there is no absolute dynamic calibration method for an appropriate calibration of

reference pressure transducers available. Some national metrology institutes as well as SPEKTRA are working on an absolute pressure calibration method. A promising candidate that is investigated at PTB and SPEKTRA is refracto-vibrometry using a laser vibrometer. It measures changes of optical wavelength due to density changes in the hydraulic fluid. For this purpose the beam of a laser vibrometer is crossing the hydraulic fluid and is reflected back into the vibrometer. Density changes of the fluid due to a pressure change will cause a velocity signal output of the vibrometer. Because there is a physical relationship between the density change of the fluid and the optical wavelength, the pressure change can be calculated from the vibrometer signal.

Fig. 7. Refracto-Vibrometry by means of a Laser Vibrometer

Alternatively SPEKTRA is working on a simpler method that is again using a pistonphone-like pressure exciter that allows an overlay of a dynamic pressure change over a static pre-pressure in the hydraulic fluid. Here the dynamics of the piston will be measured directly in order to obtain the pressure change (see Fig. 8). A similar approach was published by the national metrology institute of Finland, MIKES in the European in EMRP project.

Fig. 8 Working principle of a new pressure exciter

First results are also quite promising and will be published later in the year.