**FACTA UNIVERSITATIS**
Series: **Working and Living Environmental Protection** Vol. 21, Nº 4, Special Issue, 2024, pp. 317 - 328
https://doi.org/10.22190/FUWLEP240912030B

**Original scientific paper**

# CASE STUDY: PREDICTION OF THE EFFECT OF PERFORMED ACOUSTIC INSULATION ON MACHINE PARTS ON REDUCING OCCUPATIONAL NOISE EXPOSURE

*UDC 534:331.4*

**Biljana Beljić Durković[1], Jovan Miočinović[2]**

[1]Zmaj Jova Jovanović Primary School, Belgrade, Serbia
[2]TEHPRO d.o.o., Belgrade, Serbia

ORCID iDs: Biljana Beljić Durković N/A
Jovan Miočinović N/A

**Abstract**. *In the plastic injection moulding plant, at the operator's position at the machine, the noise was measured in situ before and after the acoustic insulation lining of the parts of the machine to determine whether the intervention has an impact on reducing occupational noise exposure. As the work environment is variable (different modes of operation of the machine and other machines in the plant), a model of the contribution of the noise sources to the measured noise was made, and based on the model, the effect of the intervention was predicted.*

**Key words:** *occupational noise, indoor noise reduction, indoor noise model*

## 1. INTRODUCTION

In one plastic injection moulding plant, there was a desire to reduce the noise emitted by the machines and equipment through subsequent interventions on the machines.

When considering industrial noise reduction, before implementing engineering or administrative measures to control noise, it is necessary to define the problem regarding the persons affected by the exposure, the type and location of noise sources, and the appropriate criteria for assessing the severity of the situation [1]. Although every noise control problem must be examined individually, there are three separate components which should always be considered, namely the source, the propagation path, and the receiver (worker) [2]. Acoustical treatment may be applied to any or all of these components [3] with the general order of precedence being as listed, i.e., the most satisfactory solution usually results from noise reduction at or near the source [1,3,4]. That hierarchy of control

Received September 12, 2024 / Accepted November 21, 2024
**Corresponding author**: Jovan Miočinović
TEHPRO d.o.o., Lole Ribara 120, 11250 Belgrade, Serbia
E-mail: jovan.miocinovic@tehpro.rs

measures also corresponds to the representation of applied noise control techniques in case studies presented in the literature [5,6,7].

In this case, the noise source has been pointed out before any noise survey prior to the selection of control measures, and technique to reduce the noise – acoustic lining of the machine parts was selected as the most practical solution. As one of the techniques to reduce the generation of airborne and structure borne noise in machines, acoustical lining [8] in enclosures requires a carefully balanced combination of absorbing, damping, and insulating materials incorporated to prevent high reverberant sound levels within the enclosure from degrading the overall insulating properties [1].

The idea was to measure the noise before the intervention on one such machine and after and compare the measured noise levels in order to see if it makes sense to carry out such interventions on other machines as well. Such a comparison would make sense for ideally the same test conditions before and after, e.g. the same mode of operation of all machines. It would be best if all the machines were running at full capacity.

The measurements were carried out as part of the testing of the working environment [9]. However, the test conditions in working environment testing in practice are usually such that there is limited test time and little or no possibility of influencing the operating mode. While the impact on plant operation by the examiner's influence would result in production downtime, scrap production, and additional time to restart and full production, the test is usually carried out under the conditions of the current operation of the production plant found at the time of the test.

Here it was the case, as will be shown in detail, that the machines in the first trial were operating in one mode, in the post-intervention trial in another, with little to no possibility of influence on the operation of the machines by the examiner.

In the first test, the machines in the hall worked each in its own mode with the possibility of turning off the tested machine, when two measurements were performed. In the second, the machines worked in a different mode from the first without the possibility of influence, when the third measurement was performed.

