Noise Suppressor for the Textile Industry

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Abstract
This article presents a method for suppressing the noise level of weaving machines by enclosing them in individual sound-insulating casings. This method, which is already used in different industries, can also be applied for machines and devices in the textile industry. The possibility of suppressing the noise transmitted by the ventilation installation, which feeds the casings with air and carries it away, is analysed. We discuss a design and construction of a new noise suppressor, in the shape of a silencer, for a free-standing exhaust device. We also present the application of this silencer, which has been granted a Polish Patent for noise suppression in ventilation and air conditioning installations.

Key words: *noise suppressor, silencer, circular looms, exhaust installation.*

Introduction and Aim of Work

The aim of the work is to choose a method of noise suppression which could be applied for most of the machines and devices working in the textile industry. These machines are very diverse, but most of them are characterised by a high noise level. The maximum noise level of textile machines and devices can reach 105 dB. If they are placed together in a great number in a room equipped with air conditioning and ventilation installations, the noise level may rise by a further 5-8 dB [5]. Such a noise significantly exceeds the limited level of acoustic sound L_a=85 dB for working places, according to Polish Standard PN-N-01307:1994. To obtain experimental data which could form the basis for further considerations regarding the design of a noise suppressor, tests were carried out for circular looms emitting a very high level of noise. On the basis of these tests, it was determined that the best way to decrease the sound level of the looms is to enclose them in individual sound-insulating casings. However, this idea is linked to the need to dampen the noise of the air conditioning and ventilation installations which maintain the microclimate inside the closings and the entirety of the machine rooms. In this case, individual silencers are a solution, and the design of such a device, patented as ‘An element for noise suppression’, is presented in this paper.

Measurements of Noise Emitted by Circular Looms. Determining a Method for Decreasing the Noise Level

A room with 24 working circular looms was chosen from the rooms of a textile factory. At special selected points, in the surroundings of 24 working circular looms (two rows of 12 looms each in the middle of the room) the author carried out 26 measurements of the acoustic sound level (L_A, L_{Amax}, and L_{Cpeak}), and 14 measurements of the sound level for octave frequencies (L_{oct}) from 31.5 Hz to 8 Hz. The dislocation of the looms and the measuring points are presented in Figure 1. Next, for three randomly selected machines, their own acoustic sound levels (L_A, L_{Amax}, and L_{Cpeak}) and the levels for octave frequencies (L_{oct}) were measured under the same conditions. All measurement results are presented in Table 1.

The admissible acoustic sound level of 85 dB (according to standard PN-N-01307:1994) was exceeded by amounts in the ranges of 12-14 dB for one loom, 10-14 dB around the looms, and 16-19 dB between the looms. The limit of the L_{Cpeak} value was not exceeded at any of the measuring points. The measurements proved that the permissible acoustic sound level was exceeded in the following, very broad ranges of the frequency spectrum: 310-5700 Hz for one loom, 220-4700 Hz around the looms, and 160-7500 Hz between the looms (all frequency limits are approximate). On the basis of the above-mentioned results, it can be stated that the location of 24 looms in one room caused an increase in the L_{Aav} value between the looms of 4.7 dB. All mechanisms of the circular looms are sources of noise; practically no single loom-mechanism was shielded in a way which could have ensured noise suppression. Additionally, the motor casing sheets, the metal platform for the service staff, and the ventilation installation all caused an increase in the noise level.

A review of the noise suppression methods which would be the most adequate for looms led us to the following conclusions. Active methods of noise suppression are not applied in the textile industry due to their imperfection [4]. The design of textile machines, and the procedures for servicing them, significantly limit the possibility of applying special sound suppression on the mechanisms and casings which emit noise, such as pastes, suppressing masses, and foam layers. At the point of factory design, the suppression of noise emission is possible by classical methods of lowering sound propagation by appropriate localisation, acoustic adaptation of the rooms, shields, and casings, as well as special design of the air conditioning and ventilation installations [3]. Considering that the measure-

