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TESTING THE HEAVY SOFT IMPACT SOURCE AT PTB: SETUP, CALIBRATION AND UNCERTAINTY

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ABSTRACT

The heavy soft impact source is a rubber ball with a mass of 2.5 kg which is used as a standard device to excite floor constructions. This device is dropped from a height of 1 m in the source room, and the maximum sound pressure level is measured inside the receiving room either in one-third octave bands from 50 Hz to 630 Hz or in octave bands between 63 Hz and 500 Hz. The A-weighted sum of these values together with some corrections for reverberation time and room volume is finally used to assess the acoustic insulation against impact noise.

From a metrological point of view, the rubber ball is an absolute standard. Its properties are defined mainly by the force exerted on a hard receiver in octave bands between 31.5 Hz and 500 Hz. At PTB, a new facility for testing rubber balls was set up to measure this force. In the contribution, the setup is described, the calibration of the force sensor by a calibrated impact hammer is explained and a first estimate of the measurement uncertainty is derived.

Keywords: *heavy soft impact source, ball impact, dynamic force measurement, in-situ calibration, uncertainty estimation.*

1. INTRODUCTION

There are two standards, [1] and [2], which describe the measurement of sound insulation in buildings or laboratories. In both standards there are proposals for at least two impact sources and the characteristics or requirements of those. One is the tapping machine, which is the more commonly used device for measurements according to the named standards in Europe. However, the heavy soft impact source is gaining attention more and more. It is discussed whether this source can simulate certain everyday situations, such as jumping children and dropping objects, better than the tapping machine.

At PTB, a test setup for tapping machines already exists, but due to increasing interest a test setup for the heavy soft impact source is also required.

2. MEASUREMENT SETUP

The measurement setup at PTB consists of a force sensor mounted on a heavy base mass, and both are placed on a concrete floor (Figure 1). The force sensor is attached to the base mass via an adapter plate, and an aluminium impact plate measuring 100 mm in diameter is mounted at the top using a second adaptor.

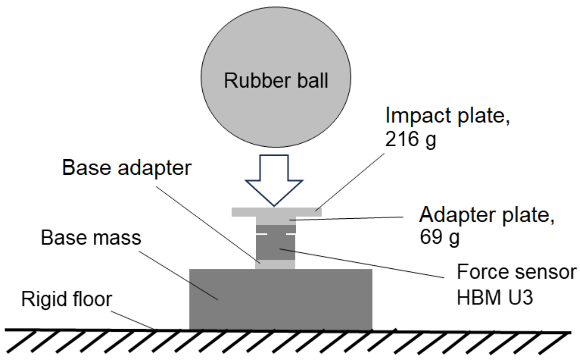

Figure 1. Measurement setup for impact forces.

Thanks to a wall-mounted spacer (not shown in Figure 1), the ball to be tested can be dropped onto the centre of the impact plate from a height of 1 m with good repeatability.

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The strain gauge force sensor is connected to a bridge amplifier before the input signal is fed into a measurement unit for further analysis.

3. CALIBRATION OF THE SETUP

The force measurement setup was calibrated in-situ by applying several hammer strokes (approx. 25) with a traceably calibrated impact hammer of a head mass of 500 g. The method of the in-situ dynamic force calibration by means of an impact hammer (see Figure 2) is described in [3].

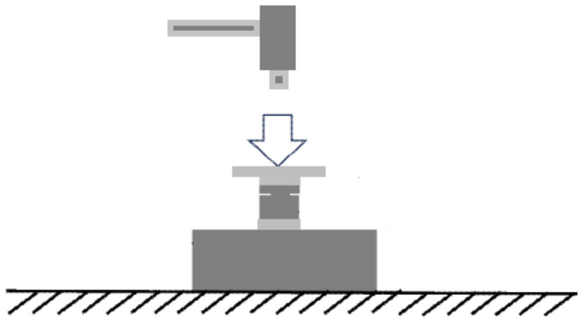

Figure 2. Calibration of the measurement setup with an impact hammer.