Since, due to the impossibility of controlling the parameters, it is not a standard experimental design, in order to draw conclusions, the starting point is the model of the contribution to noise in the working environment from individual sources and the mode of operation of the sources. It will also be necessary to analyse the contributions and introduce additional assumptions about the impact of individual contributions. A model is only as good as the assumptions on which it is based, and the conclusions and applicability of the model are limited by the validity of the assumptions.

## 2. Test Conditions and Results

There are 24 injection moulding machines in the facility. The situation plan is given in Fig. 1.

The machine on which the intervention was performed is the M-6 machine. In the first test (before intervention), neighbouring machine M-5 was operating, neighbouring machine M-4 was not operating, and machine M-6 was operating idle (first measurement). A measurement was also performed after turning off the M-6 machine (second measurement).

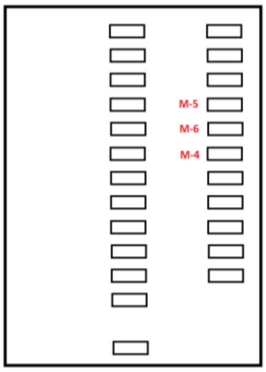


**Fig. 1** Situational plan of a plant.

In the second test (after intervention), neighbouring machine M-4 was operating, neighbouring machine M-5 was not operating, and machine M-6 was operating at full capacity (third measurement).

Measurements were made according to ISO 9612 [10] with the microphone positioned at the locations of the worker's head during normal performance of the job or task for standing worker: 1.55 m ± 0.075 m above the ground on which the worker is standing.

Fig. 2 shows a sketch of the position of the measuring point in relation to the M-6 machine and neighboring machines, and Fig. 3 shows a photograph of the position of the measuring point.

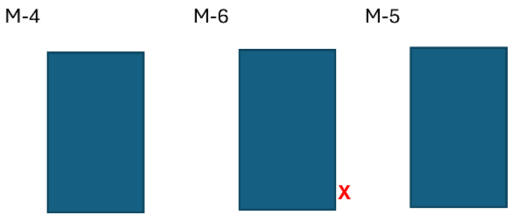


**Fig. 2** Sketch of the position of the measuring point

**Fig. 3 A** photograph of the position of the measuring point

In the first test (before intervention), the measured noise level was 80.6 dB (first measurement). In the second measurement, the measured level was 78.7 dB. In the second test (after intervention), the measured level was 84.8 dB (third measurement). It is noticeable that the noise level measured after the intervention is significantly higher than the level measured before the intervention.

As mentioned above, it would be ideal if the tests were carried out in the same operating conditions of the technological capacities, in the full capacity of the machine on which the intervention was carried out, with the same mode of operation of the other machines in the hall. Since the working conditions during the tests before and after differ greatly, in order to be able to draw relevant conclusions from the test results about the possible effect of the intervention on the machine on noise reduction, it is necessary to start from the contribution model of noise sources in the workspace.

## 3. A Model of the Contribution of Noise Sources to the Measured Noise in the Workspace

In making the model, we start from several observations and initial assumptions.

Since the measuring point is between machines M-5 and M-6 and machine M-4 is much further away from the measuring point than machine M-5 (see Fig. 2), the noise contribution from machine M-5 at the measuring point is greater than the contribution from machine M-4.

Starting from the model of the sum of noise contributions at the measuring point, the noise can be expressed as the sum of the contributions from machine M-6, denoted here as $L_{(\mathrm{M-6})\mathrm{pAeq}}$, machine M-5, denoted $L_{(\mathrm{M-5})\mathrm{pAeq}}$ and, since M-4 is further from the measuring point, the sum of contributions from machine M-4 and the other machines in the hall, denoted $L_{(\mathrm{E})\mathrm{pAeq}}$.

$$L_i = L_{(M-6)pAeq}{}_i^j (+) L_{(M-5)pAeq}{}_i^j (+) L_{(E)pAeq}{}_i^j \quad (1)$$

Here *i* stands for *i*-th measurement (*i* = 1, 2, 3, for the first, second and third measurement), *j* stands for test (*j* = B for the test before intervention and *j* = A for the test after the intervention). The addition sign in bracket stays not for arithmetic addition but for the logarithmic addition of sound pressure levels from multiple noise sources [11].