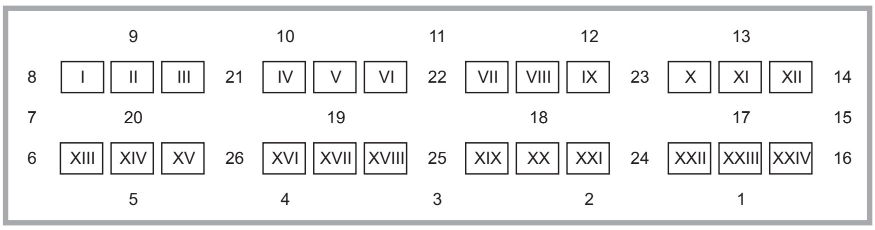

***Figure 1.** Diagram of the arrangement of 24 circular looms and 26 measuring points in the textile factory room.*

Table 1. Values of the acoustic sound levels in the room with circular looms.

Measurements	Acoustic sound level, dB												
	L_A from - to	L_{Aav}	L_{Amax}	$L_{C,peak}$	$L_{oct,av}$ - middle frequency of the octave band, Hz								
					31.5	63	125	250	500	1000	2000	4000	8000
For one loom	97-99	97.7	99.0	<135	61.8	71.5	83.5	83.3	88.5	92.3	95.0	88.0	81.8
Around loom	95-99	96.4	99.0	<135	75.5	80.0	82.5	85.4	89.5	92.6	93.3	86.0	79.5
Between looms	101-104	102.4	104.0	<135	74.3	80.3	83.8	88.2	91.7	96.0	97.5	91.0	84.3

ments carried out allowed us to state that the noise distribution in the room is uniform, and without directional sound emission, the application of sound absorbing curtains and screens is of no use. The solution basing on applying sound-absorbing hanging ceilings or covering the ceiling and walls by sound-absorbing materials was eliminated due to the very high investment costs, and because the noise level could be decreased by only 3 dB. The use of means which lower the influence of noise on the worker, and do not decrease the noise level (limiting working time, personal protection such as ear inserts, ear protectors, safety helmets etc.) are not the subject of consideration.

If we exclude from our considerations the possibility of decreasing the emitted sound level at the machine design phase, and assume we must solve the problem of already operating machines, the best solution for decreasing the perceptible acoustic noise level of looms is to enclose them in individual sound-insulating casings. Such casings should be made from light, sound-insulating plates, assembled to framings, easy to dismantle and remove by sliding or opening while servicing the machines during work. It was proved that such casings fulfil their aim excellently, and silence the noise outside the casing by up to 30 dB, even if the acoustic sound level inside the casing rises by 4-5 dB. However, machines operating in hermetic casings undergo an increase in temperature, and the need to feed air into the casings arises in order to maintain the required microclimate in them; the installation which feeds and carries away the air also transmits the noise from inside the casings to the environment. Thus, when applying special means for noise suppression, silencers and other such equipment will become necessary. The author has taken the decision to design a silencer which would be better than those hitherto used, which at the same time would be simple and inexpensive to manufacture. To achieve this aim, it was necessary to determine the noise conditions of a real object and to compare the designed construction with the other devices used so far in similar circumstances.

The Level of Sound Intensity of Machines with Free-Standing Exhaust Installations

As the author did not have available an appropriate object with textile machines, the design of the silencer and its comparison with other noise suppressors was carried out with machine tools equipped with casings and free-standing exhaust installations. The working conditions of these machines were similar tothose which obtain in the air conditioning and ventilation installations used for rooms and casings in the textile industry.

In one hall of an industrial plant in Łódź, in which an overly high noise level ($L_{real,room}$) of 89.6 dB was recorded, 20 machine tools were in operation; ten of them were equipped with free-standing exhaust installations for removing treatment waste [2]. The exhaust installation was assembled on a trolley, and consisted of a motor, a belt transmission, a centrifugal fan with a container (as an air ejector) equipped with pocket filters, and a silencer at the outlet. The HP 260 centrifugal fans of the exhaust installation were the main source of noise. They worked at an air-flow speed at the outlet of about 23 m s^{-1}, output Q of 650 m^3h^{-1}, and total pressure p_0 of 9.4 kPa. The real acoustic sound level of the fans L_{va}, measured without sound suppressors and air ejectors, was 123.5 dB. The so-called 'Japanese' silencer, manufactured on the pattern of silencers made by Muto Electric, Co. Ltd, Japan, and silencers from the Jelcz automobile, made in Poland, have been used as noise suppressors. Incidentally, the latter damped the air flow too much, and expelled the treatment wastes inefficiently.