The measurements were made with three hammer tips of different stiffness (soft, medium, hard), and the force spectra for the hammer and force sensor were analyzed in octave bands from 31.5 Hz to 500 Hz. The calibrated sensitivity of the considered hammer tip configuration was also determined in the frequency domain. Therefore, the respective sensitivity S_{cal} of the force measurement setup could be calculated.

In Figure 3, the deviation ΔL_S from the nominal sensitivity S_{nom} is visualized. The average of the frequency-dependent sensitivity was used to scale the measured time signals. However, it became clear that it makes a difference which hammer tip is used.

$$\Delta L_{\mathrm{S}} = 20\,\mathrm{lg}\frac{S_{\mathrm{cal}}}{S_{\mathrm{nom}}}\ \mathrm{dB} \quad (1)$$

For better estimation, the difference between the individual values and the nominal sensitivity was determined in dB according to Equation (1). The nominal sensitivity for the measuring chain of force sensor and bridge amplifier is 0.1 mV/N. For the octave bands up to 250 Hz, the sensitivity differences between different hammer tips are below ± 0.2 dB and show a smooth shape. This changes at 250 Hz, as the differences with all the tips become larger. Hirakawa et al. made a similar discovery in their work [4] (Page 5, Figure 7). They were using only a hard hammer tip to calibrate their setup, but the difference is also getting larger with increasing frequencies. At 500 Hz the difference is about 1 dB in [4]. It is assumed that the impulse generated by the hammer no longer produces a force that is sufficiently large compared to the noise at these frequencies. This applies more to softer tips than to harder ones.

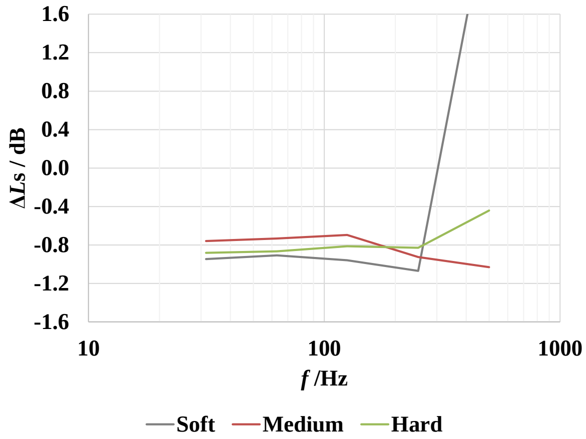

Figure 3. Calibrated sensor sensitivity for different hammer tips in octave bands.

$$u_{\mathrm{cal}} = 20\,\mathrm{lg}\left(1 + \frac{\sigma}{S_{\mathrm{cal}}}\right)\ \mathrm{dB} \quad (2)$$

Finally, the uncertainty for the sensitivity of the force measurement setup was estimated according to formula (2) from the experimental standard deviation σ of repeated hammer impacts (Figure 4), which is 0.2 dB at the lower octave bands and increases towards higher octave bands for the medium and soft hammer tips. The variations in sensitivity due to different hammer tips shown in Figure 3 are well covered by this estimated uncertainty.

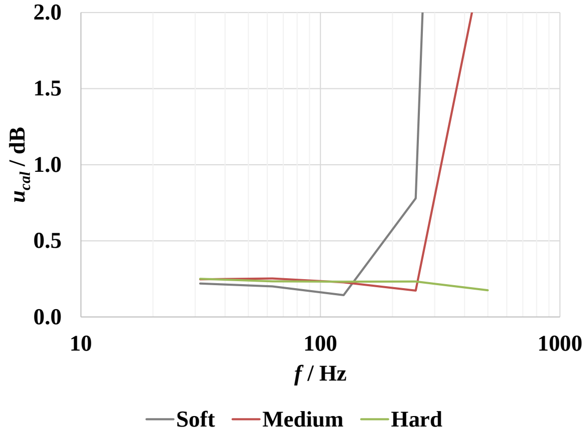

Figure 4. Estimated uncertainty of the sensitivity of the force measuring setup.