Thus, for all three measurements, we can express the measured equivalent levels via components.

$$L_1 = L_{(M-6)pAeq}{}_1^B (+) L_{(M-5)pAeq}{}_1^B (+) L_{(E)pAeq}{}_1^B \quad (2)$$

$$L_2 = L_{(M-5)pAeq}{}_2^B (+) L_{(E)pAeq}{}_2^B \quad (3)$$

$$L_3 = L_{(M-6)pAeq}{}_3^A (+) L_{(E)pAeq}{}_3^A \quad (4)$$

The components $L_{(\mathrm{M-6})}$ from Eq. (3) and $L_{(\mathrm{M-5})}$ from Eq. (4) are missing because M-6 and M-5 do not operate during the corresponding measurements (see 2. above).

The Eqs. (2), (3) and (4) can be reformulated as follows.

$$L_1 = L_{(M-6)}{}_I^B (+) L_{(M-5)} (+) L_{(E)} \quad (5)$$

$$L_2 = L_{(M-5)}(+)L_{(E)} \tag{6}$$

$$L_3 = L_{(M-6)_F^A}(+)L_{(M-4+E)} \tag{7}$$

From the Eqs. (5) and (6) indexes are omitted because $L_{(\text{M-5})}$ and $L_{(\text{E})}$ are the same while the operating conditions of contributing equipment are the same. In Eq. (5) with index *I* the idle operating mode of M-6 is marked, and in Eq. (7) with index *F* the full capacity operating mode of M-6 is marked. With M-4+E in $L_{(\text{E})}$ component in Eq. (7) the contribution of M-4 is pointed out while it does not contribute to the noise in Eqs. (5) and (6).

Graphic printout for the measurements is given in Fig. 4 (first measurement), Fig. 5 (second measurement), and Fig. 6 (third measurement). The parameters shown in the graphic are A-weighted equivalent continuous sound pressure level $L_{\text{AFeq}}$, C-weighted peak sound pressure level $L_{\text{Cpeak}}$, A-weighted impulse equivalent continuous sound pressure level $L_{\text{AIeq}}$, and A-weighted minimum sound pressure level $L_{\text{AFmin}}$ [12].

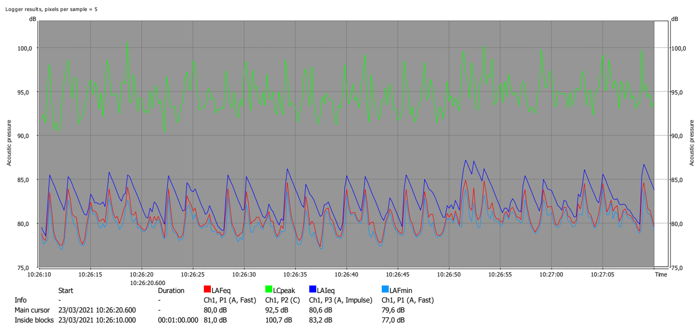


**Fig. 4** Graphic printout of the noise level during the first measurement (The calibration factor is −0.4 dB)

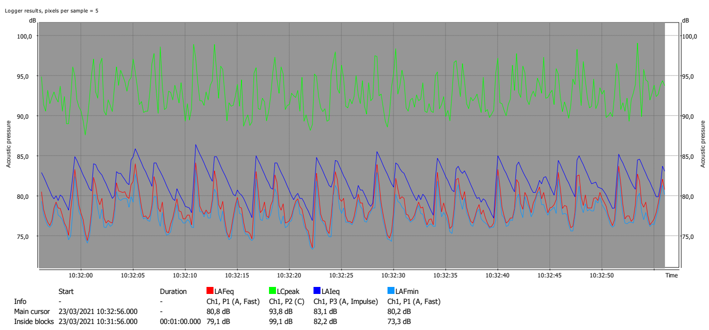


**Fig. 5** Graphic printout of the noise level during the second measurement (The calibration factor is −0.4 dB)

$L_{(\text{E})}$ can be estimated from the second measurement as the minimum sound level measured during the measurement period, $L_{\text{AFmin}}$. The assumption is that now when the neighbouring machine M-5 is the quietest, the noise contribution from the other machines comes to the fore. It is 72.9 dB (the $L_{AFmin}$ value from Fig. 5, minus the calibration factor).

