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TOWARDS A SIMPLIFIED PERIODIC TESTING OF TAPPING MACHINES

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ABSTRACT

ISO-tapping machines are used as a standardised excitation when measuring impact noise. It is required that 5 hammers with a mass of 500 g each impact the floor at a velocity of 886 mm/s at time intervals of 0.1 s. There are several other requirements like the distance between the hammers, the hammer diameter and the radius of the impact surface of the hammer. These requirements are today defined in different international standards but there is an activity ongoing to develop a new standard ISO/PWI 21791 "Acoustics – Sound sources for building acoustics" which shall also cover the testing of tapping machines.
The current standards prescribe that some of the parameters have to be measured only once like the distance between the hammers whereas other parameters shall be checked regularly like the velocity at impact and time between impacts.
The contribution introduces an alternative periodic test of ISO tapping machines which is based on a simultaneous measurement of the acting force at each of the five hammer positions. Results of test measurements are presented and conclusions with respect to the applicability of such a method are derived.

Keywords: *tapping machine, blocked force, direct force measurement*

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1. INTRODUCTION

It has been agreed that a new standard ISO/PWI 21791 "Acoustics – Sound sources for building acoustics" is developed. This standard shall contain all information for different types of sound sources used for measurements in building acoustics which are currently described in the different standards. Possible extensions to the currently standardised situation are also discussed. One of these possible extensions is a simplified method for a periodic testing of tapping machines. The motivation for this is that the verification of the current requirements for tapping machines is laborious, which may be one of the reasons why periodic testing of tapping machines is avoided quite often.

2. FORCE EXERTED BY TAPPING MACHINES

A straightforward way of testing tapping machines is to measure their force directly and to compare this to a required force. This leads directly to the question how large the force of a tapping machine should be.
Starting point to answer this question is the blocked force level $L_{F,\mathrm{b}}$ of a tapping machine. It could be shown in [2] that this can be described by a sum of two terms

$$L_{F,\mathrm{b}} = L_{F,\mathrm{b},1} + \Delta L_{F,\mathrm{b}} \tag{1}$$

Here $L_{F,\mathrm{b},1}$ is the level of the blocked force when each hammer impacts the receiver only once in each cycle. It is calculated from

$$L_{F,\mathrm{b},1} = 20\lg\left[\frac{m\ v_{\max}\,(1+k)}{F_0}\sqrt{\frac{2\ (10^{1/20}-10^{-1/20})\,f}{T}}\right]\mathrm{dB} \tag{2}$$

with the hammer mass m, the velocity at impact $v_{\max}$, the restitution coefficient k, the reference force $F_0 = 10^{-6}$ N, the centre frequency of the one-third octave band f and the time between impacts T. The second summand $\Delta L_{F,\mathrm{b}}$

in eq. (1) is the increase of the force level due to double or triple impacts. It is

$$\Delta L_{F,\mathrm{b}} = \begin{cases} 10\lg\,[1+k^2+k^4]\,\mathrm{dB} & \text{for } k<k_1 \\ 10\lg\,[1+k^2]\,\mathrm{dB} & \text{for } k_1<k<k_2 \\ 0\,\mathrm{dB} & \text{for } k>k_2 \end{cases} \quad (3)$$

with

$$k_1 = -0{,}5 + \sqrt{0{,}25 + \frac{t_{\mathrm{lift}}\, g}{2\sqrt{2\,g\,h}}} \quad (4)$$

and

$$k_2 = \frac{t_{\mathrm{lift}}\, g}{2\sqrt{2\,g\,h}} \quad (5)$$

In eqs. (4) and (5), g is the gravitational acceleration, h is the hammer falling height and t_{lift} is the time between impact and lift of the hammer. The standard [1] requires that t_{lift} is smaller than 80 ms. This ensures that $\Delta L_{F,\mathrm{b}}$ is smaller than 0.8 dB [2].

For a mobility mismatch situation, i.e. the hammer mobility is sufficiently large compared to the receiver mobility, the exerted force is equal to the blocked force of a tapping machine. Then equations (1) to (5) clearly show that the force exerted by tapping machines depends on the required quantities of the current standard [1] (hammer mass, hammer impact velocity, time between impacts) but also on additional quantities, namely the restitution coefficient and the occurence of double or triple impacts. These additional quantities are not known and can not be predicted easily [2].

3. TEST MEASUREMENTS

To test a direct measurement of the force of tapping machines, a brass plate with five force sensors [2] is used. The hammers of the tapping machine hit directly on the force sensors. Six different tapping machines are used. Prior to the measurements, their properties (impact velocity, time between impacts) had been tested. Five tapping machines were within the specifications from [1], one tapping machine revealed an impact velocity which was too small. For the force sensors, the sensitivity provided by the manufacturer is used.

Fig. 1 shows the difference between the measured force level and the calculated blocked force level for five hammers of one tapping machine. The measurement has been performed three times. Between the measurements, the tapping machine was dismounted and remounted, in some cases several days were between the measurements. The result of the second measurement is shifted by -1 dB and the results of the third measurement by -2 dB for a better graphical representation. For the comparison, the restitution coefficient is set to 0.65 and $\Delta L_{F,\mathrm{b}}$ to 0. The impact velocity, the time between hammer impacts and the hammer mass are set to the default values from the standard. This input for the calculation of the blocked force level is the same for all tapping machines. The measured force levels are close to the calculated blocked force level for all five hammers between 20 Hz and 1 kHz. At higher frequencies, the measured force levels become smaller than the calculated blocked force level due to the mobility ratio [2]. In all three measurements, a certain pattern is observed. Hammer 3 always exhibits the largest force, hammer 1 always the smallest.