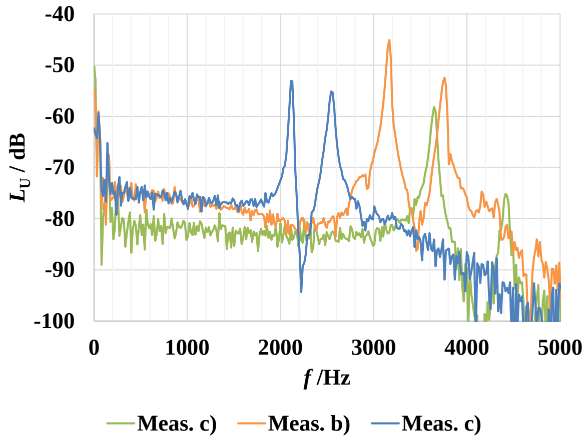

Figure 5. Sensor response for different mass loads.

4. TEST MEASUREMENTS

4.1 Sensor response

The aluminium impact plate and adapter mounted on the force sensor are required to enable impact measurements with the dropping ball. However, these components provide additional mass that acts on the sensor element and changes its dynamic response. This effect was investigated by measuring the pulse response of the force sensor using different mass loads. A narrowband spectrum was measured for the following mechanical configurations:

a) Force sensor without mass load
b) Force sensor with upper adapter plate (69 g)
c) Force sensor with adapter and impact plate (mass 285 g)

The results can be seen in Figure 5. All three narrowband spectra exhibit two resonances, which are shifted towards lower frequencies with increasing mass. However, these resonances should not have any significant influence on the octave band analysis, as these are well below 2 kHz.

4.2 Time signals of ball drops

A series of test drops with three rubber balls was performed (Table 1). Ball 3 is a prototype that is about 30 years old, while the two other balls are newer types that can be purchased today. Also, ball 3 is slightly heavier than the other two balls. Each ball was dropped ten times onto the force measuring setup and the time signals were recorded (Figures 6 to 8).

Table 1. Mass values of the rubber balls under test.

	Ball 1	Ball 2	Ball 3
m / kg	2.448	2.364	2.589

The time signals of balls 1 and 2 have more in common than those of ball 3: their pulse shape is similar, the force reaches a peak value of around 1.6 kN, and the pulse duration is around 20 ms for both balls. Ball 3 generates impacts with a considerably larger peak force, more than 3.5 kN, and the duration here is approximately 10 ms.

Another aspect can be seen in all time signals. The force pulses exhibit a superposed wavy disturbance, especially on the rising slope. To estimate the frequency of this ripple, the time interval between two maxima or minima was determined. The values show that we deal with the resonances of the system previously presented in Figure 5c), which occur in the range from 2 kHz to 3 kHz. The same effect can actually be observed in the pulse curves shown in the standards [1] and [2], or in similar studies with other force sensors [4].

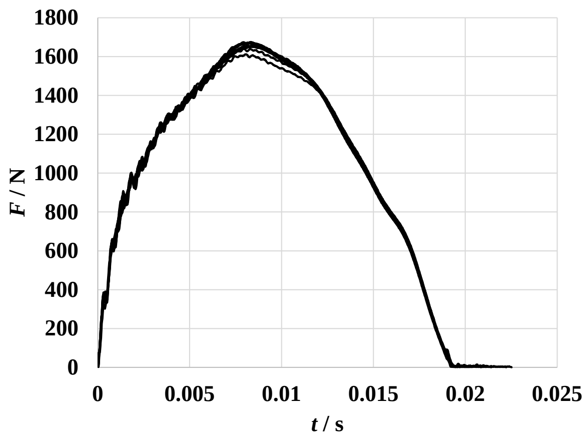

Figure 6. 10 force pulses obtained with ball 1.