From Eq. (6) noise contribution from M-5, $L_{(M\text{-}5)}$ can be determined as the difference of the measured noise in the second measurement, $L_2$ (78.7 dB, the $L_{AFeq}$ value from Fig. 5, minus the calibration factor), and $L_{(E)}$ as in the previous step determined.

$$L_{(M-5)} = L_2(-)L_{(E)} \tag{8}$$

Again, the difference is the value that, when added to the known value of $L_{(E)}$ using the logarithmic addition of sound pressure levels, equals the known value of $L_2$. Thus, for the noise contribution from M-5, $L_{(M\text{-}5)}$ we get 77.4 dB.

From Eq. (5) noise contribution from M-6 (when idle, before the intervention), $L_{(M\text{-}6)}{}^{B}{}_{I}$, can be determined as the difference of the measured noise in the first measurement, $L_1$ (80.6 dB, the $L_{AFeq}$ value from Fig. 4, minus the calibration factor), and the sum of noise contributions from M-5, $L_{(M\text{-}5)}$ and the rest of the machines and equipment, $L_{(E)}$ as in the previous steps determined.

$$L_{(M-6)}{}_{I}^{B} = L_1(-)\{L_{(M-5)}(+)L_{(E)}\} \tag{9}$$

Once again, the difference is the value that, when added by means of logarithmic addition of sound pressure levels to the known values of $L_{(E)}$ and $L_{(M\text{-}5)}$, equals the known value of $L_1$. Thus for the noise contribution from M-6 (when idle), $L_{(M\text{-}6)}{}^{B}{}_{I}$, we get 76.1 dB.

Now we will introduce an additional assumption, which is that the noise of the machine operating at full capacity consists of the superimposed operating noise and the idle noise, so that the idle noise can be found in the minimum measured in the measurement interval (see Fig. 7).

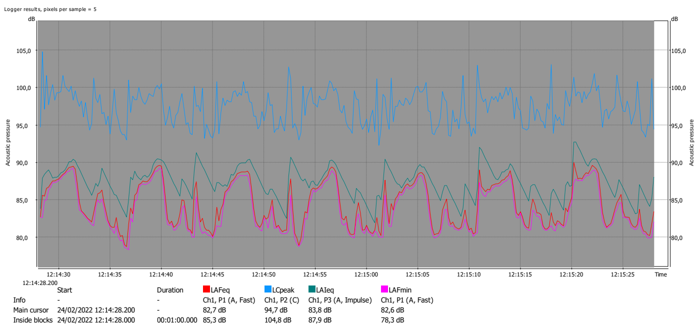


**Fig. 6** Graphic printout of the noise level during the third measurement (The calibration factor is −0.5 dB)

Thus the noise contribution from M-6 (when idle, after the intervention), $L_{(M\text{-}6)}{}^{A}{}_{I}$, equals the difference of the minimum sound level measured during the measurement period (77.8 dB, the $L_{AFmin}$ value from Fig. 6, minus the calibration factor) and the contribution from M-4 and the rest of the machines and equipment, $L_{(M\text{-}4+E)}$.

$$L_{(M-6)}{}_{I}^{A} = L_{3AFmin}(-)L_{(M-4+E)} \tag{10}$$

Here again, the difference implies logarithmic subtraction [11].

Now we need to evaluate the contribution of M-4 to the contribution of the rest of the machines and equipment, $L_{(M\text{-}4+E)}$. If neglected and taken $L_{(E)}$ for $L_{(M\text{-}4+E)}$:

$$L_{(M-4+E)} = L_{(E)} \tag{11}$$

From Eq. (10) we get for the contribution of M-6 (when idle) 76.1 dB.