With the aim of determining the particular noise sources, the following measurements were carried out. The ten machine tools, which worked with the free-standing exhaust devices, emitted noise (L_m) of 81 dB. The remaining ten machines emitted noise on the level (L_{m1}) of 86 dB. The five exhaust devices which worked with the 'Japanese' silencer emitted noise at a level (L_{u1}) of 90.2 dB, whereas those using the Jelcz silencer emitted noise at a level (L_{u2}) of 84 dB.

The total sound level L_s for the machine tools working together with the exhaust device of sound levels L_m and L_u can be calculated from the following equation [5]:

$$L_s = L_m + 10\lg(10^{-\frac{\Delta L}{10}} + 1), \text{ dB}$$

where: $\Delta L = L_m - L_u$

The calculated total noise level for machines with exhaust devices was 90.7 dB for the set with the 'Japanese' silencer (L_{S1}), and 85.8 dB for those with the Jelcz silencer (L_{S2}).

Next, the noise level in the hall was determined. The calculated level ($L_{cal.room}$) for the room of an area of 661.5 m^2 and an average acoustic absorptivity of $\alpha_{av} \approx 0.2$, with 20 working machine tools and 10 free-standing exhaust installations, equalled about 90 dB. The measured level ($L_{meas.room}$) was similar.

Determination of the Suppression Rate of the Silencers

The assumption was set that the exhaust devices should be silenced to such a degree that the sound level in the hall would decrease from 89.6 dB to at least 85.0 dB, that is equal to or below the permissible limit. As our thesis is that the cause of insufficient noise suppressing was the assembled silencers, it was decided to design a new noise suppressor. The problem to solve was to determine at what difference of the noise levels of the machine (L_m) and the exhaust device (L_u) the exhaust device can minimally influence the total noise level ($L_{w,max}$).

From equation (1), it results that at a difference of ΔL=10 dB, the influence of the noise emitted by the exhauster increases the total noise by below 0.4 dB [5]. Taking this into account, the upper limit of the acoustic sound level of the exhaust device was calculated as follows:

$$L_{w,max} < 85 \text{ dB} - 10 \text{ dB} - 0.4 \text{ dB} = 74.6 \text{ dB}$$

Next, the level of the acoustic sound level of the exhaust device (the fan with the container-air ejector) without silencer was measured, and the result obtained was L_{van+ej}=101.1 dB. This value was used to obtain the required damping L_d of the silencer:

$$L_d > L_{van+ej} - L_{w,max} = 101.1 \text{ dB} - 74.6 \text{ dB} = 26.5 \text{ dB}$$

Design of the New Silencer for the Free-Standing Exhaust Device

On the basis of measurements carried out by the author of the acoustic sound level for many different machines and devices, it was possible to state that the noise value corresponded almost exactly with the maximum value of the sound emitted within the range of the acoustic spectrum. Thus, the new silencer should enable the suppression of the sounds from the exhaust device (the fan with the container-air ejector, but without silencer) which exceed $L_{w,max}$=74.6 dB. To design the new silencer correctly, it was necessary to determine for which frequencies (acoustic wave length) the acoustic sound level $L_{w,max}$ is exceeded. For this reason, the acoustic sound level was measured for the middle frequencies of the octave bands ($L_{d,oct}$, in dB); the results are presented in Table 2.