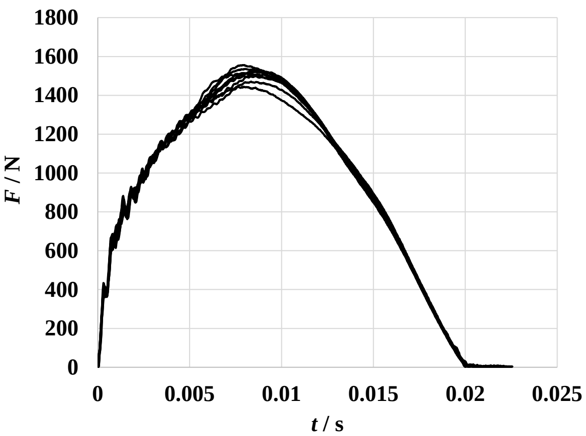

Figure 7. 10 force pulses obtained ball 2.

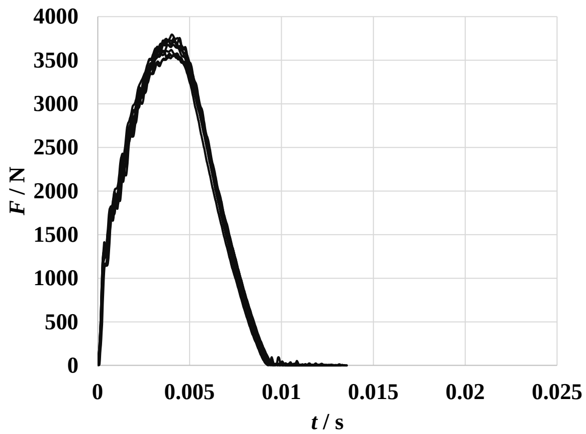

Figure 8. 10 force pulses of obtained with ball 3.

4.3 Integration time for octave band measurement

The ball impacts have a duration of up to 20 ms. However, the main criterium for the validation of a heavy soft impact source is the impact force exposure level measured in octave bands. Depending on the filter centre frequency *f*, the filters require a settling time depending on 1 / *B* with a bandwidth of *B* = *f* / √2. It is therefore necessary to investigate which integration time is appropriate.

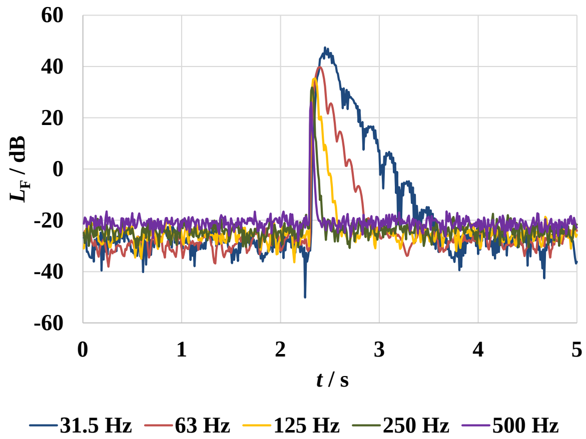

Figure 9. Force levels over the measurement time for different octave bands.

For one ball drop, the time history of the octave bands was measured for a duration of 5 s. Figure 9 shows the time history of the filter output for five octave bands. With increasing frequency, the filters need less time to process the impact. While the lower bands require more time, this will be a disadvantage for the higher bands, as the amount of noise increases. This is illustrated in Figure 10. Here, the impact force exposure level $L_{F,E}$, according to Equation (3), is shown as a function of the integration time T_{av} for each octave band. The data in Figure 9 has been split so that the pre-impact part of the measurement is included in the analysis as background noise (dashed, shorter curves). An integration time of less than 50 ms results in distorted impact force exposure levels for the lowest frequency bands; for all octave bands above 63 Hz, the levels reach a constant value more quickly. Again, the noise curves show that the influence of noise increases with integration time. For example, for the highest octave specified in the standard at 500 Hz, the SNR is approx. 24 dB.

$$L_{\mathrm{F,E}} = L_{\mathrm{F}} + 10\,\lg\left(\frac{T_{\mathrm{av}}}{T_{\mathrm{ref}}}\right)\ \mathrm{dB} \tag{3}$$

To make a decision on the required integration time, the difference between each force exposure level and the level at the longest integration time of 2.7 s was determined for each octave band. Figure 11 shows that for all octaves of the standard (31.5 Hz to 500 Hz) the deviations after 1 s are very small. Such an integration time also has the advantage that the reference value of Equation (3) is 1 s, so the measured impact force level is equal to the desired impact force exposure level.