However, considering that it is the closest neighbour and the biggest source of noise in the environment when M-5 not operating, if we assume its contribution is at least equal to the contribution of other machines and equipment

$$L_{(M-4+E)} = L_{(E)}(+)L_{(E)} \tag{12}$$

From Eq. (10) we get for the contribution of M-6 (when idle) 73.3 dB.

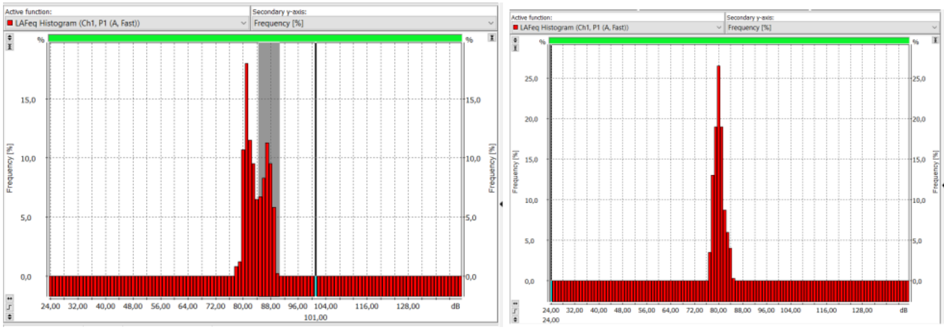


**Fig. 7** Statistical distribution of the noise level for the third and first measurements. A machine operating at full capacity can be viewed as consisting of superimposed operating noise (shaded part) and idle noise

## 4. Evaluation of the Effectiveness of the Intervention on the Machine to Reduce Occupational Noise Exposure

### 4.1. Assessment of noise level reduction of the equivalent noise level

Based on the model, the noise contribution of M-6 (when operating idle), $L_{(M\text{-}6)}{}^{B}{}_{I}$, of 76.1 dB was estimated from the measured noise value at the measuring point before the intervention of the acoustic insulation of the machine.

From the calculated value of the noise at the measuring point after the intervention of the acoustic insulation of the machine, based on the model, the noise contribution of M-6 (when operating idle) $L_{(M\text{-}6)}{}^{B}{}_{I}$, was estimated between 73.3 and 76.1 dB.

It was established that the noise level originating from the machine (when operating idle) will be reduced from the initial 76 dB by an amount of 0 – 2.5 dB after the intervention of acoustic insulation of the machine.

### 4.2. Assessment of noise level reduction in a specific frequency domain

Let's try to establish from the frequency analysis of the measurement results at which of single octave bands, assuming that it works, the acoustic insulation intervention works.

To compare noise levels by octave bands coming from the M-6 machine before and after intervention on the machine we use the model of components contribution (Eqs. (5), (6), and (7)).

From Eqs. (5) and (6), for the noise component coming from M-6 before the intervention, may be seen to be obtained by subtracting the Eq. (6) from Eq. (5)

$$L_1(-)L_2 = L_{(M-6)}{}_I^B \tag{13}$$

While considering the octave bands, Eq. (13) may be rewritten as

$$\{L_1(-)L_2\}^i = \left\{L_{(M-6)}{}_I^B\right\}^i \tag{14}$$

where $i = 1, \ldots, 9$ stays for octave bands 31.5; 63; … 8000 Hz.

That is, Eq. (14) represents 9 equations for corresponding single octave bands.