The measurements carried out indicated that the acoustic sound level of 74.6 dB is exceeded for frequencies between about 85 Hz and 5 kHz (i.e. for wave lengths λ from about 4.05 m to 0.07 m). Taking this into consideration, it was accepted that the acoustic sound level should be decreased for these wave lengths which emit sounds exceeding the level of 74.6 dB. Assuming that sound suppression will take place by absorption, which means that the energy of sound waves will be changed into heat energy, a sound-absorbing material should be placed in the path of the waves. Based on the wave lengths for which the exceeding of the acoustic sound level limit occurs, it was calculated that the minimum thickness of the suppressing layer of the silencer should be 1.02 m. The silencer was made as a pipe, with the air channel sloped at such an angle that the inlet and outlet cross-sections did not coincide in the perpendicular projection of the air outlet. It was stated that a larger angle does not essentially affect the silencer's efficiency, and is less convenient and more expensive. The space between the channel and the outside casing was filled with sound absorbing material. The textile material which was selected for this purpose, mineral wool, is characterised by a high coefficient of absorption of sound wave energythroughout the wavelength ranges in which the acoustic sound level exceeded the calculated limit. The silencer length was made equal to the thickness of the damping layer, and the diameter of the air channel equal to the fan outlet diameter.

On the basis of the foregoing considerations, the silencer as presented in Figure 2 was designed. The outside casing of the rectangular cross-section was made of metal sheets, whereas the inner which was a circular cross-section, consisted of a perforated metal pipe, inclined at such an angle to the inlet axis that the outlet was displaced at the distance of k=1.2 d from the perpendicular (to the air inlet) projection of the outlet. The absorbing material was placed between the outside casing and the inner pipe. The perforation enabled better penetration of the sound waves into the absorbing layer. The silencer was designed for assembly with the fan by a flange. The above-described silencer was patented as a 'Noise suppressing element' [1].

Table 2. Results of measurements of the acoustic sound level of the exhaust device (fan with container-air ejector, but without silencer) for the middle frequencies of the octave bands ($L_{d,oct}$, in dB).

Middle frequencies of the octave bands, Hz	31,5	63	125	250	500	1000	2000	4000	8000
Length of acoustic wave, m	10.921	5.46	2.752	1.376	0.688	0.344	0.172	0.086	0.043
Sound level of fan without silencer, dB	70.9	72.2	79.5	81.5	92.6	99.8	87.2	77.0	69.0

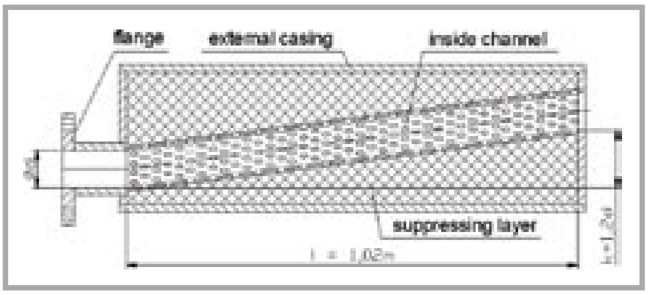

Figure 2. Silencer - 'Noise suppressing element'.

Measurements of the Acoustic Sound Level of Silencers Assembled to a Free-Standing Exhaust Device

The measurements of the acoustic sound level were carried out with the use of the IM-10 integrating sound level meter, made by SONOPAN, Poland. With the aim of comparing the acoustic sound levels of different types of silencers, the measurements were carried out for the following devices; an independently working free-standing exhaust device without a noise suppressor (A), and with five different silencers: the 'Japanese' (B), the Jelcz car silencer (C), the 'cylindrical' (D), the 'cylindrical with filling' (E), and the 'Noise suppressing element' (F). The 'Japanese' silencer was made in the shape of a cylindrical metal sheet with a concentrically-located tube from a perforated metal sheet, and the space between them filled with mineral wool. The D-silencer consisted only of a metal sheet tube, whereas the C-silencer had the tube, as in the D-silencer, covered on the inside with a sound-absorbing layer prepared from water dispersion of a sound-absorbing synthetic resin (generally used for covering metal and plastic constructions). The measurement points were positioned at a distance of 1 m from the side centre of each of the free-standing exhaust devices, 1.2 m above the floor, and marked 1, 2, 3, and 4, beginning at the fan suction inlet. The measurement results of the acoustic sound level (L_S) for the devices without a sound suppressor (but with a corrective filter), and with the five silencers at points 1-4, are shown in Figure 3. The less advantageous measurement results of the acoustic sound level in the octave bands (L_{oct}) determined at point 1 (fan suction) are presented on dependence of the wave length from 10.921 m (31.5 Hz) to 0.043 m (8 kHz) in Figure 4.