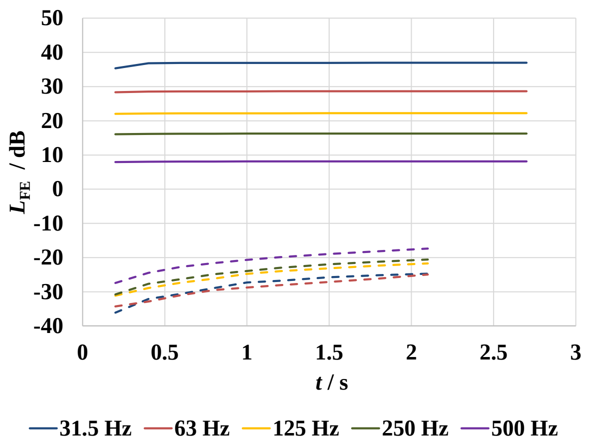

Figure 10. Impact force exposure level and noise level in dependance of integration time.

4.4 Results of octave band measurements

With the knowledge presented in the previous section, the triggered measurement was set to 1 s integration time and the results of 10 ball drops were analyzed in octave bands. Figure 12 shows the difference between the average of the measured octave band levels and the required level of the standards [1] and [2] for each ball. The results for ball 1 and ball 2 are between the limits, with a small deviation at 500 Hz for ball 1. The impact force exposure levels of ball 3 are outside the limits in every octave band.

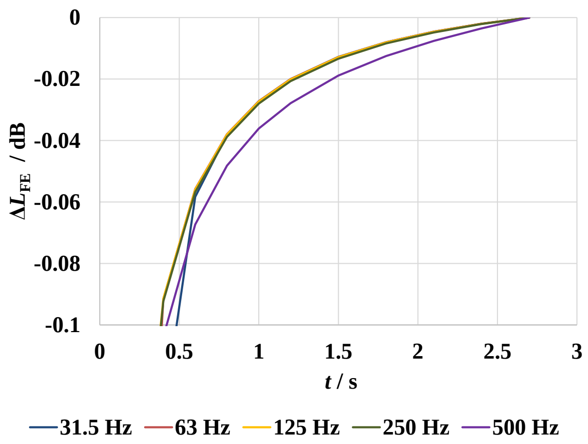

Figure 11. Dependence of the impact force exposure level on integration time for each octave band, plotted as deviation ΔL from the longest integration time of 2.7 s.

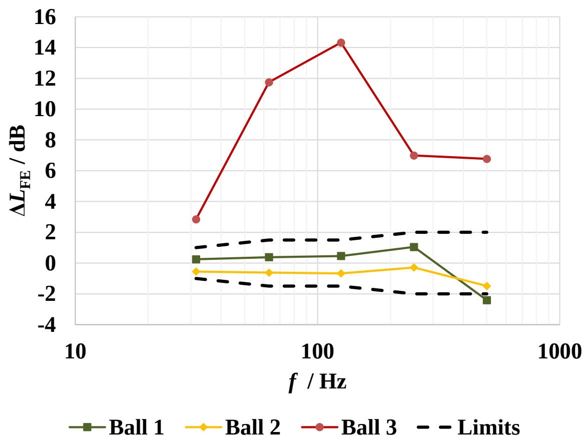

Figure 12. Impact force exposure level of the three balls in comparison with the limits.

The standard deviations of the impact force exposure levels from the 10 ball drops were also calculated. The values are between 0.1 dB and 0.5 dB (Figure 13). For the two balls complying with the standard requirements, they are below 0.3 dB.