To find the contribution of M-6 (operating idle) after intervention, we rely on the machine idling model (that is, Eq. (10)) and Eq. (7). Considering contribution of the rest of the machines and equipment by Eq. (11) and $L_{(E)}$ estimated from the second measurement as the minimum sound level measured during the measurement period, $L_{AFmin}$ as considered above, we find that wanted contribution is subtraction of the minimum sound level measured during the second measurement period, $L_{2AFmin}$, from the minimum sound level measured during the third measurement period, $L_{3AFmin}$ (see Eqs. (6) and (7)):

$$L_{3AFmin}(-)L_{2AFmin} = L_{(M-6)}{}_I^A \tag{15}$$

While considering the octave bands, Eq. (15) may be rewritten as

$$\{L_{3AFmin}(-)L_{2AFmin}\}^i = \left\{L_{(M-6)}{}_I^A\right\}^i, \tag{16}$$

where $i =1, \ldots, 9$ stays for octave bands 31,5; 63; … 8000 Hz.

That is. Eq. (16) represents 9 equations for corresponding single octave bands.

Noise levels by octave bands coming from the M-6 machine before the intervention calculated by Eq. (14) (when adding by means of logarithmic addition of sound pressure levels) are given in Tab. 1.

**Table 1** Noise levels by octave bands coming from the M-6 machine before the intervention

| Octave band [Hz] | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
|---|---|---|---|---|---|---|---|---|---|
| Noise level [dB] | 17.8 | 32 | 44.3 | 61.1 | 74.3 | 70.2 | 67.2 | 62.6 | 59 |

Noise levels by octave bands coming from the M-6 machine (operating idle) after the intervention are given in Tab. 2. The values for the octaves are obtained as the equivalent levels for the seven minimum values during the measurement period. This is done in order to preserve the minimum equivalent value calculated from the octaves. Namely the minimum octave values are expected to be reached at different moments of time, so the equivalent value calculated from the octave minimums would be below the true equivalent minimum value. Values thus obtained calculated by Eq. (16) (when adding by means of logarithmic addition of sound pressure levels) are given in Tab. 2.

**Table 2** Noise levels by octave bands coming from the M-6 modelled idle operating machine after the intervention

| Octave band [Hz] | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
|---|---|---|---|---|---|---|---|---|---|
| Noise level [dB] | 38.7 | 45.8 | 58.3 | 65.1 | 72.1 | 74.0 | 72.6 | 70.9 | 65.7 |

By comparing the octave band values from Tabs. 1 and 2, it may be seen that at the 500 Hz octave, the level decreased by 2.2 dB.

If we calculate the equivalent levels for situations before and after the intervention from the octave band sound levels modelled in this way [13], we see that the total level of noise coming from the machine when operating idle is 76.7 dB before the intervention and 79 dB after the intervention, which would mean that the machine is noisier than before, which was shown not to be the case. That is, in the model, we overestimated the contribution of the M-5 operation compared to the noise coming from the other machines.

If we do not compensate for the noise of M-5 but assume instead that the contribution of all machines in the environment is the same for the measurement as well before and after the intervention

$$L_{(M-4+E)} = L_{(M-5)}(+)L_{(E)} \tag{17}$$

contribution of M-6 (operating idle) after the intervention is

$$L_{3AFmin}(-)L_2 = L_{(M-6)}{}_I^A \tag{18}$$

While considering the octave bands, Eq. (18) may be rewritten as

$$\{L_{3AFmin}(-)L_2\}^i = \left\{L_{(M-6)}{}_I^A\right\}^i \tag{19}$$

where $i$ =1, …, 9 stays for octave bands 31.5; 63; … 8000 Hz.

Thus obtained noise levels by octave bands coming from the M-6 machine (operating idle) after the intervention are given in Tab. 3.

**Table 3** Noise levels by octave bands coming from the M-6 modelled idle operating machine after the intervention when the contributions of noise from other machines in the hall were taken as equal in the situations before and after the intervention

| Octave band [Hz] | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
|---|---|---|---|---|---|---|---|---|---|
| Noise level [dB] | 38.4 | 39.2 | 57.7 | 57.5 | 68.1 | 69.2 | 63.8 | 58.2 | 59 |

By comparing the octave band levels from Tabs. 1 and 3, it may be seen that at the 500 Hz octave, the level has decreased by 6.2 dB. If we calculate the equivalent level from octave band sound levels [13], 73.0 dB is obtained, which corresponds to the calculated maximum expected reduction of the noise contribution of M-6 (see 4.1.). Figure 8 shows a graphic representation of the data from Tabs. 1 – 3.