Conclusions of the Measurement Results

If we analyse the measurement results presented in the preceding chapter, we can state that only the 'Noise suppressing element', which decreases the sound level by 27.3 dB, dampens the noise better as indicates the demanded noise level of 26.5 dB. Furthermore, from the dependencies of the acoustic sound levels in the octave bands, is clearly visible that the 'Noise suppressing element' dampens the sounds most uniformly.

The decisive element, which enabled a great decrease in the acoustic sound level to be achieved, was the inclination of the inner channel in the 'Noise suppressing element'. This solution enabled the sound absorption features of the mineral wool to be better used, especially the absorption of sound waves below 4.05m in length. The author will provide a further optimisation of the slope degree in the future.

Silencers manufactured in accordance with the Polish Patent [1] are at present successfully applied for noise suppression in fans and complex ventilation and air conditioning installations.

Noise Suppressor for Circular Looms

An analysis aimed at selecting a noise suppressor based on the 'Noise suppressing element' for a ventilation installation of individual casings of circular looms is presented below. On the basis of the acoustic sound level measurements listed in Table 1 for circular looms, measured for the middle frequencies of the octave bands, it can be stated that the permissible sound level of 85 dB is exceeded for the following wavelength (λ) ranges: from about 1.27 m to 0.06 m for each loom, from about 1.06 m to about 0.07 m around the looms, and from about 2.15 m to about 0.05 m between the looms. The measurement results are presented in Figure 5.

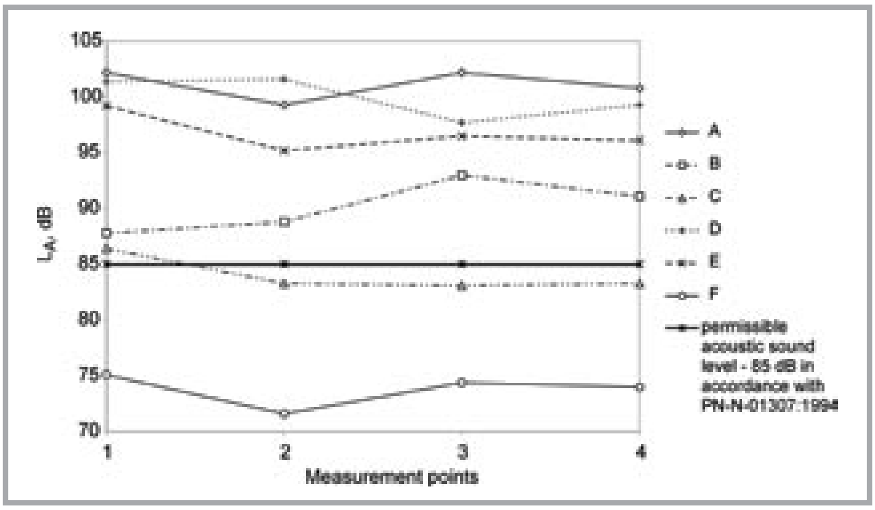

Figure 3. Acoustic sound levels for the devices: without sound suppressor and with the five silencers at the measurement points 1-4; A - without silencer, B - 'Japanese' silencer, C - Jelcz car silencer, D - 'cylindrical silencer', E - 'cylindrical silencer with filling', F - 'Noise suppressing element'.