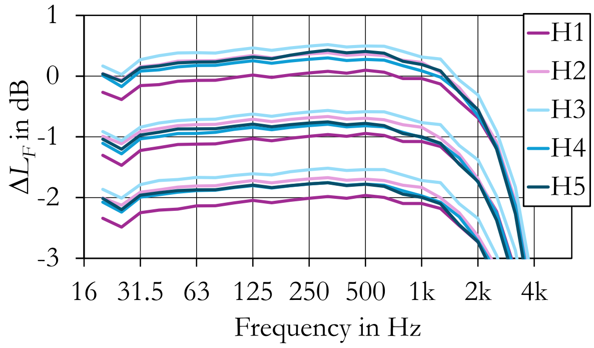

Figure 1. Difference between the measured force level and the calculated blocked force level for five Hammers of a tapping machine; Measurements were repeated three times and the results shifted by -1 dB (second measurement) and -2 dB (third measurement) for better visibility.

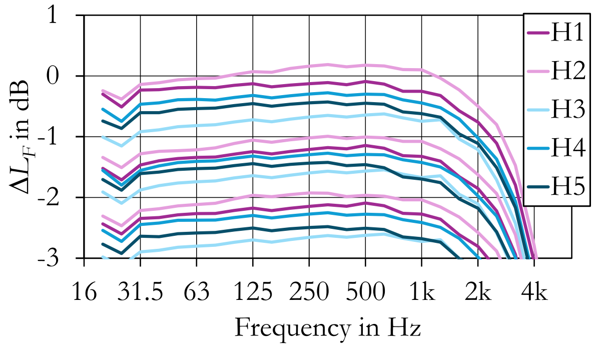

Figure 2. Same as Fig. 1 but different tapping machine.

The observed pattern may suggest that the sensitivity of the force sensors may show some systematic deviation. Fig. 2 proves that this is not the case since the pattern is very different for another tapping machine. The reason is probably that the restitution coefficient is not identical for different tapping machines. In [2], a standard deviation of the restitution coefficient of about 10 % had been observed when different tapping machines act on the same position of the same receiver.

It is now interesting to see which force is measured for the tapping machine where the impact velocity was too small. This result is displayed in Fig. 3. Hammer 1 clearly shows a much smaller force than the other hammers.

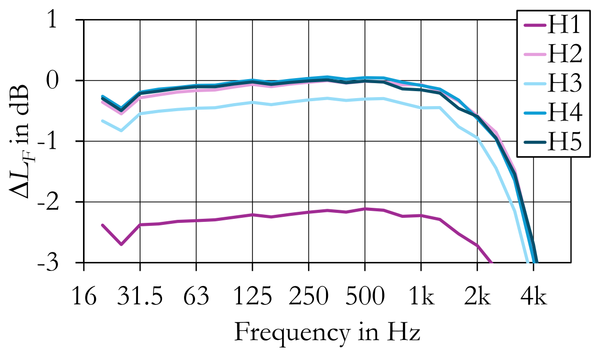

Figure 3. Same as Fig. 1 and Fig. 2 but tapping machine not complying to the specifications from [1] and no repeated measurement shown.

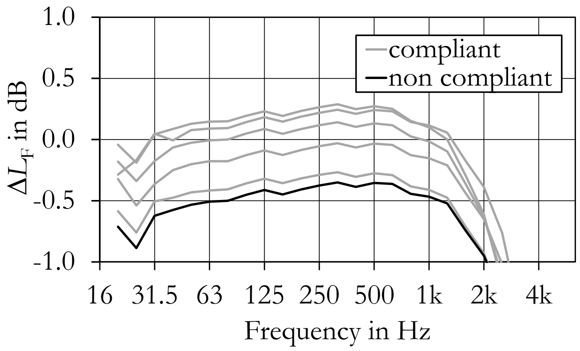

Figure 4. Deviation between the measured force level and the calculated blocked force level averaged over all five hammers for the six tapping machines tested.

Finally, the differences of the measured force levels to the calculated blocked force levels were averaged for the five hammers of one tapping machine. This result is shown in Fig 4. At frequencies from 50 Hz to 1 kHz, this difference is between -0.5 dB and 0.3 dB for the tapping machines complying to the standard requirements. For the tapping machine not complying to the standard requirements, this difference is only slightly larger. The reason is that only one out of five hammers has a much smaller force level which is largely compensated by the averaging over 5 hammers.

4. CONCLUSIONS

A periodic testing of tapping machines by measuring their force levels seems to be possible. An application of a criterion for each single hammer and for the average of all five hammers seems to be appropriate. It is essential for the method that the occurring restitution coefficients are determined, possibly by a set of tapping machines which are known to meet the requirements from [1]. Before such a method can be standardised, further investigations need to be performed, e.g. on the reproducibility of the results and on the uncertainty of the measured force levels compared to the uncertainty of the calculated blocked force level.

5. REFERENCES

[1] ISO 10140-5:2021 Acoustics — Laboratory measurement of sound insulation of building elements, Part 5: Requirements for test facilities and equipment.

[2] V. Wittstock, H. Bietz, and M. Schmelzer: The influence of the restitution coefficient and multiple impacts on the force exerted by ISO tapping machines, *Acta Acustica*, 2025, 9, 14