If we now look at the octave spectrum before the intervention (Tab. 1), we see that the machine is the noisiest at the level of 500 Hz, where the acoustic insulation according to the model proves to be the most effective (values in column 500 in Tabs. 2 and 3). If we calculate the equivalent level from the octave band sound levels from Tab. 1 with the determined reduction of 2.2 - 6.2 dB for the octave level of 500 Hz, we get the equivalent level of 75.5 - 74.2 dB, which corresponds to a total reduction of noise from the machine by 1.1 - 2.5 dB.

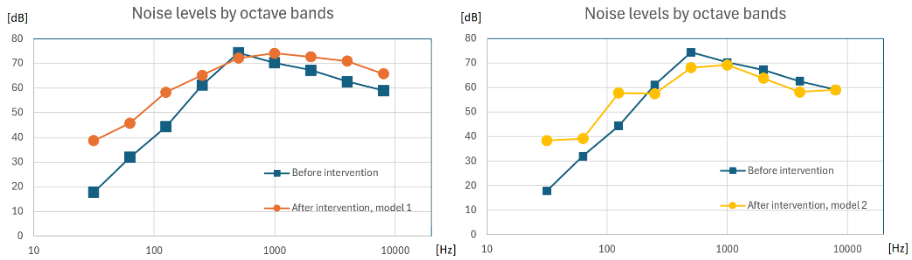


**Fig. 8** Models of octave band levels of noise from the M-6 operating idle modelled before and after the intervention. In the first one (on the left), the contribution of M-5 is considered separately from background noise, and in the other as a part of it.

The trend of reduction at higher frequencies (Tabs. 1 and 3 and Fig. 8 on the right) corresponds to the predicted selection of technique to reduce the noise. Namely, since the absorption coefficient of absorbent lining is generally highest at high frequencies, the high-frequency components of any noise will suffer the highest attenuation [4]. The obtained increase at low frequencies may be a reflection of the inadequacy of the approximations for that range or an unaccounted external source, but due to the A-weighting of the equivalent level, it does not significantly affect the overall results. If we compare the noise level reduction obtained in this way with typical values for insulating wrapping [3], we see that it is at best twice less than expected (5 - 10 dB according to ISO 11690-2). The reasons can be found in the noise reduction technique itself (see considerations in 1.), as well as in possible defects in the insulating layer, e.g. for enclosures with leak ratios of 10 %, the expected reduction of A-weighted emission sound pressure levels is limited to 10 dB [4] and, accordingly, for larger leaks, lower limitations are to be expected.

### 4.3. Consideration of the impact of the intervention on the machine on noise reduction at full capacity operation mode and of the subsequent interventions on all machines in the workplace

When considering full capacity operation mode, there are two issues. First, there is no data on the noise of the machine in full operating mode before the intervention, and second, as already discussed in 3. (see Fig. 7) machine noise is modelled as consisting of superimposed operating noise and idle noise. Looking at its construction, the machine consists of a physically separated drive part and a working part, while the acoustic insulation was performed on its drive part. With this in mind, the noise from the machine at full capacity before the intervention can be modelled as the sum of the idle noise before the intervention and the working part component after the intervention, assuming that the intervention does not affect the noise from the working part. When calculated like this, a 2.5 dB idle noise reduction yields a corresponding noise reduction at a full capacity of 0.3 dB. The reasons for such a result can be found in the following. First, in the very construction of the machine, i.e. separation of the working part from the driving part, whereby intervention is performed only on the working part. Secondly, due to the fact that the procedure was not followed during the selection of control measures (see considerations in 1.), and third, in the model limitation, a model developed on the basis of a very limited set of tests and assumptions that gives good predictions in one domain (predictions of insulating acoustic properties at idle) is extended in application (to predictions of properties at full operation).