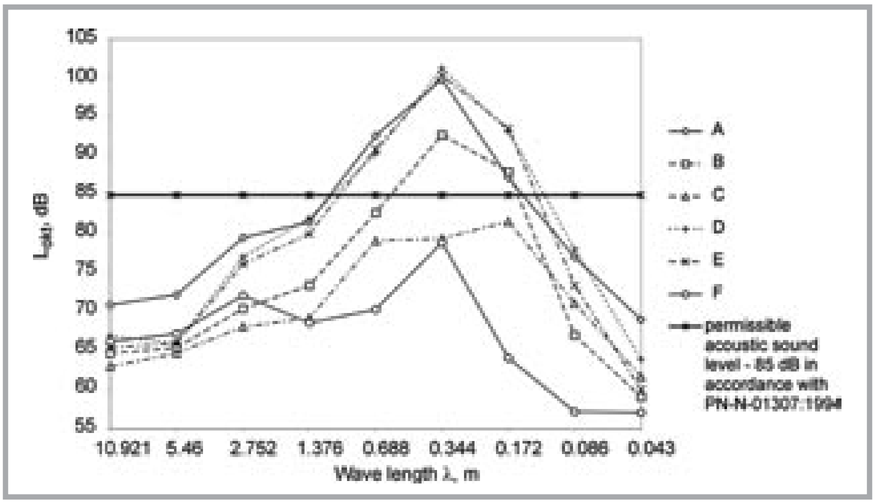

Figure 4. Acoustic sound levels in the octave bands as a function of wavelength, for the following devices: without sound suppressor and with the five silencers at the measurement points 1-4; A - without silencer, B - 'Japanese' silencer, C - Jelcz car silencer, D - 'cylindrical silencer', E - 'cylindrical silencer with filling', F - 'Noise suppressing element'.

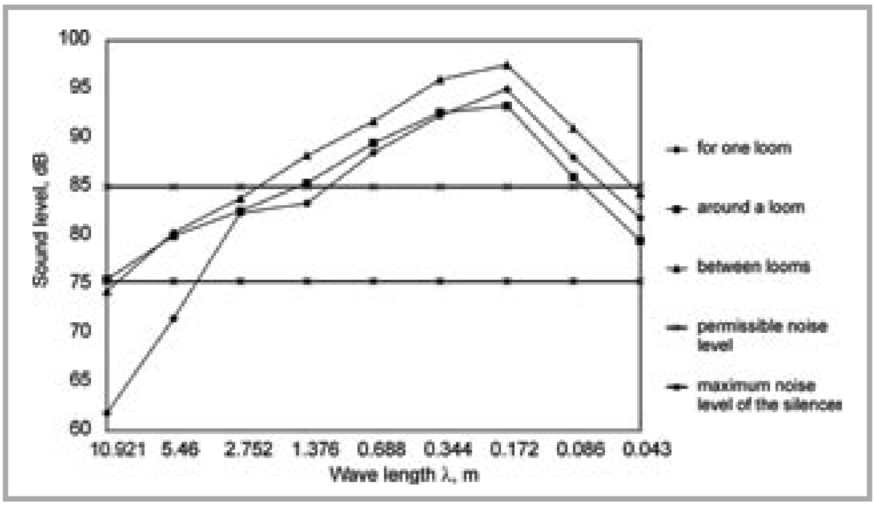

Figure 5. Dependencies of the acoustic sound levels as a function of wavelength.

On the basis of the wavelength at which the acoustic sound level is exceeded for one loom, the length of the 'Noise suppressing element', which should suppress the noise of the loom's casing, can be determined. A length of 0.32 m was calculated for the conditions presented in this paper. However, considering the increase of noise inside the sound-insulating casing of each loom within the range of 4-5 dB, and an increase in the average sound level (A_{Aav}) between 24 looms by 4.7 dB, the real noise value which can be emitted outside the casing of one loom must be below 75.3 dB. From the above considerations, it can be concluded that exceeding the sound level of 75.3 dB already begins for one loom for the sound wave length of about 4.3 m (frequency 80 Hz), which results in a silencer length of at least 1.08 m.

The above-presented analysis proves that selection of an appropriate silencer for individual circular loom casings is possible. On the basis of these considerations, designs for a casing for circular looms and a silencer which enabled noise suppression of the ventilation installation, were carried out upon the commission of a textile enterprise.

Conclusions

The measurements, calculations, and analyses carried out enabled the following conclusions to be drawn:

- The most efficient and economical noise suppression method is to enclose the textile machines and devices in sound insulating casings with an air ventilation installation equipped with noise suppressors.
- Silencers can be successfully used as noise suppressors.
- This method of sound suppression is also convenient for circular looms.
- The method presented enabled the design of an appropriate noise suppressor and the calculation of its dimensions.
- The silencer invented and patented by the author proved better than the silencers used hitherto for suppressing the noise of ventilation and air conditioning installations.
- The above-mentioned silencer has been successfully applied in the textile industry.

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