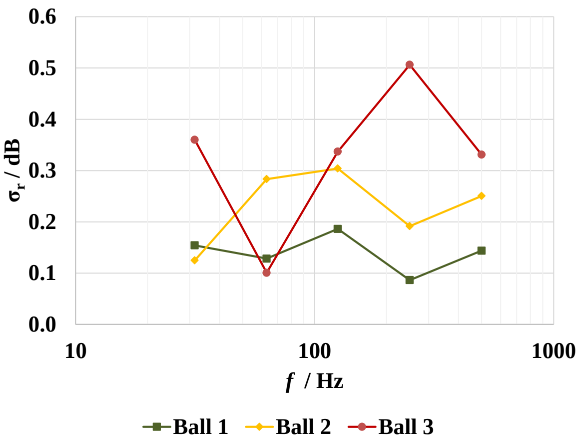

Figure 13. Standard deviation of the impact force level determined from ten repeated ball drops.

5. UNCERTAINTY ESTIMATE

To estimate the uncertainty of the measured force exposure level, the mean value from the 10 ball drops is used as the measurand. A first uncertainty estimate for this measurand is determined by using the uncertainty estimate of the calibration u_{cal}, the standard deviation of repeatability σ_{r} and the influence of the noise due to the averaging. The latter is estimated from Figure 11 to be u_{N} = 0.05 dB.

$$u\left(L_{\text{F,E}}\right) = \sqrt{u_{\text{cal}}^2 + \frac{\sigma_{\text{r}}^2}{n} + u_{\text{N}}^2} \quad (4)$$

The resulting uncertainty is about 0.3 dB for the calibration with the hardest hammer tip (Figure 14). For the soft hammer tip, the uncertainty is much larger at 250 Hz and 500 Hz, and the medium hammer tip is between these two cases. In view of the standard's tolerance range for the impact force exposure level of ±1.0 dB to ±2.0 dB, this uncertainty is comparatively large and must be investigated further.

6. SUMMARY

A new setup for measuring the impact force exposure levels of heavy soft impact sources has been installed at PTB. It consists of a strain gauge sensor with a bridge amplifier and an octave band analyzer. This device was calibrated by an impact hammer which had been traceably calibrated at PTB. The uncertainty of the measured force exposure level of heavy impact sources was estimated to be about 0.3 dB. This very first uncertainty estimate indicates that the uncertainty is not negligible when comparing measured force exposure levels to the requirements from the standard. Further investigations are necessary before a test service can be established at PTB.

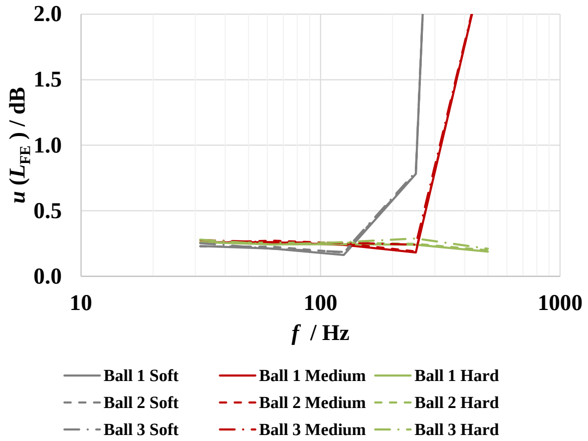

Figure 14. Uncertainty estimates for the measured force exposure level.

7. REFERENCES

[1] DIN EN ISO 10140-5, "Acoustics - Laboratory measurement of sound insulation of building elements - Part 5: Requirements for test facilities and equipment", First edition 01 September 2010

[2] DIN EN ISO 16283-2, "Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 2: Impact sound insulation", German edition EN ISO 16283-2:2020

[3] M. Kobusch, L. Klaus: "In-Situ dynamic force calibration using impact hammers", Acta IMEKO, December 2020, Volume 9, Number 5, Page 118 - 123

[4] S. Hirakawa, C. Hopkins: "Verification procedures for the impact force applied by the rubber ball used for impact sound insulation measurements", 29th International Congress on Sound and Vibration (ICSV), 9 – 13 July 2023