This poor result of the impact of the intervention on the machine on noise reduction at full capacity operation mode, even if it turns out to be a good prediction, is not necessarily bad for the overall result of noise reduction in the workplace. Namely, the accumulative impact of performing such an intervention on other machines in the workspace could contribute to a cumulative reduction of background noise (in the model marked with $L_E$). Then, any intervention of this type on the working part of the machine without prior proper evaluation would be inappropriate [4,5,6]. Measures taken in practice on working parts of injection moulding machines are measures of specific interventions on the design (source control by design [4]). If additional appropriate measures were taken on the working parts to the extent that they would be effective, in conjunction with the performed measures of the acoustical lining of drive parts, they could contribute to a significant reduction of noise in the working environment.

## 5. Conclusion

Based on the results of measuring occupational noise in the production plant of plastic injection moulding and the model developed for this purpose, it has been shown that the contribution of noise from the machine operating idle to the noise in the work environment had been reduced by 0 to 2.5 dB by the intervention of performing acoustic insulation - the lining of the machine parts. Also, the effect of noise reduction in the frequency domain in which the machine is the noisiest (in the 500 Hz octave band) was determined, in amounts of 2.2 to 6.2 dB, which corresponds to a total reduction in the noise level of the machine by 1.1 to 2.5 dB. When considering the impact of the intervention on noise reduction at full capacity operation mode and the reduction of noise at the workplace in general, under the condition of carrying out such interventions on other machines in the workplace as well as additional adequate noise control measures on the working parts of the machines, all the measures taken in conjunction could lead to to a significant reduction of noise in the working environment.

## References

1. Orr, W. G. Handbook for Industrial Noise Control NASA SP-5108, NASA, Washington D.C. 1981
2. SRPS EN ISO 11690-1:2021, ISO 11690-1:2020 Acoustics - Recommended practice for the design of low-noise workplaces containing machinery - Part 1: Noise control strategies
3. SRPS EN ISO 11690-2:2021, ISO 11690-2:2020 Acoustics - Recommended practice for the design of low-noise workplaces containing machinery - Part 2: Noise control measures
4. Hansen, C. H. and Goelzer B. I. F. Engineering noise control, in: *Occupational exposure to noise evaluation, prevention and control*, pp.245-296, Office of Occupational Health, World Health Organization, Geneva, 1995
5. Sound Solutions: Techniques to Reduce Noise at Work (Guidance Booklets) HSG138, HSE Books, Norwich, 1995
6. Sound Solutions Case Studies, published by the Health and Safety Executive and licensed under the Open Government Licence https://www.hse.gov.uk/noise/casestudies/soundsolutions/index.htm

7. Industrial Noise Reduction, Advanced Noise Solutions Ltd., Colney Heath Ln, St Albans AL4 0UP https://www.advanced-noise-solutions.co.uk/industrial-noise-reduction/
8. Berendt, R. D. and Corliss, E. L. R. Quieting: a Practical Guide to Noise Control, NBS Handbook 119, US National Bureau of Standards, 1976
9. Rulebook on the procedure for inspecting and checking equipment for work and inspecting and testing electrical and lightning protection installations and testing working environment conditions, *"Official Gazette of RS"*, number 76 of September 13, 2024
10. ISO 9612:2009, SRPS EN ISO 9612:2016 Acoustics — Determination of occupational noise exposure — Engineering method
11. Logarithmic Addition of Sound Levels, WKC Group https://www.wkcgroup.com/tools-room/logarithmic-addition-sound-pressure-levels/
12. Acoustic Glossary, Gracey & Associates, W T Gracey Ltd., Upper Dean, PE28 0NQ https://www.acoustic-glossary.co.uk/definitions-l.htm
13. Calculating dB(A) from Octave Band Sound Levels, Cirrus Research plc, North Yorkshire, YO14 0PH https://cirrusresearch.com/calculation-of-dba-from-octave-band-sound-pressure-levels/